



**Financial and Currency Crises:  
Contagion and Welfare Costs  
in Emerging Markets**

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*This thesis has been composed by me under the supervision of Dr. Richard Holt and Dr. Andrew Snell from the University of Edinburgh; the work is my own and it has not been submitted for any other degree or professional qualification.*

*Heriberto Larios-Martínez*

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## ABSTRACT

Crises in emerging markets during the 1990's pose a challenge to understand why economies with apparently strong fundamentals did face severe devaluations and severe disruption in their functioning. We study three different aspects of crises:

- i) Contagion is defined as the possibility of a domestic financial or currency crisis to spread to other countries. We study the 1990's crises and introduce a new measure for defining financial crises and isolating their impact on currency crises and vice versa;
- ii) During the 1990's emerging countries in crises suffered severe adjustments in the level of consumption. We build on Lucas's measure of welfare loss and derive a more comprehensive measure that includes: total loss; loss related to changes in consumption growth rate; to volatility of consumption; and, to changes in the level of consumption;
- iii) Trying to explain the behaviour of consumption after crises in emerging markets during the 1990's we found contradicting theoretical approaches and empirical results. We solve the model of intertemporal maximisation of consumption assuming that agents maximise over several periods at a time. We extend the intertemporal framework to include the decision of participating not only in the loanable funds market but in other financial assets and derive the solution for a stock market. The results imply an alternative to the specification of the Euler equation for consumption with more explanatory variables previously omitted.

## **Prologue: Why should we care about crises?**

*A horse! A horse!  
My kingdom for a horse!*  
Richard III, 5.4.  
William Shakespeare

*“Oh, hush thee, my babe, granny’s bought some  
shares  
Daddy’s gone out to play with the bulls and the  
bears  
Mother’s buying on tips, and she simply can’t lose,  
And Baby shall have some expensive shoes”*  
Appeared in the Saturday Evening Post, 1929

The purpose of this prologue is to give a historical perspective on currency and financial crises. From apparently isolated events, crises have evolved to become events of possible global impact not only in their occurrence but as well in their effects. Understanding the mechanisms by which a crisis can spread from one country to another and the welfare costs that it imposes to the economy can provide with the policy instruments to prevent and to react accordingly to minimise the negative impact it may have. The main body of the work focuses on three main aspects of crises: the first one is the identification of possible causes of currency and financial instability. This part discusses the issues of contagion, interdependence, performance of leading indicators and the possible feedback between financial and currency markets. Secondly, the measure of welfare costs have been often set aside by the literature, although there are several attempts to measure the costs of crises, these efforts address fiscal impact, losses of international reserves and micro-level studies in income and expenditure rather than welfare proper. We derive a comprehensive measure of welfare costs which include the different effects on the behaviour of consumption; we build up on Lucas (1987) and take into account not only effects on the growth rate and volatility of consumption but on the level as well. Finally, we attempt to explain the behaviour of consumption by re-examining the intertemporal consumption framework and expanding it to explain not only decisions in the loanable funds market but in other asset markets. An important result is that under this approach the Euler equation for consumption needs to be modified to include the effects of wage and portfolio holdings and monetary policy through the real interest rate has a more complex impact than previously thought. The objectives of the research, the structure of the work and an outline of the principal contributions are to be found at the introduction.

Financial and currency crises have been part of the History of monetary and financial markets. Whenever there have been assets to trade, whatever their form (*Quetzal* feathers, salt, carved stone, tulips, real estate, coins, printed currency, debt or stocks) there have been unexpected events, excessive needs for funding, mismanagement, honest mistakes or plain fraud which may trigger a crisis and alter the functioning of these markets. For example, Williams (1997) explains the process by which after four centuries of monetary stability, by the third century AD the Roman Empire had to degrade the silver standard of the coinage because of uncontrolled monetary expansion needed to finance the running and expansion of the Empire and because of the exhaustion of silver mines in Spain. The consequence was a debasement of the coinage and inflation. A rough illustration of this process can be seen in the increase of the pay of a Roman legionary soldier that accelerated after AD 200:

<i>Reign</i>	<i>Amount per annum</i>
Julius Caesar (c. 46 BC)	225 denarii
Domitian (AD 81-96)	300 denarii
Septimus Severus (AD 193-211)	600 denarii
Caracalla (AD 211-217)	900 denarii
Maximinus (AD 235-238)	1,800 denarii

This process can be hardly considered a crisis by today's standards, when information flows instantly from one corner of the world to another and the time for reaction to these events has to be almost instant. However, the depletion of reserves (in the form of silver supply); a government deficit (to keep running an overstretched bureaucracy and huge military expenses) and the use of monetary expansion to finance it; and finally, inflation, are still ingredients in the modern world for a currency or a financial crisis.

There is a long way from the outbreak of inflation in the Roman Empire and the Argentinean crisis in 2001 but these episodes have always appealed to the imagination not only of academic circles but of the general public. The sudden realisation of the value of a kingdom in terms of a more useful horse in battle (the real estate asset vs. the liquid asset is what Kindleberger (2000) characterises as the manic and panic phases of a financial crisis) is an amusing way to think about the presence of these episodes in Literature; but more seriously, Alexander Dumas's *The Count of Monte Cristo* provides with an ample recount of common financial speculation projects available during the 19<sup>th</sup> century. When Edmund Dantes, in his role of the revengeful Count, talks Mr. Danglars into investing in several projects that range from silver mines in Peru and Mexico to farms in Siberia is just portraying the investment opportunities and the artificial bubbles that were taking place during the 1800's. If this is thought to be just a curiosity of the period, Dumas describes a typical bank run caused by the sudden realisation of the public that the capitalisation of the Danglars Bank is not enough to

cover the totality of deposits, phenomenon that still can happen in today's banking systems. And to complete the picture of financial misfortunes, Monte Cristo circulates false information into the French stock market about the capacity of the Spanish government to fulfil the payment of outstanding bonds, forcing the prices to fall because investors are exhibiting herding behaviour; when truthful news were known, the prices of the bonds returned to their fundamental level.

Along history and with the development of financial markets and integration of economies through commerce, these episodes have become more sophisticated in terms of technology advance in designing new type of assets and communications; they happen faster, from the beginning to the end it can be just matter of hours to have a global impact; but the most worrying feature of financial and currency crises is that, when they happen, they can disrupt the normal functioning of a country's economy, unbalance the international financial system and impose large welfare costs to the general public even if they do not participate directly (or even indirectly) in financial markets. We have to make a brief review of some of the historical crises in financial markets in order to understand how we arrived to the complexities of the 1990's and the crises that affected emerging countries with apparently successful economic and financial reforms.

## ***P.1. Bubbles and manias: modern panics in the beginning***

Here we briefly discuss some of the most famous financial crises that constitute typical examples of these phenomena. We start with the Tulip-mania and the South Sea Bubble bursting; both can be thought as modern panics in financial assets, one happening in the commodities market (as strange it may sound today, trading of futures of tulips is not different to trade in futures of oil, live stock or orange juice in modern times) and the other in the real estate market (which several authors point to be at the hub of the Thai crisis in 1998).

### ***P.1.1. Tulip-mania (1636-1637)***

Kindleberger (2000) explains that the tulip arrived to Holland from Turkey in 1593 and it became a symbol of status and wealth. Some of the tulips exhibited flame patterns that make them unique and as a consequence these specimens (at the beginning it was thought to be a species) were highly valued. These patterns, seen in the spring of 1636, increased the price of tulips in the market and were the trigger of the "mania" in September of the same year. However, between September and January of 1637 there were no specimens in display (because the season for lifting the flower was in June) therefore, the asset in this case is the promise of flamed flowers in a future date. The mosaics were thought to be a 'fundamental' value to the

asset and it traded as that; however, being a disease<sup>1</sup> and not a mutation they were not genetically bicoloured varieties (which exist but with predictable patterns). During this period, the bulbs traded effectively as any financial contract future, trying to buy low and to sell high without the bulb being planted.

The end of this tulip-mania came to an end when the tulips were planted and two things happened: i) tulips were not scarce anymore, in fact they became excessively common; because, ii) the disease was not genetically transmitted from one generation to another. With perfect information, the market realised that tulips were greatly overpriced above their fundamental value and the market crashed in a selling frenzy of worthless bulbs.

### ***P.1.2. The Mississippi and South Seas Bubbles (1720)***

The South Sea and the Mississippi bubbles share the similar feature of company's share prices soaring and then crashing. Each episode had a different underlying asset though. For the South Sea Company it was trade with South America while for the Compagnie d'Occident it was the proposal of switching from gold and silver into paper. The South Sea Company and the Compagnie d'Occident sought rapid expansion of its balance sheet through corporate takeovers and/or acquisition of government debt financed with successive issues of stock.

Garber (1990) explains the process by which John Law created the Compagnie d'Occident; Law argued that any investment project could be financed by the issuance of high powered money which would be absorbed by the increase of money demand that would come from the income and wealth effects of the project once completed; the liabilities represented by the emission of convertible instruments would be backed by the profits of the company. Law's monetary theory was that printing money would boost investment and commerce, therefore he authorised the Banque Royale the issuance of notes linked with the emission of stock. However, Kindleberger (2000) argues that the equivalence between bonds and shares as money is a fallacy and soon investors started to redeem shares in the form of gold putting pressure on Law's scheme. Law reacted by pegging the price of shares and paying with money at a fixed rate, doubling in one month the quantity of legal tender in circulation. After several devaluations in order to combat the resulting inflation, the share price fell to 2,000 livres by September 1720 and to 1,000 livres by December, by September 1721 it was back to 500 livres per share.

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<sup>1</sup> The College of Agricultural, Consumer and Environmental Sciences of the University of Illinois explains the symptoms that a tulip presents when it is affected by a virus; "tulip breaking" as it is called, consists in the appearance of dark patterns on lighter coloured background (mosaics).

The South Sea Company failed because it was based on the assumption that Great Britain would be granted permission by Spain to commerce with its colonies and obtain a monopoly. However, the Spanish policy throughout its colonies in America was to control tightly all trade in and out the continent and this permission was never granted. The Company's strategy was to convert government debt into shares. According to Garber (1990) prices of company's shares in January 1720 were 120 pounds per share, 950 pounds in July and finally 290 pounds in October. The insiders and management of the company knew that the company and the government could not afford the liquidation of shares and started selling after realising capital gains before the second payment to shareholders was due. Kindleberger (2000) explains this bubble as a variant of a Ponzi game that was attainable as long as share prices rose indefinitely in order to finance the payments to shareholders since the trade aspects of the company were inexistent.

## ***P.2. The 20<sup>th</sup> Century: Citius, Altius, Fortius***

The 20<sup>th</sup> century witnessed the most rapid advances in technology than in the rest of Human History. International relations, trade and financial markets have benefited from the advances in telecommunications (from the first underwater telegraph cables passing through the wireless up to satellite communications); it has never been easier to transfer information from one place to another. This as convenient as it is, poses risks to the functioning of international markets, the crash in 1987 was blamed to the automated stop-loss orders that spiralled out of control and herding behaviour is more likely to appear when there is little time to react to news. On the other hand, the amount of international assets held by countries has never been higher, USD 37,888 billions in 2003 according to figures from the International Monetary Fund (IMF) database. This integration of capital markets allowed emerging countries to have access to more resources of funding for investment. However, because of the amount of resources and the high mobility of capital, when things go wrong, a sudden stop and/or a reverse in capital flows can produce deep recessions with important loss of output, welfare costs and decrease the opportunities and conditions to achieve a stable growth.

### ***P.2.1. The Great Crash (1929)***

Starting in October 24<sup>th</sup>, the "Black Thursday" and passing through the "Black Monday" and finally the "Black Tuesday", October 28<sup>th</sup> and 29<sup>th</sup>, the Great Crash constitutes perhaps the stereotype of a financial crisis. With a fall of 12.8% of the Dow Jones index on Monday 28<sup>th</sup> this crisis marked the sharpest fall in the index up till then and for another 30 years. Rivers of ink have been devoted to recount the events leading to the crash of the New York Stock Exchange

(NYSE). Three great accounts of the crash have been written by Galbraith (1954), Morgan-Witts (1979) and Steele-Gordon (1999) not only about the events in the stock market but about the American society and the general mood surrounding the events so we will only provide a brief glimpse of the events around the Crash.

In 1928, President Coolidge was optimistic about the perspectives of the American economy and the boom of the NYSE was being fuelled by low interest rates and the good investment prospects. Speculation played an important role as well, this was a largely unregulated market where short sales (bear strategy in which someone sells borrowed stock for which the seller will pay later for it in the hope that the price will fall), bear raids (a group of sellers start selling short in order to push the price down and benefit from the price fall), syndicates (groups of investors that manipulate the prices selling and buying among themselves) and corners (syndicates would buy all the floating stock secretly and then impose prices once the market is 'cornered') were day to day operations and that, as Steele-Gordon (1999) documents, were already in use during the Tulip-mania. Hence, despite the belief that the episode was an anomalous misfortune that hit the USA, the resulting boom of Wall Street was nothing else but a speculative bubble. One thing is certain and it is that this crisis constitutes the first one in which technology accelerated the rate of events and once the process started, it took only 3 days to erase the value of 5 billion USD out of the stock market. Because of the volume traded, during the three days of crash, the teletypes carrying the information with stock prices started running with one and a half and two hours lag adding to the confusion and the uncertainty.

### ***P.2.2. Farewell to Bretton Woods: The end of stability***

According to Cohen (1977), in July 1944 at Bretton Woods, New Hampshire, 45 countries met to discuss the post-war conditions for the recovery of Europe and several monetary issues. Between them was the stability of exchange rates to avoid unexpected fluctuations; the Bretton Woods Agreement established an international monetary system of convertible currencies, fixed exchange rates and free trade based on the convertibility of currencies into gold. The objective was to avoid violent fluctuations like the ones experienced after World War I and to impose monetary and fiscal discipline to the participating countries (similar to the Euro scheme). As fundamental parts of this new system the International Monetary Fund (IMF) and the International Bank for Reconstruction and Development (World Bank) were established. The IMF was the monetary moderator that held deposits in gold, US Dollars and national currencies.

These subscriptions were set according to the share in international commerce and the paying capacity of the country<sup>2</sup>.

However, within the Bretton Woods system the pre-eminence of the US Dollar turned out to be its downfall. Cohen (1977) describes in detail the events leading to the abandonment of the Agreement. After a brief period of surplus in the trade balance in 1957 because of the closure of the Suez Canal, the US plunged into continued deficits that pressured the dollar to be devalued. Additional pressure came from the fact that the US had liabilities that exceeded its gold reserves. The problem that the rest of the world faced was that speculation against the dollar depended on the elimination of deficits; however, the availability of USD depended on the US continued trade deficits and because of these there was a problem of trust in the ability of the US to convert USD into gold. After several negotiations and attempts to disincentive the speculation against the dollar, President Nixon asked for a realignment of international currencies to eliminate the overvaluation of the currency. On August 15<sup>th</sup> 1971, the US suspended the gold convertibility of the dollar and let the currency to adjust according to its market value. The abandonment of convertibility implied the adoption of floating exchange rates and of domestic monetary and fiscal policies not necessarily compatible with the stability of the currencies. Several countries adopted fixed exchange rates but without the backing of an international system, only on their own reserves opening the possibility of speculative attacks against their currencies. Other adopted, mainly developed countries, flexible exchange rates. It was not until the European monetary union was adopted that a similar international coordination effort was seriously adopted.

### ***P.2.3. Debt crises in less developed countries (LDC)***

On August 12<sup>th</sup>, 1982 the Mexican minister of finance informed the US Treasury and the IMF that Mexico was unable to meet its obligation to service its debt for USD 80 billion. By October 1983, 27 countries with a total of USD 239 billion of debt had already rescheduled their debts. This chain of debt defaults threatened 8 of the largest US banks with failure. The lending boom to less developed countries started with the rise in oil prices during the 1970's and the average growth of LDC averaged 6% during this period, even the Mexican President José López Portillo stated in 1977 during the annual presidential address to Congress "These are times to learn to manage the abundance".

By 1979 the servicing of debt represented already 30% of the value of exports, while Brazil presented a debt-service ratio of 60% (Federal Deposit Insurance Corporation FDIC, 1997). One

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<sup>2</sup> Sources: World Bank and IMF



explanation of the Latin American debt crisis that started in 1982 refers to the fiscal deficits incurred by most of the major countries in the region. According to Wiesner (1985) between 1979 and 1982, Argentina, Brazil and Mexico more than doubled the size of their non-financial public sector deficits from 6% to over 15%. But together with fiscal expansion, the financing of this expansion has to be pointed as a major cause, instead of financing with direct investment and access to capital markets, the governments of these countries used international debt to finance their expenditure. According to figures of the IMF (in Wiesner, 1985), domestic savings and investment as percentage of the Gross Domestic Product (GDP) were declining.

<b>Savings and Investment (As percentage of GDP)</b>				
<b>Source: IMF</b>				
	<b>1980</b>	<b>1981</b>	<b>1982</b>	<b>1983</b>
<b>Argentina</b>				
Gross domestic investment	25.7	20.0	18.1	17.1
National savings	21.1	16.2	13.0	13.3
External savings	3.1	3.8	5.0	3.8
<b>Brazil</b>				
Gross domestic investment	21.1	19.2	18.4	15.0
National savings	16.0	15.1	12.9	12.0
External savings	5.1	4.1	5.5	3.0
<b>Mexico</b>				
Gross domestic investment	28.1	29.0	21.2	16.5
National savings	24.0	23.2	17.8	20.2
External savings	4.1	5.8	3.4	-3.7

However, the world recession and high international interest rates contributed to the aggravation of the situation. The external financing allowed the appreciation of the currencies creating fears of devaluations that triggered an outflow of capital and the dollarisation of economies. The attempt by the US to curb the inflation caused by high oil prices by increasing interest rates, and the subsequent increase in the LIBOR (London Interbank Offered Rate) rates made the debt services hard to meet. This crisis was fuelled by the belief that growth was finally stable and permanent. However, Wiesner (1985) argues that the availability of resources was flawed in two ways: i) it was used to finance consumption instead of investment; and, ii) instead of attracting more resources from capital markets, the financing continued to be via debt contracting. Risk sharing is not the same in debt markets where the country is committed to pay a certain amount to service the debt than in capital markets, where the investor assumes the risk of the loss. However, countries like Mexico were following a policy of protection of trade and domestic investors while maintaining a repressed financial system which in the facts meant that the only agent in the economy with access to international funds was the government. All these factors determined most of the reforms to be implemented during the next decade, liberalisation

of markets, free trade agreements and structural reforms. However, as is the topic of this dissertation, these efforts ended up not in a debt market & currency crisis but in a financial system & currency crisis.

#### ***P.2.4. The Great Crash II (1987)***

Monday October 19<sup>th</sup> 1987 set a new loss record in the NYSE. The Dow Jones lost 22.6% in a single day the biggest loss since the Black Monday in 1929. Prior to the crisis, the stock market experienced a bull market episode fuelled by hostile takeovers, mergers and leveraged buyouts which were financed with junk bonds. Initial public offers (IPO's) were being used to finance all kinds of investment, especially those related to the relatively new market of computers. The swift rise of stock prices raised concerns about a crash as it happened in 1929. There were other indicators that increased these concerns, interest rates were rising and a sell out of US Treasury bonds by the Nippon Telephone and Telegraph contributed to the rise of interest rates above 10%. The high interest rates, threats of currency devaluation by the Treasury Secretary, a large trade deficit and other events shattered the confidence in the stock market and on Friday October 16<sup>th</sup> it fell 17.5% the biggest drop recorded till that day.

The next chain of events revealed a feature of globalisation and technology: contagion. On Monday as markets started to open from east to west heavy falls in local stock markets: Japan, Hong Kong, Singapore and London fell as they opened. However, when the turn of Wall Street to open arrived, the sharpest fall of all occurred. Only 25 shares of the Standard & Poor's 500 continued trading while the rest didn't have any buy orders. The Chicago Mercantile Exchange where derivatives are traded followed suit (Steele-Gordon, 1999). At the hub of the crash were the adoption of out-of-time portfolio insurance strategies (by selling futures an investor can insure the portfolio against changes in prices, when it is done at the moment of a plunge the only effect is the collapse of derivatives' markets) and program trading. At the time, computers had been recently put in charge of balancing and rebalancing portfolios in real time, information about prices and traded volumes is received and the computer decides the optimal composition of the portfolio; while in 1929 the teletypes lagged with the transmission of information adding to the uncertainty, in 1987 the constant flow of information translated into massive sells when automatic stop-loss orders were executed and prices spiralled down triggering more and more sell orders. Hillebrand (2004) tests Black's hypothesis about the causes of the crash; this hypothesis states that a correction in the mean reversion process of the stocks is in place when the true size of portfolio insurance becomes known, that is asymmetric information that is revealed. However, the result of this test is that on the day of the crash there was only a 7% of probability of a crash greater than 20%. Schiller's (1987) findings in a survey realised after the

crash revealed that portfolio insurance played only a small role in the execution of stop-loss orders and did not play the central role predicted by the Black hypothesis.

The UK Treasury analysis of the crash recognises that the response of US companies after the plunge helped to support the market, these companies bought back their own shares. In Tokyo, the long term investing institutions provided buying support prompted by the Ministry of Finance (HM Treasury, 2005). Additional measures included the lowering of interest rates and the injection of liquidity to the economy by increasing the money supply. In a sharp contrast to 1929 when the financial market took 22 years to recover the level before the crash the panic ended swiftly and the market recovered its previous level in two years.

### ***P.3. Conclusions of the prologue***

Summing up, if there is an asset that, due to an external shock, its fundamental value is thought to be increased permanently, its price is going to adjust upwards to reflect this change. Once complete information is revealed and turns out that the shock was temporarily, a price adjustment downwards is necessary. A crash may appear when the asset holders react at the same time without the market being able to absorb the sell orders. This process will be detailed in the body of the work, but for now this description can be applied to any market that faces a mania (or bubble) doesn't matter if its tulips in 1636, real estate in 1929 or financial derivatives in 1987.

In this prologue we wanted to make the reader aware that financial crises, in either of their forms, and currency crises are part of the functioning of economies; even if in developed countries it is hard to imagine the devastating consequences that these phenomena can have and the impact in wealth distribution, impoverishment and welfare that emerging countries had to face. This account is by not means exhaustive, Steele-Gordon (1999), Mackay (1841), Galbraith (1954 and 1975) give much more detailed examples of financial distress along history. Technology advances have only made crises faster, deeper and with potential global effects.

## **Introduction**

The main objective of this work is to analyse three main aspects of currency and financial crises during the 1990's:

1. Measuring contagion and the interaction between financial and currency crises;
2. Measuring welfare costs; and,
3. To provide with a theoretical explanation of consumption behaviour.

In order to do so, we have first to understand and define what constitutes a crisis. During the process of doing this research the first question that came up was, when do we face a crisis? It turned out that answering this question was like defining bad weather, an elusive concept that everybody talks about but it is difficult to describe. Therefore Chapter 1 tries to give a comprehensive overview of the theoretical and empirical research on this field; we discuss different theoretical approaches and models that try to explain currency and financial crises. Most of the literature treats these phenomena as separate events; in other words, we find currency crises models and financial crises models with several distinctions within each type of crisis. We provide some of the pros and cons of each kind of model in order to obtain a working definition for our empirical work.

According to Kurgan (1979) first generation models of currency crises find that they can occur because of inconsistent and unsustainable government policies. These models explain fairly accurately crises experienced by Latin American countries in the late 1970's and early 1980's. However crises in the 1990's in emerging countries in South East Asia and Latin America happened in countries that were undergoing reforms that provided with sound macroeconomic fundamentals, liberalisation of financial markets and integration to the world economy. On the other hand, banking crises á-la Diamond-Dybvig (1983) were not the main characteristic of problems in the banking sector. Allen and Gale (2000) describe the usual sequence of events in this new type of crisis: problems in the banking sector that are followed by a currency crises that feedbacks and deepens the banking crisis. However, the banking system has not been the first cause of the twin crisis; instead, the common cause is usually a fall in asset values due to a slowdown in the economy. We also provide a review of the empirical work that has be done in this field; this literature, which constitutes the bulk of studies of financial and currency crises, has focused on the process and early warning indicators that may help to forecast a crisis. Chapter 2 presents an overview of the events that took place during the

Mexican, Brazilian, South East Asian, Russian and Argentinean crises and we study the common factors that may help to understand what happened in these countries.

Chapter 3 analyses the phenomenon of contagion by applying the recent developments by Pesaran and Pick (2005) to the IMF data that we used in this research; this methodology not only allows establishing the presence of contagion but as well identifies the main macroeconomic that may help to explain these crises. We developed and included a measure of the Financial Market Pressure (FMP) in order to capture the possible effect of a financial crisis on a currency crisis. We found that there is no consistent role of fundamentals previous to these crises but that financial crises feedback on currency crises and vice-versa, consistently.

A less developed field is the measurement of the costs imposed by economic disruption and the welfare loss after a twin crisis. In chapter 4 we review Lucas's (1987) methodology which measures the welfare loss of separate changes in the growth rate and volatility of consumption. We modify this measure in order to include changes in the level of consumption as the ones observed in several countries during the 1990's and we obtain a single measure that captures:

1. Total welfare loss;
2. Welfare loss due to changes in level of consumption;
3. Welfare loss due to changes in the growth rate of consumption; and,
4. Welfare loss due to changes in the volatility of consumption.

We found that the most important welfare effects are linked to the growth rate in the long run and the level of consumption in the short run whereas volatility has a small or no impact on welfare losses.

Finally, Chapter 5 studies the impact of policy options available to counter the effects of the crises on consumption; we need a framework that can explain the behaviour of consumption. We found that the Obstfeld and Rogoff (1999) approach based on the original work done by Lucas (1987) does not explain the idiosyncrasies of crises during the 1990's and that the Euler equation approach is not enough to explain consumption behaviour, therefore we go back to basics to describe consumption within the intertemporal maximisation framework and to derive a consumption path equilibrium. We drop one assumption of the Euler approach solution, which is that individuals maximise an infinite number of two-period sequential problems and instead we analyse the case for which individuals maximise over lengthier periods of time (the extreme being a single maximisation problem with infinite periods); this implies that the intertemporal budget constraint always binds. This approach explains some puzzles in the

behaviour of consumption regarding the impact of monetary policy, mainly that a change in the interest rate has a negative impact on the level of consumption in the short run and a positive one in the growth rate on the long run and improves on the estimation by including income as an explanatory variable in an expanded version of the Euler equation.

We also recognise that this problem only deals with the loanable funds market and while useful to analyse potential crises and credit crunches in the banking system, it does not address the behaviour of other financial assets' markets. Therefore we apply a simple optimisation problem to allocate wealth between consumption and a financial asset that follows a binomial stochastic behaviour. Applying the results for the individual to a market structure such as the one proposed by Emmons and Schmid (2002) we can model the behaviour of a financial market where:

1. Asset mispricing is the result of the errors in the appreciation of the unknown probabilities of each state of nature.
2. The market price of the asset includes the information from full-information investors and noise traders.
3. The ask-bid gap depends on the proportion of noise traders in the market.
4. Changes in the risk free interest rate have a negative effect on consumption.
5. A rational bubble appears when the asset is overvalued and it is optimal for both types of traders to sell at the higher price. In a sequential framework, this market frenzy can lead to a bursting bubble and a crisis. Additionally, there is an impact on goods prices; therefore an overvalued asset market spills over an increase of goods prices. If we link this effect to an open economy we may end up with pressure over the currency market and facing the probability of devaluation.

Each chapter contains an introduction that explains in more detail as well as the relevant conclusions obtained. Finally, there is a set of global conclusions that complement and summarise the ones within each part. Recurring, sudden and deep financial and currency crises are phenomena that countries like Mexico want to avoid because of their negative impact on welfare, growth and wealth distribution.

## Chapter 1: Currency and financial crises; defining bad weather

*Bud Fox: ...there are no many takers; the stock is plummeting...*

*Gordon Gekko: ...I am losing millions...*

*Bud Fox: ...the bid is ... going down. Gordon. What do you want to do?*

*Gekko: Dump it*

Dialogue in Oliver Stone's Wall Street (1987)

*How could I have been so mistaken as to have trusted the experts?*

John F. Kennedy (after the Bay of Pigs fiasco in April, 1961)

During the 1990's several countries carried out structural reforms in order to eliminate fiscal imbalances, reduce inflation and achieve higher growth rates. In some countries these reforms were part of a long-term effort towards industrialising and developing the economy (South East Asia and Russia) and in others (mainly all countries in Latin America) they were aimed to wards preventing the occurrence of the hitherto recurrent speculative attacks and currency crises. According to Tirole (2002) these initially successful reforms were followed by dramatic financial and currency crises with economic contractions often compared with the Great Depression.

The literature produced after these episodes is vast and has tried to provide some answers to the problems posed by the sudden crises affecting countries with undergoing economic reforms. Tirole (2002) argues that these crises in emerging markets have shattered the consensus among economists not only with regard to the benefits of capital liberalisation or structural reforms in emerging countries but also regarding the nature and causes of these crises. As a first step, it is important to define clearly what is meant by the term "crisis" and be aware that a financial crisis does not imply *per se* a currency crisis since it can happen in a closed economy, however it may be the case that opening the economy may increase the probability of a financial crisis occurring by providing investors with a wider range of assets (i.e. foreign currencies) to hedge risk. In other words when a country opens its economy, not only foreign capital can be pulled out but also domestic investors can find relatively safer returns in foreign markets and may have the incentives to disinvest in the domestic financial markets. Pericoli and Sbracia (2003) highlight that depending on the object of the analysis, the literature has identified a *currency crisis* with devaluation from a "hard peg" (i.e. fixed or crawling peg) or with an extreme value of an exchange rate pressure indicator; a *stock market crisis* with a sharp fall in the stock market index or with an upsurge in the volatility of asset prices; and, a *banking crisis* with a collapse in

the ratio of non-performing assets to total assets, the closure of failure of important banking institutions, the occurrence of major bail-outs, large scale nationalisations of banks or widespread bank runs.

Section 1 of this chapter surveys the macroeconomic feedback and asymmetric information models of financial and currency crises. The first approach studies different interactions between macroeconomic fundamentals, the external sector and the financial system. The other approach focuses on asymmetric information and market imperfections that can trigger a financial crisis at any given time. As we will see, policy implications are quite different and involve a mixture of policy actions that should be effective to prevent a crisis. However, some of them were in place or being implemented at the time of these crises. This indicates that these recent crises need to be studied more in-depth as Tirole (2002) clearly points out. Studying the debt market allows to understand the analysis of the borrower-lender relationship in a broader way than the usual bank-depositor approach; the latter ignores the developments in financial theory such as the possibility of diversification, self-insurance and immunisation of liabilities.

Deposit contracts and bank runs are far from being at the hub of recent crises. It is more likely that firms with high leverage faced early liquidation of debt (either in secondary markets or by direct claims for repayment of loans) due to increased risk in the economy and that the efforts made by governments to provide the investors with short-term attractive yields denominated in foreign currency increased those risks rather than correct them. This do not imply that bank based lending is not relevant in a financial crisis; on the contrary in most of the cases the weaknesses of the banking system has been a consequence of the previous currency crisis. But these weaknesses are to be found in the asset side of the balance sheet, non-performing loans and low recovery have placed the banking systems in financial distress. In other words, liquidity shortages in the banking system come from deterioration of asset quality and not from an initial run on deposits as this literature implies. As Tirole (2002) mentions, there is a necessity for going back to basics in order to think over again the consequences of economic reform and understand where did these countries fail.

### ***1.1. Crisis!!!... But, what is a crisis?***

There is a consensus that crises during the 1990's were not caused by bad economic policies or by an unsustainable growth of the money supply and/or uncontrolled inflation. On the contrary, these economies were implementing stabilisation programmes that were considered as promising and these countries offered good investing opportunities as the large capital inflows suggest. Figures from the World Bank database show that net capital inflows as part of GDP



represented 9.4% in Brazil (1992-95); 25.8% in Chile (1989-95); 9.3% in Korea (1991-95); 45.8% in Malaysia; 27.1% in Mexico (1989-94); and, 51.5% in Thailand (1988-95). For these countries, access to international financial markets meant access to creditors with short investment horizons requiring relatively secure investments (such as pension and mutual funds). The use of short-term maturities and dollar denominated debt were two important factors that put pressure on the ability of both private and public sectors to face their liabilities in case of withdrawal of these funds.

Eichengreen and Rose (1999) point out that the output costs of currency and banking crises can be a year or more of economic growth, and only the resolution costs of banking crises have often been the equivalent of two or more years of Gross National Product (GNP) growth. As capital becomes increasingly mobile, the severity and persistence of the consequences of a crisis of either type have grown as the recent experiences in Asia and Latin America show. Tornell (2001) describes the boom-bust cycle experienced by Mexico and Thailand as typical of countries undergoing twin currency and banking crises. Typically, prior to such a crisis, an economy experiences: i) a lending boom, along which bank credit to the private sector grows unusually quickly; and, ii) an appreciation of the real exchange rate. When a twin crisis occurs, the real exchange depreciates and the banking system fails. Tornell (2001) highlights the fact that that such a failure is not caused by a run on banks by depositors, but rather by a sharp deterioration in the bank's loan portfolio. In the aftermath of a crisis, the consequences are usually: i) a recession, which is typically short-lived (GDP usually recovers its growth in the second year after the crisis); and, ii) a long-lived credit crunch that develops parallel to an expansion in GDP. This credit crunch mainly affects households and small and medium-sized firms in the non-tradable sector.

In this section we try to give a definition of what it is considered to be a crisis and the different types of crises that can occur in the economy. A more in depth discussion of the models that have been developed to explain crises will be presented in section 2 of this chapter.

### **1.1.1. Financial crises.**

To define financial crises we need to identify the sector that is initially affected by them. A 'financial system' includes domestic banks and other financial entities that perform bank-like operations (intermediation of resources between lenders and borrowers) such as insurance companies, stock exchange institutions, savings and loans, etc., as well as a central bank that is committed to act as lender of last resort. According to Mishkin (1991), monetarists beginning with Friedman and Schwartz (1963) have linked financial crises with banking panics. A banking

crisis refers to a situation in which actual or potential bank runs or failures induce banks to suspend the internal convertibility of their liabilities or which compels the government to intervene to prevent this by extending assistance on a large scale. A banking crisis may be so extensive as to acquire systemic proportions. Systemic financial crises are potentially severe disruptions of financial markets that, by impairing markets' ability to function effectively can have large adverse effects on the real economy. These authors stress the importance of banking panics because they perceive them as a major source of contractions in the money supply, which in turn, have lead to severe contractions in aggregate economic activity in the United States; hence, under this view a financial crisis only takes place if there is the possibility of a banking panic and as consequence a sharp decline in the money supply.

Kindlberger (1978) and Minsky (1972) outline a broader view; financial crises either involve sharp declines in asset prices, failures of large financial and non-financial firms, deflations or disinflations, disruptions in foreign exchange markets or some combination of all of these. With a similar view, according to the G-10<sup>3</sup> Working Party on Financial Consolidation a 'financial crisis' is defined as "an event that will trigger a loss in economic value or confidence in a substantial portion of the financial system that is serious enough to... have significant adverse effects on the real economy" and "systemic risk" as the probability of a crisis occurring. One of the problems associated with these views is that they do not supply with a rigorous definition of what characterises a financial crisis, and it thus lends itself to being used too broadly as a justification for government interventions that might not be beneficial for the economy. It is important to note that as the IMF recognises (1998) systemic financial crisis may involve a currency crisis, but a currency crisis does not necessarily involve serious disruption of the domestic payments system and thus may not amount to a systemic financial crisis.

It is interesting to note that according to Sachs and Tornell (1996) recent crises were far from being bank-run driven, even in the cases where a banking crisis was present, such as Mexico and Argentina, the bankruptcies within the banking system were result of a currency run and of important weaknesses that undermined the banking system capacity to deal with shocks (as in the case of Argentina and the "corralito" as described by de la Torre, Levy and Schmukler, 2002) or due to an explosion of bank loan defaults and risk exposure (as it occurred in Mexico) rather than a "classic" depositors' bank run. Other candidates to be taken into account when studying a financial crisis are the stock market and the debt market. The crash of the stock market in 1929 is one of the most well-known and studied episodes in the history of

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<sup>3</sup> The Bank for International Settlements (BIS) defines the group of ten as to be conformed by Belgium, Canada, France, Germany, Italy, Japan, the Netherlands, Sweden, Switzerland, the United Kingdom and the United States. G-10 consults and co-operate on economic, monetary and financial matters.

financial crashes and is still under debate its contribution to the Great Depression. The 1929 crash has some resemblances to the recent crises mainly because of: i) the existence of a market environment with hidden and non-disclosed information; ii) a financial system not efficiently regulated or supervised; and, iii) all kind of financial manoeuvres and excesses (as documented by Steele-Gordon, 1999). However, one of the common features of recent crises that Tirole (2002) documents is not the use of the stock market as source of financing, but the use of short-term debt denominated in foreign currency that is easier in terms of information disclosure due to the stock market regulations.

According to the IMF (1998) the factors that underlie the emergence of imbalances and that render an economy vulnerable to financial disturbances may be grouped under the following not mutually exclusive headings: unsustainable macroeconomic policies, weaknesses in financial structure, global financial conditions, exchange rate misalignments and political instability. In addition, there is a natural tendency for economic activity to fluctuate giving rise to shifts in market sentiment that can contribute to stress the financial system. These factors contribute to the conditions under which crises occur and should be distinguished from the immediate causes (or triggers) of crises, which are usually events or news that lead economic agents to reassess their positions. Macroeconomic factors, especially lending booms, have been found to play an important role in creating financial sector vulnerability in many Latin American countries and in other emerging market economies as well. Because of the characteristics of recent structural reforms, it is expected that such debt would be contracted predominantly by large firms: in almost every country analysed, reforms included a shrinking public sector where government owned enterprises (usually large monopolies) were privatised and their size and expected profitability allowed them to obtain financial credits in international markets. Unlike crises that happened before the 90's, these countries were trying to control fiscal expansion and to avoid "undisciplined" economic policies. As Tirole (2002) points out, this characteristic is one of the main sources of risk for a crisis occurring; he finds a collective action problem that refers to the monitoring of the financial arrangement, to intervention in case of violation, and to renegotiation in case of distress. Investors individually have a very suboptimal incentive to commit the resources to accomplish these tasks and free riding is likely to ensue.

### **1.1.2. Financial instability and currency crises.**

A currency crisis may be said to occur when a speculative attack on the exchange value of a currency results in a devaluation on the exchange value of a currency results in a devaluation (or sharp depreciation) of the currency, or forces the authorities to defend the currency by

expending large volumes of international reserves or by sharply raising interest rates. The IMF (1998) argues that the composition of capital inflows has been considered an important factor in a number of currency crises in emerging market countries. In both the South East Asian and Mexican crises, the reliance on short-term borrowing to finance large current account deficits was a crucial ingredient precipitating the crisis. Foreign direct investment, in contrast to debt contracting inflows, is often regarded as providing a safer and more stable way to finance development because it refers to ownership and control of plant, equipment and infrastructure and therefore funds the growth-creating capacity of an economy, whereas short-term foreign borrowing is more likely to be used to finance consumption. Another lesson of recent crises is that currency mismatches in private sector balance sheets (of either financial institutions or corporations) may be more of a problem in countries with inflexible rates, since an exchange rate peg may encourage borrowers to ignore exchange rate risk. In sum, the argument of the IMF is that experience suggests that countries with high levels of short-term debt or foreign debt intermediated through domestic financial institutions are likely to be particularly vulnerable to internal or external shocks and thus susceptible to financial and currency crises.

Distortions in the financial sector, in conjunction with macroeconomic volatility, constitute another group of factors behind the recent currency crises. Often these distortions arise in times of rapid financial liberalisation and innovation in countries with weak supervisory and regulatory policies or where the government intervenes directly in the allocation or pricing of credit. Insufficient regulatory regimes in more liberalised financial environment have created moral hazard by encouraging financial institutions with low capital ratios to assume imprudent risks. They have also tended to increase possible mistakes evaluating and monitoring risks in more competitive environments arising from deregulation or privatisation of state-owned banks. In some cases, politically motivated lending and fraud further worsen the quality of asset portfolios and deficiencies in accounting, lack of disclosure and biased legal frameworks add to the problem by allowing financial institutions to disguise the extent of their difficulties. To these factors, the IMF adds the frequent failure of governments to take prompt corrective action when problems emerge with the consequence that losses become larger and more difficult to manage. Investors who perceive that the investment portfolios will not reach the expected return and furthermore, that the central bank will not be able to meet the liabilities denominated in foreign currency will opt to withdraw their funds from the country in trouble. It is when the phenomenon of sudden stop and reversal of capital flows takes place; as we will see, the causes of currency crises differ radically from the debt crises in the 1980's that were driven by fiscal imbalances and insufficient reserves to meet public sector external debt.

## 1.2. Models of currency and financial crises

*"Has your husband any Spanish bonds?" he asked of the baroness. "I think so, indeed! He has six millions' worth." "He must sell them at whatever price."...When it was seen that Danglars sold, the Spanish funds fell directly... Next morning Le Moniteur ..."It was without any foundation that Le Messenger yesterday announced...the revolt of Barcelona...A telegraphic signal, improperly interpreted, ..." The funds rose one per cent higher than before they had fallen. This...made the ... (loss) of a million to Danglars.*

In *The Count of Monte Cristo* by Alexander Dumas, 1846

Caballero and Krishnamurthy (2002) point out that in past years there has been a significant re-evaluation of the models used to analyse crises in emerging markets. Some of the recent models typically stress the existence of financial constraints or distorted financial incentives. These authors develop a model that tries to address particular problems of emerging markets rather than to adapt the existing ones that deal better with well-developed economies. Their model is based on a dual liquidity approach that tries to differentiate domestic liquidity shocks from international liquidity shocks. This approach still depends on liquidity shocks hitting the economy but in our view external liquidity shocks with “sunspot” triggering do not explain why emerging economies with large capital inflows suffer sudden stops and reversals of the direction of the flows. Therefore, it is necessary to turn to other models that try to explain the causes of crises in a more detailed way; in order to do that, we need to identify the stylised facts that are common to crises in emerging countries.

Mishkin (1991) describes the usual timeline that a financial crisis follows; rather than starting with bank panics, most of financial crises begin with a rise in interest rates, a stock market crash and the widening of the domestic-foreign interest rate spread; this is also true for pre-1990’s crises where the main source of instability was the government indebtedness and fiscal imbalances that forced Latin American countries to declare incapacity to pay their external debt. Furthermore, a financial panic frequently is immediately preceded by a major failure of a financial firm and the beginning of the recession that increases uncertainty in the market place. Only after these problems have manifested themselves in financial markets do we find that a bank panic occurs.

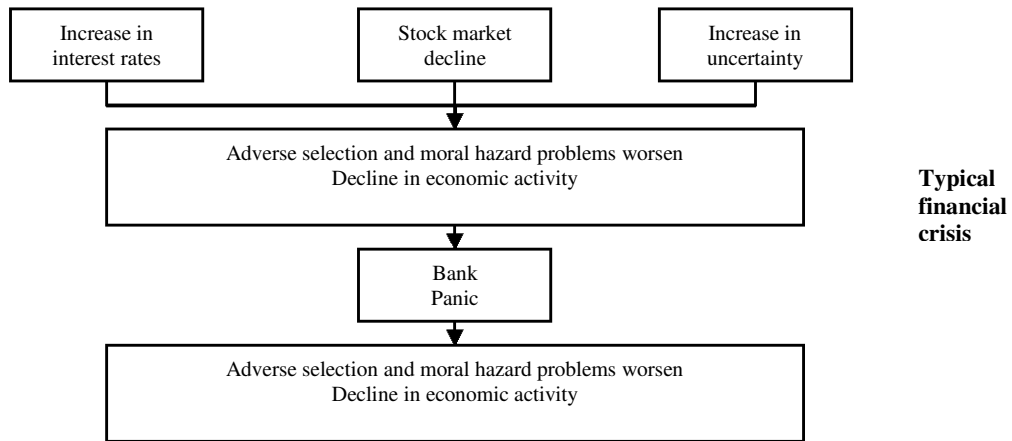


Diagram 1: Sequence of events in a financial crisis (Mishkin, 1991)

Glick, Moreno and Spiegel (2001) describe common elements of financial crises in emerging markets during the past decade:

1. Financial crises took place after extensive liberalisation, particularly in financial markets. In recent years countries that have gone through processes of economic stabilisation have tried to tackle down inflation and to correct fiscal imbalances by diminishing the size of the public sector through privatisation of government owned enterprises, in order to achieve these goals, economic reform, liberalisation and global integration have been key elements of their strategies. During the late 1980s and early 1990s, most Latin American countries – particularly Mexico, Brazil, Chile and Argentina- undertook ambitious reforms aimed at modernising their economies. All of these, except Chile<sup>4</sup>, have faced a financial crisis, a currency attack and an economic meltdown that has lead, in particular, to a worsening of income distribution and, in general, to a slowdown in economic activity after the crisis. Domestic financial markets were liberalised, with credit controls and lending restrictions removed, access to international financial markets broadened and the permissible activities of domestic financial institutions expanded.

The outstanding Asian growth over the past thirty years was largely the result of liberalisation and opening of real sectors across the region. In contrast, Asian financial sectors were relatively less developed with domestic credit often channelled through the banking sector

<sup>4</sup> Chilean stability may be explained by several reasons. Economic reform was made under the military regime of General Pinochet and has been explicitly one of the models to follow by other countries. Financial liberalization included the privatization of the pension system in an early stage of the reforms deepening the financial intermediation. Foreign investment was encouraged to be done directly rather than in short-term assets. Furthermore, a Tobin tax for withdrawals of the country done before a year had passed is in place. Supervision and enforcement are strict as well leaving little room for corruption episodes.

to particular privileged domestic sectors and firms, though usually in accordance with export-promoting industrial policy. Beginning in the 1980s, financial markets were liberalised gradually across the region, first by allowing more market-oriented adjustment of interest rates and allocation of credit, and later by permitting domestic financial institutions greater freedom in asset and liability management. As Corsetti et al. (1998) argue, some efforts were made to contain short-term inflows, but these policies did not reduce the vulnerability of domestic financial sectors to shocks.

2. They were preceded by significant capital inflow surges that ceased abruptly. The Mexican and Asian crises were preceded by substantial capital inflows that reflected a number of factors, including the search for higher yields on the part of international investors in an environment of low interest rates in industrial countries, strong macroeconomic and structural reform policies on many emerging markets and capital account opening. When the crises broke out, sharp cutbacks in short-term financing occurred as access to international capital markets was sharply curtailed.

3. At the time of the crises, relatively rigid nominal exchange rate regimes tended to be in place and un-hedged foreign currency and interest rate exposure was high. Nominal exchange rate pegs were in place in almost every country that experienced financial difficulties. In the late 1980s, a number of Latin American countries adopted exchange-rate-bias inflation stabilisation programs, relying on the exchange rate as a nominal anchor. Investor confidence in the stability of these exchange rate pegs encouraged borrowers in emerging markets to take advantage of lower foreign interest rates through foreign borrowing without hedging foreign currency or interest rate risk. Exposure to exchange rate risk was particularly troubling for commercial banks. As a legacy of financial liberalisation, banks were particularly able to capitalise on interest rate differentials through foreign borrowing and domestic lending. In addition, the degree of exchange rate risk stemming from foreign borrowing by banks was commonly exacerbated by maturity mismatching between long-term illiquid assets and short-term liabilities.

4. The crises tended to involve a number of countries simultaneously. After the Mexican Peso crisis in December 1994, the larger Latin American countries experienced varying degrees of volatility in their foreign exchange markets and declines in their equity markets. Argentina, though it successfully maintained its currency peg, suffered substantial costs while defending its currency by keeping interest rates high. After the floating of the Thai Baht, financial disturbances spread elsewhere in East Asia. The Russian default in August 1998 was

accompanied by an even more widespread turbulence. Bond spreads rose globally, and the access to foreign capital of emerging markets in all regions was severely curtailed.

One of the most important features is that economic fundamentals were sound. Mexico's fiscal policy was conservative; inflation had been under control for several years, and market interest rates preceding the crisis of 1994 did not appear to indicate an expected devaluation of the Peso<sup>5</sup>. When analysing macroeconomic conditions prevailing in some of the Asian countries, growth rates were far superior to those in other emerging markets, inflation rates were moderate, and government budgets were in balance or showed surpluses. However, some authors attribute the crises to policy mistakes. Dornbusch and Werner (1994) found that in Mexico there was a sharp increase in private spending and overvaluation of the real exchange rate and an increase in domestic credit that was aimed to sterilise the foreign exchange losses caused by an asset demand decline occasioned by higher interest rates in the USA. Both in Mexico and Asia, there were some indications of increasing vulnerability in the period prior to the 1997-1998 crises provided by the large and growing current account deficits, slowing exports and real appreciation of currencies. However, the main factor that triggered the attack was the realisation that short-term liabilities imposed an excessive burden on international reserves.

An additional element that some authors use to explain the extension of the crises is related to the weaknesses and distortions of financial sectors. Asian financial crisis was a consequence of bad lending and investment practices fostered by an environment of relationship lending, disincentives to fully monitor risk and inadequate supervision and regulation of domestic financial institutions during the lending boom of the 1990s. As in Mexico, credit tended to flow to borrowers with relationships to government or private bank owners and to favoured sectors rather on the basis of projected cash flows and risk assessment. At the time this was unknown in almost every country as one of the deliberate policies was to hide information regarding international reserves and amount and conditions of the contracted debt. In all of them the supervision and enforcement of rules was in the best of cases unreliable. Galbraith (1954) explains "According to the accepted view of events, by the autumn of 1929 the economy was well into a depression... Thus viewed, the stock market is but a mirror which... provides an image of the underlying or fundamental economic situation. Cause and effect run from the economy to the stock market, never the reverse. In 1929 the economy was headed for trouble. Eventually that trouble was violently reflected in Wall Street". However, some of the models

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<sup>5</sup> They base this argument in the fact that interest rate differential between dollar denominated Tesobonos and US T-Bills was relatively constant before the crisis, indicating no increase in market risk premium for holding Mexican assets.



that have been developed do not make this linkage or focus on other mechanisms that address market failures. In these models, triggers can be sunspots, rumours and shifts in expectations justified or not. This is especially true in those models that model bank runs only as the only source of financial instability. Masson (2001) discusses three different types of models which produce multiple equilibria for financial assets prices: i) macroeconomic feedback models; ii) bank run models; and iii) fad and herding models. Each one adopts a different approach and of course the implications for policies aimed to prevent a crisis are different. Shifting from an initial equilibrium to another can be the result of a crash or a temporary adjustment depending on the setting. In the next section, we are going to discuss these three types within the two main bodies of literature that address the possibility of financial crisis in an economy: a) macroeconomic feedback models; and, b) asymmetric information models. The latter comprise bank run models, fad and herding behaviour in the classification of Masson (2001). In table 1 we summarise the sources of instability and the mechanisms that trigger a financial market crash in both types of models. In macroeconomic feedback models, the sources of instability are mainly coordination failures of agents that observe macroeconomic fundamentals and the financial markets play an accelerator role that feedback into the macroeconomic performance. On the other hand, asymmetric information models focus on market failures derived from incomplete information and in the study of the revelation mechanisms that can lead to panics even if macroeconomic fundamentals are sound.

<b>General sources of instability</b>		
	Macroeconomic feedback models	Asymmetric information models
Regarding crisis initiation	<ul style="list-style-type: none"> <li>• Coordination failure among depositors</li> </ul>	<ul style="list-style-type: none"> <li>• Market inefficiencies due to asymmetric information or market power that restrict liquidity</li> </ul>
Regarding crisis propagation	<ul style="list-style-type: none"> <li>• Macroeconomic adjustment through the financial accelerator</li> </ul>	<ul style="list-style-type: none"> <li>• Information spillovers</li> <li>• Credit exposure</li> <li>• Debt financing in asymmetric information and limited commitment environments</li> </ul>
<b>Triggers of crises</b>		
	Macroeconomic feedback models	Asymmetric information models
Sunspots	<ul style="list-style-type: none"> <li>• Arbitrary shifts in expectations that can trigger bank runs or speculative attacks</li> </ul>	<ul style="list-style-type: none"> <li>• Arbitrary shifts in expectations that can trigger bank runs or speculative attacks</li> </ul>
Productivity shocks	<ul style="list-style-type: none"> <li>• Runs can be caused by coordination failure in a full information environment</li> <li>• In multi-bank models, credit exposure can lead to contagion</li> </ul>	<ul style="list-style-type: none"> <li>• In multi-bank models, herding behaviour can lead to contagion</li> </ul>
Financial shocks	<ul style="list-style-type: none"> <li>• Asset price declines can turn liquidity problems into solvency problems</li> </ul>	<ul style="list-style-type: none"> <li>• Bank runs can turn liquidity problems into solvency problems</li> </ul>
New information	<ul style="list-style-type: none"> <li>• Shifts in expectations</li> </ul>	<ul style="list-style-type: none"> <li>• Shifts in expectations</li> </ul>

Table 1: Sources of instability and triggers of financial crises

Policy implications are also different depending on which model we rely on. We summarise them in table 2.

<i>Policy implications</i>		
Elimination/ reduction of coordination failure	Macroeconomic feedback models	Asymmetric information models
Ensuring liquidity provision of markets		Deposit insurance, suspension of convertibility, transparency, taxing early withdrawals from the country, minimum capital requirements, subsidised lending and recapitalisation of banks
Reducing contagion risks		Injection of liquidity through repurchase agreements, monitoring and enforcing capital requirements
Reducing the impact of the financial accelerator	Counter cyclical monetary and fiscal policies	Bailout guarantees, lender of last resort operations, collateral requirements for payment system participation, restricting credit exposures

Table 2: Policy implications

We now turn to discuss in more detail different types of models that have been developed to try to explain crises. It is important to keep in mind that depending on the approach, models may or may not make a distinction between a financial and a currency crisis.

### 1.2.1. Macroeconomic feedback models

In these models there is no distinction between a financial and a currency crisis, furthermore, differentials between domestic and international financial markets are not explained and are assumed to receive exogenous shocks. A higher domestic interest rate, triggered by fears of devaluation or default, feeds back in an adverse way on the economy's prospects. The linkages are various, in the first-generation models, the decision to devalue is triggered when foreign exchange reserves, falls below a certain threshold; higher interest rates can make reaching this threshold more likely because they increase the economy's foreign debt servicing, as in Masson (1999) or because higher interest rates trigger a run in the banking system and expansion of domestic liquidity and an outflow of reserves as in Chang and Velasco (1998b).

These models address the notion of the link between the financial system and the real economy. The financial system is viewed as an important source and driver of real business cycle fluctuations. Bernanke and Gertler (1989, 1990) show that the optimal financial contract in the presence of information asymmetries involves an agency cost arising from the need to

monitor or audit the borrower, both of which are costly actions to the lender. This monitoring cost is passed on to the borrower in that the lender demands a bigger share of the returns from successful projects. Borrowers can reduce the agency cost of debt by investing their own wealth. Hence there is a negative relationship between capital and agency costs. Similarly, there is an inverse relationship between borrower's wealth and cost of investment since the resources are owned. They show that in a dynamic model of investment, this feedback between agency costs of investment and borrower net worth creates a mechanism whereby shocks to the economy are amplified and propagated through their effects on the borrowers' cash flows. The net worth of borrowers is also affected by changes in the value of real and financial assets, creating an asset-price channel. Kiyotaki and Moore (1997) argue that the inability of lenders to prevent borrowers from defaulting strategically leads them to require that borrowers post collateral. Hence, firms' net worth is important to determine their debt capacity or credit limit.

The effect of the financial accelerator on the real economy is twofold. First, the borrower is pro-cyclical and this introduces an additional source of fluctuation and persistence into a standard real business cycle. Second, exogenous shocks to borrower net worth can initiate real macroeconomic fluctuations. A necessary condition for the financial accelerator to exist is borrowing by firms. In a downturn, an increasing number of firms become cash constrained, increasing the effects of the accelerator. In an upturn, the external funds premium falls and debt capacity increases as firm's balance sheet positions improve and this may lead them to use their own resources for investing in the firm. In these theories, financial crises are represented by a deepening of an economic downturn at the end of an upturn. The triggers are unanticipated and therefore, financial crises tend to be unpredictable. The importance of this group of models is that they formalise the idea that financial crises can amount to substantial costs in terms of real output.

Arellano and Mendoza (2002) surveyed models on emerging market crises, which have financial frictions as a central element for explaining the sudden stop phenomenon. Nonetheless, few of them have had as an objective the study of quantitative implications of these models and to integrate them with an equilibrium business cycle framework. Emerging markets are characterised by a set of empirical regularities that Calvo (1998) labelled the "sudden stop" phenomenon: i) a sudden loss of access to international capital markets; ii) large reversal of the current account deficit; iii) collapse of domestic production and aggregate demand; and, iv) sharp corrections in asset prices and in the prices of non-traded goods relative to traded goods. The sudden stop phenomenon is not compatible with the predictions of the majority of existing models of current account determination and business cycles in small open economies, both frictionless real business cycle models and models with nominal rigidities.

Arellano and Mendoza (2002) argue that the common starting point of much of the literature on emerging market crises has been to model international capital markets as subject to a variety of financial market imperfections and to attribute these imperfections to various forms of informational frictions that are more pervasive in emerging markets than in industrial country capital markets. There are two proposed financial transmission mechanisms. The first mechanism is related to the debtor's ability to pay: debtors may be willing to repay their debts, but their ability is threatened by the realisation of bad states of nature. Creditors aim to cover their exposure to default risk by imposing lending conditions on borrowers (collateral or liquidity requirements). Quantitative applications in an RBC setting are rare and there are two major shortcomings, first borrowing constraints are always binding along an equilibrium path and this rules out equilibrium dynamic in which one can observe large reversals of the current account triggered by a switch from a state of nature in which the constraint did not bind to one in which it does. Most models deal with perfect foresight experiments in which the credit constraint arrives as an unexpected shock. Hence, economic agents are not given the opportunity to adapt their optimal plans to the possibility of being suddenly unable to access international capital markets. The second mechanism is the debtor's willingness to pay: debtors decide optimally to default. The implications of this incentive-compatibility or participation constraint vary depending on the structure of the economic environment on which it is imposed.

Although financial crises usually come hand in hand with currency crises, it is important to be aware of the distinctions between them. In order to do this, we will review the different approaches for speculative attacks that lead to a currency crises. First, we need to define a currency crisis, in all models a speculative attack is waged against a pegged exchange rate that depletes the foreign exchange reserves leading to the abandonment of the exchange rate peg. This is because there are expected gains to all the agents that attack the currency before international reserves are depleted. When there is a floating exchange rate regime then there are no gains since the exchange rate adjusts immediately. Eichengreen and Rose (1999) argue that currency crises cannot be identified with changes in the exchange rate regime, which is contrary to the assumption made in other studies. Their argument is that not all decisions to devalue or float the exchange rate are preceded by speculative attacks. More importantly, a central bank may successfully defend its currency against attack by using its international reserves to intervene in the foreign exchange market or by raising interest rates. This phenomenon is completely different from a financial crisis. A financial crisis can happen in a closed economy with prices of domestic assets crashing because of the actions of domestic agents<sup>6</sup>. Why does a

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<sup>6</sup> The well known episodes along History in where the price of real estate in Florida prior to the 1929 crash, tulips in the Netherlands, municipal bonds of the Orange county and local runs such as the US savings and loans collapse are example of a financial crisis without a currency crisis .

financial crisis usually come along with a currency crisis in emerging markets? This is a question that could be answered straight forward by arguing that the currencies were pegged and losses in financial markets were expected to recover with gains derived by attacking the currency. However, this does not respond basic questions like: Which are the risks of opening the economy to foreign capital? And, which is the role that the exchange rate regime plays on agents' decisions when a financial crisis is about to happen? In order to answer these questions we discuss the models that have been developed to analyse speculative attacks.

### **1.2.1.1. First generation models**

A review of first-generation speculative attack models, developed by Krugman (1979), Flood and Garber (1984) and Blanco and Garber (1986) presented in Hallwood and MacDonald (2000), describes them as combinations of elements of the monetary approach to the balance of payments and the flexible price monetary approach to the exchange rate. The former theory is used to make the point that a rate of domestic credit expansion faster than the rate of growth of demand for domestic money causes a fall in foreign exchange reserves- which ultimately forces the abandonment of the peg. The monetary approach to the exchange rate is used to a) calculate the shadow floating exchange rate, which is the rate that would prevail if there was a flexible regime; and, b) to support the observation that a speculative attack on a currency will occur before foreign exchange reserves are exhausted. This is because in the monetary approach to the exchange rate, the current exchange rate is determined not only by current fundamentals but also by the discounted value of expected excess money supplies. Another point is that the exchange rate will not jump to a new market rate as such a transition would imply that some profitable opportunities for currency speculation had been ignored; rather the transition will be smooth to a floating rate that approximates the old pegged rate, thereafter depreciation sets in.

A simple way to understand this type of models is shown in diagram 2 by Agenor, Bhandari and Flood (1992). The line MM depicts the money supply that is the sum of the domestic credit (line DD) and international reserves (line RR). Before the abandonment of the peg, domestic credit increases and reserves decrease in the same proportion. When the reserves are not enough to sustain the peg this is abandoned and the money supply adjusts because the only component now is domestic credit. Thus, the money supply follows the path MMD. As the credit expands and the reserves decline, the shadow exchange rate tends to depreciate until it intersects with the fixed valued. This is when the exchange rate is abandoned and the observed exchange rate coincides with the shadow one.

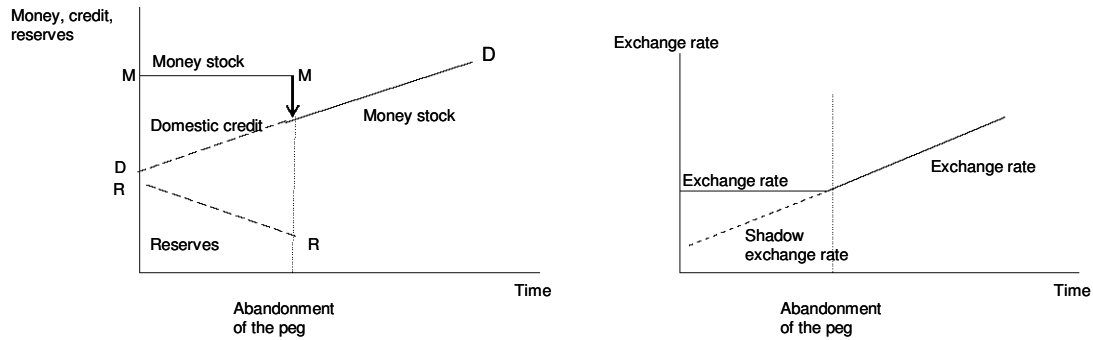


Diagram 2: First generation model of currency attacks

These models reveal some important aspects of a speculative attack. However, their main deficiency lies in the fact that they assume perfect foresight. In reality agents are unsure about when the attack will actually take place and they are also uncertain about how much the exchange rate will change if there is an attack. As we have already said, in most of the cases when there is a speculative attack, the exchange rate overshoots before stabilising around a new equilibrium rather than following a stable path. Flood and Marion (1997) say that in the first generation models inconsistent policies prior to the attack can push the economy into a crisis.

### 1.2.1.2. Second generation models

In second-generation speculative attack models, the government's decision to devalue is endogenous, which increase the set of relevant macro fundamentals that are affected by investors' devaluation expectations and that can positively affect the devaluation probability. Obstfeld (1994) gives two examples: one in which exchange rate expectations increase the unemployment-inflation trade-off, another where inflation expectations increase the burden of servicing government debt. In the former, the expectation of devaluation raises inflation expectations and wage demands, making it more likely that the authorities will give in to those demands and devalues in order to avoid unemployment. In the latter case, higher interest rates reflect increased fears that the authorities will inflate away outstanding debt, raising the burden of that debt and hence the likelihood that the inflation option will be chosen.

Cole and Kehoe (1996) develop a general equilibrium model with optimising private sector agents. In this model, the key variable influencing vulnerability to self-fulfilling attacks is the amount of short-term government debt. It is assumed, as in first generation models, that domestic credit grows at a rate  $\mu_0$ , same, but if there is an attack, then it will grow at a faster rate  $\mu_1$ . Hallwood and MacDonald (2000) summarise the speculative attack in the second generation models in diagram 3.

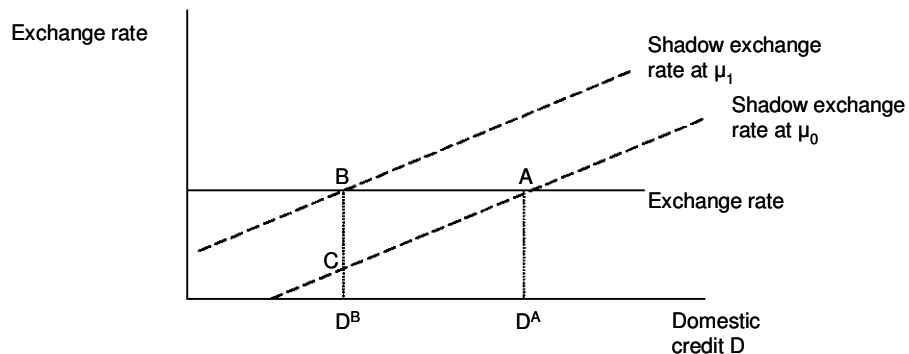


Diagram 3: Second generation model of currency attacks, Hallwood and MacDonald (2000)

Imagine that domestic credit lies to the left of  $D^B$  in such a case, if there is an attack then the shadow exchange rate jumps from the one compatible with  $\mu_0$  to the other that is compatible with a faster rate of growth  $\mu_1$ . Since this shadow exchange rate is still below the fixed level of the exchange rate, there is a loss of capital for speculators. Exactly at  $D^B$  there is no clear incentive to the economy to move from C to B and even if that happens there would be no profit for speculators derived from a speculative attack. Between  $D^B$  and  $D^A$  there are incentives to mount an attack, however this depends on coordination of the agents to be successful. Morris and Shin (1998) argue that the apparent multiplicity of equilibria associated with self-fulfilling beliefs that lead to a currency attack is to oversimplify the role played by information in a speculative episode. Information plays a subtle role in speculative crises. What is important is not the amount of information per se, but rather how public and transparent is this information. If market participants are well informed about the fundamentals, but they are unsure of the information received by other participants, and hence unsure of the beliefs held by others, speculative attacks may be triggered even though everyone knows that the fundamentals are sound<sup>7</sup>, in their words “a ‘grain of doubt,’ allowing that others may believe that the economy is, in fact, unstable will lead to a currency crises even if everyone knows that the economy is not unstable.”

Hallwood and MacDonald (2000) explain that the purchasing power parity (PPP) underlies much of the literature of the modern literature on the balance of payments and exchange determination in second-generation models. The PPP doctrine suggests that we should be able to buy the same bundle of goods in any country for the same amount of currency. The

<sup>7</sup> These authors cite the Mexican case to support their findings. They say that one of the most important causes was the uprising of the EZLN in Chiapas. In this specific case during all the year of 1994 there were political incidents that weren't the “subtle information” that they assume but clear evidence of political and social unrest that included riots, local uprisings, high profile political assassinations (not seen in the country for 70 years) which involved the president's brother.

fundamental notion is that the exchange rate depends upon price levels. Given two countries with homogeneous tradable goods, no barriers to trade, no capital flows and full employment in both economies, the law of one price, an arbitrage condition, must hold:

$$P_t^i = S_t P_t^{i*} \quad (1.1)^8$$

This condition simply states that at date  $t$ , the price of good  $i$  in the home country ( $P^i$ ) must equal its price in the foreign country ( $P^{i*}$ ) multiplied by the foreign exchange rate  $S$ . If this equation does not hold, then it is profitable for arbitrageurs to trade. From this simple condition, there are two main views of PPP; the first one is the absolute PPP, which states that the ratio of the price index (weighed sum of prices) in both countries is equal to the exchange rate in this case the real exchange rate  $Q$ , defined as  $Q_t = S_t \frac{P_t^*}{P_t}$  takes the value of 1. Another version is the relative PPP which relates the inflation rates of both countries to the depreciation of the exchange rate  $\Delta s_t = \Delta p_t - \Delta p_t^*$ .

Another view alternative to the PPP is the uncovered interest rate parity (UIP). To the economy described above, it is assumed that each country issues a bond which is assumed to be a perfect substitute for the foreign currency denominated bond. The UIP is therefore assumed to hold  $\Delta s_{t+1}^e = i_t - i_t^*$  which is equivalent to:

$$\frac{s_{t+1}^e - s_t}{s_t} = (r_f^{cb} - r_f^{cb*}) + (\Delta p_{t+1}^e - \Delta p_{t+1}^{e*})^9. \quad (1.2)$$

Usually it is assumed that real interest rates are equal in both countries and therefore the expected nominal depreciation of the exchange rate is equal to the inflation differentials.

<sup>8</sup> Corresponds to equation 1 of chapter 1

<sup>9</sup> The nominal interest rates  $i$  and  $i^*$  may be decomposed into real and expected inflation

components  $i_t = r_f^{cb} + \Delta p_{t+1}^e$ . Using the Fisher decomposition:  
 $i_t^* = r_f^{cb*} + \Delta p_{t+1}^{e*}$

$$\Delta s_{t+1}^e = (r_f^{cb} - r_f^{cb*}) + (\Delta p_{t+1}^e - \Delta p_{t+1}^{e*})$$



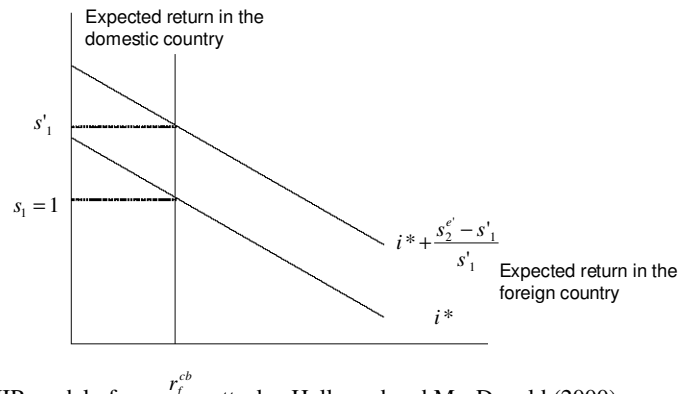


Diagram 4: UIP model of currency attacks, Hallwood and MacDonald (2000)

The use of a portfolio approach to the determination of the exchange rate explicitly links the performance of the financial market in the domestic country with the performance of the rest of the world. Hence, differences in this performance can lead to a currency crisis. However, the factors behind expectations of a poor performance and the information mechanisms that can trigger such a crisis are not explained. In summary, these models explain currency crises, but the financial crisis component is not addressed. These first and second-generation models do not explain weaknesses in the financial system. Chang and Velasco (1998a) argue “...recent events in Mexico, East Asia, Russia and Brazil have confirmed that a satisfactory explanation of emerging market financial and currency crises remains elusive”. Furthermore, they argue that first generation models have fallen out of fashion because many actual crises seem to lack the crucial fiscal disequilibria. On the other hand, they argue that second generation models implied that crises may be driven by self-fulfilling expectations, since the costs of defending and exchange peg may depend on anticipation that the peg will be maintained. However, the emphasis on economic slowdown of economic activity was at odds with the crises of Mexico in 1994 and of East Asia in 1997. They conclude that instead of fiscal imbalances or weakness in real activity, recent crises in emerging markets have revealed financial sources of vulnerability.

One of the main objections that can be made to the interpretation of crises as jumps between multiple equilibria in macroeconomic feedback models is that the linkages involved take time to operate. Expectations need to be coordinated on the bad equilibrium; this has not been modelled. When introducing large speculators rather than atomistic agents this removes the discontinuity needed for multiple equilibria. This coordination issue needs some sort of information transmission mechanism that is not studied in the literature and needs to be explained in order to really understand a financial crisis. This kind of models fail to explain why seemingly successful economic reforming countries have experienced sudden crises, in other words, the question if there are there any risks associated with the reforming processes that increase the vulnerability of the economy is still unanswered. The IMF (1998) position is “it is

of course impossible to predict crises reliably, and any successful attempts to construct models to do so would presumably affect the behaviour of policymakers and financial market participants alike, which would quickly render the models obsolete. Furthermore, for crises arising from pure contagion effects early warning signals may be unavailable because the crises stem from inherently unpredictable market reactions. What is more feasible is to identify the kinds of weaknesses that typically render economies vulnerable to financial crises, including to spill-over effect, whether or not a crisis does materialise". The IMF (1998) proposes as indicator for a lead up to a currency or banking crisis to look for evidence of the economy being "overheated": inflation relatively high (though recent crises clearly fail to comply with this); appreciation of the real exchange rate; increased current account deficit; excessive domestic credit expansion and a rapidly rising ratio of broad money to international reserves. Additionally, because of the experience of the Mexican and South East Asian crises the IMF includes the indicators of non-performing loans in the banking system and of short-term currency exposure in both the financial system and the corporate sector.

In the next sections we will discuss the asymmetric information approaches to financial crises. Most of the literature is focused on bank runs and this literature has build up from the seminal paper by Diamond and Dybvig (1983), we will outline its main characteristics and other models that incorporate herding behaviour. However, since these models only deal with bank runs by depositors they do not offer an explanation of what has happened in the cases of financial crashes and economic meltdowns that involve defaults on public and corporate debt and on bank loans rather than a sudden run by depositors. Herding models have been used as well to try to explain information avalanches in financial markets and have been successful in explaining localised frenzies and crashes in financial markets but not a collapse that involves the financial, the real and the external sectors all together.

### 1.2.2. Asymmetric information in financial markets

*Marvin: ...I need the information now, before the close...No, in ten minutes is history, at four o'clock I'm a dinosaur*

*Gordon Gekko: The most valuable commodity I know is information. Wouldn't you agree?*

*Bud Fox: Yeah...*

Dialogues in Oliver Stone's film Wall Street (1987)

Mishkin (1991) argues that transactions that take place in financial markets are subject to asymmetric information in where one party often does not know all that he or she needs to know about the other party to make correct decisions. Asymmetric information creates problems in the

financial system in two basic ways: before the transaction is entered into (adverse selection) and after the transaction is entered into (moral hazard). As an example, adverse selection in debt markets occurs when the potential borrowers who are the most likely to produce an undesirable (adverse) outcome (i.e. bad credit risks) are the ones most likely to be selected. Since adverse selection makes it more likely that loans might be allocated to bad credit risks, lenders may decide not to make any loans even though there are good credit risks in the market. Credit rationing may appear; some borrowers are denied loans even when they are willing to pay a higher interest rate. This occurs because individuals and firms with the riskiest investment projects are exactly those who are willing to pay the highest interest rates since if the high-risk investment succeeds, they will be the main beneficiaries. Thus a higher interest rate leads to even greater adverse selection. Moral hazard occurs after a loan is extended when the lender is subjected to the hazard that the borrower might engage in activities that are undesirable from the lender's point of view because they increase the probability of default. Bernanke and Gertler (1989) argue that moral hazard can also occur because high enforcement costs might make it too costly for the lender to prevent it even when there is complete information about the borrower's activities. One way that financial markets can solve the problems created by asymmetric information is the use of collateral, since it reduces the consequences of adverse selection or moral hazard because it reduces the lender's losses in the case of default. Net worth performs a similar role to collateral. If a firm has high net worth, then even if it defaults on its debt payments as a result of poor investments the lender can take title to the firm's net worth, sell it off and use the proceeds to recoup some of the losses from the loan.

Another way that asymmetric information problems can be solved is through the private production and sale of information that allows all the participants to have full information about the individuals of firms who need to finance their investment activities. Monitoring and enforcement of restrictive covenants is another method for reducing moral hazard. By monitoring a borrower's activities to see whether he is complying with the restrictive covenants and enforcing them if he is not, lenders can prevent borrowers from taking on risk at their expense. Banks help reduce the adverse selection problems in financial markets by becoming experts in the production of information about firms so that they can sort out good credit risks from bad ones. Then they can acquire funds from depositors and lend them to good firms.

Mishkin (1991) provides a definition of financial crisis using the asymmetric information framework: "A financial crisis is a disruption to financial markets in which adverse selection and moral hazard problems become much worse, so that financial markets are unable to efficiently channel funds to those who have the most productive investment opportunities". A financial crisis thus results in the inability of financial markets to allocate resources efficiently

and this in turn leads to a sharp contraction in economic activity. Under this definition there are five factors that can lead to substantial worsening of adverse selection and moral hazard in financial markets.

1. *Increases in real interest rates*: individuals and firms with the riskiest investment projects are exactly those who are willing to pay the highest interest rates. If market interest rates are driven up sufficiently, because of increased demand for credit or because of a decline in the money supply, good credit risks are less likely to want to borrow while bad credit risks are still willing to borrow. Because of the resulting increase in adverse selection, lenders will no longer want to make loans, possibly leading to a steep decline in lending which will lead to a substantial decline in new investment and thus in economic growth.

2. *Stock market declines*: a sharp decline in the stock market can increase adverse selection and moral hazard problems in financial markets because it leads to a large decline in the market value of firm's net worth. Mishkin (1991) notes that the decline in asset values could occur because of a rise in market interest rates that lowers the present discounted value of future income streams. The decline in net worth as a result of a stock market decline makes lender less willing to lend because the net worth of firms has a similar role to collateral, and when the value of collateral declines it provides less protection to lenders so that losses from loans are likely to be more severe.

The decline in corporate net worth as a result of a stock market decline increases moral hazard incentives for borrowing firms to make risky investments because these firms now have less to lose if their investments have already lost value. The resulting increase in moral hazard makes lending less attractive, providing another reason why a stock market decline and hence a decline in net worth leads to decreased lending and economic activity.

3. *Heightened uncertainty*: this makes it harder for lenders to screen out good from bad credit risks. The resulting inability of lenders to solve the adverse selection problem makes them less willing to lend, leading to a decline in investment and aggregate activity.

4. *Bank panics*: this is the classic scenario for a financial crisis. Banks perform an important financial intermediation role by engaging in information producing activities that facilitate productive investment for the economy. Thus, as described by Bernanke (1983), a financial crisis which results in a bank panic, reduces the amount of financial intermediation undertaken by banks, and will hence, lead to a decline in investment and aggregate economic activity.

The source of a bank panic is asymmetric information. In a panic, depositors, fearing for the safety of their deposits, withdraw them from the banking system, causing a contraction in loans and a multiple contraction in deposits, which then causes banks to fail. Asymmetric information is critical to this process because depositors rush to make withdrawals from solvent as well as insolvent banks since they cannot distinguish between them. Furthermore, if the banks opt for protecting themselves by increasing their reserves, then it is likely that the loans and deposits contract and promote other bank failures. The net result is that a bank panic reduces the funds supply for loans and the cost of financial intermediation rises causing a reduction in investment and a decline in aggregate economic activity. A bank panic can also have as a consequence an increase in interest rates because the panic results in decreasing liquidity since the supply of funds available to borrowers has been curtailed and through this channel, the bank panic leads to economic contraction.

5. *Unanticipated declines in the price level*: the decrease the net worth of the firms. Because debt payments are contractually fixed in nominal terms, an unanticipated decline in the price level raises the value of firms' liabilities in real terms, but does not raise the real value of firms' assets. The result is that the net worth in real terms declines. A sharp drop in the price level therefore causes a substantial decline in real net worth and an increase in adverse selection and moral hazard problems facing lenders. The resulting increase in adverse selection and agency problems causes a decline in investment and economic activity.

In the remainder of this section we discuss bank run models and herding behaviour models. Within the bank run discussion, we will discuss the Diamond and Dybvig model (1983), which is considered to be the seminal work in the bank run literature. Then we turn to the extension to this model made by Chen (1999) who introduces the possibility of herding behaviour (that is when an agent ignores its own information and act based on the observed actions of other agents). These two models provide analytic tools used in the literature on asymmetric information and herding behaviour. Additionally we discuss the general equilibrium model by Allen and Gale (1998) who address the problem of optimal monetary policy. These phenomena are extremely important in financial markets since prices are mainly driven by the incorporation information signals into the market, whether it is new information or noisy signals.

### 1.2.2.1. Liquidity or bank runs models

*“...I received this morning five millions, which I paid away; almost directly afterwards another demand for the same sum was presented to me; I put this creditor off till tomorrow, and I intend leaving today, to escape that tomorrow, which would be rather too unpleasant for me to endure.”*

Letter from banker Baron Danglars to his wife in *The Count of Monte Cristo* by Alexander Dumas, 1846

Depositors need to form expectations of what other depositors are doing: if other depositors run, then it is optimal for the rest to run too, if the amount of liquid assets available to the bank is less than demand deposits outstanding. In the formalisation of Diamond and Dybvig (1983), the trigger that determines whether each individual wants to consume now rather than later is a coordination mechanism when faced with the realisation of a shock. Even those wanting to consume later may want to withdraw if a bank run is likely to occur. Several variants and applications of this model have been developed. Sachs (1984) shows that if international debt to a large number of domestic bank creditors is within a certain range relative to a country's income, then panic can occur. Sachs, Tornell and Velasco (1996) model the Mexican crisis as a self-fulfilling panic in a macroeconomic feedback model while Radelet and Sachs (1998a) argue that a run by international creditors played a role in the Asian crisis.

As Masson (2001) argues, such liquidity models rely on the existence of many uncoordinated agents, in direct contrast to macroeconomic feedback models. Rogoff, (1999) argues that a frequent criticism is that it depends on sequential servicing of withdrawals, and this implies that it would be easy to eliminate runs by suspending convertibility, this argument however may be true for speculative attacks on a fixed rate (if we ignore the possibility of a black market appearing) but not for a financial crisis where the main debtors are firms. Another objection is that these models lack a triggering mechanism and rely on a sunspot pattern.

We have to be aware that these models have been only used in bank runs and the crises we are interested in have not been bank run driven. Contracting of direct debt by firms has been one of the problems that the Mexican and the Asian crises share. Gavito, Silva and Zamarripa (1997) argue that the Mexican banking crisis only happened after the currency crisis and the bond market collapse and was the result of the high rates of non performing loans that endangered the financial position the banks and lead them to bankruptcy while forcing the intervention of the government to bail out the failing banks. In the case of the Asian crisis,

Corsetti et al. (1998) point out that the *chaebols*<sup>10</sup> were bankrupt before the currency attack and this was one of the main reasons of it, the inability of the government to bail out the firms.

The role of banks is to transform illiquid technologies into liquid payoffs, and also to provide liquidity insurance as the Diamond and Dybvig (1983) model shows. In this model, banks offer demand deposits to match the agents' liquidity needs with projects' maturities. However, these demand deposits open up the possibility of bank runs. Bank runs and bank panics are special forms of herding behaviour. A bank run occurs when the deposit holders of a bank suddenly withdraw their money. If a run on a single bank spreads over to other banks, it can cause a panic in the whole banking system. Although withdrawals by deposit holders occur sequentially in reality, the literature typically models bank runs as a simultaneous move game. During a bank run, depositors rush to withdraw their deposits because they expect the bank to fail. These sudden withdrawals may force the bank to liquidate its assets if capital reserves are not enough to face the withdrawals. If the panic is widespread and other banks face the same loss of confidence then the banking system and the monetary system may be severely disrupted inducing a fall in production.

We now turn to two asymmetric information models that study the relationship between banks and depositors. Asymmetric information creates conditions that can lead depositors to panic and this may trigger a bank run. The first model we discuss is the Diamond-Dybvig (1983) that is considered to be the seminal paper that addressed this issue. The other is Chen's (1999) who introduce sequential information disclosure about the financial situation of banks. This may cause a herding behaviour in agents and a crisis due to bad expectations of banks' performance. Additionally, we discuss the Allen and Gale (1998) model which addresses the optimal monetary policy after a crisis.

### ***Diamond-Dybvig (1983)***

The motivation of this model is that bank runs are thought to be a common feature of extreme crises along monetary history. It tries to explain why during a bank run depositors expect the bank to fail and how these expectations give them incentives to withdraw their deposits. There are three main findings in the model. First, banks issuing demand deposits can improve on a competitive market by providing best risk sharing among people who need to consume at different random times. Second, the demand deposit contract providing this improvement has an undesirable equilibrium (i.e. a bank run) in which all depositors panic and withdraw immediately, including even those who would prefer to leave their deposits in if they

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<sup>10</sup> Economic conglomerates in Thailand.

were not concerned about the bank failing. Third, bank runs cause real economic problems because even sound banks can fail, causing the recall of loans and the termination of productive investment. The model also offers a framework in which mechanisms as suspension of convertibility of deposits and the existence of a lender of last resort are fully justified.

Banks are able to transform illiquid assets by offering liabilities with a different, smoother pattern of returns than the illiquid assets offer. These contracts have multiple equilibria. If confidence is maintained, there can be efficient risk sharing, because in that equilibrium, a withdrawal will indicate that a depositor should withdraw under optimal risk sharing. If agents panic there is a bank run and incentives are distorted. In that equilibrium, everybody rushes in to withdraw their deposits before the bank gives out all of its assets. The bank must liquidate all its assets, even if not all depositors withdraw, because liquidated assets are sold at a loss.

The model has three periods and a single homogenous good. All investors receive an initial endowment of 1 unit. The productive technology yields a positive return  $R$  if the investment is held to maturity, if it is interrupted before then the investor only gets back the initial investment. All consumers are identical at the initial period and each one faces a risk of requiring liquidity the next period when they will learn if they can keep their investment or if they will need to withdraw. Agents do not store goods at the initial period because the productive technology has a positive expected return while storage has zero return. If an investor faces a liquidity shock, then he will withdraw and consume his initial endowment and hence, productive investment is destroyed. If he can keep the investment to maturity he will consume  $R$  at the third period and nothing at the other period 1. Therefore, the pattern of consumption  $\{c_1, c_2\}$  for each consumer will be  $\{1, 0\}$  when withdrawing early and  $\{0, R\}$  for late withdrawals.

<b>Timetable</b>	
<i>Date</i>	<i>Events</i>
Date 0	Depositors decide to deposit. Banks invest the proceeds in long-term projects.
Date 1	1. Liquidity shocks are revealed. Depositors in need of liquidity withdraw. 2. Negative expectations about the bank's soundness. Late consumers may decide to withdraw
Date 2	Investment projects mature. If the bank is still open, late consumers who have not yet withdrawn withdraw.

Table 3: Diamond and Dybvig model (1983) timeline

The demand deposit contract gives each agent that withdraws at date 1 a fixed claim of  $r_1$  per unit deposited at date 0. There is no priority in the order of withdrawal; it is done on a first-come, first-served basis. Agents not withdrawing in period 1 get a pro rata share of the bank's assets in period 2. Let  $V_1$  be the period 1 payoff per unit deposit withdrawn at  $T=1$  and  $V_2$  the period 2 payoffs per unit deposit not withdraw at date 1. Therefore, we can characterise each payoff as:



$$V_1(f_j, r_1) = \begin{cases} r_1 & \text{if } f_j < r_1^{-1} \\ 0 & \text{if } f_j \geq r_1^{-1} \end{cases}$$

and

$$V_2(f, r_1) = \max \{R(1 - r_1 f) / (1 - f), 0\}$$

Where  $f_j$  is the number of withdrawers' deposits serviced before agent  $j$  as a fraction of total demand deposits;  $f$  is the total number of demand deposits withdrawn. Hence, at date 1 the payoff will be the agreed payment of  $r_1$  if the number of withdrawers is less than the available assets that can be paid.

The demand deposit contract can achieve the full-information optimal risk sharing as an equilibrium. This happens at the equilibrium when the fixed payment per dollar of deposits withdrawn at  $T=1$  is equal to the optimal consumption of a type 1 agent given full information that is  $r_1=c_1$ . If this contract is in place, type 1 agents will withdraw at date 1 and type 2 agents will wait till date 2. However, there can be equilibrium with a bank run, where all agents will find it optimal to withdraw early. This is because the face value of deposits is larger than the liquidation value of the bank's assets.

The capability of transformation of illiquid assets into liquid assets is both at the core of the problem of bank runs at the same time that it is for the liquidity service that banks provide. For all  $r_1 > 1$ , runs are an equilibrium; if  $r_1 = 1$  a bank would not be susceptible to runs because  $V_1(f_j, 1) < V_2(f, 1)$  for all values of  $0 \leq f_j \leq f$ ; but if  $r_1 = 1$ , the bank is mimicking direct holding of the assets and is not an improvement on simple competitive claims markets<sup>11</sup>. Therefore, to improve this allocation the bank has to assume the risk of a run. The trigger of a run can depend of some commonly observed random variable in the economy, bad earnings report, a commonly observed run on another bank. According to Diamond and Dybvig (1983) once deposits are made, anything that can be perceived as a danger of a run, will lead to a run; hence, maintaining confidence is a main worry of banks with pure demand deposits.

### ***Chen (1999)***

This model is an extension of the Diamond and Dybvig (1983) discussed above. Chen (1999) proposes that both the first-come, first-served rule and information externalities are important in causing contagious bank runs. The underlying intuition of the model is as follows.

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<sup>11</sup> This point is discussed in depth in chapter 4.

At a bank some depositors may be better informed than others about the value of bank assets. The informed depositors enjoy an advantage over the uninformed ones by being able to withdraw earlier when they realise that the bank cannot fully repay all depositors. Facing this informational disadvantage, the uninformed depositors may have an incentive to respond to other sources of information before the value of bank assets is revealed to all investors. Previous failures of other banks can be such information source. If banks' returns are positively correlated, a high bank failure rate implies that returns of the remaining banks are likely to be low. Although this information is likely to be very noisy, the uninformed depositors may still respond to it and withdraw. The incentives to disregard own information and respond to the actions of other participants give way to herding behaviour and bank runs become contagious. In Chari and Jagannathan (1988) a panic run is the phenomenon that uninformed depositors misinterpret liquidity withdrawal shocks as withdrawals caused by pessimistic information about bank assets. But while they define panic as the ex-post mistake depositors make during their information updating process, Chen (1999) defines panic as the depositors response to early noisy information because of the payoff externality imposed in the deposit contract. He calls contagious runs "panic" for two reasons: i) during contagious runs, depositors are compelled to respond to early information; and, ii) because a contagious run is based on noisier information, it incurs higher social costs than a run triggered by more precise information about banks. This model shares a common feature with Diamond and Dybvig (1983) in that the payoff externality is important in causing inefficient bank runs. In contrast, the results do not display multiple equilibria. What is emphasized is how the negative payoff externality affects the way depositors respond to information, not how it creates multiple equilibria.

As in Diamond and Dybvig (1983), this is a three date model ( $T=0, 1, 2$ ). There are  $N$  banks (in the Diamond and Dybvig (1983) model the analysis does not depend on the number of banks) and numerous depositors. The initial endowment is again one unit and investors can deposit at the bank or store it. Liquidity shocks are again present in this model but the number of withdrawals is known from date 0. Under this assumption, investors facing liquidity shocks will always withdraw at date 1 and the others will wait till date 2. Banks do not have capital; they collect deposits from depositors to make investments in long term projects with returns that depend on the realised state of nature at date 2. Each state of nature has a probability and they are mutually exclusive. After a bank invests in a long term project at date 0, at date 1 the bankers receive perfect information about the outcome of the investment. At each bank a fraction of depositors receive the same information, these are the informed depositors and they learn at date 0 whether or not they are going to have access to bank information. Informed and uninformed depositors have the same probability of facing the liquidity shock at date 1.

In order to introduce the possibility of herding behaviour, early at date 1 a fraction  $N_1$  of the  $N$  banks will be the first to receive the information and the remaining  $N-N_1$  will get their information later but during the same period. Information revelation may result in a number  $K_1$  of bank failures among the first  $N_1$  banks. An individual bank faces failure when informed investors learn that the bad state of nature is the one that is going to happen, therefore they withdraw alongside with the investors with liquidity shocks. Hence, informational withdrawals cannot be distinguished from liquidity reasons. When uninformed agents observe a larger than expected number of withdrawals then they receive the signal that the outcome is likely to be bad and they may decide to withdraw triggering a bank run on the individual institution.

The number of bankrupting banks among the first  $N_1$  is public information and is available to all participants at the same time. A large number of failures imply that the prospects of the banking industry are likely to be pessimistic. Investors in the remaining  $N- N_1$  update the probability that the prospects of the banking industry are unfavourable given  $K_1$ . If this probability exceeds a threshold value, then investors in the remaining  $N- N_1$  banks will not have incentives to wait for the disclosure of the information of their own banks. Hence, they will respond to the information from the  $N_1$  banks in a herding behaviour fashion.

<b>Timeline</b>	
<i>Date</i>	<i>Events</i>
Date 0	Depositors decide to deposit. Banks invest the proceeds in long-term projects.
Date 1	<ol style="list-style-type: none"> <li>1. Information and liquidity shocks of the first <math>N_1</math> banks are revealed. Depositors at these banks then decide whether to withdraw.</li> <li>2. Depositors at the remaining <math>N- N_1</math> banks observe <math>K_1</math> which is the number of failures among the first <math>N_1</math> banks. They update the prospects of the banking industry and decide whether to withdraw or not.</li> <li>3. Information and liquidity shocks in the remaining <math>N- N_1</math> banks are revealed. If a panic run has not yet occurred, depositors at these banks then decide whether to withdraw or not.</li> </ol>
Date 2	Investment projects mature. If a bank is still open, its depositors who have not yet withdrawn withdraw

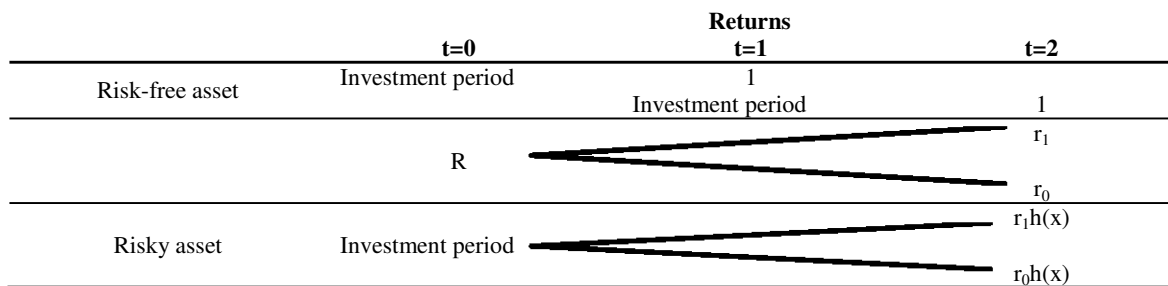
Table 4: Chen model (1999) timeline

This model introduces herding behaviour as a rationale for contagious bank runs. It explains better the possible causes of a bank run which can be identified with underlying weak fundamentals of the economy. However, it still focuses on the bank-depositor relationship of the economy and not in other aspects of the borrower-lender relationship in a broader debt market. In general bank run literature does not take into account diversification mechanisms and sets aside a portfolio approach which is necessary to fully understand the decisions of institutional investors that in a crisis are far more important than common depositors with limited access to financial markets.

**Allen and Gale (1998)**

In Allen and Gale (1998), financial crises can improve risk sharing but they also involve deadweight costs when investment projects are prematurely liquidated. A central bank can avoid these costs by implementing an appropriate monetary policy. We review the open economy version of Allen and Gale (2000) which derives the optimal response of the monetary authority that faces the possibility of a crisis.

There are three dates in this model,  $t = \{0, 1, 2\}$ . At each date, there is a single good for consumption or investment. There are two kinds of assets, a risk-free asset and a risky one. If one unit of the risk-free asset is invested at date  $t$ , it yields one unit at date  $t+1$  for  $t=0, 1$ . The risky asset takes two periods to mature; if  $x$  units are invested then the return is  $Rh(x)$ , where  $h(x)$  is a neoclassical production function with decreasing returns to scale. The random variable  $R$  has realisation  $r = \{r_0, r_1\}$  where  $0 < r_0 < r_1 < \infty$ .



At date 1, agents observe a signal (such as a leading indicator) that predicts perfectly the value of  $r$  at date 2. Also, each consumer receives a time-preference shock at date 1, some become early consumers and the remainders become late consumers. There are equal numbers of early and late consumers and each consumer has an equal chance of belonging to each group. The size of each group is normalised to one. The initial endowment for each agent is 2. Thus the agent's utility function can be written as:

$$U(c_1, c_2) = u(c_1) + u(c_2) \tag{1.3}$$

**Optimal solution for a closed economy**

Ex-ante, a central planner will maximise the ex-ante expected utility to obtain the optimal portfolio of the risky ( $x$ ) and risk-free asset ( $y$ ). Let  $c_t(r)$  denote the consumption at date  $t=1, 2$  when  $r$  is the realisation of the risky return. Therefore, the planner's problem is:

$$\begin{aligned} & \max E_{\mathbf{R}} [u(c_1(r)) + u(c_2(r))] \\ \text{s.t. } & x + y \leq 2 && \text{Budget constraint at date 0, portfolio equal or less to the initial endowment} \\ & c_1(r) \leq y && \text{Budget constraint at date 1, consumption less or equal to risk free asset holdings} \\ & c_2(r) \leq rh(x) + y - c_1(r) && \text{Budget constraint at date 2. consumption less or equal to risky asset return} \\ & && \text{minus consumption of the risk-free asset at date 1} \\ & c_1(r) \leq c_2(r) && \text{Incentive constraint so that late consumers wait to date 2} \end{aligned}$$

Solving this simple problem yields the optimal solution for the closed economy:

$$c_1(r) = c_2(r) = \frac{rh(x) + y}{2} \quad \text{if } y \geq rh(x) \quad (1.4)$$

In other words, consumption in both periods will be the same if the return of the risky asset is less than holding the risk free asset. Another possibility is that if the return of the risky asset is higher than holding the risk free asset consumption on date 2 will be higher.

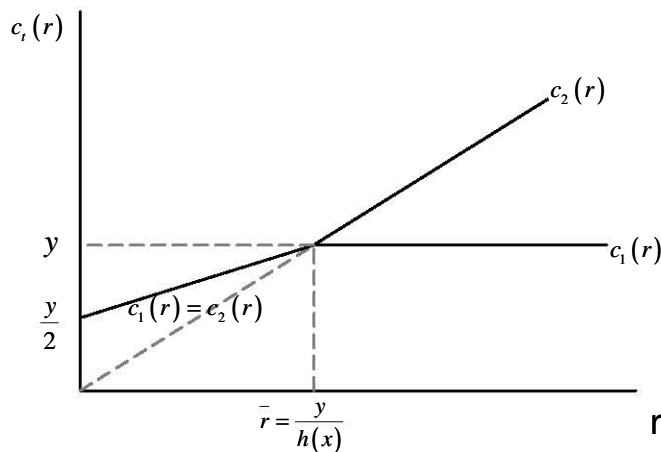


Diagram 5: Allen and Gale model (1998) for a closed economy

In this simple stock market there is no insurance against the intertemporal preference shock. If an agent invests in the risk-free asset to provide consumption at date 1, then he will miss the higher returns from the risky asset. If he invests in the risky asset, there is the risk of having to sell the asset at a low price to provide consumption at date 1.

Risk sharing can be achieved through a competitive banking system in which individual banks can purchase assets to provide for the future consumption of depositors. As in the Diamond-Dybvig (1983) model banks can take deposits from agents at date 0 and offer them a deposit contract specified in real terms promising  $d_1 \geq 0$  units of consumption at date 1 and  $d_2 \geq 0$  units at date 2. Deposit contracts are not explicitly contingent on the returns to the risky

asset in order to allow for the possibility of a bank run. Allen and Gale (1998) demonstrate that these contracts are *de facto* contingent of  $r$  if there is no way to liquidate the risky asset with low returns. Given the limited amount of liquidity available, the amount each agent receives is smaller the greater the number of early withdrawals. If the risky asset can be liquidated then it can be modelled with liquidation costs ( $0 < \gamma < 1$ ) proportional to the return at maturity therefore the return at date 1 when liquidated can be expressed as  $\gamma rh(x)$ . Bankruptcy rules of the bank are as follows:

Bank	Date 1	Date 2
Can pay $d_1$	Must pay $d_1$ even if it has to liquidate holdings of the risky asset as a loss	Assets remaining at date 2 are paid to the remaining depositors
Cannot pay $d_1$	Must liquidate all its assets and pay out the liquidated value.	Cannot pay to any depositors the result is a bank run at date 1

This implies that there is a critical value of  $r$  ( $r^*$ ) to avoid a run. In order to avoid a run it should be possible to pay  $d_1 = d_2 = d$  units of consumption. Because of the constraint  $u(c_1(r)) + u(c_2(r)) > 2u\left(\frac{y + \gamma rh(x)}{2}\right)$  it is not optimal for the bank to pay  $d > y$ . It would be better for the bank to increase  $y$  and avoid liquidating the risk asset. Thus, in equilibrium  $d \leq y$  and liquidation occurs only when there is a run. Consumption in both periods will be the same if the return of the risky asset is less than holding the risk free asset. Other possibility is that if the return of the risky asset is higher than holding the risk free asset then consumption in date 2 will be higher.

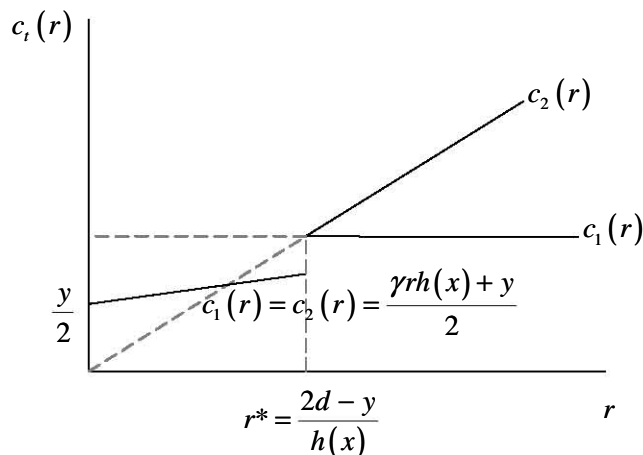


Diagram 6: Allen and Gale (1998) closed economy with a central bank

Compared with the case without a banking system, the existence of banks that face costly liquidation is inefficient. The inefficiency of the equilibrium with a banking system arises because of the costly liquidation of the risky asset at date 1. This can be avoided if the deposit

contract is specified in nominal terms and the central bank adopts a monetary policy that makes the price level contingent on the state of nature. Now we have to assume that deposit contracts promise a constant amount of the domestic currency in every state of nature. In other words, the deposit contract is non-contingent in nominal terms and contingent in real terms. The central bank can introduce the appropriate variation in the price level so banks can avoid costly bank runs and achieve efficient risk sharing.

A deposit contract promises the depositor  $D_1$  units of money if he withdraws at period 1 and  $D_2$  if withdrawal is at period 2. The price level at date  $t$  is contingent on the risky asset return, hence  $p_t(r)$ , an arbitrage condition is  $p_1(r) = p_2(r) = p(r)$ . If we take the solution to the planner's problem, consumption must be equal to the real value of the payment:

$$\frac{D}{p(r)} = c_1(r) \quad (1.5)$$

This ensures that the optimal allocation is achieved and aligns the planner's problem with the bank's solution. This implies that the illiquidity of low returns can be offset by increasing the monetary supply and increasing the level of prices diluting the real debt.

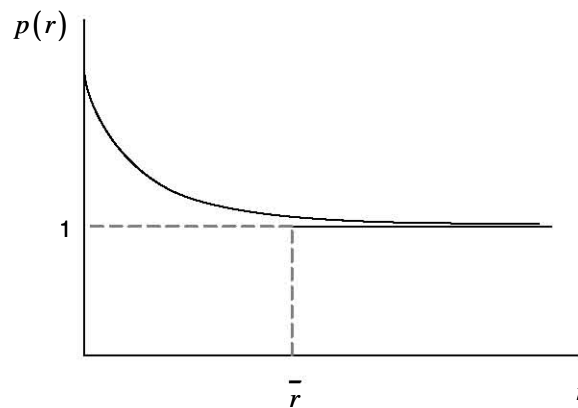


Diagram 7: Allen and Gale (1998) price level in a closed economy

### Optimal solution for an open economy

Allen and Gale (2000) introduce an international bond market to open the economy. The assumptions are

- Small economy relative to the rest of the world.
- The value of foreign currency is fixed in terms of consumption.
- Interest rates are fixed.

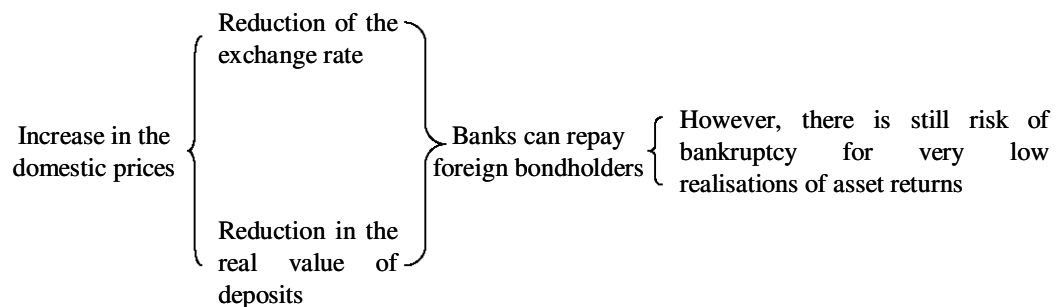
- One unit of the foreign currency is normalised so that it purchases one unit of the consumption good.
- Short-term bonds in the international market which are now the risk-free asset.
- The risk-free return on short-term bonds is fixed on  $\rho \geq 1$ .
- The risk of default is reflected on the face value of the bond, therefore all changes are on the price not on the expected return.
- The exchange rate is controlled.

The nominal interest rate interest rate is set to 0. Arbitrage between foreign-currency bonds and domestic currency ensures that  $p_1(r) = \rho p_2(r)$ . Prices at date 2 are normalised such as

$$p_2(r) \equiv \frac{p_1(r)}{\rho} \text{ and we can set } p_1(r) = p(r).$$

Access to international markets is valuable for three reasons: i) because the return on bonds is lower than the expected return on the risky asset, banks can make a profit by borrowing short in the international market and investing the proceeds in the risky asset at date 0; ii) second, when  $r$  is high liquidity can be obtained for early consumers by borrowing in the international market at date 1; and, iii) third, it may be possible to transfer the small country's asset risk to lenders in the international bond market.

We turn directly to the case where bank deposits are denominated in terms of the domestic currency. Domestic depositors are holding domestic currency debt, since a bank deposit promises a fixed amount of the domestic currency at each date. International bondholders are holding foreign currency denominated debt. In this case, the same as in the closed economy, the central bank can alter the real value of the domestic-currency debt, but additionally can alter indirectly the returns received by international bondholders.





Banks now face two types of creditors in the event of bankruptcy, foreigners who have claims over international reserves and domestic depositors who hold claims in the domestic currency. Let  $q$  denote the price of one domestic currency bond and  $b$  the amount to be repaid at date 1. The incentive constraint is now  $c_1(r) \leq \frac{c_2(r)}{\rho}$ .

Let's assume that in case of bankruptcy, foreign debt holders are senior to domestic ones. The bank will go bankrupt when the output available is insufficient to pay the foreign debt. The foreign bondholder obtains his opportunity cost, which is the sum of the repayment with early liquidation at a loss plus the complete repayment. For  $r < r^*$  foreign bond holders receive everything at date 1 and domestic depositors receive nothing. For  $r \geq r^*$  the price level is given by the ratio of nominal claims to output when the incentive constraint binds and the central bank allows risk sharing between the early and late consumers for all values of  $r$  as in the closed economy case. However, there is no risk sharing with the international bond market, unless the economy is dollarised and the central bank loses independence.

### **1.2.2.2. Other approaches.**

#### ***Herding behaviour***

The process of inferring information that feeds into expectations may lead to a mismatch in the relationship between observed fundamentals and the prevailing equilibrium. Banerjee, (1992), Bikchandani et al. (1992), Caplin and Leahy (1994), Lee (1997) and Chari and Kehoe (1998) explain how fads and herding behaviour among investors can be rational. The main idea behind these models is that if each individual investor has some private information. Then by observing the actions of others they will infer the information held by them, as there is no way to share information, and this can make rational the imitational behaviour. Depending on the sequence of the signals received, the equilibrium asset price can take one of several values. These signals can provoke a cascade or avalanche of sell orders and a large change of price. All these models try to explain crashes in the stock market rather than in the debt market so they are not used to explain economic meltdowns such as the ones that happened in emerging economies.

A stock market crash is a significant drop in stock prices and it may occur when there are no major news events. According to Brunnermeier (2001), theoretical models that explain crashes can be grouped into four categories of causes. Each of these models can explain crashes even when all agents act rationally. However they may differ on their prediction of the price path after the stock market crash. Depending on the model, the crash can be a correction and the

stock market can remain low for a substantial amount of time or it can immediately bounce back.

- *Liquidity shortage models*: the market dries up when nobody is willing to buy stocks at a certain point in time. This can be due to unexpected selling pressure by program traders. These sales can be mistakenly interpreted as sales driven by bad news. This leads to a large price decline. This type of crashes is of a temporary nature. In other words, one would expect a fast recovery of the stock markets.
- *Sunspot models*: a sunspot is an extrinsic event, in other words, is a public announcement that contains no information about the underlying economy. However, they affect economic decisions since agents use them as a coordination device and, thus, they affect agent's beliefs. The economy may have multiple equilibria and the appearance of a sunspot might indicate a shift from the high asset price equilibrium to equilibrium with a lower one.
- *Bursting bubbles*: a crash that may occur even when the fundamental value of the asset does not change. In this setting there is an excessive asset price increase prior to the crash. The asset price exceeds its fundamental value and all market participants know this, yet each trader thinks that the other participants do not know that the asset is overpriced. Therefore, each trader believes that it is possible to sell the risky asset at a higher price to somebody else. At some point the bubble has to burst and the prices plummet. This type of crash is a correction and prices would not be expected to rebound after the crash. Bubbles are hard to explain without introducing asymmetric information or bounded rational behaviour.
- *Lumpy information aggregation*: a sharp price drop can also occur even when no bubble exists. In other words, it is not mutual knowledge that the asset price is too high. Traders do not know that the asset is overpriced but an additional price observation combined with the knowledge of the past price path makes them suddenly aware of the mispricing. These models are closely related to herding models. The difference with pure herding models is that herding is not only due to informational externalities. In most settings, the predecessor's action causes both information and payoff externalities. A stock market crash caused by lumpy informational aggregation is often preceded by a steady increase in prices. The crash itself corrects this mispricing and hence, one does not expect a fast recovery of the stock market.

### ***Crashes in competitive rational expectations equilibrium (REE) models***

In a competitive REE model, many traders simultaneously submit orders. They take prices as given and can trade any quantity of shares in each trading round. In this setting, crashes can occur because of temporary liquidity shortages, multiple equilibria due to portfolio insurance trading and sudden information revelation by prices.

Grossman (1988) highlights the informational difference between traded options and synthesized options. Its main conclusion is that derivative securities are not redundant, even when their payoffs can be replicated with dynamic trading strategies. Large price movements are due to a lack of liquidity provision by market timers<sup>12</sup>, which underestimate the extent of sales due to portfolio insurance trading. Contrary to the experience of recent shocks, Grossman's model also predicts that the price would rebound immediately after the temporary liquidity shortage is overcome.

In Genotte and Leland (1990) the market crashes because some market participants incorrectly interpret the price drop as a bad signal about the fundamental value of the stock. In this model, traders hold asymmetric information about the value of the stock and, thus, the price of the underlying stock is also a signal about a fundamental liquidation value. Consequently, even these other market participants start selling their shares. Combining asymmetric information about the fundamental value of the stock with uncertainty about the extent of dynamic hedging strategies can lead to a larger decline in price at the end of the period. The reason is that the traders wrongly attribute the price drop to a low fundamental value rather than to liquidity shortage. These authors employ a static model even though stock market crashes or price changes occur over time. As the parameters change over time the price equilibrium changes, this is the dynamic component of this model. A stock market crash occurs if a small change in the underlying information parameter causes a discontinuous drop in the equilibrium price. This explanation of a stock market crash provides a different answer to the question whether the market will bounce back after the crash or not. The price can remain at this lower level even when the supply returns to its old level. The results may change in a fully dynamic model since agents could anticipate the effects of parameter changes and incorporate them into their strategies and in consequence smooth the large variations in the price.

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<sup>12</sup> These are less-than-average risk adverse investors who are willing to bear part of the risk and provide liquidity at a much lower expected rate of return. These market timers can only provide liquidity to the extent that they have not committed their funds in other investment projects in  $t=1$  (Grossman, 1988).

### ***Crashes in sequential trade models***

Sequential trade models are more tractable than REE models and allow focusing on the dynamic aspects of crashes. The economic insights of the herding literature provide a basis for understanding stock market crashes. An informational cascade or a partial informational cascade can arise in trading models.

Avery and Zemsky (1998) illustrate a sequential trade model with  $\mu$  of informed traders and  $(1-\mu)$  uninformed liquidity traders. Liquidity traders buy, sell, or stay inactive with equal probability. Each informed trader receives a noisy individual signal about the value of the stock  $v \in \{0, 1\}$ . In a sequential trade model, predecessors' action not only causes a positive informational externality but also a negative payoff externality. The price changes since the market maker also learns from the predecessor's trade. Hence, he adjusts the bid and ask schedule accordingly. This action changes the payoff structure for all successors. They show that the price adjusts in such a way that it offsets the incentive to herd. This is because the market maker and the insiders learn at the same rate from past trading rounds. Therefore herding will not occur given pure value uncertainty. Indeed, informational cascades can be ruled out even for information structures which lead to herding behaviour since the authors assume that there is always a minimal amount of useful information. Hence, the price converges to the true asset value and the price process exhibits no excess volatility regardless of the assumed signal structure, due to price process' martingale<sup>13</sup> property. This implies that large mispricing followed by a stock market crash can occur only with a very low probability. A more complex information structure is needed to stimulate crashes.

The setting that Avery and Zemsky (1998) consider has two types of informed traders in order to explain large mispricing. One group of traders receives their signals with low precision  $q_L$ , whereas the other receives them with high precision  $q_H=1$ , that is, they receive a perfect signal. The proportion of insiders with perfect signals is either high or low and is not known to the market. This composition structure makes it difficult for the market maker to differentiate between a market composed of well informed traders following their perfect signal from one with poorly informed who herd. In both situations a whole chain of informed traders follows the same trade. If the prior probability is very low that poorly informed traders are operating in the market, a chain of buy orders make the market maker think that a large fraction of traders is perfectly informed. Thus he increases the price. If the unlikely event occurs in which only poorly informed traders herd, the asset price may exceed its liquidation value  $v$ . The market

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<sup>13</sup> Consider a filtered probability space together with an adapted stochastic process  $Z = \{Z_t; t=0, 1, 2, \dots, T\}$ . The process  $Z$  is said to be a martingale if  $E[Z_{t+s} | \mathcal{F}_t] = Z_t$  all  $s, t \geq 0$

maker can infer only after many trading rounds that the uninformed traders have herded in which case the asset price crashes.

### **1.3. Currency and financial crises: Forecasting the weather**

*What does all this mean? Why did it happen?  
...What were the causes of these events? ... These  
are the instinctive, plain, and most legitimate  
questions humanity asks itself.*

Second Epilogue in War and Peace by Leo Tolstoy,  
1869

*I keep the subject of my inquiry constantly before  
me, and wait till the dawning opens gradually, little  
by little, into a full and clear light.*

Sir Isaac Newton (1642-1727)

*Prediction is very difficult, especially about the  
future*

Niels Bohr (1885-1962)

The understanding of financial crises is important not only from an “academic” point of view. It is a phenomenon that has real consequences and important policy implications. During the 1980’s several countries found themselves involved in currency crises which were commonly explained by fiscal and monetary imbalances. However, during the 1990’s countries with economic reforms and financial liberalisation processes faced sudden and unexpected collapses in their financial systems, currency crises and severe episodes of economic contraction. Thus, the understanding of the causes and risk factors that increased the vulnerability of these economies will allow not only to have a wider knowledge but to implement effective economic policies that may allow avoiding or preventing the occurrence of this kind of crises.

When explaining ‘financial’ crises the majority of previous studies refers to currency crises and banking crises as occurring together and disregards their sequence and the possible channels of transmission. Few have addressed the occurrence of a ‘financial’ crisis as a phenomenon that shocks the financial markets (either in stock or debt markets, the banking system or speculation in other asset markets such as real estate). We will discuss some of the most recent studies that deal specifically with shocks to the financial markets and that can be applicable to recent crises in emerging economies. These studies analyse more in depth the behaviour of investors and the consequences that shocks to financial markets may have over macroeconomic conditions and *vice versa*. However, these studies focus on the role and impact that macroeconomic variables have in investors’ decisions rather than analyse the microeconomic foundations of these decisions; in other words there is still a gap to be filled between financial markets’

microstructure and the aggregate performance of the economy. In this section we discuss some of the most representative empirical studies regarding financial and currency crises; these studies range from those proposing and testing new hypothesis to explain the causes of financial and currency crises to those that try to identify indicators that could allow the prediction of these crises. Eichengreen and Rose (1999) argue that while the number of theoretical models of the causes and consequences of banking and financial crises is considerable, systematic empirical work has been scarce. Most of the empirical work has focused in the search to identify which variables may be relevant for explaining the onset of a crisis and to identify which of those may be relevant and reliable predictors; on the other hand, work has been seldom done on testing the performance and predictive abilities of the structural models available. Among the issues discussed are: i) the definition of “crisis” that each approach adopts; ii) the variables included in order to explain a crisis (regardless the definition) and the methodology used to analyse the interaction between variables; iii) the results obtained; and, iv) the problems faced by each approach.

### **1.3.1. Financial market structure approach**

Within this approach, there is a clear distinction between types of crises; the economy may face a currency crisis, a financial crisis or both at the same time. This distinction has acquired a great relevance since the 1990’s currency crises have been paired with severe disruptions of the normal functioning of the financial system. These disruptions may appear in several fashions, as a collapse in the price of assets (such as real estate and equity holdings), a collapse of the payment system (banking crises due to debtors’ defaults) or a collapse in bond markets due to the perception that liabilities (private or public) may not be covered. When doing this distinction, a currency crisis is defined as it has been done to define currency crises in the past, an attack on the domestic currency exchange rate and loss of reserves. However, the cause of this loss of confidence in the domestic currency is no longer an imbalance on public finances, but the likelihood or actual occurrence of a financial crisis. In this section we first present the theoretical background that these empirical studies propose. Secondly, we present some of the results obtained; and, finally we discuss some of the advantages and disadvantages of this studies.

Kletzer and Chinn (2000) and Gourinchas, Valdés and Landerretche (2001) focus on the role played by the banking system in recent financial crises. Both papers highlight the impact that capital inflows have had in the allocation of credit; they both note that these pre-crisis inflows have implied a growth in loans to the private sector and because there are implicit

guarantees given by the government in case of default, sovereign debt growth liabilities rise accordingly. With a similar approach, Aizenman and Marion (2001) examine how increased uncertainty about an emerging market's debt overhang might affect the willingness of foreign investors to supply new international credit. It can contribute to the liquidity shortage often experienced by emerging markets during a crisis. Chinn, Dooley and Shreshta (1999) argue that there must be three "insurance fundamentals" present in order to generate a private capital inflow followed by a speculative attack: i) a credit constrained government must have positive net assets; ii) the government's commitment to exhaust these net reserves to pay off an implicit or explicit insurance contract must be credible; and, iii) private investors must have access to transactions that produce insured losses. These three factors must be present to trigger a capital inflow and the subsequent attack on the currency.

Regarding the definition of crises, Eichengreen and Rose (1999) make a clear distinction between a currency crisis and a financial crisis. However, they only focus in banking crises and do not analyse the possible problems and shocks that happen in other financial markets. Accordingly, Gourinchas, et al. (2001) argue that lending booms are the cornerstone of numerous recent theories of financial and banking crises. These booms may arise following a poorly regulated financial liberalisation, a surge in capital inflow driven by external factors or a terms-of-trade shock that boosts domestic investment or consumption or both. They may also be the consequence of a macroeconomic stabilisation programme. During a lending boom, credit to the private sector rises quickly. Leverage increases and financing is extended to projects with low or negative net present value, either because monitoring becomes more difficult or because domestic borrowers' net worth increases. Another risk factor is introduced by the existence of bailout-guaranties, either explicit or implicit, that induce private borrowers and lenders to develop and carry over riskier projects. The authors examine the case of Latin America for two reasons: first, the region experienced a relatively large number of lending booms especially in the 1990's; second, a number of Latin American countries experienced exchange-rate stabilisation programs throughout the sample period.

As Gourinchas, et al. (2001) found, the link between lending booms and currency crises is very clear in the case of Latin America but it does not address possible crises in over-the-counter debt markets. This is especially true in the East Asian crisis where the firms were the ones that suffered liquidity constraints to meet their liabilities and the first attempts to bail them out by the government failed leading to the sudden reversal of capital flows and devaluation of the currencies. In the same sense, Kletzer and Chinn (2000) propose a theoretical model of the dynamics of bank lending, domestic production and the accumulation of foreign currency liabilities by domestic financial intermediaries that ultimately leads to a financial crisis. The

equilibrium for the model economy predicts twin banking and currency crises that end a period of high gross domestic output growth and inflows of foreign capital. In this model, the loan portfolio choices of banks are subject to adverse selection in the presence of government deposit insurance for domestic savers and government guarantees of foreign currency loans for foreign creditors with insufficient monitoring. These features allow the banking crisis to be located in the asset side of the balance sheet rather than on the liability side (i.e. traditional models of bank runs by depositors). The empirical analysis on South East Asian countries that these authors carry out provides support for the implications of the models although formal hypothesis testing was not possible. In particular, countries that underwent a crisis appear to experience higher rates of international capital inflows and domestic bank intermediation. External debt has played a key role in crises in countries that have been experiencing historically high rates of economic growth before the crisis

Regarding the surges of inflows followed by financial crises Chinn, Dooley and Shreshta (1999) claim that the most obvious explanation is to be found in the behaviour due to changes in expectations of investors. This is compatible with Aizenman and Marion's (2001) study of the events in South East Asia during the 1997 crisis where they compare reported external debt levels before the crisis with higher figures uncovered once the crisis began, this suggests that there was debt unaccounted for prior to the crisis and that was disclosed during the crisis. This increased the uncertainty and perceived risk for investors and was a factor that influenced their decision to withdraw their funds from the affected countries. Chinn et al. (1999) claim that the traditional explanation of this kind of phenomenon that relies on conflicts between exchange rate policies and fiscal policies of emerging market governments is no longer adequate as it was ten years ago. The policy conflict in the model to be tested is between the desire of a credit-constrained government to hold reserve assets as a form of self-insurance and the government's desire to insure financial liabilities of residents. The first objective is met by the accumulation of foreign exchange reserves and line of credit. The second objective generates incentives for investors to acquire the government's liquid assets when yield differentials make this optimal. The authors summarise a capital inflow/crisis sequence as follows: the availability of free insurance raises the expected yield on a set of liabilities issued by residents for a predictable time period. The yield differential relative to international returns generates a private growth of capital inflow that continues until the day of the attack. When the government's marketable assets are matched by its contingent insurance liabilities, the expected yield on domestic liabilities falls below international rates and investors sell the insured assets to the government exhausting its assets



Other efforts to try to explain the determinants of crises have included the impact of institutional variables, such as corruption, rather than the macroeconomic environment. We briefly discuss one of these alternate studies. Wei and Wu (2001) argue that crony capitalism and self fulfilling expectations by international creditors have been often suggested as two opposing explanations for currency crises (these authors make no distinction between financial and currency crises). They propose corruption as a linkage between these two alternative explanations. Their main argument is that corruption may affect a country's composition of capital inflows in a way that makes it more likely to experience a currency crisis that is triggered/ aided by a sudden reversal of international capital flows. The importance of this composition has been highlighted by the financial and currency crises in East Asia, Russia and Latin America during the 1990's. Previous research has addressed three composition measures of capital flows relevant for the occurrence of a currency crisis: i) the lower the share of foreign direct investment in total capital inflows; ii) the higher the short-term debt-to-reserves ratio; or, c) the higher the share of foreign currency denominated borrowing in a country's total borrowing, the more likely a currency crisis becomes. In their study, the authors make a greater emphasis on the Foreign Direct Investment (FDI) share in total capital inflows because of the larger set of observations available and the higher reliability of them. The authors define corruption not only in the 'narrow' sense that refers to the extent to which firms (or private citizens) need to pay bribes to government officials but they use a broader definition that encompasses 'poor public governance' which also includes deviations from rule of law or excessive and arbitrary government regulations.

### **1.3.1.1. Results obtained**

As we have seen, these empirical studies indicate that the term structure of debt is important, as well as the currency in which it is denominated, but also that there are institutional and regulatory arrangements that have an impact on the performance of financial markets and in their vulnerability to liquidity shocks. It is important to note as well that bank lending is not the only vulnerable mechanism, but also the wider debt market in which the domestic banking system may not be involved directly. In other words, as in the South East Asian case, indebted firms looking for direct foreign financing may face liquidity problems that in the short run put them in a default situation, with the consequence that foreign investors decide to withdraw from the country because of worsening expectations of the performance of the economy. This process can be worsened if there are institutional factors such as corruption that may hinder long-term investment and increase the uncertainty about the ability of the country to fulfil its short-term and foreign currency denominated debt. We will now discuss the specific findings of this type

of studies regarding three main issues: i) credit booms; ii) investors expectations; and, iii) capital mobility.

### ***Credit booms***

Credit growth is considered one of the key determinants of banking crises, but this does not necessarily mean that credit booms are always harmful for the economy. In other words, “while the conditional probability of a lending boom occurring before a banking crisis may be quite high, it does not tell us much about the converse, namely the conditional probability that a banking crisis will *follow* a lending boom”. In order to analyse whether boom episodes are related to financial crises, and particularly whether they signal future banking troubles, Gourinchas, et al. (2001) compared the probability of having a banking crisis before and after a boom episode with the probability of experiencing such a crisis during tranquil periods. They found that: first, the probability of a banking crisis after a lending boom is relatively low; and, second, that the likelihood of having a banking crisis up to two years after a lending boom is somewhat higher than during tranquil periods, although the increase is often not statistically significant. The conclusion to be drawn from these results is that lending booms generically lead to banking crisis is largely erroneous, that is while most banking crises may be preceded by a lending boom, and most lending booms are not followed by a banking crisis. Lending booms are associated with: an investment and – to a lesser extent- a consumption boom; trend output growth declines over 1 percent; a large increase in domestic real interest rates; a large increase in the current account deficit and a counterpart in the form of capital inflows; a real appreciation of the domestic currency; some worsening of the fiscal situation; a decline in foreign reserves and a shortening of the maturity of the external debt. In Latin America, lending booms are often followed or accompanied by banking and/or currency crises. Given the characteristics on the behaviour of some key variables across the sample allow to associate booms in Latin America primarily to financial liberalisation and development of the economies. Kletzer and Chinn (2000) found that the gap between capital inflows destined to non-crisis and crisis countries widened in the run-up to July 1997. Lending ratios exhibited a similar behaviour. In both sets of countries bank lending accelerates from the 1982:1-1993:4 period to the 1994:1-1997:1 period. If total lending is considered, then the acceleration is even more marked. While the growth rate in lending to GDP ratio rises from 2.8 percentage points per year to 4.7 percentage points per year in the non-crisis countries, it rises from 4.4 percentage points per year to 7.8 percentage points per year in the crisis countries.

In order to determine the role of the exchange rate regime in banking crises, Eichengreen and Rose (1998) first analyse the simple correlation, i.e. the unconditional probability of a

banking crisis under fixed exchange rates. There is only very weak evidence against the hypothesis that banking crises are randomly distributed across regimes. The next step is to examine whether there is a partial correlation between pegged exchange rates and banking crises after controlling for macroeconomic variables. The dummy variables for countries with pegged and intermediate exchange rate regimes enter with coefficients indistinguishable from zero whether they are entered separately or together. To test the hypothesis that pegged rates are preferable when disturbances are domestic, flexible rates when disturbances are external, dummy variables for pegged and intermediate exchange rate regimes were combined with the measures of external shocks. In no case did any of the individual coefficients approach significance at standard confidence levels. And in no case did the group of regime dummies and interaction terms achieve joint significance at even the 90% confidence level.

### ***Investors' expectations***

Another group of empirical studies focuses on investors' expectations about financial markets. Aizenman and Marion (2001) obtained suggestive evidence on investor beliefs about external debt levels in Thailand by constructing confidence bands around a debt forecast. Spiegel (2001) argues that this approach has some caveats, the first one being the lack of investment in the model. Therefore, an increase in borrowing invariably raises the probability of default. However, if the increased debt were profitably invested, the default implications of an increase in the stock of debt are unclear. Default risk would then be a function of shocks to the quality of investment undertaken rather than the stock of debt. Another caveat regards the relevance of the empirical evidence about the build-up of debt stocks in the two countries. The model predicts that the effective ceiling on net resource transfers to creditors will be the lesser of contractual repayments or the magnitude of the default penalty. However, the default penalty is proportionately increasing in debtor nation output. This implies that the relevant ceiling will be on the ratio of contractual debt obligations to output rather than the stock of outstanding debt. Analysing the ratio of total Thai debt service as a percentage of GDP over the build-up period, it is clear that debt-service-to-GDP ratios did not markedly increase because output growth matched increases in borrowing. Secondly, this ratio seems to be relatively stable over this period.

On the other hand Eichengreen and Rose (1999) and Wei and Wu (2001) consider the impact of corruption, their argument is that it is bad for both international direct investors and creditors but direct investment suffers more from it and hence the composition of capital inflows favours financial over direct investment. Countries with this problem are more likely to

default on bank loans, or to nationalise the assets of foreign direct investors (on this point the authors do not explain if nationalisation is necessarily a consequence of corruption or if on the contrary it can obey to other considerations of economic and/or political necessity). The need for international investors to pay bribery and deal with extortion by corrupt bureaucrats tends to increase with the frequency and the extent of their interaction with local bureaucrats. Another deterrent for foreign direct investment is that international creditors are more likely to be bailed out than direct investors in the case of a crisis occurring. In summary, both studies found that corruption affects the composition of capital inflows in an unfavourable way to the country. A country with high levels of corruption receives substantially less foreign direct investment. However, it may not be as much disadvantaged in obtaining bank loans. In consequence, corruption in a capital importing country can tend to bias the composition of its capital inflows away from foreign direct investment and towards foreign loans.

### ***Capital mobility***

Eichengreen and Rose (1999) also address the role of external debt and stability of the financial system. It is usually thought that countries with large amounts of short-term, variable rate, foreign currency denominated debt are especially prone to exchange rate crises. There is evidence that the structure of the external debt matters for banking crises, even after controlling for a country's other macroeconomic fundamentals. Regarding financial fragility, the authors argue that there are difficulties in measuring financial fragility in ways that are internationally comparable since countries do not report loan losses or loan-loss provisioning in a systematic way. The authors found that devaluations, as distinct from currency crises, have generally occurred after periods of overly expansionary monetary and fiscal policies. These expansionary policies lead to price and wage inflation, deteriorating international competitiveness and weak external accounts and to a loss of reserves, which jeopardises exchange rate stability and eventually forces the government to devalue the exchange rate. This pattern is also to be found in Latin American crises during the 1980's were the result of overly expansionary policies that led to high levels of government debt and inflationary policies but there were result as well of loss of confidence of the domestic currency and speculative attacks. What they characterise as a currency crisis is a speculative attack without apparent macroeconomic imbalances (the type of crisis that has been observed during the 1990's in emerging markets) and is harder to predict. The result is that pegged exchange rate regimes are often abandoned for a free floating one and the parity is let to be determined by the market without further intervention of the monetary authority. On the other hand they test the suggestion of theoretical models that speculative attacks unfold differently in situations of high and low capital mobility. They confirm this

supposition; the presence of capital controls makes devaluations less likely and increases the likelihood that a government will be able to resist a speculative attack.

### **1.3.1.2. Discussion**

One of the main problems that all studies face is the availability of data for many of the variables of interest; some key variables were not even directly observable, such as the riskiness of investment, the size of contingent liabilities and the share of bank capital, as opposed to foreign capital in domestic investment. To find evidence of increased capital inflows into countries that experienced a crisis may indicate that the financial markets may eventually face a liquidity constraint when these liabilities are required to be repaid. However, different channels of intermediation of these resources and risk sharing schemes of financial assets may have different impacts on the aggregate risk, both for the financial system and for the economy. Foreign direct investment was not as important as financial investment for multiple reasons: financial institutions, regulation of financial markets, types of allowed operations and the composition of direct and financial investment are key variables that determine the risk of financial integration processes and the investors' decisions of where to allocate funds. The study by Kletzer and Chinn (2000) confirms that financial intermediation increased as a result of an increase in the availability of resources for lending; however, they fail to explain the implications that this phenomenon has for risk-taking in the economy. In other words, more availability of financial resources may distort risk-taking assessments and decisions when allocating resources, especially within the banking system.

On the other hand, rather than asking if increased capital inflows occur before a crisis, the relevant question to ask is if an opening economy that is undergoing a financial integration process places itself in a vulnerable position where the risk of a reversal in capital flows may lead to a financial meltdown; this is because the very nature of the reform processes that these crisis countries implemented involves financing with external resources and capital inflows so it is tautological to ask if there were capital inflows before each of these crises. This problem arises as well in Chinn et al. (1999) who offer an insurance based explanation of investors' behaviour that takes the analysis closer to a microeconomic explanation of market failure rather than the use of macroeconomic variables. However, the measurement and testing of their hypothesis still depend on the analysis of the behaviour of aggregate variables that have been considered in other studies with different theoretical approach. In this sense it is difficult to distinguish the underlying mechanisms that are affecting investors' behaviour. Despite the efforts to include microeconomic-based explanations for the occurrence of financial crises, still

there is a lack of in-depth analysis of underlying mechanisms that are present in financial markets and that can lead to a sudden collapse. Some of the missing elements worthy to explore may be related to the institutional setup, the incentives to stay or withdraw from a country, risk pooling, asymmetric information and herding behaviour. All these issues have to be addressed to improve the understanding of financial crises in countries with apparently solid and successful reforms.

Regarding the importance of debt markets and asymmetric information in the onset of a financial crisis, empirical evidence from Aizenman and Marion (2001) indicates that debt markets played a substantial role in the East Asian currency crises. However, the stability of the debt-service-to-GDP ratio may be not completely indicative of what was happening at the debt market. The data shows an important and interesting feature which is the lack of information and the inconsistency in figures before and after the crisis. This is an important feature that indicates that at the time of the onset of the East Asian crisis, investors and economic agents did not count with all the information relevant to take accurate decisions. This lack of information disclosure is a characteristic shared with the rest of the countries that had this type of crisis and implies the existence of a severe problem of asymmetric information that can be at the core of these episodes.

Gourinchas, et al. (2001) and Eichengreen and Rose (1999) make important distinctions when analysing the data of different crises along a period of time. The study by Gourinchas, et al. (2001) links explicitly the occurrence of lending booms and currency crises, especially in Latin America. The distinction between types of crises is important if we try to understand these recent episodes. As we will see in following sections, currency crises models do not go further than using some financial variables (such as interest rates) to explain speculative attacks. This approach fails to explain what happens within the financial system that makes it vulnerable to crises. These authors try to find an explanation in the lending behaviour of the banking system. They succeeded to find it relevant in the case of Latin America where most currency crises have been intertwined with banking crises. However, the absence of evidence in other countries may not indicate that problems with financial markets are not present. One explanation may be that the problems that are so evident in the Latina American banking systems are to be found in other debt markets. One solution to this problem could be not only to consider lending booms as a risk source but also the increased access to international debt markets that are not intermediated by the domestic banking system. This broader definition of the credit market may also point to problems of insufficient risk sharing and therefore increased vulnerability to early recalls of the credits. A very important result from Eichengreen and Rose (1999) is that they highlight the differences between the crises during the 1980's and the 1990's; while during the

former decade currency crises were preceded by large fiscal deficits and incompatible monetary policies; during the latter one, it still not clear what happens to be the cause of sudden devaluations but it is clear that the credit lending system (in this particular case the banking system) plays an important role. However, it is still necessary to model the financial system as a whole, in particular the debt market, in order to fully understand the underlying question, does financial liberalisation implies that the financial system will grow more vulnerable to sudden liquidity shocks and under what circumstances this may be true?.

While it is useful to explore alternative explanations linked to institutional factors, the stress that Wei and Wu (2001) put on government corruption as a determinant of financial crises may not be as relevant as the fact of the composition of the term structure of foreign borrowing. When a country finds itself with short-term liabilities, rolling over this debt involves a risk in terms of interest rates, liquidity shocks and profitability of the investment projects being financed. In general, it is safe to assume that in order to repay the short-term liabilities, firms and banks will decide to allocate resources in a socially suboptimal way in order to avoid finding themselves in a default position. Despite that corruption may be a plausible explanation to this bias in the composition of the borrowing portfolio, it is not limited to be the only reason. We can think for instance in regulation frameworks that incentive short-term investment over long-term investment; preferences of lenders are also important to take into account, if fund managers have incentives to compete on a short-term profitability basis as in Emmons, W. and Schmid, F. (2002) and Schleifer, A. (2000), then lending to emerging countries will be limited to this kind of term structure.

Variables used in the reviewed empirical studies						
	Macroeconomic variables	External sector variables	Financial Variables	International Variables	Institutional Variables	
Kletzer and Chinn (2000)		Capital flow to GDP ratio	Dummy variable that takes a value of unity for those East Asian countries that experienced a financial crisis; bank lending; lending to GDP ratio; growth rate in lending to GDP ratio; corporate returns on assets (ROA) in percentages, the lagged non-performing loan (NPL) ratio, in percentages, bank lending to GDP ratios	International real interest rates		
Gourinchas, Valdés and Landerretche (2001)	Gap between actual and potential GDP; potential output growth, ratio of investment to GDP, ratio of private consumption to GDP, real interest rate, spread between lending and deposit interest rates; inflation rate government surplus as percentage of	Ratio of current account to GDP; real exchange rate; private capital inflows as percentage of GDP. terms of trade measured as deviation from long-run trend; months of imports covered by international reserves	Proportion of short term in total debt			
Aizenman and Marion (2001)			Log of external debt levels			
Chinn, Dooley and Shreshtha (1999)	Change in log real domestic credit over a 2 year period	Ratio of foreign exchange reserves to domestic credit	Volume of capital flight: the sum of the current account surplus and increases in external debt, less recorded net private capital inflows and increases in official reserve assets as a proportion of GDP	The US real interest rate	Quality of regulation in domestic financial markets.	
Eichengreen and Rose (1998)	Government budget balance as percentage of GDP; domestic credit growth; and, the growth rate per capita	International reserves expressed as a percentage of monthly imports; external debt and the current account balance to GDP ratio.		Growth rate of real GDP in the OECD and "Northern" interest rates.		
Wei and Wu (2001)			Portfolio capital inflow/GDP, borrowing from banks/GDP and inward FDI/GDP; term structure of foreign borrowing denomination of foreign borrowing			

Table 5: Variables used by empirical studies with a financial markets approach



### **1.3.2. Macroeconomic indicators approach**

In the literature we can find as well empirical studies that rather than test for a specific theoretical model try to find some indicators that may allow predicting crises. These studies vary in the methodology used to estimate the probability of the occurrence of a crisis. It is important to highlight that contrary to the studies reviewed in the previous section, the studies in this section often do not begin with a specific well defined model to test but they check for robustness in the regression by including alternative explanatory variables. There are three main methodologies used by these studies:

- i) In probit and logit models the initial shock is an extreme value of an indicator of speculative pressures and the leading indicators approach, which attempts to select a parsimonious set of indices of vulnerability to external or internal shocks in order to forecast currency crises.
- ii) Leading indicators are part of a warning system proposed in the papers by Kaminsky, Lizondo and Reinhart (1997) and Kaminsky (1998) which involves the evolution of a number of economic indicators that tend to systematically behave differently prior to a crisis. Every time that an indicator exceeds a certain threshold value, interpreted a warning “signal”, that a currency crisis may take place within the following 24 months. The threshold values are calculated in a way that they achieve a balance between the risk of having many false signals and the risk of missing many crises. The behaviour of the indicators that are issuing signals can also be used to identify some of the sources that underlie the probability of a crisis.
- iii) In Markov switching models crises are defined in terms of discontinuities in the data-generating process which directly test the presence of multiple equilibria, and tests on structural breaks in correlation.

According to Kaminsky, Lizondo and Reinhart (1997) the most commonly used approach has been to estimate the one-step-ahead (or k-step) probability of devaluation in the context of a multivariate probit or logit model. This methodology has the advantage that it summarises the information about the likelihood of a crisis in one useful number, the probability of devaluation; it also considers all the variables simultaneously, and it disregards those variables that do not contribute information that is independent from that provided by other variables already included in the analysis. However, this methodology has important limitations: i) first, it does

not provide a metric for ranking the indicators according to their ability to accurately predict crises and avoid false signals; measures of statistical significance do not provide information on whether the relative strength of that indicator lies in accurately calling a high proportion of crises at the expense of sending numerous false alarms or instead missing a large share of crises; ii) it does not provide a clear reading of where and how widespread the macroeconomic problems are. Within this approach, it is difficult to judge which of the variables is out of line. An alternative approach is the focused on the ability of a set of macroeconomic and financial “indicators” to forecast the occurrence of a currency crisis correctly, this approach has been proposed by Kaminsky (1998) and Kaminsky Lizondo and Reinhart (1997). In line with the previous models, a crisis period is defined as a month in which the variable measuring the exchange rate market pressure reaches extreme values. For each indicator there is an established threshold, the indicator is said to release a signal whenever its value is larger than the threshold.

Another part of the literature has focused in the use of GARCH models to analyse the transmission of shocks across financial markets, the phenomenon known as contagion (Pericoli and Sbracia, 2003). These studies try to analyse the transmission of volatility between markets and to determine if the observed volatility in any financial market has only country-specific correlation (heat waves) or is affected by spillovers from other countries (meteor showers). A third set of studies has used Markov-switching models to test discontinuities. The use of this framework has the advantage that discontinuities can be directly attributed to jumps between multiple equilibria.

### **1.3.2.1 Results obtained**

In this section we discuss the main results of these studies. These empirical studies have an important difference with the studies that adopt a financial markets approach and it is that they test several hypotheses rather than a specific theory. Therefore, the results are limited to the estimation of the role that different variables have in the onset of a crisis; here we identified three main hypotheses that are tested and that relate to the following: i) the importance of debt; ii) the role of external imbalances; and, iii) the role of expectations and fundamentals. Additionally, there is a fourth kind of studies that do not assume any hypothesis a priori but it is limited to measure possible deviations from their long term trend of selected variables and tries to identify a common set of conditions and build a dependable early warning system for policy makers.

### ***The impact of debt in the probability of a crisis***

Assuming a central hypothesis of financial market instability, Radelet and Sachs (1998a) could predict that countries with a high ratio of short-term debt to short-term assets would be more vulnerable to crisis. A high ratio of short-term debt to reserves, however, will not necessarily induce a crisis in a given year, but it indicates the vulnerability of the country to a crisis. Second, they measure the ratio of the financial system claims on the private sector relative to GDP, and then they calculate the change in that ratio over the preceding three years. Countries with sharply rising financial sector claims relative to GDP are expected to be more vulnerable to financial crisis. Third, in order to include the role of large current account deficits the current account ratio to GDP was included along with the capital account ratio with GDP. Other variables were also examined such as the real exchange appreciation and a comparative index of corruption. Their results found that the variables related to the onset of a crisis were: higher ratios of short-term debt (both private and public) to reserves and a rapid build up in the claims of the financial sector. This suggests that financing structural changes with debt are the elements that had put these economies in high risk.

On the other hand, Ferreti and Razin (1997) did not find suggestions that reversals are systematically correlated with the GDP growth rate before the event. They also did not find significant links between the real exchange rate (or of its rate of change) and the current account reversals. None of the variables directly measuring the burden of external debt comes in significantly in the probit regressions contrary to the results of Radelet and Sachs (1998a). These two studies with similar methodologies (namely probit models) and sets of variables apparently reach opposite conclusions, for Radelet and Sachs (1998a) the level of debt is an important predictor of a currency crisis, while for Ferreti and Razin (1997) it is not. However, if we pay attention to the time periods for which the estimations are carried out, we can see that they focus on different sets of crises. While Radelet and Sachs (1998a) focus on 1990's emerging market crises, Ferreti and Razin (1997) focus on previous crises that have different causes and dynamics. If this is the case, then the two studies are not mutually exclusive, it could be the case that Ferreti and Razin (1997) are in fact studying another type of crises rather than the 1990's phenomenon of crises in emerging markets. Therefore, there is a need of classification and identification of types of crises in order to understand this phenomenon.

### ***The role of external imbalances***

Ferreti and Razin (1997) argue that the Mexican experience and contagion effects on other emerging market economies have been the subject of a large number of studies; however, there

is no comprehensive cross-country study of sharp reductions in current account imbalances. A sharp reduction in external imbalances can be originated by the implementation of stabilisation plans or by sudden reversals in international capital flows. Fratzcher (1999) develops a model in which the exchange rate pressure in one country depends on a set of domestic fundamentals, some measures of real integration (such as trade) and of financial integration with other countries and the possibility of probability regime switching. In particular, the model indicates that the transmission of shocks plays a major role in determining exchange rate pressure both in tranquil and crisis periods. Another conclusion is that for any country, a prediction of the severity of the exchange rate pressure during the Mexican and the Asian crisis and a rank of the vulnerability of countries for both episodes. According to Pericoli and Sbracia (2003) this model does not perform much better when compared with analogous predictions from some leading indicator models.

### ***The role of expectations and fundamentals***

Jeanne (1997) attempts to reconcile the usually opposed view that speculation is motivated by the fundamentals and the one that it is self-fulfilling. The analysis is based on a model that encompasses both views, i.e. in which speculation may be fundamental-based and/or self-fulfilling. The logic of the self-fulfilling speculation is that it makes it more costly for the policymaker to stay in the system. An important property of the model is that self-fulfilling market spirals cannot arise under arbitrary circumstances, but only when the fixed exchange rate arrangement has been undermined by weak fundamentals. The case used to illustrate his method is the French franc that suffered several speculative attacks in 1992 and 1993 and could only stay in the Exchange Rate Mechanism of the EMS at the cost of a considerable widening of the fluctuation margins at the beginning of August 1993. The data is monthly and runs from January 1991 to July 1993. The macroeconomic variables are: the real exchange rate, the trade balance GDP ratio and the unemployment rate. The model performs better in tracking devaluation expectations of the French franc in 1992-93 than a linear regression. They argue that if applied to episodes as the Mexican Peso devaluation in 1994, the model should perform similarly as in the case of the French franc because the fact that it was so sudden to be satisfactorily explained by fundamentals only.

Jeanne and Masson (2000) characterise the equilibrium and give a simple criterion for existence of multiplicity. They show that the model they consider in their study can be brought to the data using a standard econometric approach, the Markov-switching regimes model. Linearising their model results in a Markov-switching regimes model for the devaluation

probability, in which the switch across regimes corresponds to jumps between different equilibria. This provides some theoretical justification for the use of the Markov-switching regimes approach in empirical work on currency crises, and can also help to assess the empirical plausibility of the multiple equilibria hypothesis. They use the case of the French franc as in Jeanne (1997) but for the period 1987-1993 and find that a model allowing for sunspots performs better than a purely fundamental-based model, in particular by improving the relationship between the economic fundamentals and the devaluation expectations.

### ***Early warning systems***

Kaminsky, Lizondo and Reinhart (1997) and Kaminsky (1998) study 76 currency crises from a sample of 15 developing and 5 industrial countries during 1970-1995 using their own methodology of “signals”. This approach involves monitoring the evolution of a number of economic variables. When one of these variables deviates from its normal level beyond a threshold value, it is said to be a warning signal about a possible currency crisis within a specified period of time. The authors define crisis as a situation in which an attack on the currency leads to a sharp depreciation of the currency, a large decline in international reserves, or a combination of the two. Hence, this definition of a crisis includes both successful and unsuccessful attacks on the currency; it also includes not only currency attacks under a fixed exchange rate but also attacks under other a crawling-peg regime or an exchange rate band. Crises are identified ex-post by the behaviour of an “index of exchange market pressure”. The signalling period is considered as that within which the indicators would be expected to have ability for anticipating crises. Regardless of the problems of working with different data settings, some conclusions can be drawn from the Kaminsky, et al. (1997) study:

- First, an effective warning system should consider a broad variety of indicators; currency crises seem to be usually preceded by multiple economic, and sometimes political, problems. The evidence points to the presence of both domestic and external imbalances which span both the real side of the economy and the domestic financial sector.
- Second, those individual variables that receive ample support as useful indicators of currency crises include international reserves, the real exchange rate, credit growth, credit to the public sector, domestic inflation, trade balance, export performance, money growth, M2/international reserves, real GDP growth and the fiscal deficit.

- Third, only tentative conclusions can be drawn regarding the other indicators. The main reason being that they have been included in only one or two of the studies under review.
- Fourth, the variables associated with the external debt profile did not fare well. Contrary to expectations, the current account balance did not receive much support as a useful indicator of crises.

Berg and Patillo (1999) discuss Kaminsky's assertion that her method of leading indicators can be applied successfully to the 1997 crises in South East Asia. However, they found that Kaminsky does not provide tests of the validity of this method against others. Furthermore, given the non-statistical nature of Kaminsky's approach it is difficult to evaluate its success. The analysis carried out by Berg and Patillo (1999) suggests that the approach can indeed be useful but most crises are still missed and most alarms are false. In order to compare Kaminsky's study, the authors apply a probit regression technique to the same data and crisis definition. They embed the Kaminsky, et al. (1997) approach in a multivariate probit framework in which the independent variable takes a value of one if there is a crisis in the subsequent 24 months and zero otherwise. This has three advantages: the usefulness of the threshold concept can be tested; predictive variables can be aggregated into a composite index taking into account correlations among them; and, statistical significance of individual variables can be tested as well as the constancy of coefficients across time and countries. Two main conclusions can be drawn from this exercise: first, the probits tend to slightly outperform the Kaminsky, Lizondo and Reinhart (1997) based probabilities. Second, the ranking among the various probit models is ambiguous.

Applying the Kaminsky, et al. (1997) methodology to predict crises in four Asian countries in 1997 (Korea, Indonesia, Malaysia and Thailand) and one Asian and three Latin America non-crisis countries (Philippines, Argentina, Brazil and Mexico), there were no particular indicators that flashed similarly in all of the crisis-countries. The only indicators to signal in more than one country were the growth rate of exports, which flashed in both Thailand and Korea, the growth of M2/reserves which signalled in both Thailand and Malaysia and reserve growth which flashed in Korea, Malaysia and Thailand. In sum, the findings were that the Kaminsky, et al. (1997) approach has some success to identify which countries are vulnerable in a period following a global financial shock. Still the overall explanatory power is low and the overall goodness of fit for the out-of-sample predictions illustrates the low predictive power of the test and probit-based alternatives perform slightly better. As Berg and Patillo (1999) found, leading indicators methods still need to be perfected in order to provide useful warning systems for policy makers. It may be that dealing with aggregate indicators specific problems in certain

markets are not being given an appropriate weight since it may be idiosyncratic to the market structure of a specific financial market.

Variables used in the reviewed empirical studies			
	Financial Variables	International Variables	Institutional Variables
Kletzer and Chinn (2000)	Dummy variable that takes a value of unity for those East Asian countries that experienced a financial crisis; bank lending; lending to GDP ratio; growth rate in lending to GDP ratio; corporate returns on assets (ROA) in percentages, the lagged non-performing loan (NPL) ratio, in percentages, bank lending to GDP ratios		
Gourinchas, Valdés and Landerretche (2001)	Proportion of short term in total debt	International real interest rates	
Aizenman and Marion (2001)	Log of external debt levels		
Eichengreen and Rose (1998)		Growth rate of real GDP in the OECD and "Northern" interest rates.	
Wei and Wu (2001)	Portfolio capital inflow/GDP, borrowing from banks/GDP and inward FDI/GDP; term structure of foreign borrowing denomination of foreign borrowing		
Radelet and Sachs (1998)	Short-term debt to reserves ratio of the financial system claims on the private sector relative to GDP		Comparative index of corruption
Ferreti and Razin (1997)	Foreign exchange reserves as a fraction of imports or as a fraction of M2, the ratio of external debt to exports or to output, the ratio of interest payments to GNP, the share of concessional debt in total external debt, the share of public debt in total debt, the share of short-term debt in total debt, the share of FDI flows to GDP and the share of portfolio flows to GDP.	Level of real interest rates in the US and the real growth rate in industrial countries.	
Kaminsky et al. (1997)	Differential between foreign and domestic real interest rates on deposits the ratio of domestic credit to GDP, the real interest rate on deposits, the ratio of lending to deposit interest rates, the stock of commercial banks deposits, , an index of output and an index of equity prices		

Variables used in the reviewed empirical studies		
	Macroeconomic variables	External sector variables
Kletzer and Chinn (2000)		Capital flow to GDP ratio
Gourinchas, Valdés and Landerretche (2001)	Gap between actual and potential GDP; potential output growth, ratio of investment to GDP, ratio of private consumption to GDP, real interest rate, spread between lending and deposit interest rates; inflation rate, government surplus as percentage of GDP	Ratio of current account to GDP; real exchange rate; private capital inflows as percentage of GDP; terms of trade measured as deviation from long-run trend; months of imports covered by international reserves
Aizenman and Marion (2001)		
Chinn, Dooley and Shreshtha (1999)		
Eichengreen and Rose (1998)	Government budget balance as percentage of GDP; domestic credit growth; and, the growth rate per capita	International reserves expressed as a percentage of monthly imports; external debt and the current account balance to GDP ratio.
Wei and Wu (2001)		
Radelet and Sachs (1998)		Current account ratio to GDP capital account ratio with GDP real exchange appreciation
Ferret and Razin (1997)	Share of investment in GDP, economic growth, GDP per capita and the fiscal balance as a fraction of GDP	Current account balance excluding official transfers as a share of GDP, official transfers as a share of GDP, CPI-based real effective exchange rate, terms of trade and the average share of exports and imports to GDP.
Kaminsky et al. (1997)	Excess real M1 balances, the money multiplier (of M2), the ratio of broad money to gross international reserves	International reserves, imports, exports, terms of trade, deviations of the real exchange rate from trend

Table 6: Variables used by empirical studies with a macroeconomic indicators approach

### 1.4. Conclusions of the chapter

We have discussed macroeconomic feedback models and asymmetric information models of currency crises and banking. There is a common belief that first generation and second generation models of currency attacks fall short to explain crises in the 1990's; this is because



they were developed to explain crises in countries with unstable macroeconomic conditions, high fiscal deficits and inflationary environments rather in countries that were heading to economic stabilisation when currency crises took place. Chapter 2 reviews the specific macroeconomic conditions and the timelines of crises in different countries during the 1990's; in Chapter 3 we study the phenomenon of contagion at the same time that we use a leading indicators approach to determine the causes of currency and financial crises and the direction of the effects between currency and financial markets. An issue that has been less discussed and analysed is the impact on welfare that these crises have had; chapter 4 provides a measure of the welfare impact of these crises.

Regarding financial crises, bank run models have been commonly used to explain crises in the past but these models have a narrow view of what constitutes a financial market crisis. The sole use of bank runs models may not be suitable for explaining the recent crises since none of the countries faced this kind of depositors' attacks to the banking system. We can say that withdrawal of funds from the countries under study included the retiring from the domestic debt market (usually short term debt denominated in foreign currency) and the selling of securities which derived in crashes of the stock markets. It may be more plausible to explain these phenomena by focusing on the presence of asymmetric information that leads to a market failure and in the extreme case to a complete collapse of the financial markets. Models that address the issue of stock market crashes and rational bubbles focus on the mechanisms within the specific market and more often than not, postulate ad hoc demand functions which do not allow expanding the analysis into a more general framework; in order to provide a unifying framework to financial decisions (participation in loanable funds and stocks markets) chapter 5 analyses the theoretical implications of intertemporal maximisation on financial markets that provides at the same time solution to some of the puzzles created by the Euler equation approach.

The importance of the study of these crises will allow not only to review the existing theories about currency crises, but also will allow to design better economic policies aimed to achieved stabilisation, control of inflation and integration to the international capital markets without the risk of inducing imbalances that sooner or later have negative consequences for the economy and the distribution of income, which is the main problem in most of emerging countries.

## Chapter 2: Emerging markets in distress; from December's blunder to the "corralito"

*"Wall St. Lays an Egg"*  
Variety, NY 30/X/1929

*"Twenty months ago Mexico faced the most severe contraction since the Great Depression"*  
Speech delivered in New York by the Mexican Minister of Finance and Public Credit, 7/X/1996

*"...a defining event in the economic history of East Asia. Like the Great Depression in the West, it has the capacity to change thought about economic development and economic policy in fundamental ways."*  
Ross Garnaut (1998)

Past crises in emerging markets had important impact on the performance of affected economies. Most of the studies that address the issue of the effects of currency instability that can be deemed as crises but these studies refer only to OECD countries and their conclusions cannot be applied to emerging countries for a variety of reasons: i) the institutional and regulatory frameworks of non-OECD countries are usually in a developing process; ii) the private sector finances investment projects through debt instead of equity and this debt is usually denominated in foreign currency which makes them take larger exposure to exchange rate risk; iii) these economies suffer from the 'original sin' of not having a strong currency and therefore investors' decisions take into account exchange rate risk as an important factor for investment in the country; and, iv) expectations about the viability of government policy is usually enough to arise turmoil periods in domestic financial markets. Because of the abovementioned reasons, it is important to study separately those cases of emerging markets that have faced crises and try to determine the effects of crises in the performance of the economy.

In order to fully understand the recent crises we need first to review the conditions prevailing at the time in each of these countries. With this in mind, we discuss and provide a description of the economic background at the time of the crisis episode in Mexico, South East Asia, Russia, Brazil and Argentina. All of these countries share initially successful economic reforms and large capital inflows. All of them faced a financial crisis coupled with a currency crisis; all of these crises were unexpected and were at odds with the traditional fiscal expansion

based models that can be applied to the 1980's crises. The Argentinean crisis has some particularities that set it aside from the rest of the crises, principally because it was the case of macroeconomic disequilibria provoked by the adoption of a currency board; we briefly present a discussion of its characteristics because hitherto it has been the last major crisis in emerging markets.

## **2.1. Mexico, 1994**

*Debo, no niego; pago, jno tengo!*<sup>14</sup>  
Mexican popular saying

The stabilization process of the economy that took place between 1988 and 1994 included the privatisation of the state-owned enterprises, commercial liberalization and deregulation of the financial sector. To break the inertial component of inflation was necessary the adoption of a coordinated effort with the private sector in the form of the Agreement for Economic Solidarity (Pacto de Solidaridad Económica, PSE). Among the compromises taken were the elimination of public sector imbalances, the adoption of a crawling pegged exchange rate, the opening of the economy, coordination with the private sector in price and wage setting and the credit restriction for the public sector. According to the compromises taken by the government, it was necessary to set basic targets to achieve internal stability, one of the main was the reduction of inflation (in 1988 it was reduced to 52%), economic growth and recovery of the real wage. The financial sector was reformed to allow the privatisation of the banking system (process that took place between 1991 and 1992), and the autonomy in 1994 of the Central Bank (BANXICO)<sup>15</sup> with the clearly defined primary objective of seeking stability of the purchasing power of the domestic currency. From 1989<sup>16</sup> and up to early 1994, favourable expectations, abundant liquidity low international interest rates and the exchange-rate band led to large capital inflows allowed a rapid increase in consumption and investment.

By the end of 1994, Mexico was an economy where financial deepening had vastly enlarged the stock of liquid assets which could be turned into dollars in a moment of crisis. The ratio of M2<sup>17</sup> to GDP had increased from 25% in 1989 to over 33% by year-end 1993. Liberalisation of the capital account also contributed to the process of financial deepening and increasing financial vulnerability. Mexican law was changed in 1990 to allow foreigners to hold government bonds and to buy (non-voting) shares in almost all sectors of the economy. This

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<sup>14</sup> I owe, I don't deny it; I pay... I don't have with what!

<sup>15</sup> All figures from BANXICO and SHCP (Mexican Ministry of Finance and Public Credit)

<sup>16</sup> World Bank (2001)

<sup>17</sup> M2=Coins and notes in circulation and cheque accounts (M1) + domestic financial assets owned by residents.

policy and the improvement of the perception of Mexican economy increased the capital inflows in the short term. The central bank sterilised these inflows by issuing short-term Peso debt (Cetes). As a result, the ratio of M3 (M2 + non-bank short term securities) to GDP grew from 36% in 1989 to 41% in 1993. At the end of 1993, Cetes alone represented close to 100% of net international reserves and total M3 was six times larger than reserves. Until March 1994, the Mexican private sector was selling securities at a rate of more the \$20,000 million pesos per year to foreign investors. After March those sales of securities stopped. Instead, the private sector sold securities to the Mexican central bank, at about the same pace and at interest rates below those demanded by the foreign investors. These sales of securities appear in the central bank accounts as domestic credit expansion to the private sector and to the government. The pesos generated by the credit expansion were used to fund the current account deficit. This implied a pressure to the reserves in the amount of the current account deficit. They conclude that it was the attempt of the central bank to resist a further rise in interest rates demanded by foreign investor through various channels of domestic credit expansion that led to the collapse of reserves (Edwards, 1997).

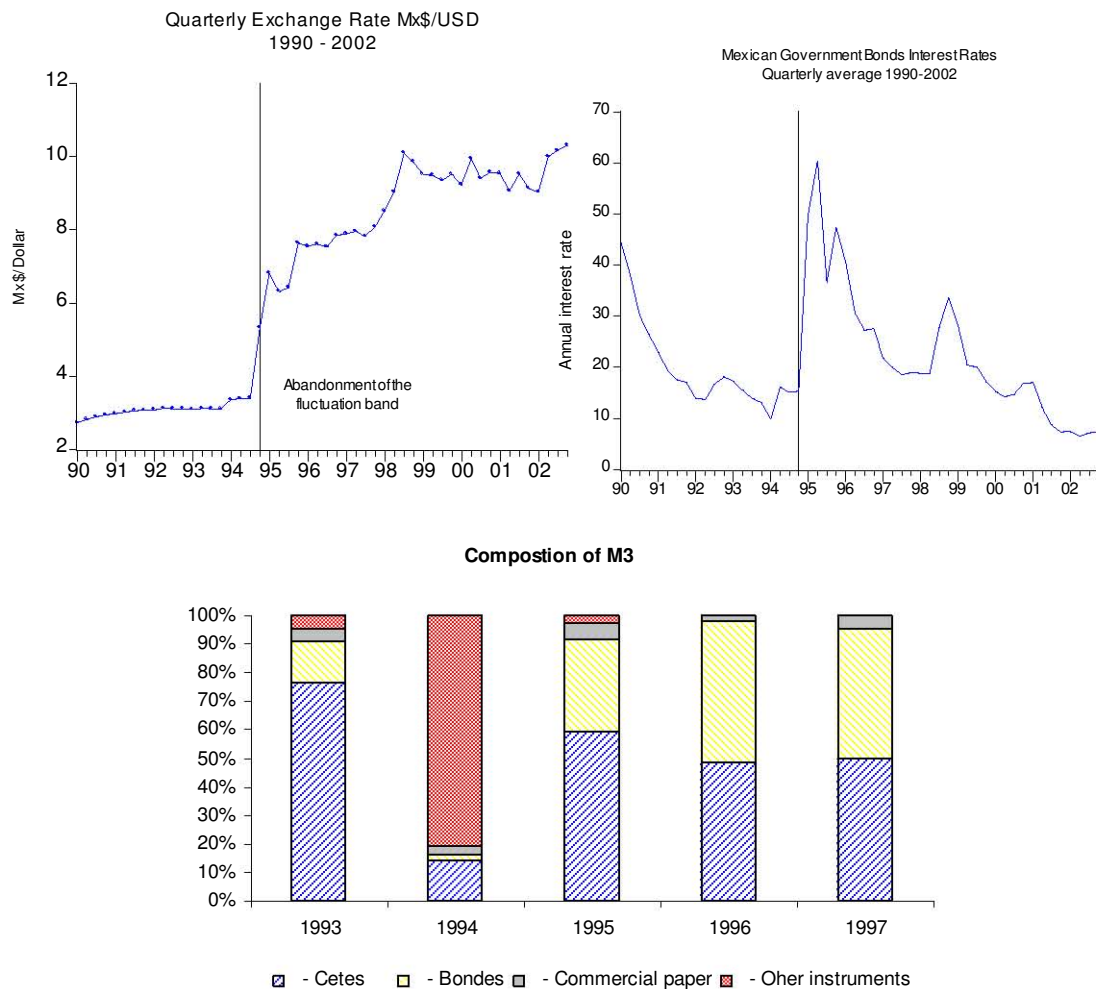


Figure 1: Mexican monetary indicators

In summary, total government domestic debt grew moderately. Expressed in dollars, domestic debt amounted to 1.7 times December 1993 reserves and to 2.6 times September 1994 reserves. Second, the average maturity of domestic debt shrank in the course of 1994 as a deliberate policy, the increased turmoil during the year made steeper the yield curve and issuing long term debt became increasingly expensive. Third, perceived devaluation risk increased after the assassination of the ruling party's presidential candidate in March 1994. Facing growing reluctance to hold Peso debt, and hoping to avoid a further increase in domestic interest rates, the Mexican government began rolling over its short term Peso denominated debt (Cetes) into short term dollar indexed debt (Tesobonos). Starting at USD\$1,000 million at the beginning of the year, by the end of September the stock of Tesobonos outstanding had reached the same amount as reserves. In December the stock of Tesobonos reached USD\$18,000 million.

The World Bank (2001) highlights some policies that had profound implications on the depth and characteristics of the Mexican financial crisis of 1994: a) the predetermined exchange rate regime, which encouraged large short-term capital inflows. This policy produced a real exchange rate misalignment, inducing an unsustainable current account deficit and a rapid surge of domestic bank's credit to the private sector; b) interest rates were inflexible as the Government imposed caps on them in the primary auctions. Since the Central Bank open market operations were conducted based on the primary auction rates, the rigidity of interest rates extended to the secondary market; c) the surge in consumption and investment in non-tradable goods as a result of the rapid increase in bank credit and of the exchange rate misalignment, led to an asset price bubble, which attracted more short term capital flows; d) at the same time the fiscal stance was deteriorating, due primarily to a large expansion of a credit for the Development Banks; and, e) as a result, the domestic savings rate declined.

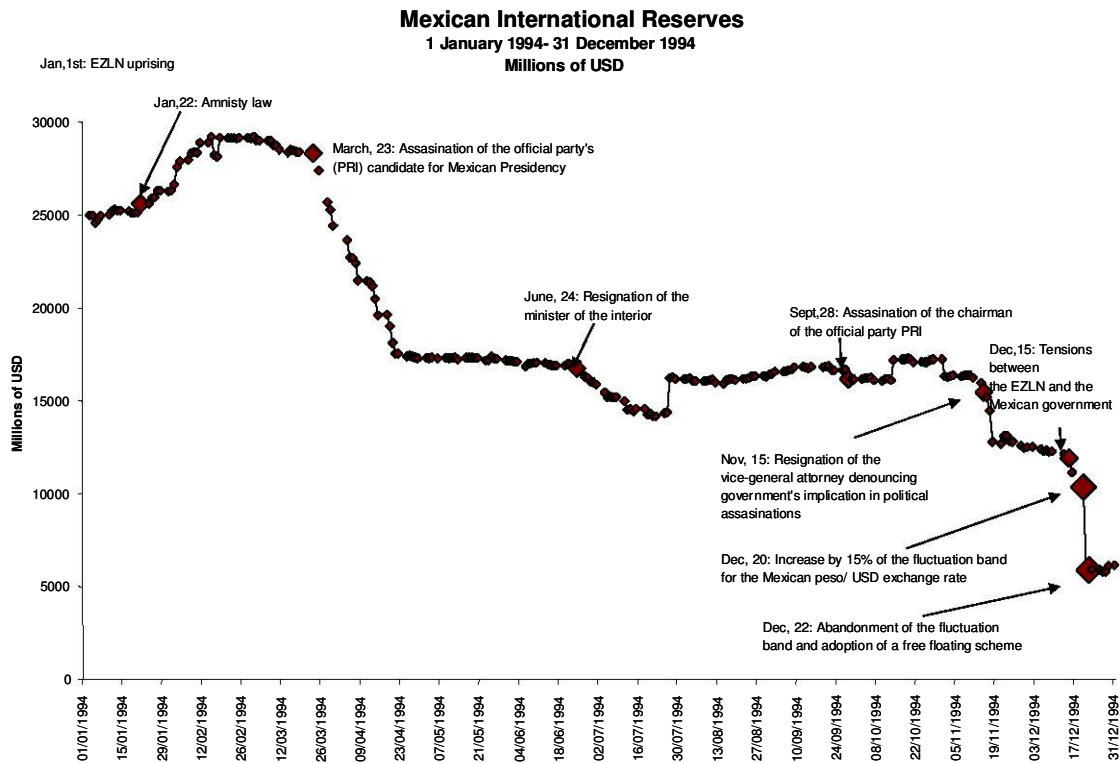


Figure 2: Mexican international reserves, 1994

Sachs, Tornell and Velasco (1995) found that the real exchange rate had appreciated relative to the long term average. However, inflation had declined sufficiently (to around 5-8% per annum) that the extent of overvaluation had stabilised. The conclusion that they draw is that while a relative adjustment was necessary, it did not have to be very large, traumatic or sudden. The current account started deteriorating in 1990 reaching 6.8% of GDP in 1993 and 7.9% of GDP in 1994. The widening of the current account deficit was result of an increase in total investment – from 20.4 to 23.6 % of GDP – and a decline in the national savings rate, from 19 to 15.7% of GDP. The increase in private consumption was largely financed by the capital inflows that took place. The link was the banking system that converted much of this additional flow of resources into real estate and consumption loans. Mexican public debt levels were moderate. It was reduced from 67% of GDP in 1989 to 30% of GDP in 1993. Of this, 19% of GDP was foreign debt (most of which was long term at the end of 1993 as a result of the 1989 debt restructuring) and 11% was domestic debt.

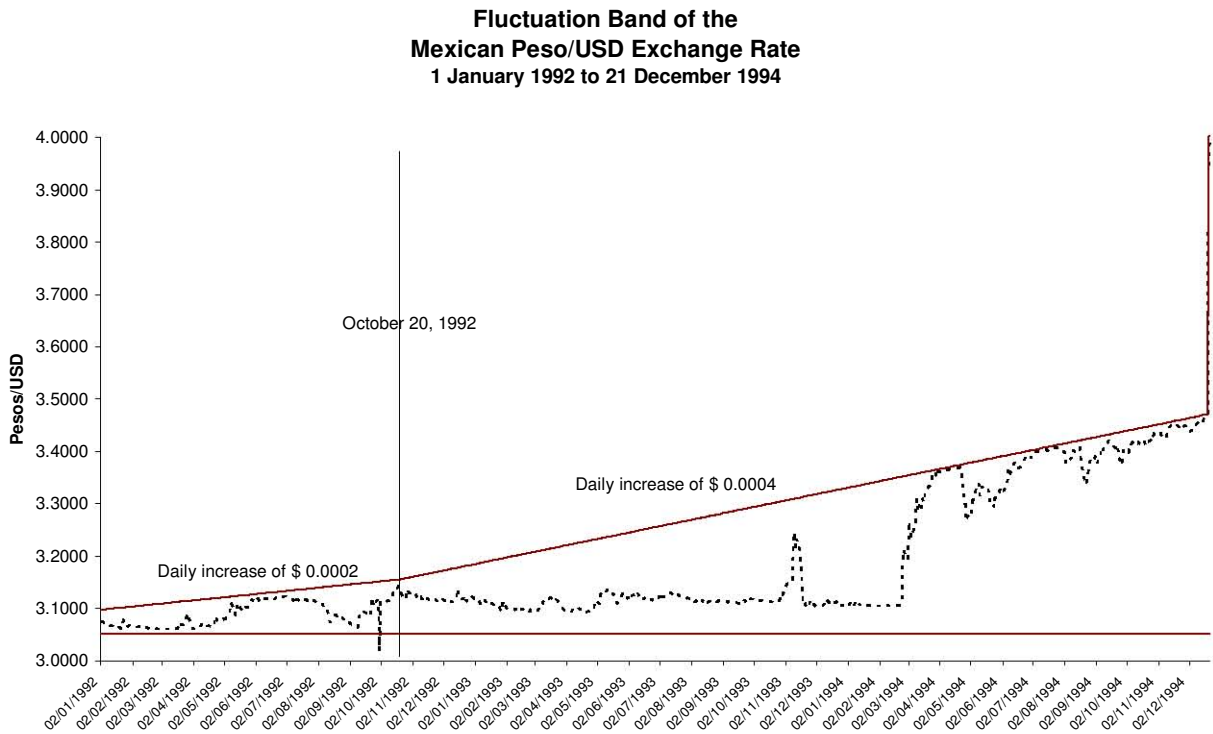


Figure 3: Mexican crawling peg before the crisis.

## 2.2. South East Asia, 1997

According to Corsetti et al (1998), the incentives embedded in the structure of the economy are central to understanding the financial crisis in East Asia. They describe the corporate, financial and international levels in order to clarify the problems faced by these economies. At the corporate level, there were political pressures to maintain high rates of economic growth that led to the existence of public guarantees to private projects. Some of these were effectively undertaken under government control, directly subsidised or supported by policies of directed credit to favoured firms or industries. Even in the absence of promises of bail out the practice was so extended that the projects overlooked costs and risk of the investment. Investment rates and capital inflows in Asia remained high even after the negative signals sent by the indicators of profitability. In the financial level, the banking system increased its borrowing from abroad and expanded domestic credit. Financial intermediation was channelling resources toward projects that were marginal if not unprofitable from the social point of view. In the international dimension, the international banks lent large amounts of funds to the region's domestic intermediaries with apparent neglect of the standards for sound risk assessment. A very large fraction of foreign debt accumulation was in the form of bank related short term uncovered

foreign currency denominated liabilities, by the end of 1996, a share of short term liabilities in total liabilities above 50% was the norm in the region. Moreover, the ratio of short-term external liabilities to foreign reserves was above 100% in Korea, Indonesia and Thailand.

For Chang and Velasco (1999) the data on the Asean-5 countries (Korea, Indonesia, Malaysia, Thailand and the Philippines) does suggest that the international liquidity position of their financial systems deteriorated before the crisis. The evidence strongly suggests that the short-term external liabilities of the relevant Asian financial systems were growing faster than their liquid international assets. In their interpretation, this trend weakened the international liquidity position of these countries to the extent that a loss of confidence from foreign creditors could force the financial system into a crisis. With data from the IMF (IFS database) we can have a glance to the liquidity position of the banking system in foreign assets and liabilities with respect to the stock of international reserves. As we can see the countries that had the worst problems of international liquidity were Thailand, which is actually the crisis originating country, and Philippines followed by Korea. In general, the countries had similar problems, Thailand suffered a problem of international liquidity; Malaysia was experiencing a bubble burst in the real estate sector and Korea was facing important bankruptcies of its conglomerates – the *chaebols*- that impacted negatively the banking system. Relative to the other countries in the region, macroeconomic conditions were more solid in the Philippines. The government's budget was in surplus. Bad bank loans were at a rate of 3.4 percent by the end of 1996. However, the current account deficit was large and the currency had significantly appreciated in real terms. A very rapid lending boom to the private sector had fuelled investment in risky projects, as well as a speculative boom in the property sector.

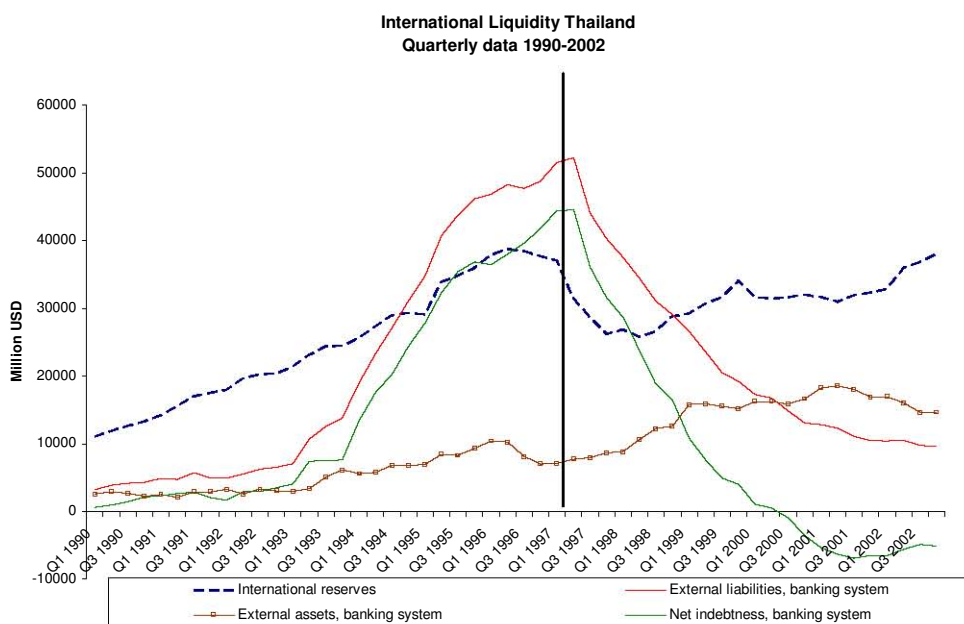


Figure 4: International Liquidity, Thailand



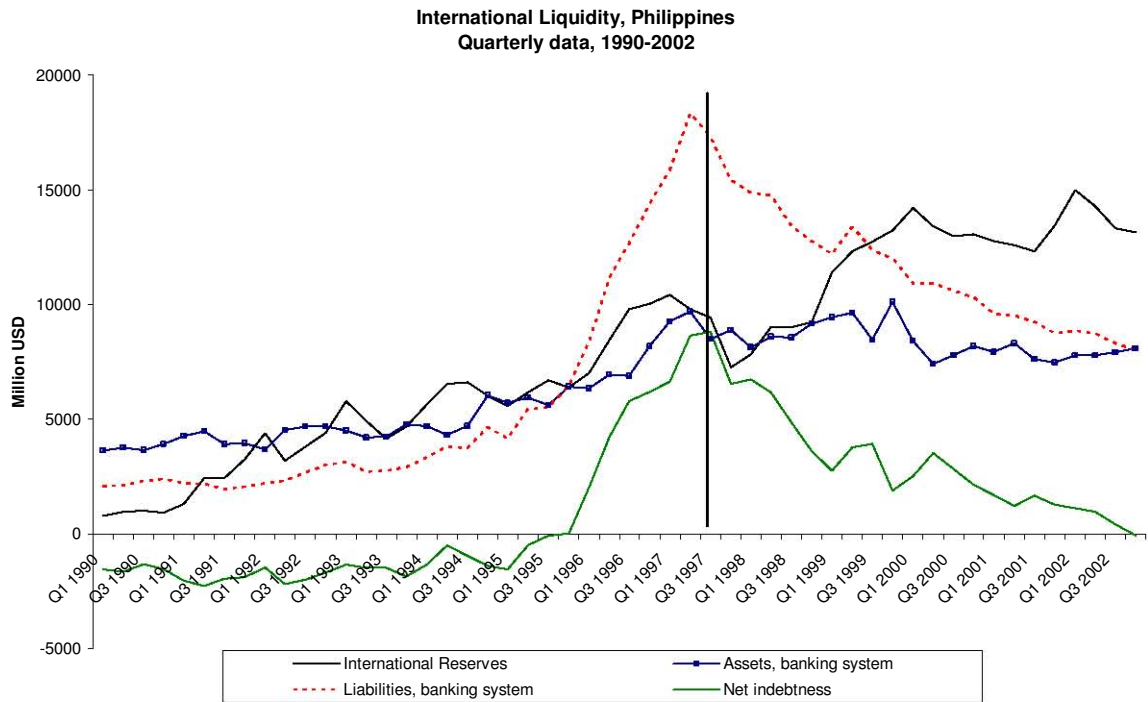


Figure 5: International Liquidity, Philippines

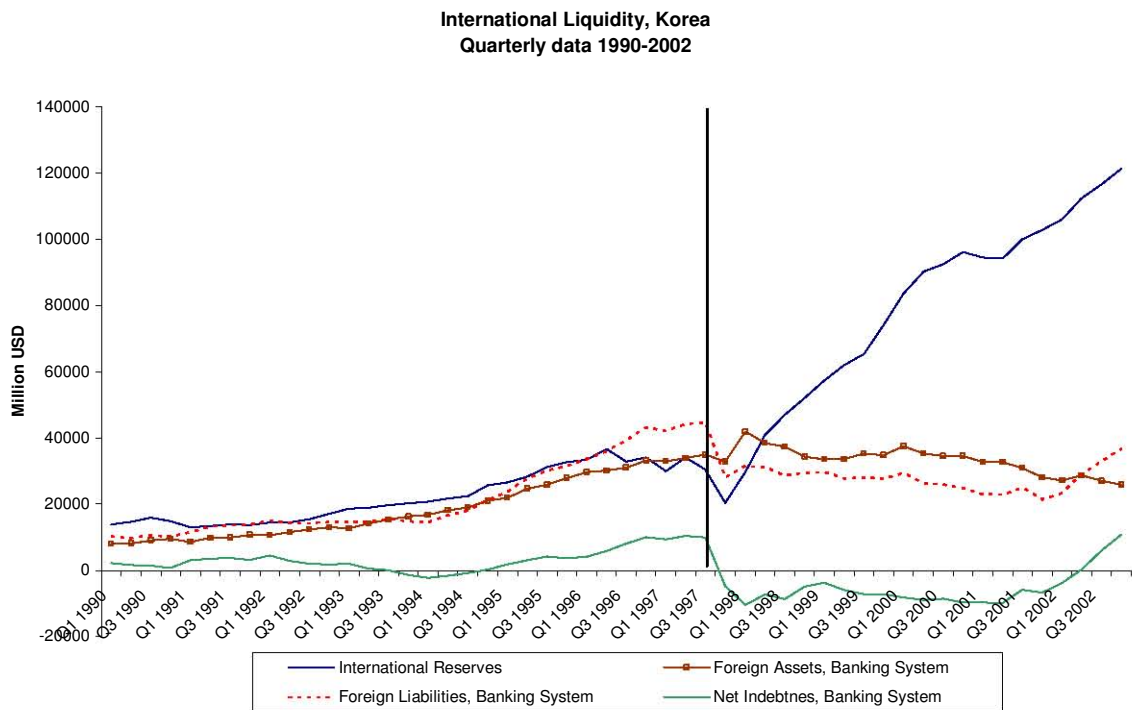


Figure 6: International Liquidity, Korea

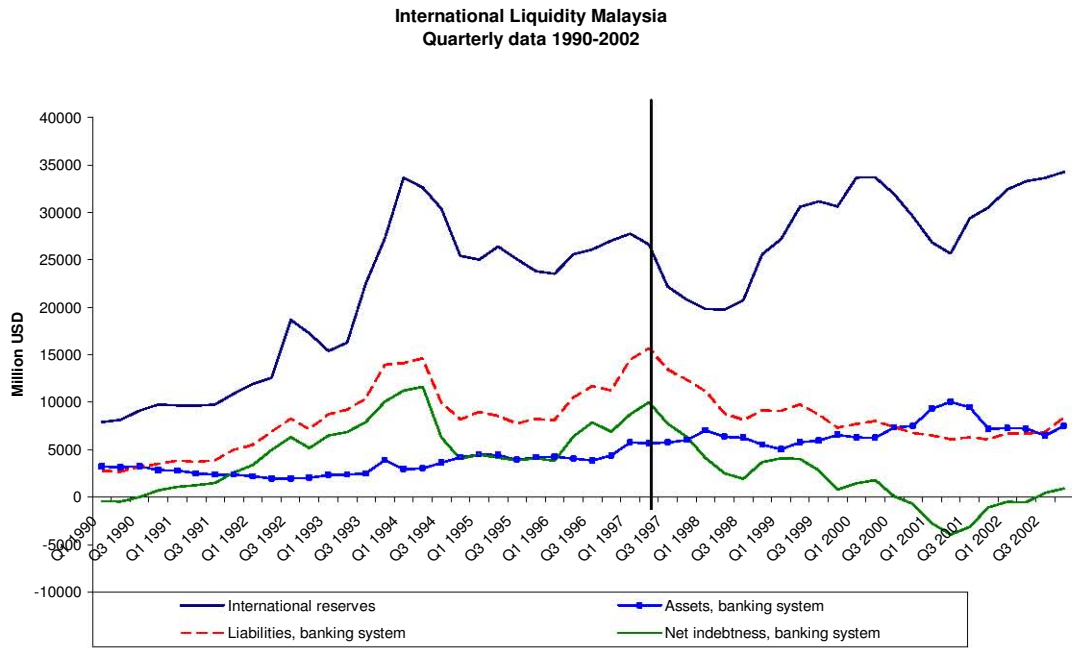


Figure 7: International Liquidity, Malaysia

With respect to the behaviour of interest rates, we can see that they follow different patterns in each country, but they have in common a period of instability and increased volatility before the crises and a peak after the currency crisis.

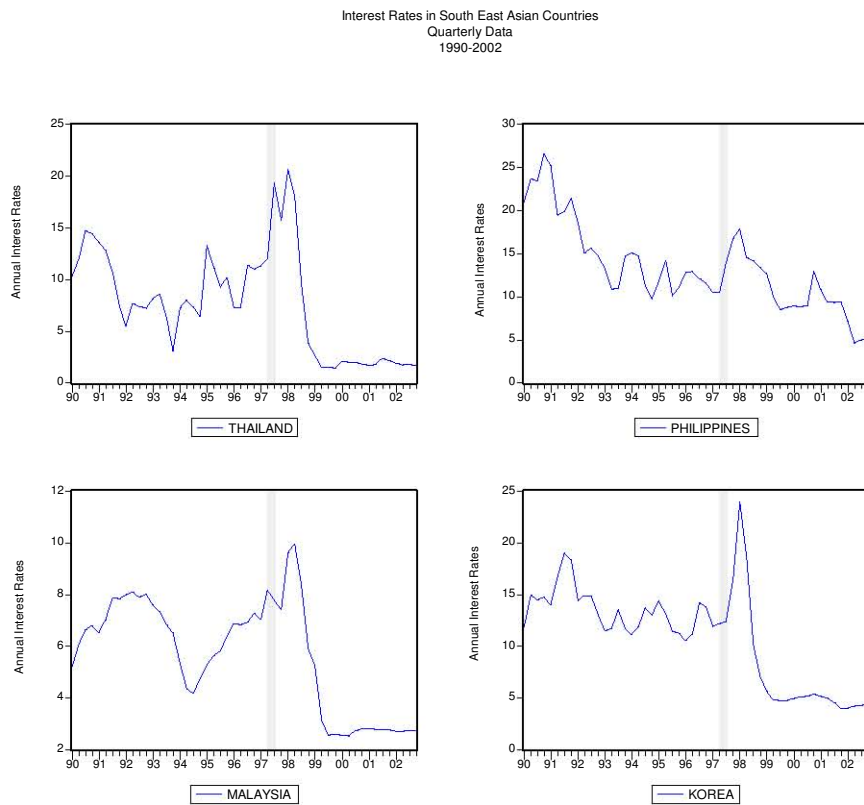


Figure 8: Behaviour of interest rates in South East Asian countries

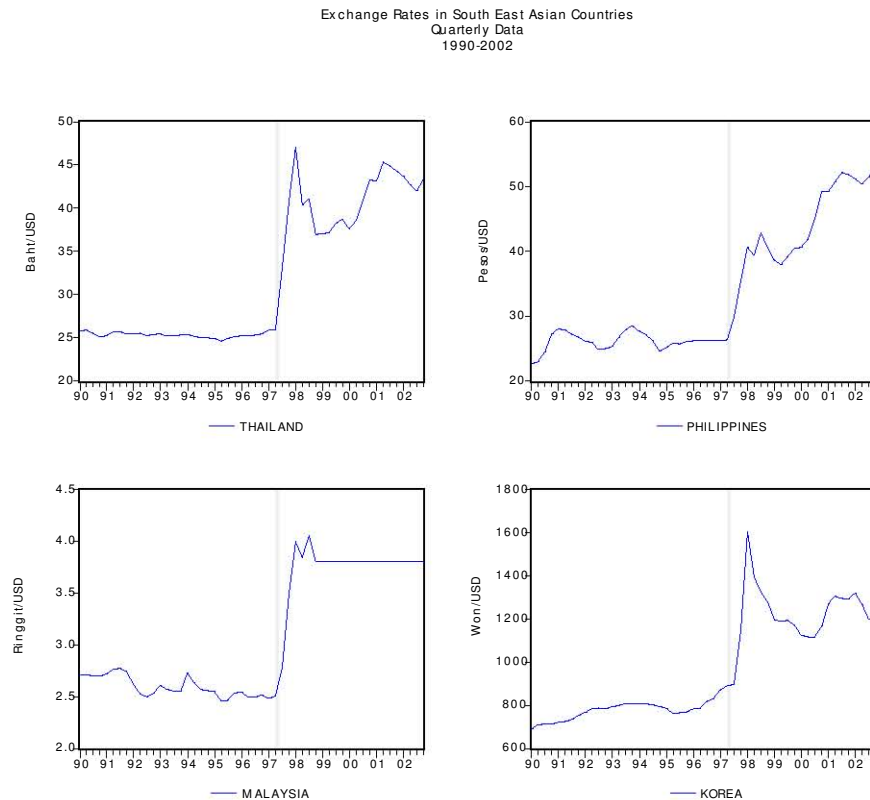


Figure 9: Behaviour of exchange rates in South East Asian countries

In **Thailand**, by the end of 1996 there was a large external deficit, fragile finance conditions of corporate firms and finance companies that had heavily borrowed abroad to finance the speculative boom in real estate and equity investments. In Indonesia, high inflation rates and a drop in trade surplus accompanied an acceleration of growth in 1995. The Bank of Indonesia raised interest rates throughout 1995 and increased reserve requirements for commercial banks from 2% to 3% in January 1996. In September 1996, the BI announced that the reserve requirements would further increase to 5% in April 1997. In an effort to reduce the effects of a monetary contraction on capital inflows, the BI widened the Rupiah's trading band from 2% to 3% around the daily mid-rate. The band was further widened from 3% to 5% in June 1996 and again to 8% in September 1996. But the broader bands did little to discourage capital inflows as expectations of higher interest rates pushed the Rupiah upward on each of these occasions.

Restricted measures were implemented by the **Malaysian** central bank, Bank Negara, in order to avoid overheating of the economy. It placed administrative controls on consumer lending for cars and houses in October 1995 and tightened reserves on Malaysian banks. By the end of 1996 growth had marginally slowed down from 8.2% to 8%. In 1996, the short term capital inflows surged to M\$ 11,300 million compared to an inflow of M\$2,400 million in 1995

and an outflow of M\$8,400 million in 1994. Malaysia also experienced an overall in bank lending as high as 27.6% with a sharp switch from lending to the manufacturing sector to lending for equity purchases.

**Korea** experienced a serious deterioration of the macroeconomic conditions in 1995-96. The current account deficit widened from 1.55% of GDP in 1994 to 4.8% in 1996, leading to an unprecedented accumulation of short-term foreign debt. Export growth fell sharply especially after negative terms of trade shocks in 1996. The stock market fell sharply in the two period 1995-96 down by 36% relative to the 1994 peak.

Relative to the other countries in the region, macroeconomic conditions were more solid in the **Philippines**. The government's budget was in surplus. Bad bank loans were at a rate of 3.4 percent by the end of 1996. However, the current account deficit was large and the currency had significantly appreciated in real terms. A very rapid lending boom to the private sector had fuelled investment in risky projects, as well as a speculative boom in the property sector.

By early 1997, the macroeconomic conditions had seriously deteriorated in most of the region (Chang and Velasco, 1999). Finance companies in **Thailand** experienced an explosive growth of lending to the real estate and property sector, mostly financed by borrowing from foreign financial institutions. Troubled financial institutions were receiving official backing. This public intervention implied a very large injection of liquidity in the economy. From January to June the government announced repeatedly its intention to bail-out the troubled financial companies. However on June 25 the new finance minister discovered that the stock of international reserves available was a fraction of the officially stated. During the spring, USD 28,000 million out of USD 30,000 million had been committed in the course of forward market interventions to defend the value of the Baht. The government realised that the overall costs of defending both the domestic value of the financial firms and the external value of the currency were unsustainable given the available fiscal and quasi fiscal resources.

The speculative attack on the Baht that followed forced **Thailand** to let the currency float on July 2. By August 5, the Thai Baht had already depreciated by 20%; Thailand unveiled a plan to revamp the finance sector as part of a more general plan agreed upon with the IMF. The central bank suspended 48 finance firms already bankrupt and eventually, 56 finance companies went bankrupt. However, despite the timing of the bankruptcy a large number of these financial institutions were bankrupt well before the currency crisis, when the sharp depreciation increased the burden of their foreign liabilities.

In early 1997, **Korea** was shaken by a series of bankruptcies of its large conglomerates (*chaebols*) that had heavily borrowed in previous years to finance their grand investment projects. The macroeconomic indicators in early 1997 showed an increasing current account deficit, export growth was falling and industrial production growth rate were way below previous levels. As a general pattern, *chaebols* that went bankrupt or had severe financial problems in 1997 had above average debt-equity ratios. The string of bankruptcies translated into serious financial difficulties for the banking system. These banks had heavily intermediated external funds, borrowing in foreign currency and lending to domestic *chaebols* in domestic currency.

In **Malaysia** the problem was with the real estate sector. Facing a booming speculative bubble in real estate and equity lending, Bank Negara waited before intervening. On March 1997, announced ceilings on lending to the property sector and for purchases of stocks and shares. The impact of these measures on the Kuala Lumpur Composite Index (KLCI) which is heavily weighted toward property and financial shares was immediate and caused foreign investors to start selling their stocks. Within a week of the announcement the index had dropped 6.6% and was 17.2% lower than the peak of February 25.

In **Indonesia**, the signs of overheating did abate in 1996 leading the BI to cut rates by 0.5% in March 1997 in the hope to moderate the inflow of capital, to ease the debt burden on Indonesian firms and to foster exports. In the meantime, however, Indonesian companies kept borrowing very heavily in international capital markets. As late as December 24 a report that total Indonesian debt was likely to be closer to USD 200,000 million almost twice as much as the government's official figure USD 117,000 million. This report estimated that the government data ignored the bulk of short term off shore borrowings and that the total foreign borrowing by the corporate sector was underestimated by USD 67,000 million.

The first currency to come under attack in the spring was the Thai Baht. Once the Baht started to depreciate in July 1997, the currencies that came under speculative pressure were Malaysia, Indonesia and the Philippines. After several episodes of depreciation, in September the Baht was 43% under its January level, the Rupiah 37% below, the Ringgit 26% and the Peso 29%. The first reaction of the authorities to speculative pressures in the foreign exchange market was to avoid a significant monetary contraction and a significant increase in the domestic interest rates. This policy was later abandoned when the extent of the currency depreciation was too high. The depreciation jeopardised the financial viability of financial and non-financial firms, which a loose monetary policy was meant to preserve, while increasing the cost of bail out beyond the fiscal means of these countries.

**Key Economic Variables of East Asian Economies**

Source: The Asian Financial Crisis and the Architecture of Global Finance

	Indonesia	Korea	Thailand	Philippines	Malaysia
Exchange rate	Crawling peg	Managed float	Peg	Managed float	Managed float
Significant accumulation of short-term foreign debt in relation to foreign exchange reserves	Yes	Yes	Yes	No	No
Significant real exchange rate appreciation 1996	Partial	No	Yes	Yes	Yes
Capital account liberalisation	Yes	Partial	Yes	Yes	Yes
Inadequate prudential regulation	Yes	Yes	Yes	Yes	Yes
Current account deficit 1996	Moderate	Moderate	Large	Moderate	Moderate

Table 7: Key economic variables of East Asian economies, Glick et al. (2001)

### 2.3. Russia, 1998

In 1992, the Russian government launched a package of measures influenced by reforms in Poland. It included a general liberalisation of prices and trade, and an attempt to restrict aggregate money supply in order to halt the possible price-wage inflation spiral. In the liberalisation of prices, production and trading, Russia was relatively slow. One estimate is that at the beginning of 1995 as much as 30 percent of GDP was still covered by price controls. Privatisation has proceeded comparatively rapidly. The spheres in which Russian economic reform has most clearly lagged behind the more successful ex-communist economies are macroeconomic stabilisation, the building of market institutions and the restructuring of enterprises.

According to Hanson (1999) financing the state deficit in a non-inflationary way was not seriously attempted between mid-1992 and late 1994. Then it was done, under IMF guidance, by issuing short-term government securities, mainly treasury bills. It is important to mention that both the government's spending and its revenue-raising have been compromised by weak administration and corruption. Regarding financial supervision and control, the attempts made by the government were made by the Federal Securities Commission (FKTsB) and the Central Bank of Russia (TsBR). The FKTSB made strong efforts to protect minority shareholders and

enforce some financial transparency in corporate affairs. The TsBR, meanwhile, was slowly tightening the bank's capital and other requirements and withdrawing licences from weaker banks. Banking was the fastest growing industry in post-Communist Russia. During the banking boom of 1988-1994, which spawned 2,500 commercial banks, a major part of banks' profits were earned through speculation in foreign currency, money laundering and manipulation of state loans.<sup>10</sup> In the absence of a traditional treasury system, many large banks were authorized to carry out transactions for national, regional and city governments. Given high inflation and high interest rates, authorized banks were able to earn favourable returns in the interbank market if they held government funds on their books for a few months. The profits made on delaying government payments created fortunes for the owners of Russian banks.

By 1997, the Russian State Statistics Committee (Goskomstat) reported \$10.5 billion in new foreign investment, a 60 percent increase over 1996, and that foreign direct investment amounted to \$6.2 billion. The United States was the top source of both portfolio and direct foreign investment in 1997.

Officially recorded GDP, after declining continuously from 1989 through 1996, had shown a marginal increase of 0.9 percent between 1996 and 1997. Consumer price inflation had been brought down from 224 percent in 1994 to 11 percent in 1997. It slowed further in the first half of 1998. The rate of change of the broad money supply (M2) had been reduced from 224 percent growth during 1994 to a slight decline in the first half of 1998. In 1998 GDP was 4.6 percent below that of 1997, and consumer price inflation was 84 percent over the year as a whole.

Hanson (1999) points out that the release of the IMF loan on July 13, 1998 was the trigger of the turmoil. The IMF deal was supposed to persuade investors to stay in the markets. Instead, however, it provided both Russian and foreign investors with more liquidity in the foreign exchange market. Once the deal was made and the first \$4.8 billion was released investors ran for the exit even faster, and panic set in. Because speculation is leveraged with borrowed money, declining prices lead to margin calls and liquidation. Russian banks found themselves in a vulnerable position as markets plunged following the release of the IMF package. In the first two weeks of August 1998, Russian banks paid out an estimated \$3 billion to meet margin calls. Adding to the impending disaster was the banks' position in currency forwards, essentially speculative bets on the stability of the Ruble against the dollar and other foreign currencies. This bet was so large that 10 percent devaluation would have wiped out one third of the banking sector's \$6.4 billion in capital.<sup>35</sup> On July 14, 1998, financier George Soros published an open letter to the Russian government in the *Financial Times* recommending that Russia devalue the

Ruble by 15 to 25 percent and introduce a currency board. When the markets opened on Monday August, 17 morning, most of the biggest banks would be insolvent, the Central Bank would be forced to spend over \$1 billion each day to support the Ruble at the rate of 6.2 to the dollar, \$5 billion worth of GKO's would come due on Wednesday and \$4 billion in pensions and wages were already long overdue.

## **2.4. Brazil, 1998**

In 1992, after the administration of President Collor de Mello left the presidency of Brazil in the middle of a corruption scandal, inflation reached 1,000 percent per year. A stand-by agreement was signed with the IMF in January, 1992. However, it failed and in 1993 when inflation exceeded 2,000 percent the *Plan Real* was launched in 1993. Under the *Plan Real*, stabilisation went through three stages: a brief fiscal adjustment, monetary reform, and the use of the exchange rate as a nominal anchor. In January 1994, Brazil's Congress approved a fiscal adjustment that included cuts in current spending and creation of the emergency social fund. The second component, the temporary monetary reform measure, linked contracts prices, wages and the exchange rate to a single daily escalator and unit of account (URV). Finally, on July 1, 1994, a new currency the real was introduced by converting contracts denominated in the URV into *Reais* at a rate of one to one.

The *Plan Real* brought inflation under control with remarkable speed: it fell from four digits in 1994 to two digits in 1995 and to less than two percent in 1998. GDP averaged 4 percent per year between 1994 and 1997, compared to flat or declining output in the prior five years. However the interest rates remained high, with average passive real interest rates of 22 percent per year. Fiscal problems were compounded by the emergence of substantial quasi-fiscal deficits in federal and state banks. With the end of inflation, bad loans from state banks to state governments became a serious problem. Measures to stabilise weak state banks further increased the federal government's vulnerability to capital shocks. Although the economy was growing on average above 3 percent per year between 1994 and 1998, the ratio of net public debt to GDP increased from 28 percent in 1995 to 44 percent in 1998 and jumped to more than 50 percent after the devaluation in January 1999.

Stabilisation under the Plan Real was supported by tight monetary policy, including and increase in reserve requirements. The required reserves to deposit ratio rose from an average of 26 percent during January-June 1994 to 64 percent during November 1994 April 1995. With the rise of lending restrictions the share of total seignorage seized by the Central Bank increased



from an average of 60 percent in the first half of 1994 to 84 percent a year later. The increase in required reserves and the lending restrictions to the banking sector in part explains the increase of interest rate spreads, of active real interest rates and nonperforming loans after stabilisation. During the early 1990s, Brazil followed the lead of other Latin American countries and opened trade by reducing tariffs, eliminating non-tariff barriers and abolishing subsidies and incentives to exports. The combination of liberalisation and exchange rate appreciation implied that the trade balance, which for ten years had been in surplus, showed a deficit during the last two months of 1994 that persisted through 1995 and contributed to a rising current account deficit. When Mexico's crisis hit in December 1994, Brazil's high foreign reserves gave the economic authorities some latitude in choosing how to respond to the crisis.

Fiscal and monetary measures were taken in March 1995 to control aggregate demand and to improve the balance of payments. Fiscal measures included spending cuts for federal and state enterprises, restrictions on federal payroll outlays and changes in legislation to increase tax revenues. Measures were also taken to control credit growth including a mandatory 60 percent deposit with the Central Bank on bank assets used for collateral guarantees and select loans; an increase in the tax rate on financial operations involving bank loans from 6 percent to 18 percent.; a prohibition on financial intermediation involving commercial paper by banks; and, an increase in the reserve requirement for time deposits. The policy measures to reduce the impact of Mexican crisis had the desired outcome. Economic growth slowed and by August 1995 the monthly trade balance was positive.

The control of inflation was associated with real exchange rate appreciation. The rapid appreciation under the *Plan Real* occurred at the end of 1994. The strong currency harmed the industrial sector and increased unemployment. The government reacted by creating subsidised credit to exporters through the National Development Bank (BNDES) and by approving legislation to exempt primary and semi-manufactured exports from indirect taxes. This phenomenon of accumulated real appreciation has been observed in other Latin American stabilisation programs using the exchange rate as a nominal anchor such as in Chile during the period 1975-81; Mexico during 1987-93; and, Argentina during 1990-95. The *Plan Real's* strategy to contain inflation by using monetary and exchange rate policies reduced domestic savings and created unsustainable current account deficits. These policies in turn, led to an increase in capital flows that initially helped stabilisation. Capital flows that averaged \$39 million per month between 1988 and 1991 increased up to a monthly net flow of \$970 million between 1992 and 1995. In 1996 and 1997, total net annual capital flows reached US \$33 thousand million and US \$ 26 thousand million respectively.

High interest rates accompanied a sharp increase in the debt of the public sector. In 1995, the stock of Central Bank securities and treasury securities outside the Central Bank grew 53 percent in real terms. Between 1994 and 1996 the ratio of the net debt of the public sector to GDP increased from 28.5 percent to 35 percent. Net debt continues to grow in the following years, reaching 44 percent of GDP in 1998. Prior to 1998, most domestically denominated debt was at fixed rates, and about 15 percent was dollar indexed. By early 1999, 21 percent was dollar denominated and 70 percent was indexed to the overnight interest rate. Moreover maturities fell: the interest due on domestic debt in January 1999 alone exceeded 6 percent of GDP. According to Cardoso and Helwege (1999) the Mexican crisis led to a significant loss of investor confidence, which gradually returned over the course of 1995; the 1997 Asian crisis caused a brief panic but the real jolt came with the Russian crisis in August 1998, Brazil's foreign currency reserves fell by \$30 thousand million as the government struggled to defend the real.

## **2.5. Argentina, 2001**

The decision of the government to peg the Peso to the US dollar through a currency board in 1991 set into motion a process of rapid financial deepening. Argentina introduced banking system reforms quickly and effectively. The result was an internationalized and much more resilient banking system. However, according to De la Torre, Levy and Schmukler (2002) the banking system had some important weaknesses that undermined its capacity to deal with shocks. First, it lacked prudential norms explicitly designed to address the adverse effects on the capacity to pay of the non-tradable sector of a major adjustment in the real exchange rate towards a more depreciated equilibrium level. In the absence of a nominal devaluation such an adjustment had to take place through slow nominal deflation and unemployment. Second, the financial system became significantly and increasingly exposed to the public sector and thus vulnerable to a sovereign debt crisis. Third, the liquidity safeguards for the banking system, which were by design available to any depositor on a first come first served basis, proved inadequate to protect the payments system in the context of a depositor run.

A series of external shocks as well as high fiscal spending set the economy overvalued the currency, made growth stagnant and the public debt hard to service. The new government that assumed power in December 1999 tried to induce growth through a tax-based fiscal adjustment and consequent confidence effects. It complemented fiscal adjustment with labour flexibility measures to overcome the exchange rate overvaluation and with a new IMF supported international package to refinance the debt. However, as De la Torre Levy and Schmukler

(2002) highlight, labour flexibility did not materialised, the fiscal package had an adverse effect on growth, the debt became unsustainable and there was a run on the currency and bank deposits. Policies taken after April 2001, also failed to revive growth, instead uncertainty about the currency and the value of debt led to a depositor run and the imposition of the "corralito" (popular name given to the freezing of all bank deposits) to avoid the collapse of the banking system, several changes in the country's presidency, a default on government debt and the abandonment of the currency board.

## **2.6. Conclusions of the chapter**

In this section we presented the timelines of events that preceded the abandonment of currency pegs in selected countries. There are countless accounts of this nature and the objective was to provide the reader a brief outlook of these events. However, there are few empirical studies that test the implications of new methodologies on this data; as we have discussed in the previous chapter, most of the leading indicators studies focus on OECD countries and all the comparisons of new developments are made using the OECD data set. One of the reasons is the reliability of the data available for emerging countries; the IMF database provides a standard for reporting national statistics but there are still many gaps in series and several inconsistencies still remain. The data used in the next chapters covers only from 1991 till 2002 which is the period with the most complete and reliable information. Chapter 3 analyses the causes of crises and enquires into the causes of crises (both in currency and financial markets) in order to support or reject the common perceptions of the nature of these events.

## Chapter 3: Contagion; when a storm brings a flu

*“When the US sneezes,  
Mexico catches pneumonia”*  
Mexican popular saying

*“No one could have predicted that a local conflict,  
in a remote city, in the limits of the Hellenic world  
would lead to the devastation of the Peloponnese  
War, which was the equivalent of a World War in  
the 20th century”*  
Donald Kagan, On the origins of war and the  
preservation of peace.

Since the 1980's crises in different countries have spread to other countries that are often geographically distant. There are several immediate questions that arise from the occurrence of these phenomena; first, which are the channels for the international transmission of these shocks? Second, are these channels only active during a crisis? And third, should international investors and policy makers worry about the propagation of these shocks? In order to answer these questions it is necessary to define the concept of contagion in the first place. According to Rigobon (2001) the issue of contagion has been one of the most debated topics in international finance but there is still no accord on what contagion means. However, one interesting aspect of this discussion, which the author highlights, is the strong agreement among economists on which events have constituted instances of contagion: the debt crisis in 1982, the Mexican *Tequila* effect in December of 1994, the Asian *Flu* in the last half of 1997, the Russian *Cold* in August 1998, the Brazilian *Sneeze* in January of 1999 and the NASDAQ *Rash* in April of 2000. Contagion has been measured in different contexts; one is on asset returns: interest rates, exchange rates or linear combinations of them emphasising correlation between returns or contagion through volatility. On the other hand, contagion has been measured in frameworks that try to determine the probability of a currency crisis occurring in a country of interest given domestic and international information. As a result there are two branches of contagion literature: the financial markets literature and the macroeconomic indicators one.

According to Kaminsky and Reinhart (1999) contagion has taken different forms across different studies and it has been used to describe different kinds of phenomena. Pesaran and Pick (2005) and Kaminsky, Lyons and Schmuckler (2000) agree on grouping the literature on contagion in three major categories depending on the causes of the spreading of the crises and the linkages between countries:

Type of “contagion” by cause	Characteristics	Linkage	Predictability
<b>1. Common cause (monsoonal effect)</b>	Financial crises appear to be contagious because they suffer a common external shock.	Interdependence	Crises resulting from interdependence could, in principle be predictable using macroeconomic fundamentals. If the interdependence during non-crisis periods is known, the effect of a financial crisis in one country on the likelihood of a crisis in another country can be evaluated.
<b>2. Spillovers</b>	A crisis occurs to multiple, economically interdependent countries through external links such as trade.		
<b>3. Pure contagion</b>	The market jumps from a “good” to a “bad” equilibrium. It can stem from any kind of disturbance; the defining characteristic is that the rapid transmission to multiple countries is beyond what is warranted by fundamentals	Contagion	Largely unpredictable, higher correlation during crises times compared to normal times. This implies that a crisis in a country increases the likelihood of a crisis in another country over and above what would be implied by existing interdependence between those countries during non-crisis times.

Table 8: categories of contagion

As we can see, the two first categories correspond to the phenomenon of interdependence, while the third one is the one which we can properly call contagion; in this study we use the classification by linkage, which is that one of inter-dependence and pure contagion. We found that most of these studies use interchangeably pure contagion and interdependence while none of them measure these two phenomena separately. We need a useful framework to include the distinction between interdependence and contagion; in other words, apart from common links (international variables) and domestic factors that may lead to a crisis we want to include a variable that captures pure contagion effects. Pesaran and Pick (2005) propose a canonical model of contagion and provide a solution in a two-country setting. Their main argument is that in order to identify contagion effects in the presence of interdependencies the equations for the individual markets or countries must contain country specific variables; country specific fundamentals are needed to distinguish contagion from interdependence. Therefore, contagion tests that do not include fundamentals (domestic or international) cannot be valid, an example of these are pure correlation based tests<sup>18</sup>. Pesaran and Pick (2005) show that ignoring the endogeneity of the contagion indicator and/or interdependence can introduce a substantial bias in the estimate of the contagion coefficient.

<sup>18</sup> Correlation based tests of contagions attempt to overcome the identification problem by assuming that the crises periods can be identified a priori and that they are sufficiently prolonged and contiguous so that cross-country market correlations can be consistently estimated and compared. The authors argue that they are strong assumptions that are unlikely to hold in practice and their implementation tends to be subject to sample selection bias.

Another problem we found is that these methodologies address contagion present either in financial data or in macroeconomic data so currency and financial crises are treated separately. As we will discuss later on, some of these methodologies are not susceptible of modification to be applied to certain type of data (e.g. GARCH models use high frequency data from markets where heteroscedasticity is more likely to arise while models using fundamentals use low frequency data) and therefore cannot be expanded to include both types of crises in order control for the effects of a twin crisis. Because of the characteristics of crises in emerging markets during the 1990s ignoring these facts could be introducing a strong bias when measuring contagion.

Pesaran and Pick (2005) provide a useful framework that can be modified to nest different methodologies. This is a methodology based on simultaneous equations where crises in each country are transmitted as signals to other countries. Hence, it provides a useful extension of existing models that are estimated as a single equation for one country which requires some a priori assumptions about the direction of contagion and about the role of different variables. The main feature of this model is that it provides with a clear contagion definition which can be summarised as: the effect on a domestic performance indicator of an extreme value of other country's indicator given the effects of domestic variables and common links. This definition does not depend on the channel of transmission of contagion since the performance indicator can take the form of probability of a crisis event happening, a composite index, changes of a variable or the variance of disturbances. Depending on this assumed via of contagion the corresponding econometric approach is to be applied. However, the clear distinction between interdependence and contagion remains a critical issue in the estimation.

**First we present an overview of the different methodologies and definitions of contagion that have been applied in the literature. Secondly, we present the derivation of the Pesaran and Pick (2005) model, some estimation issues and how this approach compares to other studies. Third, we apply the Pesaran and Pick's (2005) model to Mexican, Brazilian and South East Asian data in order to estimate the contagion effect while controlling for interdependence and we try to find a link between financial and currency crisis. As we will see, the estimations are compatible with the findings by Chang and Velasco (1998a) when analysing the causes of the crises in these countries. We used the Exchange Rate Pressure index proposed by Eichengreen, Rose and Wyplosz (1996) as the main indicator for a currency crisis and propose a Financial Market Pressure index for a financial crisis. We use the standard set of macroeconomic variables used in the study and analysis of crises in OECD countries. Finally, we present the conclusions of the study.**

### **3.1. The study of contagion: are crises airborne or do they spread by contact? Do we identify the symptoms or the disease?**

According to Dornbusch, Park and Claessens (2003) although research has progressed, there is not yet a uniform definition of contagion. However, contagion in general is used to refer to the spread of market disturbances from one country to another; this process can be observed through co-movements in exchange rates, stock prices, sovereign spreads and capital flows. Kaminsky, Lyons and Schmuckler (2000) argue that the non-fundamental explanation of contagion has attracted more attention than the fundamental-driven approach. This theoretical work focuses on rational herding. In Calvo and Mendoza (1998) and Calvo (1999), the costs of gathering country-specific information induce rational investors to follow the herd and uninformed investors replicate selling by liquidity-squeezed informed investors because the uninformed mistakenly (but rationally) believe these sales are signalling worsening fundamentals. Kodres and Pritsker (1999) focus on investors who engage in cross-market hedging of macroeconomic risks. International market co-movement can occur in the absence of any relevant information and even in the absence of direct common factors across countries. Kaminsky and Schmuckler (1999) find that spill-over effects unrelated to market fundamentals are quite common, and spread quickly across countries within a region.

On the other hand, following a fundamental-driven approach Eichengreen, Rose and Wyplosz (1996) examine whether contagion is more prevalent among countries with either important trade links or similar market fundamentals. In the first case, devaluation in one country reduces competitiveness in partner-countries, prompting competitive devaluations (which are a case of fundamental spill-over contagion). In the second case, devaluation acts like a wake up call: investors seeing one country collapsing learn about the fragility of 'similar' countries, and speculate against those countries' currencies (common cause contagion). Following this reasoning, Corsetti, Pesenti and Roubini (1998), claim that trade links drive the strong spillovers during the Asian crisis.

Kaminsky and Reinhart (1999) focus instead on financial-sector links; in particular, they examine the role of common bank lenders and the effect of cross market hedging (a type of common cause contagion). They find that common lenders were central to the spreading of the Asian crisis as they were to the spreading of the Debt Crisis of the 1980's. Choe, Kho and Stultz (1998) use transaction data in the Korean equity market to examine whether foreign investors destabilise prices. They find evidence of herding by foreign investors before Korea's economic crisis in late 1997, but these effects disappear during the peak of the crisis and there is no

evidence of destabilisation. However, these authors cannot examine the transmission of crises across countries. Dekle, R., Hsiao, C. and Wang, S. (2001) examines the role of contagion in the Asian currency crisis. These authors use a more precise definition of contagion as an excessive co-movement across countries in asset returns, including exchange rates, the co-movement is said to be excessive if it persists even after fundamentals have been controlled for. Baig and Goldfajn (1998) find that during the crisis period, the Southeast Asian currencies were highly correlated with each other but not with the Korean won. However, Forbes and Rigobon (1998), find that correlation coefficients are not significantly higher during crisis periods.

In medical terms a disease can be transmitted either by contact or the infecting agent can be airborne. Similarly a crisis can be transmitted by interdependence and existing linkages (contact) or by pure contagion (airborne), how it is transmitted has different policy implications for protecting the economy against these external shocks. Similarly, when studying possible contagious crises we need to determine: i) which were the external factors that may have contributed to fuel the crisis; ii) which were purely domestic factors; and, iii) if both external and domestic factors are not enough to explain the crisis, if there was contagion. Returning to medical terms, we need to determine not only if two persons are coughing at the same time but also their diseases; if one of them has a common cold and the other one lung cancer then we can discard contagion and interdependence.

Out of the literature, Pericoli and Sbracia (2003) identify five representative definitions of contagion that are commonly used when testing empirically for its existence. These definitions follow the categorisation by cause of contagion rather than by linkage; hence, they do not correspond entirely to the definition we are using. Depending on the definition of contagion there are different methodologies used to measure it. In this sense contagion is not a unique phenomenon, some channels of transmission may be present in turmoil periods and other may be inactive. This has as consequence that some studies can contradict each other when accounting for contagion; in other words, this can be attributed more to the different definitions of contagion and the type of linkage they imply rather than contradicting evidence. It is important to mention that although these definitions of contagion may differ and focus either on interdependence, pure contagion or a mixture of both, the type of linkage do not determine the methodology to use. In other words, any methodology can be adapted to include the effects of interdependence and pure contagion; the choice of methodologies is given by the mechanism of transmission that contagion is assumed to follow: volatility, states of nature, fundamentals, etc.

As we can see, there is not a unified approach of what constitutes contagion (usually it is used as a synonymous of interdependence) or which is the mechanism it spreads through. This



lack of consistency in the results is exacerbated when interdependence and pure contagion are not measured as separate effects and the results are compared with studies that do and everything is labelled “contagion”. In this section we discuss each approach and try to follow when possible the notation that is consistent with Pesaran and Pick (2005) for future comparison:

	Variables	Parameters
Dependent variable of country i	$y_{it}$	
Independent common variables	$z_t$	$\delta_i$
Independent country-specific variables	$x_{it}$	$\alpha_i$
Pure contagion dummy variable	$I(\cdot)_{it}$	$\beta_i$
Country specific error terms	$u_{it}$	

Table 9: Definitions of variables and parameters

We discuss the different definitions of contagion, the underlying assumptions and the econometric approach used for its estimation. This will allow us to examine the implications of each definition and its adequacy to describe the phenomenon.

### 3.1.1. Correlation

**Definition of contagion:** *contagion is a significant increase in co-movements of prices and quantities across markets, conditional on a crisis occurring in one market or group of markets.*

Empirical examination on the evidence for contagion has largely focused on co-movements in asset prices. By stressing the quantitative dimension (a significant increase), this definition conveys the notion of contagion as ‘excessive co-movements’, relative to some standard. The open issue is thus to draw a distinction between normal co-movements due to simple interdependence and excessive co movements in prices and quantities due to some structural break in the data. Correlation based tests are the most common when using this definition. However, because of its simplicity and lack of economic structure these tests provide with no meaningful interpretation. Another important setback is that it only captures the existence of a linear relationship and ignores higher orders. Several other problems arise because they require a priori assumptions about the length and occurrence of crises, as we will discuss.

These tests consist of estimates of correlation coefficient of changes in interest rates, stock prices and sovereign spreads of different economies (Dornbusch, Park and Claessens, 2003). Under this approach, an increase in the correlations among different countries markets is considered as evidence of contagion. Forbes and Rigobon (2001) found evidence of contagion in one case out of 27 cases in 1997; zero out of 27 cases, in 1994; and none in 1987, out of 9. Boyer, Gibson and Loretan (1999) fail to find any case of contagion; furthermore, these authors show that changes in correlations over time or across different regimes cannot be detected reliably by splitting a sample according to the realised values of the data. This result is consequence of the selection bias when splitting a sample.

Studies of co-movements in financial markets are based in the following idea: consider the rates of return in countries  $i$  and  $j$  and assume a single-factor model with constant variance (Pericoli and Sbracia, 2003):

$$y_i = A_i + \alpha_i x_i + u_i$$
$$y_j = A_j + \alpha_j x_j + u_j$$

Where  $\alpha_i > 0$  and  $\alpha_j > 0$  and where  $x$ ,  $u_i$  and  $u_j$  are mutually uncorrelated random variables.

The correlation between  $r_i$  and  $r_j$  is:

$$\text{Corr}(r_i, r_j) = \frac{\text{Cov}(y_i, y_j)}{\sqrt{\text{Var}(y_i) \text{Var}(y_j)}} \quad (3.1)$$

However, a close look to this measure reveals that a significant increase in the sample correlation of rates of return is not necessarily evidence of contagion, as it may be caused by an increase in the variance of the global factor. During crises periods some increase in co-movements across markets is merely an implication of interdependence as both countries depend on  $x$ . On the other hand, contagion will occur when the observed pattern of co-movement in asset prices is too strong with respect to what it can be predicted when the international transmission mechanism is constant. Hence, in these studies it is necessary the specification of an appropriate theoretical relationship that can capture interdependence and contagion separately; correlation alone cannot distinguish between both phenomena since there is no theoretical structure behind the explanation of co-movements. In other words, correlation can only tell us when the series of returns of different countries move together but not if this is due to common factors affecting returns in both countries, to interdependence or to neither contagion nor the direction of the effects.

### 3.1.2. Volatility spillovers

**Definition of contagion:** *Contagion occurs when volatility of asset prices spills over from the crisis country to other countries.*

This definition exploits the increase in asset price volatility which occurs during periods of financial turmoil. Accordingly, it identifies contagion as a volatility spill-over from one market to another. Asset price volatility is generally regarded as a good approximation of market uncertainty. Hence, in an interpretation of this definition, contagion also refers to the spread of uncertainty across international financial markets. However, a simultaneous rise in volatility in different markets might be due to normal interdependence between these markets or to a structural change affecting cross-market linkages. GARCH models are used to model contagion via volatility of asset prices returns.

Engle, Ito and Lin (1990) carry out volatility-contagion tests on exchange rate data. This is based on the idea that volatility of disturbances in one market can spread and affect the volatility of disturbances in other markets. They assume that news affecting markets can follow two different processes. The first is like a *heat wave* so that a local disturbance won't affect global conditions. An alternative behaviour is a *meteor shower*, which is a disturbance that spreads from one market to another with some lag. The *heat wave* hypothesis is consistent with a view that major sources of disturbances are changes in country-specific fundamentals and that one shock even if it is large will remain in the affected market. On the other hand, the *meteor shower* hypothesis could be consistent with failures of market efficiency; expectations of currency movements in one market can trigger speculative movements across global markets. Another interpretation of *meteor showers* is cooperative or competitive monetary policies. If the policy switch by the Fed increases the uncertainties of the monetary stance of the Bank of Japan, or vice versa, then this would show up as the *meteor shower* and in this case efficiency is not affected.

GARCH models provide a useful tool to measure the spread of shocks across financial markets. In particular when using a GARCH specification we are looking for contagion transmitted via intra-day volatility of asset returns; in other words, it is applied to measure the effects of domestic financial market instability on international financial markets. As Engle (1982) argues, when modelling financial and currency markets there are clusters of small errors and periods with greater variability in the errors this indicates the possibility that recent past might provide information about the conditional disturbance variance. In other words, a series may exhibit periods of large volatility followed by periods with less volatility; in these cases the

assumptions of serial independence and homoscedasticity of errors is inappropriate. In a GARCH ( $p, q$ ) model the variance would follow the process that depends on lagged squared disturbances and on lagged conditional variances:

$$\sigma_t^2 = \phi_0 + \phi_1 u_{t-1}^2 + \dots + \phi_p u_{t-p}^2 + \gamma_1 \sigma_{t-1}^2 + \dots + \gamma_q \sigma_{t-q}^2 \quad (3.2)$$

In the simplest specification, a GARCH (1, 1) there is an error that can be defined as:

$$u_t = e_t \sigma_t \text{ Where } e_t \sim N(0,1)$$

$$\sigma_t^2 = \phi_0 + \phi_1 u_{t-1}^2 + \gamma_1 \sigma_{t-1}^2$$

The non-negativity conditions for the variance are  $\alpha_0 > 0, \alpha_1 \geq 0, \gamma_1 \geq 0$ . Substituting iteratively  $\sigma_{t-1}^2$ , and provided that  $0 < \gamma_1 < 1$  we can obtain the form:

$$\sigma_t^2 = \frac{\phi_0}{1 - \gamma_1} + \phi_1 \sum_{i=0}^{\infty} \gamma_1^i u_{t-(i+1)}^2$$

The properties of the model are:

1.  $u_t$  has zero mean.
2. The conditional variance is given by  $\sigma_t^2 = \frac{\phi_0}{1 - \gamma_1} + \phi_1 \sum_{i=0}^{\infty} \gamma_1^i u_{t-(i+1)}^2$
3. The unconditional variance is (as demonstrated by Shin, 2002):

$$E(u_t^2) = \sigma^2 = \frac{\phi_0}{1 - (\phi_1 + \gamma_1)}$$

4. The auto-covariances of  $u$  are zero  $E_{t-1}(u_t u_{t-1}) = u_{t-1} E_{t-1}(u_t) = 0$

Hamao, Masulis and Ng (1990), Engle, Ito and Lin (1990) and Fleming and Lopez (1999) study the transmission of volatility between the US, the UK and Japan for the same period with mixed results, the first study found that the direction goes from the US and UK to Japan; the second study found that Japanese news are more likely to spill-over; finally the latter found that New York is not affected by the other two but in a lagged basis. Edwards (1998) studies the transmission of shocks through interest rates. Weekly and monthly data is used to analyse interest rate behaviour in Argentina, Chile and Mexico during the 1990s. The GARCH model of interest rates used is:

$$\begin{aligned}
y_{i,t} &= \theta + \sum \alpha_i x_{i,t} + u_{i,t} \\
\sigma_{i,t}^2 &= A + \phi u_{i,t-1}^2 + \gamma \sigma_{i,t-1}^2 + \sum \beta_i \sigma_{y,j}
\end{aligned}
\tag{3.3}$$

Where  $y$  in this case corresponds to the nominal interest rate;  $x$  is a vector of variables that affect changes in the interest rate, which may include lagged values of  $y$ , domestic and international variables;  $u$  are innovations to interest rate changes with zero mean and conditional variance  $\sigma_t^2$ ; and  $\sigma_{y,j}$  is a vector of variables of country  $j$  other than past squared innovations or lagged forecast variance that can explain interest rate volatility. The interest of the study is to investigate whether there has been “volatility contagion” from Mexico to the two South American nations. This is done by including Mexico-specific volatility variables in the estimation of the conditional variance equation for each country. The estimation of the first equation  $y_{i,t}$  for Argentina and Chile is done by Ordinary Least Squares (OLS). The analysis of the residuals clearly showed the presence of conditional heteroscedasticity. The second equation requires the selection of a group of indexes of Mexican volatility. In order for volatility to be positive at all times, these indexes and their estimated coefficients should be nonnegative. For this reason, four indicators were chosen:

- The estimated conditional variance from a fourth order GARCH model for changes in Mexican short-term interest rates.
- A dummy variable that took the value of one in any week when the Mexican Peso depreciated by 3 percent or more and zero otherwise<sup>19</sup>.
- The absolute value of weekly changes in Mexican short term nominal interest rates; and,
- The estimated conditional variance from a GARCH (1, 1) model of Mexico’s rate of devaluation.

$$\begin{aligned}
\Delta y_t &= \theta + \alpha_1 y_{t-1} + \alpha_2 time + u_t \\
\sigma_t^2 &= A + \phi u_{t-1}^2 + \gamma \sigma_{t-1}^2 + \beta MEXVOL
\end{aligned}$$

Where MEXVOL refers to any of the Mexican volatility indicators defined above.

As we can see, in this case it is possible to make a distinction between global factors, domestic variables and possible contagion affecting returns depending on the specification of the vector  $x$ . To the extent that the model to estimate includes relevant variables it would be possible to separate interdependence effects and pure contagion effects.

<sup>19</sup> This is an arbitrary threshold that could be moved to check for robustness.

### 3.1.3. Probability of crises

**Definition of contagion:** *Contagion is a significant increase in the probability of a crisis in one country, conditional to a crisis occurring in another country.*

This definition is usually associated with empirical studies of the international implications of exchange rate collapses. It accounts for the observation that exchange rate crises tend to involve a large set of countries, while some of the countries in the set may be able to avoid devaluation despite being hit by strong waves of speculative pressures. One of the approaches used in the literature is to estimate the probability of a crisis happening, as this includes external variables, it can be used to measure contagion. Kaminsky (1999) and Kaminsky, Lizondo and Reinhart (1998) use a set of macroeconomic and financial indicators in order to predict currency crises. This approach uses a leading indicator that often takes the form of a weighted average of changes in the exchange rate, in short-term interest rates and in international reserves in order to capture speculative pressures in currency and money markets. A crisis in a country is then defined as an extreme value of this indicator (n-standard deviations above the mean). Then a set of control variables can be used to estimate the probability of a crisis happening, this set of variables include domestic and external macroeconomic variables.

Johnston and DiNardo (1997) explain that probit models are based on the idea of transforming a set of variables and their parameters  $X\beta$  into a probability measure:

$$prob(y_i) = F(X_i\beta)$$

This function can be the cumulative standard normal distribution function, and with this specification we get the probit model:

$$prob(y_i = 1) = \int_{-\infty}^{X_i\beta} \frac{1}{\sqrt{2\pi}} \exp\left(-\frac{z^2}{2}\right) dz$$

Another specification for the probit model is to have a binary variable as the dependent variable  $y_i^*$  that takes the value of 1 if  $y_i > c$  a certain threshold. In this case the model to estimate is of the form:

$$y_i^* = X_i\beta + u_i$$

We can define the probability if  $y > c$  as:

$$prob(y_i^* = 1) = prob(y_i > c) = prob(X_i\beta + u_i > c) = prob\left(\frac{u_i}{\sigma} > \frac{c - X_i\beta}{\sigma}\right)$$

Where  $\sigma^2$  is the variance of  $u$ . The standard normal distribution is symmetric therefore we can rewrite it as:

$$prob(y_i^* = 1) = prob\left(\frac{u_i}{\sigma} < \frac{X_i\beta - c}{\sigma}\right) \quad (3.4)$$

This model can be estimated then by maximum likelihood, where the likelihood function is derived as follows: first we define  $prob(y_i^* = 1) = \phi$  and  $prob(y_i^* = 0) = 1 - \phi$ . If we have i.i.d. sampling the likelihood is just the product of the probability of each observation. If we have  $n$  observations from which  $m$  observations are  $y_i^*=0$  and the rest  $n-m$  are  $y_i^*=1$ . The likelihood function is denoted by:

$$L = \prod_{i=1}^m \phi \prod_{i=m+1}^n (1 - \phi) = \prod_{i=1}^n \phi^{y_i^*} (1 - \phi)^{1-y_i^*}$$

Finally, the log-likelihood function is given by:

$$\ln L = \sum_i^n (y_i^* \ln \phi + (1 - y_i^*) \ln (1 - \phi)) \quad (3.5)$$

Berg and Patillo (1999) obtain composite leading indicators of a currency crisis by estimating a probit model with individual indicators as independent variables. These authors estimate the probability of a crisis to happen within the next 24 months as a function of the set of  $N$  indicators  $x$  as:

$$Prob(c = 1) = f\left(0 + \sum_{i=1}^N \alpha_i p(x_i) + \sum_{i=1}^N \alpha_{1i} I_i + \sum_{i=1}^N \alpha_{2i} I_i \times (p(x_i) - T_i)\right)$$

Where  $p(x_i)$  is the percentile of the indicator,  $T_i$  is a threshold value for the percentile of the indicator and  $I_i$  is a binomial variable that takes the value  $I_i=1$  if  $p(x_i) > T_i$  and zero otherwise. According to Berg and Patillo (1999) results, the linear probit generates a probability of crisis above 25% in 80% of the periods that precede a crisis which although is “better than a chance guess”(sic) still leaves unaccounted for around 70% of the probability of a crisis occurring.

In another set of studies Eichengreen, Rose and Wyplosz (1996), Caramazza, Ricci and Salgado (2000) and Van Rijckmen and Weder (2001) reach similar conclusions, that trade linkages explain contagion better than macroeconomic similarities. The main finding of these studies is that financial and trade linkages are the most important elements to explain crises; these effects, according to our previous discussion, constitute cases of interdependence rather than contagion. In other words, studies based on probit models have not discriminated between interdependence and contagion because of the omission of a pure contagion variable that accounts for transmission channels different from the already existing linkages.

### 3.1.4. Regime switching

**Definition of contagion:** *Contagion occurs when cross-country co-movements of asset prices cannot be explained by fundamentals.*

This definition of contagion is theoretically precise in the framework of models that allow for multiple instantaneous equilibria in the presence of a coordination problem. If the spread of a crisis reflects an arbitrary switch from an observed equilibrium to another, fundamentals alone cannot explain its timing and modalities. The state of fundamentals may nonetheless explain why some countries are vulnerable to crises while others are not. This definition is the closest to capture pure contagion since fundamentals and interdependence do not account for the occurrence or the depth of a crisis.

Many economic variables exhibit episodes in which the behaviour changes radically. These changes may be attributed to different exogenous shocks, such as wars, panics or different government policies. The behaviour of the series in each period can be described with two different models. However, this does not take into account the process of the switch of regimes itself. Moreover, the change in regime may not be a deterministic event but a random variable and we would need a complete time series model to describe the governing dynamics of the change between regimes. Therefore, we need to include in the process an unobserved random



variable corresponding to the state or regime that the process was at date  $t$  (Hamilton, 1994). Fratzscher (2002) gives the most complete description of the standard model of regime switching which is used by Jeanne (1997) and Jeanne and Masson (2000) to study OECD countries. In order to describe this process the parameters  $\Omega$  of a VAR process are assumed to be time invariant until the state changes and this set changes as well; this set  $\Omega$  contains the variables that will allow us to estimate the transition probabilities of the unobserved states that are governing the Markov process. With 2 regimes  $s_t$  (corresponding to the crisis and non-crisis states) the conditional probability density of a vector  $y_t$  can be written as:

$$p(y_t | Y_{t-1}, s_t) = \begin{cases} f(y_t | Y_{t-1}, \Omega_1) & \text{if } s_t = 1 \\ f(y_t | Y_{t-1}, \Omega_2) & \text{if } s_t = 2 \end{cases}$$

Where  $Y_{t-1}$  is the set of past observations of the vector  $y_t$ ,  $\Omega_k$  is the VAR parameter vector for regime  $k=1,2$  and  $f(\cdot)$  describes the density function of the normal distribution conditional to the state and the set of parameters  $\Omega_k$  that correspond to that state (this parameters correspond to the mean, variance and probabilities at each state). In order to determine the regime-generating process, i.e. what determines which regime  $s_t$  prevails at any one point of time. The regime-generating process is assumed to follow a Markov chain with transition probability  $p_{kl}$  of the form:

$$\Pr(s_t = k | s_{t-1} = l, s_{t-2} = m) = \Pr(s_t = k | s_{t-1} = l) = p_{kl}$$

$$\sum_{k=1}^2 p_{kl} = 1$$

Where  $p_{kl}$  is the probability of being in regime  $k$  in period  $t$  if the regime  $l$  prevailed in period  $t-1$ ; the Markov chain of the equation above states that the probability of being in state  $k$  in period  $t$  is solely dependent on which regime prevailed in the previous period ( $t-1$ ). Accordingly, the transition matrix  $P$  can be written as:

$$P = \begin{pmatrix} p_{11} & p_{12} \\ p_{21} & p_{22} \end{pmatrix}$$

Every row in this matrix describes a different state  $k$  in period  $t$  and each column stands for a different regime  $l$  in  $t-1$ . Markov switching models specify a number of regimes for relevant economic variables and estimate the probabilities (described by a Markov transition matrix) of moving from one regime to another. When using this approach any discontinuity can be

attributed to jumps between multiple equilibria. However, the number of regimes is often arbitrarily fixed and the switch across equilibria is regulated by an exogenous process so that the nature of the phenomenon effectively captured is not clear.

Using this principle, Fratzscher (2002) builds a model in which the exchange rate pressure in one country depends on a set of fundamentals of this country, some measures of its real integration (real linkages) and financial integration with other countries all with the possibility for regime switching. One of the most important findings is that although Markov switching models without real and financial integration perform well for most countries, any regime-switching is ruled out when real and financial integration is included in the analysis. In other words, integration (which is a case of interdependence) in many cases explains regime changes that cannot be accounted for by domestic fundamentals. This suggests that the factors that explain currency crises (i.e. regime changes) are not unobservable but in many cases are captured through the inclusion of integration variables. The data generating process as specified by Fratzscher (2002) focuses on changes in the intercept  $v_i$ , and in the error variance  $\sigma^2$  which are both state dependant; the state space form equation to be estimated is:

$$y_{i,t} = v_i(s_t) + \alpha' x_{t-1} + \beta_R' \sum_j (y_{j,t-1} \times REAL_{ij}) + \beta_F' \sum_j (y_{j,t-1} \times FIN_{ij}) + \sigma(s_t) u_{i,t} \quad (3.6)$$

Where  $\beta_R, \beta_F$  and  $\beta_x$  denote the parameters for real and financial interdependence variables and domestic fundamentals respectively. Jeanne (1997) and Jeanne and Masson (2000) consider a second generation model of currency crises in which multiple equilibria arise and determine three different probabilities of a devaluation. Jumps between equilibria correspond to jumps between probabilities. In this setting, once macroeconomic fundamentals enter into a multiple equilibria zone, jumps can occur as a result of a sunspot without any further change in the economy. Moreover, such a sunspot can be represented by a 2 x 2 Markov transition matrix, which defines the probability that the economy jumps between equilibria. In these studies, a multiplicity of fundamental-based equilibria makes it possible to construct equilibria in which the economy jumps across states with different levels of devaluation expectations. A priori, jumps between states may be related to the fundamentals but this is not necessarily the case; they may also be driven by a sunspot variable which coordinates the private sector expectations on either state.

The probability of devaluation is estimated, in percentage, as the one-month interest differential between Euro-franc and Euro-DM instruments, after assuming a devaluation

threshold size of 5%. This “probability” is in reality a proportion of the observations that crossed the threshold with respect of the total observations; this ensures that the “probability” is bounded between 0 and 1. Jeanne (1997) and Jeanne and Masson (2000) consider sunspot equilibrium with  $n$  states and a devaluation probability in state-space form:

$$p(y_t | s_t) = \gamma_{s_t} + \alpha x_t + u_t \quad \forall \text{ state at date } t \quad s_t = 1 \dots n \quad (3.7)$$

Where  $\gamma_{s_t}$  a constant that depends on the state  $s$ ;  $x$  is a vector of relevant macroeconomic fundamentals and  $u_t$  is an i.i.d. shock, all of which can be written as function of the structural parameters of the model. Regime shifts affect the devaluation probability by changing the constant term on the right-hand side of the equation but leave the coefficients of the fundamentals unchanged.

### 3.1.5. Changes in the transmission mechanism

**Definition of contagion:** *Shift-contagion takes place when the transmission channel intensifies or, more generally, when it changes after a shock in the market.*

In this approach, contagion occurs when a crisis at country  $i$  spreads through a transmission mechanism that i) didn't exist before the crisis or ii) intensifies the effects of previously existing links, e.g. trade links or financial integration. Dornbusch, Park and Claessens (2000) discuss the factors that may constitute transmission channels for a crisis to propagate from one country to another. One channel involves trade links, any major trade partner of a country where a financial crisis has caused large currency depreciation could experience declines in asset prices, large capital outflows or become the target of a speculative attack, because investors foresee a decline in its exports to the crisis country and hence a deterioration in its trade account. A second channel related with trade links can be competitive devaluations. A devaluation of a country stricken by a crisis can reduce the export competitiveness of other countries which compete in third markets and can put a pressure on other countries' currencies; then a policy decision could be to compete via devaluation of the others' currency. Financial links can be another transmission mechanism, especially in countries that have extensive integration in capital and debt markets. The higher the degree of financial market integration, the more extensive could be the contagious effect of a common shock. The first shock (a domestic crisis) that is country specific becomes 'regional' or 'global' affecting another country or set of countries. If we imagine a factor  $x_i$  for which factor loadings are zero in all countries but one during calm periods and become positive during crisis periods.

$$\begin{aligned} y_i &= A_i + \delta_i z + \alpha_i x_i + \varepsilon_i \\ y_j &= A_j + \delta_j z + \alpha_j x_i + \varepsilon_j \end{aligned} \quad (3.8)$$

Where  $z$ ,  $x_i$ ,  $\varepsilon_i$ ,  $\varepsilon_j$  are mutually uncorrelated random variables. If there is interdependence,  $\alpha_j=0$  so the process for country  $j$  is equivalent to the data generating process  $y_j = A_j + \delta_j z + u_j$ . Contagion occurs when the country specific shock  $x_i$  becomes a global factor and then  $\alpha_j \neq 0$ .

Within the framework of Pesaran and Pick (2005) this is purely an interdependence test from the definition of “contagion”. The assumption is that trade and financial links and competitive “games” are the source of international transmission and these channels intensify during the crisis event. Additionally, since the variable  $x_i$  is country specific we have to assume a priori that a given country is the source of the disturbance rather to test from the direction of possible contagion.

As we can see, in the reviewed literature there is no clear-cut way to distinguish between interdependence and contagion. Pesaran and Pick (2005) argue that the identification of contagion in the presence of interdependence requires that the equations for the individual countries contain country specific forcing variables to control for normal market interactions and their effect in the economy in times without crisis; if we ignore interdependence we can introduce an upward bias in the estimate of the contagion coefficient that could be substantial. We can summarise the assumptions of the different methodologies and their implications as follows:

Approach	Definition of “contagion”	Channel of transmission	Type of linkage
1. Correlation	Increased correlation of a relevant variable.	Undetermined	Undetermined
2. Volatility spillovers	Increased volatility in one market given an increase in another market.	Volatility	interdependence or contagion
3. Probability of crises	Increased probability of a crisis on one country given a crisis in another country.	Probability	Interdependence or pure contagion
4. Regime switching	Change of regime in one country given a crisis in another country	Fundamentals, linkages or pure contagion	Interdependence or pure contagion
5. Changes in transmission mechanism	Existing channels intensify or change during a crisis.	Real or financial linkages	Interdependence

Table 10: Definitions of contagion, channels of transmission and type of linkage

In the next section we present the Pesaran and Pick (1995) model which separates interdependence from contagion this allows to have a clear understanding of the phenomenon, regardless the *vector of infection* (volatility, probability, fundamentals, etc).

### **3.2. Measuring interdependence and contagion: Pesaran and Pick (2005)**

Measuring correlation between variables does not have a solid economic interpretation and indicates only the extent of co-movements between variables; when applied to macroeconomic data we miss the explanation given by other variables that may be affecting co-movements and what may be characterised as contagion under the definition of higher correlation may in fact be due to common international factors; the effect of domestic variables is overlooked as well and therefore macroeconomic contagion measured by this method may be misleading. On the other hand, when dealing with financial data, we could be overlooking possible effects due to market conditions and possible cross-country effects of linked sectors that trade in different markets. One issue is that some methodologies are designed to measure contagion in very specific conditions; one example is the GARCH methodology that when it is applied in the context of measuring contagion in financial markets (contagion in this context is defined as a volatility spill-over across asset price movements in different markets) requires high frequency intraday data, sequential opening of markets and overlapping periods of trade; because of these requirements this methodology cannot be easily applied to macroeconomic data with lower frequency and often simultaneous events that require another econometric approach. In general, probit and transmission mechanism models already try to identify the variables that may cause a crisis taking place, this allows us to determine the fundamentals involved in the process of a crisis and to understand the underlying mechanisms that lead to one happening such as the Pesaran and Pick (2005) approach does. However, a problem is that the direction of contagion is assumed beforehand and that there is not a real difference between finding interdependence and pure contagion that is why trade links are found to be the most significant “contagion” source.

In this section we present first the outline of the Pesaran and Pick (2005) model; second, we present the derivation of the theoretical solution to the model which implies different solutions and more important different possibilities of contagion; third, we proceed to discuss how OLS estimators are inconsistent and to derive the solution using Two Stages Least Squares (2-SLS). Finally, we discuss briefly the differences and similarities of this framework with the ones already discussed.

### 3.2.1. The model

Methodologies looking for changes in the transmission mechanism have a more complete approach to determine the presence of common factors that may contribute to the spill-over of a crisis. However, pure contagion remains an unidentified variable and indistinguishable from interdependence; this is a central feature of the models since they look for a channel of transmission that intensifies, in other words interdependence. An improved measure of contagion would have to meet certain criteria to address issues of model specification, separability of effects and frequency flexibility; we defined these criteria as follows:

1. Explicit separation of interdependence and pure contagion effects.
2. Determination of the country source of contagion.
3. Inclusion of local and international variables to determine not only common factors (as in changes in the transmission mechanism approach and regime switching models) but local conditions that created a crisis (as in probit models and regime switching models).
4. Applicability to other type of contagion processes (as in GARCH-type models).

Pesaran and Pick (2005) set a canonical model of contagion for a two country framework with the following relations:

$$\begin{aligned} y_{1t} &= \delta_1' z_t + \alpha_1' x_{1t} + \beta_1' I(y_{2t} - c_2 \sigma_{2,t-1}) + u_{1t} \\ y_{2t} &= \delta_2' z_t + \alpha_2' x_{2t} + \beta_2' I(y_{1t} - c_1 \sigma_{1,t-1}) + u_{2t} \end{aligned} \quad (3.9)$$

Where  $y_{it}$  is a performance indicator for country  $i=1,2$  at time  $t=1,2,\dots,T$ , this indicator can be an index of market pressure or some other measure;  $c_{it}$  is a threshold value for the standard deviation;  $u_{1t}$  and  $u_{2t}$  are serially uncorrelated errors with zero means, conditional variances  $\sigma_{u_{1,t-1}}^2$  and  $\sigma_{u_{2,t-1}}^2$  and a non-zero correlation coefficient  $\rho$ . The regressors ( $x_{it}$ ) are  $k_i$  country-specific observed factors assumed to be predetermined and distributed independently of  $u_{jt}$  for all  $i$  and  $j$ . Country-specific dynamics can be allowed for by including an autoregressive process  $y_{i,t-j}$  in  $x_{it}$ ; ( $z_t$ ) is an  $s \times 1$  vector of predetermined observed common factors, such as international oil prices, or other common features.  $I(A)$  is an indicator function that takes the value of unity if  $A > 0$  and zero otherwise. Finally,  $\sigma_{i,t-1}^2 = \text{var}(y_{it} | \Omega_{t-1})$  where  $\Omega_{t-1}$  is the set of information available at time  $t-1$ .

In a standard simultaneous equations model, the disturbances are assumed to be distributed normally, with  $E(u_t | x_t) = 0$  and  $E(u_t u_t' | x_t) = \Sigma$  (Greene, 2000). One of the problems of simultaneous equations is given by the fact that although  $p \lim \left( \frac{1}{T} \right) X_t' u_t = 0$  and  $p \lim \left( \frac{1}{T} \right) Z_t' u_t = 0$ ,  $p \lim \left( \frac{1}{T} \right) y_t' u_t \neq 0$  which means that OLS estimators are inconsistent<sup>20</sup>. This is known as the simultaneous bias of least squares. Greene (2000) discusses several methods for consistent and efficient estimation. Pesaran and Pick (2005) choose the 2-SLS which according to Greene (2000) is the most common method to correct the problem of inconsistency. Other methods include the Generalised Method of Moments (GMM) estimation, this method is one way to address heteroscedasticity in the errors better than 2-SLS, because 2-SLS estimation is consistent but inefficient when heteroscedasticity is present; other alternative is to use Davidsons and MacKinnon's "Heteroscedastic 2-SLS" or H2SLS (Greene, 2000). When the model is nonlinear in variables, which in general is when the model takes of the form  $y_i = \sum_{j=1}^n \gamma_j f_{ji}(y, x) + X_i + u_i$  (where n is the number of nonlinear variable), OLS estimators are inconsistent but 2-SLS can be applied and the instruments would consist of  $(f_{1,i}, \dots, f_{ni}, X_i)$ . This is the case of the Pesaran and Pick (2005) approach where the elements  $\beta'_i I(y_{jt} - c_j \sigma_{j,t-1})$  for the pairs (i, j) = (1, 2) and (2, 1) introduce the nonlinearity (being a dichotomic function of the observations of the other equation) and we are left with the model specified as:

$$\begin{aligned} y_{1t} &= \delta'_1 z_t + \alpha'_1 x_{1t} + \beta'_1 I(y_{2t} - c_2 \sigma_{2,t-1}) + u_{1t} \\ y_{2t} &= \delta'_2 z_t + \alpha'_2 x_{2t} + \beta'_2 I(y_{1t} - c_1 \sigma_{1,t-1}) + u_{2t} \end{aligned} \quad (3.10)$$

Whereas a linear approach of Pesaran and Pick (2005) would take the form:

$$\begin{aligned} y_{1t} &= \delta'_1 z_t + \alpha'_1 x_{1t} + \beta'_1 (y_{2t} - c_2 \sigma_{2,t-1}) + u_{1t} \\ y_{2t} &= \delta'_2 z_t + \alpha'_2 x_{2t} + \beta'_2 (y_{1t} - c_1 \sigma_{1,t-1}) + u_{2t} \end{aligned}$$

Pesaran and Pick (2005) provide with some examples of performance indicators such as market returns used by Forbes and Rigobon (2002) and Corsetti, Pericoli and Sbracia (2002) and the "index of exchange rate market pressure" (EMP) used by Eichengreen, Rose and

<sup>20</sup> We will prove the inconsistency of the Pesaran and Pick (2005) model in a following section.

Wylosz (1996) which is a weighted average of exchange rate depreciation, interest rate differential and international reserves ratios (the precise definition is shown in the empirical section). We introduce another measure to capture the pressure on financial markets (FMP) that has a similar construction with the weighted average of the price of industrial shares and domestic credit. Pesaran and Pick (2005) assume that  $y_{it}$  is defined in such a way that a crisis is associated with extreme positive values of  $y_{it}$  and  $c_i > 0$ . In this framework, interdependence is captured through non-zero values of  $\rho$  given that we included domestic variables to control for the effects of domestic fundamentals, and is distinguished from contagion effects characterised by non-zero values of  $\beta_i$  contrary to other methodologies where interdependence and contagion effects are indistinguishable from each other. This takes into account that contagion takes place only at times of crises, whilst interdependence is the result of normal market interactions.

An important definition is that country  $i$  is said to be in crisis if the performance index rises above the threshold value and contagion is said to occur if a crisis in country 2 increases the probability of a crisis in country 1 over and above usual market interactions, and vice versa. To test for contagion, it is necessary to establish conditions under which the contagion coefficient ( $\beta_i$ ) can be identified. Once such conditions are met, a test of contagion in country  $i$  can be carried out by testing  $\beta_i = 0$  against the one-sided alternatives  $\beta_i > 0$ .

### 3.2.2. Solution and multiple equilibria

It is possible to define a new variable that groups international and domestic variables and the error term  $w_{it} = \delta'_i z_t + \alpha'_i x_{it} + u_{it}$ . As well, for simplicity, we can define the threshold value as time unvarying  $c_i$  (in other words, we will consider that a crisis occurs when the EMP or FMP values exceed a fixed non time-dependant value); with these two simplifications we can re-write the equation system as:

$$\begin{aligned} y_{1t} &= w_{1t} + \beta_1 I(y_{2t} - c_2) \\ y_{2t} &= w_{2t} + \beta_2 I(y_{1t} - c_1) \end{aligned}$$

This is a system of non-linear, non-differentiable simultaneous equations and the simplest and unique solution is when either  $\beta_1$  or  $\beta_2$  is zero. For example, suppose that  $\beta_2 = 0$ . Then the solution of the system is given by:

$$\begin{aligned} y_{1t} &= w_{1t} + \beta_1 I(y_{2t} - c_2) \\ y_{2t} &= w_{2t} \end{aligned}$$



However, there is another non-unique solution, when neither of the contagion coefficients is zero; in other words when there is mutual contagion (contagious feedback), in this case the equation system takes the form:

$$\begin{aligned} Y_{1t} &= W_{1t} + I(Y_{2t}) \\ Y_{2t} &= W_{2t} + I(Y_{1t}) \end{aligned} \quad \text{Where } Y_{it} = \frac{y_{it} - c_i}{\beta_i}, W_{it} = \frac{w_{it} - c_i}{\beta_i}.$$

This means that if there is a crisis, in country 1, then  $Y_{1t} > 0$  and the indication function takes the value  $I(Y_{1t}) = 1$  and the sign of  $W_{1t}$  can be either positive or negative with different implications depending on its sign and magnitude:

Region	Characteristics	Implication	Solution for country 1
A	$W_{2t} > 0$	<ul style="list-style-type: none"> <li>- Crisis in country 2</li> <li>- Undetermined in country 1 but increased risk of contagion</li> </ul>	$Y_{1t}^* = 1 + W_{1t}$
B	$-1 < W_{2t} \leq 0, W_{1t} > 0$	<ul style="list-style-type: none"> <li>- Crisis in country 1 (and contagion feedback)</li> <li>- Crisis in country 2 by contagion</li> </ul>	
C	$W_{2t} \leq -1$	<ul style="list-style-type: none"> <li>- Undetermined in country 1</li> <li>- No crisis in country 2</li> </ul>	$Y_{1t}^* = W_{1t}$
D	$-1 < W_{2t} \leq 0, W_{1t} < -1$	<ul style="list-style-type: none"> <li>- No crisis in country 1</li> <li>- No crisis in country 2</li> </ul>	
E	$-1 < W_{2t} \leq 0, -1 < W_{1t} \leq 0$	<ul style="list-style-type: none"> <li>- Undetermined in country 1</li> <li>- Undetermined in country 2</li> </ul>	Non-unique

Table 11: Regions of contagion

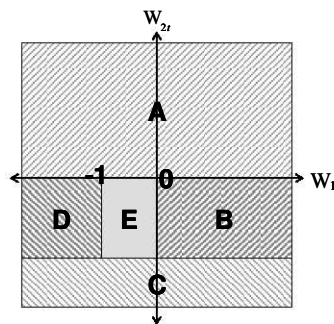


Figure 10: Regions of contagion Pesaran and Pick (2005)

In region A, there is possibility of a crisis in country 1 given a crisis in country 2 but this depends on the value of  $W_{1t}$ . In region B there is a crisis with pure contagion in country 2, in other words if there is a crisis in country 1 and even if country 2 has macroeconomic indicators not consistent with a crisis occurring because of contagion it faces one. In region C there may be a crisis in country 1 but because of fundamentals in country 2 even though there is pressure via contagion to the performance indicator there is no crisis. Region D is a stable one without crisis in either country. Non-uniqueness arises in region E if macroeconomic conditions (that

is  $W_{it}$ ) are in the limit of being consistent with a crisis occurring and get contagion but this solution is consistent with two possible states of nature, one with crisis and one without crisis:

With crisis

$$Y_{1t} = W_{1t} + I(Y_{2t})$$

$$Y_{2t} = W_{2t} + I(Y_{1t})$$

Without crisis

$$Y_{1t} = W_{1t}$$

$$Y_{2t} = W_{2t}$$

### 3.2.3. Estimation issues

This section presents some of the problems that can arise during the estimation of the model. As we are dealing with a simultaneous equations model OLS estimators are inconsistent, as we will show. In second place, the solution to the inconsistency requires the use of instrumental variables techniques (in this case 2-SLS estimation) which requires the use of strong instruments; we present a brief discussion on this issue.

#### 3.2.3.1. Inconsistency of OLS estimators

Pesaran and Pick (2005) demonstrate<sup>21</sup> that the OLS estimation of  $\beta_i$  in the simultaneous equation model is not consistent because the regressor  $I(y_{2t} - c_2\sigma_{2,t-1})$  is not independent from the disturbance term  $u_{1t}$ . However, consistent estimation of  $\beta_i$  can be achieved by using instrumental variables (IV). The IV estimator in this case may be seen as the result of a two-stage least-squares procedure using the same variables in the data set as instruments. According to Greene (2000) 2-SLS is the most common method used for simultaneous equations models and that in the absence of autocorrelation or heteroscedasticity this is the most efficient estimator that can be formed using only the included variables in the model.

#### 3.2.3.2. 2-SLS estimation

As Johnston and DiNardo (1997) explain, 2-SLS is the result of applying two times OLS: i) during the first stage, the endogenous variables of the system are regressed on the instruments (the set of all exogenous variables within the system) and obtain a matrix of fitted values; and, ii) in the second stage, the endogenous variables are regressed against the exogenous variables and the fitted values we obtained during the first stage and we obtain the vector of estimated parameters. There are three conditions that the instruments must fulfil, i) that they are exogenous; ii) they are independent of the disturbance; and, iii) they are relevant.

<sup>21</sup> See annex A3.1 (annex 1 to chapter 3) for a complete demonstration of the inconsistency of OLS estimators.

*First stage*

In order to obtain a consistent estimator, we build the instrument matrix  $\Omega = (Z', X_i', X_j')$  and the matrix that we have already defined  $H_i = (Z', X_i', D_j')$  but now we include the effect of international variables  $Z$  as well<sup>22</sup>. We obtain the fitted values  $\bar{y}_i$  as:

$$\bar{y}_i = \Omega(\Omega' \Omega)^{-1} \Omega' y_i$$

The effect of  $y_j$  on  $y_i$  in the structural equations is a non-linear one; hence, we need calculate a new matrix  $\widehat{D}_i$  of fitted values such that:

$$\bar{d}_{it} = \begin{cases} 0 & \text{if } \bar{y}_{it} - c \leq 0 \\ 1 & \text{if } \bar{y}_{it} - c > 0 \end{cases}$$

*Second stage*

In the second stage we define the fitted matrix  $\widehat{H}_i = (Z', X_i', \widehat{D}_j')$  which includes international variables, domestic variables and the estimated values of the contagion indicator. We regress the observations of the performance indicator with this estimated matrix. Then the 2-SLS estimator for each country of  $\theta_i = (\delta_i', \alpha_i', \beta_i)'$  is obtained as:

$$\widehat{\theta}_{2SLSi} = (\widehat{H}_i' \widehat{H}_i)^{-1} \widehat{H}_i' y_i$$

**3.2.3.3. Weak instruments**

Stock and Yogo (2002) and Hahn and Hausman (2002) stress the importance not only of the instruments being exogenous, but also the second condition, that is relevance holds. In the presence of weak instruments, this refers when the instruments used do not have a high explanatory power for the endogenous variables, the 2-SLS method can present problems of inference. Even in large samples, if instruments are weak the 2-SLS is biased, this problem accentuates with small samples. In this model, instruments are  $z_t$  and  $x_{it}$  for each equation; these variables serve as instruments for themselves  $x_{it}$  in equation  $i=1, 2$  and  $z_t$  in both equations; and because of the construction of the performance index,  $x_{jt}$  is correlated with  $I(y_{jt} - c_j)$  in both equations. If the variables included in the regression are the most relevant to explain pressure in

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<sup>22</sup> In the previous section we only included the domestic variables  $X$  and this matrix was defined as  $H_i = (X_i', D_j')$ .

currency and financial markets then the identification problem should be minimised. In this case we are including variables that capture the performance of the economy, trade links, monetary policy, fiscal policy and financial and exchange market pressure as explanatory variables.

Stock, Wright and Yogo (2002) explain the concentration parameter as a unit-less measure of the strength of the instruments. This parameter is distributed as chi-squared distribution with degrees of freedom  $K$  (number of instruments) and this method tests the null hypothesis that the instruments are weak; hence a large value of the concentration parameter rejects the null. For a multivariate model such as the one at hand, the concentration parameter is a  $K \times K$  matrix defined as:

$$G_T = \frac{\hat{\Sigma}_{vv}^{-1/2} \hat{H}_i' \Sigma_{\Omega\Omega} \hat{H}_i Y \hat{\Sigma}_{vv}^{-1/2}}{K}$$

Where  $\Sigma_{vv}^{1/2}$  is the covariance matrix of the vector of errors and is given by

$$\hat{\Sigma}_{vv}^{1/2} = \frac{\hat{H}_i' M_{\Omega} \hat{H}_i}{T - K} \text{ and } M_{\Omega} = I - \Sigma_{\Omega\Omega}.$$

In order to reject the hypothesis that  $\theta=0$  (weak instruments) this matrix must be large in the sense that its smallest eigenvalue is large. According to Stock, Wright and Yogo (2002) a useful interpretation of the concentration parameter is in terms of the F statistic of the first stage for testing the null hypothesis that the parameters are equal to zero. This method is straightforward and we will use it to test for weak instruments with our data.

There are other methods, such as Hahn and Hausman (2002) who reverse the null hypothesis and instead they postulate  $H_0$ =strong instruments. These authors found that when there is a single endogenous regressor and the instruments are strong, the choice of dependent variable should not matter. In other words, the 2-SLS regression of  $y$  on  $Y$  (forward regression of the observed variable regressed against its fitted values) and the 2-SLS estimator of  $Y$  on  $y$  (reverse regression) are asymptotically equivalent if the instruments are strong. Hahn and Hausman (2002) develop a statistic comparing the forward and the reverse estimators (with the extensions for 2 exogenous variables) that when tested and the null hypothesis is rejected there is indication that the instruments are weak. Stock, Wright and Yogo (2002) point out that when there are relevant instruments but they are weak, then the estimators are biased towards the OLS estimator.

### 3.2.4. Comparing Pesaran and Pick (2005) and other methods

An interesting question we can ask is whether this method can be used as a generalisation of the ones we have discussed before. In this section, we discuss briefly the possible adaptations that could be made to this model in order to include elements of the other methodologies and to compare their characteristics. Let's remember the basic formulation of the model:

$$y_{1t} = \delta_1' z_t + \alpha_1' x_{1t} + \beta_1' I(y_{2t} - c_2 \sigma_2) + u_{1t}$$

$$y_{2t} = \delta_2' z_t + \alpha_2' x_{2t} + \beta_2' I(y_{1t} - c_1 \sigma_1) + u_{2t}$$

Most of the methodologies estimate single country models; this is not an extremely important difference that invalidates the other approaches. That approach may be necessary depending of the model chosen and that is more adequate for the transmission mechanism (i.e. variance, probability or state of nature). We have to bear in mind that Pesaran and Pick (2005) main argument is that there should be an explicit separation between interdependence effects and contagion effects, independently of the form that the model takes. In other words, not distinguishing explicitly between interdependence and contagion:

- i) Constitutes a misspecification of the model and the estimators will be biased and inefficient.
- ii) Assuming a priori the direction of interdependence and/or contagion effects may constitute a sample selection bias which carries the same problems.

This is a common critique to all methodologies, independently of the form they take, when they do not recognise the two different effects.

The other main difference is the choice of contagion definition that it is assumed. The performance indicator can take the form of probability of a crisis event happening, a composite index (such as the EMP), changes in a variable or the variance of disturbances. Depending on this assumed via of contagion the corresponding methodology is to be applied. However, the distinction between interdependence and contagion remains a critical issue in the estimation.

#### *Correlation*

Correlation based models just focus the correlation between  $y_{1t}$  and  $y_{2t}$  omitting all the effects of common, domestic and contagion variables. These omissions imply that this

methodology is not really a contagion or interdependence measure but it is only a statistical description of the co-movement of the two series. Pesaran and Pick (2005) argue that they suffer from sample selection bias because the “crisis” and the “tranquil” periods are assumed a priori rather than estimated within the model. Another problem is that the observations corresponding to the crises periods are too few because of their short life span to be meaningful. Finally, the most important critique is the lack of economic structure behind it that prevents its use not only in forecasting but in the understanding of the causes of crises and the estimation of the direction of contagion effects.

#### *Volatility spillovers*

GARCH models are used to measure volatility spillovers between financial markets in different countries, specifically movements in asset prices. Because financial data often presents heteroscedastic and autocorrelated disturbances it is commonly modelled as following a GARCH process. Contagion in this setup is then assumed to happen via volatility of the disturbances. For instance, Hamao, Masulis and Ng (1990), Engle, Ito and Lin (1990) and Fleming and Lopez (1999) and Edwards (1998) use GARCH models of the general form:

$$y_{i,t} = \theta + \sum \alpha_i x_{i,t} + u_t$$

$$\sigma_t^2 = A + \phi u_{t-1}^2 + \gamma \sigma_{t-1}^2 + \sum \beta_j \sigma_{y,j}$$

Where contagion from country j is captured by the term  $\sigma_{y,j}$ .

This setup presents three main differences with Pesaran and Pick (2005), two of them refer to the structure of the model and one is of specification:

- i) Errors are correlated and heteroscedastic (which is the essence of GARCH processes);
- ii) Contagion is transmitted precisely via the volatility of the disturbance term rather than on the performance variable; and,
- iii) International variables are often not included.

The last point is easy to address, it is possible to include in the regressors a set of international variables z; if these variables are significant then we would solve a problem of omitted variables and have efficient and unbiased estimators. The other two points refer to which model is the correct one, it would be convenient to test on whether or not contagion effects are transmitted via volatility or if including them to explain the dependent variable y can account for the heteroscedasticity of the residuals. If this is not the case, and contagion

effectively transmits via volatility, an extended version of a GARCH model including domestic and international effects and a contagion signal for a crisis would look like:

$$y_{i,t} = \theta + \sum \alpha_i x_{i,t} + \sum \delta_i z_t + u_{i,t}$$

$$\sigma_{i,t}^2 = A + \phi u_{i,t-1}^2 + \gamma \sigma_{i,t-1}^2 + \beta I(\sigma_{j,t}^2 - c_j)$$

Another critique that can be made is if this model is estimated only for one country assuming the direction of contagion a priori rather than estimating the possible contagion on the other direction.

### *Probability of crises*

Berg and Patillo's (1999) probit model takes the form:

$$\text{Pr } ob(c = 1) = f \left( 0 + \sum_{i=1}^N \alpha_i p(x_i) + \sum_{i=1}^N \alpha_{1i} I_i + \sum_{i=1}^N \alpha_{2i} I \times (p(x_i) - T_i) \right)$$

In terms of Pesaran and Pick (2005), this is equivalent to assume that the performance indicator is the probability of a crisis; hence, all contagion effects will take place via probability.

In this model the set of explanatory variables can be decomposed in three subsets with different effects over the probability:

- i) The first one indicates the effect of the variables which are expressed in percentiles of the observations;
- ii) Another one that indicates a shift in the intercept due to a crisis; and,
- iii) Another one that captures changes in the slope.

The set x can include domestic variables and international variables; if we want to make explicit this separation then we can write the model:

$$P_i(c = 1) = f \left( 0 + \sum_{i=1}^N \alpha_i p(x_i) + \sum_{i=1}^N \alpha_{1i} I_i + \sum_{i=1}^N \alpha_{2i} I \times (p(x_i) - T_i) + \sum_{i=1}^N \delta_i p(z) + \sum_{i=1}^N \delta_{1i} I_z + \sum_{i=1}^N \delta_{2i} I \times (p(z) - T_z) \right)$$

This approach does not consider the effect of other countries' crisis in the form of pure contagion variables, which could be a misspecification problem as already discussed. However it may consider factors such as trade and financial linkages as part of  $p(x_i)$  but these are normal transmission mechanisms that indicate interdependence rather than contagion. Ignoring pure contagion effects would have as consequence to bias the estimators and falls into the

critique of Pesaran and Pick (2005). We can write a probit specification for country  $i$  that includes contagion effects from country  $j$  can be written as:

$$P_i(c=1) = f \left( \begin{array}{l} 0 + \sum_{i=1}^N \alpha_i p(x_i) + \sum_{i=1}^N \alpha_{1i} I_i + \sum_{i=1}^N \alpha_{2i} I \times (p(x_i) - T_i) + \sum_{i=1}^N \delta_i p(z) + \sum_{i=1}^N \delta_{1i} I_z + \sum_{i=1}^N \delta_{2i} I \times (p(z) - T_z) \\ + \sum_{i=1}^N \beta_i p_j(c=1) + \sum_{i=1}^N \beta_{1i} I_j + \sum_{i=1}^N \delta_{2i} I \times (p_j(c=1) - T_j) \end{array} \right)$$

### Regime switching

Fratzscher (2000) uses an empirical specification that takes the form:

$$y_{i,t} = v_i(s_t) + \beta_R' \sum_j (y_{j,t-1} \times REAL_{ij}) + \beta_F' \sum_j (y_{j,t-1} \times FIN_{ij}) + \beta_X' x_{t-1} + \sigma(s_t) u_{i,t}$$

There is a state-dependant variable which is not included in the Pesaran and Pick (2005) model and errors are state dependant, assuming heteroscedasticity.

We can see that contagion is defined as linkages in the real and in the financial sectors rather than pure contagion. This definition of contagion is not compatible with that one of Pesaran and Pick (2005) which defines linkages specifically as a case of interdependence and not of pure contagion. In this sense, estimators would be biased because of the omission of these latter effects. Jeanne and Masson (2000) use as dependent variable an estimate of the devaluation probability. This probability is defined as the one-month interest differential between Euro-franc and Euro-DM instruments, and corrected for the expected movement toward the centre of the fluctuation band by adjusting the series for a drift, the devaluation threshold is of 5% which was the average realignment of the franc between 1979-1986. If we remember, the model these authors estimate is denoted by:

$$p(y_t | s_t) = \gamma_{s_t} + \alpha x_t + u_t \quad \forall \text{ state at date } t \quad s_t = 1 \dots n$$

Where  $x$  are relevant economic fundamentals; it is not difficult to think that between this fundamentals there can be a subset of international variables that may affect the probability of a crisis (currency type in this case) taking place. In order to measure contagion from another country, the dependent variable fulfils the requirement of being a performance indicator that when crossing a threshold indicates a “high” probability of a crisis happening, we can interpret the contagion effect as: how the probability of a crisis in country  $i$  affects the probability of a crisis in country  $j$ . We can set an equation system such that the probability of a crisis can be thought as the performance indicator:

$$p(y_t | s_t)_{it} = \gamma_{s_{it}} + \delta_i z_t + \alpha_i x_{it} + \beta_i I \left( p(y_t | s_t)_{jt} + c \right) + u_{it}$$



If we set  $\beta_i = \beta_j = 0$  then we are left with Jeanne and Masson (2000) specification for separate countries, that is:

$$p(y_{it} | s_{it}) = \gamma_{s_{it}} + \delta_i z_t + \alpha_i x_{it} + u_{it}$$

This specification again suffers from the problem of not discriminating between interdependence and contagion effects which results in the estimators being biased. The omission of the contagion effect makes the estimators biased and inefficient. However, this omission is not due to the methodology but to the specification of the model, there is no reason why a contagion variable could not be included in this framework.

#### *Changes in the transmission mechanism*

This method is the closest in form to the Pesaran and Pick (2005) approach in its simultaneous character and the assumptions of the model. Contagion in this setup is defined as the effect of country i fundamentals on the performance indicator of country j; Pesaran and Pick on the other hand define contagion a spill over from an extreme value of the performance indicator observed at country j to the performance indicator of country i and vice versa. Strictly speaking Pesaran and Pick (2005) is a generalisation of this methodology, in which both countries are explained by their domestic fundamentals, common links and a crossed-effect of pure contagion. If we remember, under the specification:

$$y_i = A_i + \delta_i z + \alpha_i x_i + \varepsilon_i$$

$$y_j = A_j + \delta_j z + \alpha_j x_j + \varepsilon_j$$

The dependent variable depends on international variables, z and domestic variables of country i, this poses two main problems:

- i) The direction of contagion is assumed a priori rather than estimated. In other words, we are omitting possible crossed effects from country j and incurring in sample selection bias.
- ii) There is no distinction between interdependence and pure contagion.
- iii) It is possible that there are omitted variables which make the estimators biased and inefficient.

As in the case of the other methodologies, this omission of pure contagion effects and its mixing of interdependence is not a characteristic of the methodology per se but of the specification of the model to estimate.

To summarise the differences and similarities of these approaches we can compare the effects that are usually included and indicate if they can be included in the estimation.

	Pesaran and Pick (2005)	Correlation	Volatility spillovers	Probability of crises	State switching models	Changes in transmission mechanism
Performance indicator	$y_i$	Usually asset returns	Volatility	Probability of a crisis	Any real or financial selected variable	
Domestic fundamentals	$\alpha_i x_i$	Not applicable	Included			
International variables (common links)	$\delta_i z_t$	Not applicable	Usually not included but there are no restrictions to do so. It is a specification issue.	They take the form of real and financial linkages		Included
Pure contagion variable	$\beta I(\sigma^2_{j,t} - c_j)$	Not applicable	Included in the conditional volatility estimation	Usually not included but there are no restrictions to do so. It is a specification issue.		It is assumed in the form of $\alpha_j x_i$ for contagion from country i to country j.
Other effects	Not applicable	Contagion is measured as higher correlation between the variables of different countries	ARCH <sup>23</sup> process of disturbances	Not applicable	Probability of different states of nature	Not applicable
Econometric model	Simultaneous equations system with 2 countries	Correlation coefficient between 2 countries	GARCH <sup>24</sup> model with single country	Probit model for one country	Markov switching model with one country	Simultaneous equations system with 2 countries

Table 12: Comparison between methodologies

### 3.3. Contagion during the 1990's

The data to be used in the remainder of this work comes from the IFS database of the IMF; it consists of quarterly data ranging from 1993 till 2002 for Mexico, Brazil, Thailand, Malaysia, Philippines and Korea and is based on the variables contained in the data set Eichengreen, Rose and Wyplosz (1996) which has become in the standard data set for studying currency crises. The variables to build the performance indicator (the regressand) are total non-gold international reserves (f), Exchange rate with the US dollar (e); money market rates (r); domestic credit (DC); the industrial stock price index (ISP); and, the financial account (FA) measured by the IMF<sup>25</sup>. On the regressor side, the matrix X contains domestic series: data on quarterly unemployment is unavailable for these countries (Eichengreen et al. (1996), use this series in their data set) we used instead the output gap measured as the real GDP deviations from the Hodrick-Prescott trend (OGAP); money (M2); current account (CA); and, the central government budget position

<sup>23</sup> Autoregressive Conditional Heteroscedasticity.

<sup>24</sup> Generalised Autoregressive Conditional Heteroscedasticity

<sup>25</sup> Financial account is the net sum of the balance of direct investment, portfolio investment, and other investment transactions.

(GOV). World variables to use in the matrix Z are: LIBOR, oil prices (OILP), world inflation (WINF) and industrialised countries' production growth (WIPG). These variables are considered to capture all the possible risk sources for the economy; they include financial risks in international markets, trade links that play an important role in the international transmission of shocks, world economy indicators that affect the competitiveness of the country and domestic variables that capture liquidity, financial constraints and performance of the economy.

In order to apply the Pesaran and Pick (2005) methodology, we need a performance indicator. The standard approach to model currency crises is based on the behaviour of the Exchange Market Pressure (EMP) index proposed by Eichengreen et al. (1996). Similarly, we propose an additional measure the Financial Market Pressure (FMP) index to capture disturbances in the financial sector. These two indices are used as dependant variables when testing currency and financial crises respectively. Eichengreen et al. (1996) define the EMP index as:

$$EMP_{it} = \lambda_1 \% \Delta e_{it} + \lambda_2 \% \Delta (r_{it} - r_{US}) - \lambda_3 (\% \Delta f_{it} - \% \Delta f_{US}) \quad (3.11)$$

Where  $e_{it}$  is the exchange rate to the US Dollar,  $r_{it}$  the risk free interest rate, and  $f_{it}$  the international reserves of country i. Subscript US indicates variables for US, which is taken as the centre country. The weights are set to equalise the volatility of the three components. This is accomplished by setting  $\lambda_i = 1/\sigma_i$  where  $\sigma_i$  is the standard deviation of component i. We use a similar definition which captures the financial market pressure to include the distinction between currency crises from financial ones:

$$FMP_{it} = \gamma_1 (\% \Delta DC_{it} - \% \Delta DC_{US}) - \gamma_2 (\% \Delta ISP_{it}) - \gamma_3 (\% \Delta FA_{it}). \quad (3.12)$$

Where  $DC_{it}$  is domestic credit,  $ISP_{it}$  is the industrial stock price index for country i and  $FA_{it}$  is the financial account in country i. The positive sign in domestic credit captures the exposure of the economy due to an expansion of credit; the sign corresponding to the financial account captures the possible adverse effect of diminishing investment. A close look to the FMP provides a definition of what is a financial crisis under these assumptions: losses in the stock market, increased exposure through domestic credit and/or a decrease in the financial account of the country. Increases in the interest rates are captured as part of the EMP.

The dummy variable for a currency crisis is calculated as:

$$Curr_{it} = \begin{cases} 1 & EMP_{it} > \mu_{EMP} + 1.65\sigma_{EMP} \\ 0 & \text{otherwise} \end{cases}$$

Where  $\mu_{EMP}$  is the mean and  $\sigma_{EMP}$  is the standard deviation of the exchange rate market pressure index; when the exchange market pressure exceeds the threshold, then we consider that it is indeed a crisis. Commonly it is considered that 1.65 times the standard deviation is the threshold because bigger observations above are only 5% in a normal distribution, later on we vary this threshold to see how the crisis variables change. And the dummy variable for a financial crisis:

$$Fin_{it} = \begin{cases} 1 & FMP_{it} > \mu_{FMP} + 1.65\sigma_{FMP} \\ 0 & \text{otherwise} \end{cases}$$

Where  $\mu_{EMP}$  is the mean and  $\sigma_{FMP}$  is the standard deviation of the financial market pressure index.

As we already discussed, we calculated the dummy variable for a currency crisis when the EMP reaches a threshold of 1.65 times the standard deviation above the mean, by doing this we consider a crisis deviations from the mean with a probability of 5% occurring. We tried other thresholds, in particular we allowed for the upper tail having a probability of 10% (1.28 times the standard deviation) and 2.5% (2.17 times the standard deviation). By lowering the threshold, we allow for more observations to be considered as a crisis which can be at odds with the definition of an extreme value of the EMP (FMP). On the other hand, we don't gain in variability on the regressor, on the contrary since the threshold defines the value of a dichotomic variable we lose the information contained in the realisations of extreme variables, a higher threshold has the same effect by considering crisis periods as non-crisis periods. We opted to maintain the 5% threshold for two reasons: i) when raising the threshold, we could observe that most of the extreme values of the EMP didn't disappear but when doing the same exercise with the FMP series Malaysia and Brazil showed no extreme values at 2.5%<sup>26</sup>; and, ii) to be consistent with the definition of a crisis in previous studies.

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<sup>26</sup> See annex A3.2

### 3.3.1. Currency crises conditional on financial market crises

We calculated the EMP following the Eichengreen et al. (1996) specification and obtained the following series.

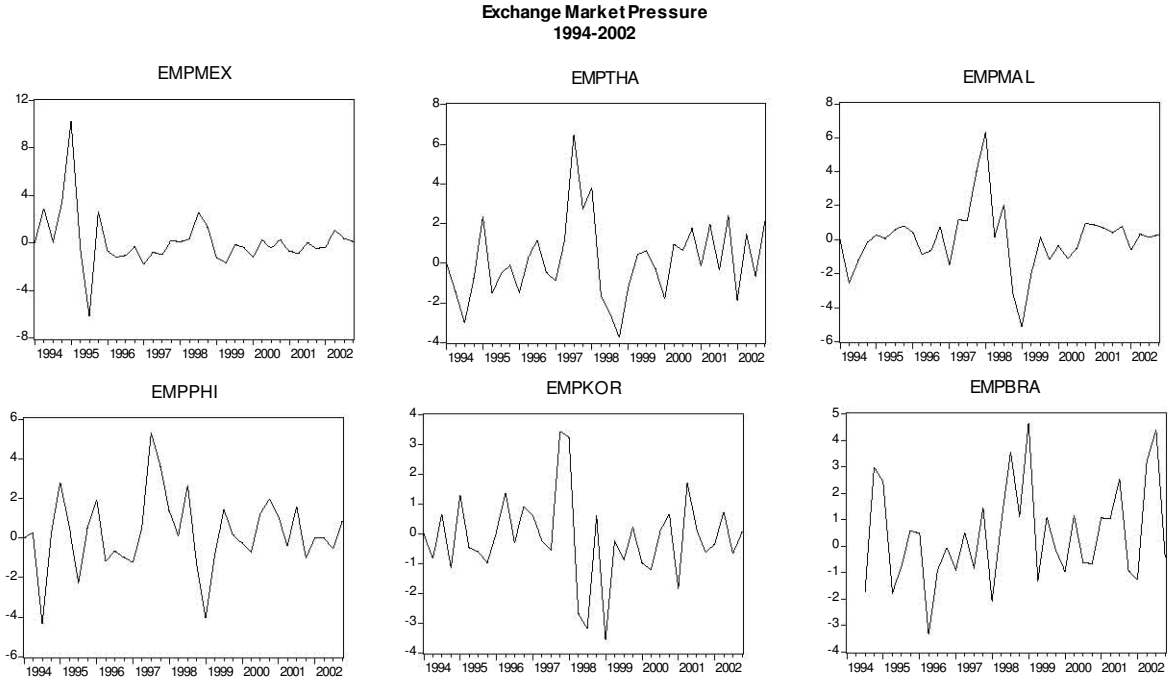


Figure 11: Exchange Market Pressure, 1994-2002.

#### 3.3.1.1. Contagion

We applied the Pesaran and Pick (2005) methodology to test for contagion in currency crises given financial crises. The model that we estimated is:

$$\begin{aligned}
 EMP_{it} = & \delta_1 LIBOR_t + \delta_2 WINF_t + \delta_3 WIPG_t + \delta_4 OILP_t + \\
 & \alpha_1 OGAP_{it} + \alpha_2 GOV_{it} + \alpha_3 CA_{it} + \alpha_4 M2_{it} + \alpha_5 FIN_{it} + \alpha_6 FIN_{it-1} + \\
 & \beta_1 CURR_{jt} + \beta_2 CURR_{jt-1} + u_t
 \end{aligned}$$

Where:

- EMP= Exchange Market Pressure index
- LIBOR= London Inter-Bank Offer Rate
- WINF= World Inflation
- WIPG= Industrialised Countries' Production Growth
- OILP=Change in Oil Prices
- OGAP=Output Gap
- GOV=Government Position
- CA= Change in the Domestic Financial Account
- M2=Change in Money M2

- FIN= Financial Market Crisis Dummy
- CURR= Foreign Currency Crisis Dummy

### *An example case: Mexico and Thailand*

Due to reasons of space we only present as an example of the process for the estimation of the Pesaran and Pick (2005) model for the EMP the case of the pair formed by Thailand and Mexico. Because of reasons of space it is not possible to include all the pairs of countries (15 estimations of the second stage, 30 of the first stage and 30 instruments tests). We chose these two countries because they are representative of the 1990's crises. Thailand was the first country to suffer a crisis in South East Asia and Mexico in Latin America. As we derived the solution earlier, the first stage of the 2-SLS consists in estimating the EMP of each country  $i$  using as instruments the matrices  $Z$ ,  $X_i$  and  $X_j$ . For this case the set of instruments is formed by the current observations of domestic and international variables and includes lagged observations of the financial crisis dummy. Our dependent variables to estimate are denoted EMPMEX and EMPTHA for Mexico and Thailand respectively. The results of these regressions are as follow.

Variable	Dependent Variable: EMPMEX		Dependent Variable: EMPTHA	
	Coefficient	Prob.	Coefficient	Prob.
LIBOR	18.4755	0.3066	26.9993	0.0929
WINF	7.998055	0.7976	-54.17457	0.0565
WIPG	8.740851	0.7994	-41.72428	0.1725
OILP	2.358198	0.6255	0.257538	0.9509
OGAPMEX	-3.139438	0.8495	20.91777	0.1562
GOVMEX	0.012365	0.7880	0.038721	0.3373
CAMEX	0.14303	0.7782	-0.689651	0.1288
M2MEX	-35.1637	0.0038	-5.25801	0.5766
FINMEX	2.947234	0.0985	0.000471	0.9997
FINMEX(-1)	-1.859297	0.3699	0.881819	0.6215
OGAPTHA	5.582366	0.7080	26.98553	0.0476
GOVTHA	-0.00532	0.9020	-0.000272	0.9942
CATHA	-0.003875	0.8330	0.001586	0.9207
M2THA	2.642778	0.6318	0.771733	0.8715
FINTHA	1.258857	0.4469	-1.10654	0.4411
FINTHA(-1)	0.85798	0.6146	0.240717	0.8703

The purpose of this stage is to eliminate the correlation between EMP and the residuals that arise in a simultaneous equation model, the errors in this first stage estimation must be i.i.d  $N(0, 1)$ . We performed a Breusch-Godfrey serial correlation test to discard autocorrelated residuals; the null hypothesis is that there is no serial correlation, as we can see we cannot reject the null. As well, we performed a Jarque-Bera under the null hypothesis that residuals are normally distributed and found that we cannot reject the null for Thailand at the 90% level of significance but for Mexico we cannot reject it only at the 1% level:

	<b>EMPMEX residuals</b>	<b>EMPTHA residuals</b>
Breusch-Godfrey	1.8122	0.5033
Probability	0.1934	0.6132
Jarque-Bera	6.3774	0.1687
Probability	0.0412	0.9191

We have to check for the strength of instruments and we can see that in both cases they are strong instruments. Even though the coefficients may not be all statistically significant, at this stage we are not interested in explaining the dependent variable but to obtain strong instruments in order to be able to obtain the best fit with the available variables.

<b>F-statistic</b>	<b>Value</b>	<b>Probability</b>
Equation: MEXTHAMEMP	2.1117	0.0608
Equation: MEXTHATEMP	2.0270	0.0714

Each of the fitted EMP series are renamed to denote the country they are conditional to; in other words, the estimated EMP for Mexico given the information of Thailand is labelled MEXTHAMEMP and the estimated EMP for Thailand given the information of Mexico is labelled MEXTHATEMP. With the fitted values of the EMP we obtain new series of the non-linear variables for a currency crisis. In this particular case these are labelled: CURRTHAMEX which is the currency crisis variable of Thailand given the information of Mexico; and, CURRMEXTHA for the currency crisis variable of Mexico given the information of Thailand.

<b>Dependent Variable: EMPMEX</b>			<b>Dependent Variable: EMPTHA</b>		
	<b>Coefficient</b>	<b>Prob.</b>		<b>Coefficient</b>	<b>Prob.</b>
LIBOR	24.82843	0.1204	LIBOR	18.36033	0.1008
WINF	6.953114	0.7963	WINF	-42.14898	0.1470
WIPG	14.81416	0.625	WIPG	-21.23943	0.4750
OILP	1.307815	0.7301	OILP	-3.541082	0.4326
OGAPMEX	-9.561929	0.5881	OGAPTHA	15.4906	0.1220
GOVMEX	0.015742	0.6565	GOVTHA	-0.008015	0.8210
CAMEX	0.395362	0.6639	CATHA	0.007451	0.5500
M2MEX	-36.91455	0.0032	M2THA	-0.843577	0.8612
FINMEX	2.612183	0.1095	FINTHA	-1.288277	0.3340
FINMEX(-1)	-2.780241	0.4593	FINTHA(-1)	0.769448	0.5588
CURRTHAMEX	2.50154	0.5997	CURRMEXTHA	-1.354231	0.4477
CURRTHAMEX(-1)	-1.119572	0.5529	CURRMEXTHA(-1)	1.977689	0.2309
R-squared	0.6176		R-squared	0.4529	
Adjusted R-squared	0.4347		Adjusted R-squared	0.1912	

As we can see the results show that there is no contagion between countries. In the case of Thailand the adjusted R-squared is of 0.1912 only, this means that this specification may not

explain very well the behaviour of the EMP in Thailand. However, when using other countries as pair for Thailand we see that the explanatory power improves. This is due to the contagion effect that is captured and can explain the behaviour in each country. We tested as well for normality and absence of autocorrelation in the residuals and we there is no evidence to reject either hypothesis.

	EMPMEX residuals	EMPTHA residuals
Breusch-Godfrey	1.6294	0.1337
Probability	0.2198	0.8755
Jarque-Bera	4.0049	0.6648
Probability	0.1350	0.7171

### *Results for all countries*

We estimated these equations (5 equations for each country paired with the other countries, in total 30 equations) and used the F-statistic to test for null hypothesis of the joint probability of all the coefficients being zero (weak instruments as defined by Stock, Wright and Yogo, 2002). In total we are estimating 5 sets of instruments for each country. We found that in the case of Philippines, the instruments were weak in all cases with the specification of the model above; hence, we modified the structural equation for Philippines in order to include lagged values of international and Philippine domestic variables which improved considerably the quality of the instruments<sup>27</sup>. In the next table we present the probability of the F-statistic of the first stage estimations, since the null hypothesis is having weak instruments, lower probability rejects the null; we can consider probabilities around 20% relevant but weak instruments following Stock, Wright and Yogo (2002). Probabilities for each country are shown in columns while each row represents the source of contagion.

Probability f-statistic; Contagion between countries (Threshold 1.65 SD)						
To \ From	Mexico	Brazil	Malaysia	Thailand	Philippines	Korea
Mexico		0.0438	0.0285	0.0714	0.0443	0.2777
Brazil	0.0118		0.0005	0.1825	0.1490	0.0775
Malaysia	0.0618	0.1162		0.0061	0.0165	0.1303
Thailand	0.0608	0.2830	0.0126		0.1100	0.1513
Philippines	0.0002	0.0112	0.0573	0.0360		0.3720
Korea	0.0780	0.0070	0.0110	0.2602	0.1082	

Table 13: Strength of instruments EMP

<sup>27</sup> Other 2 cases were Brazil and Korea when paired with Mexico; we included lagged international variables and lagged Brazilian and Korean domestic variables respectively. Modifying the specification in other pairs with already strong instruments resulted in the weakening of the instruments; therefore, those were not modified.



We found no evidence of contagion from Mexico to neither of the South East Asian countries. On the other hand we found contagion from Brazil to Malaysia and Korea with a (-) sign; due to the “bad” implication of the word contagion we will define this result as “positive contagion” which means that they benefit from other country’s movement of the EMP; such is the case of Malaysia and Thailand that benefit from Brazil. There is contagion from Malaysia to Thailand, Philippines and Korea; from Thailand, positive contagion to Malaysia; from Philippines to Thailand and Korea; and from Korea to Thailand and Philippines and positive contagion to Malaysia. As we can see contagion is not unidirectional but can result in feedback effects. We found evidence of contagion between countries in the South East Asian region and this suggests that contagion is a regional phenomenon rather than a global one. In the next table we show those countries where contagion was significant either with a (+) or (-) sign in its effect, at a given level of significance; (N) denotes that it is non-significant at that level.

Direction of currency contagion during the 1990's Contagion effect sign with different levels of significance (Threshold 1.65 SD)												
From \ To	Mexico		Brazil		Malaysia		Thailand		Philippines		Korea	
	5%	10%	5%	10%	5%	10%	5%	10%	5%	10%	5%	10%
Mexico			N	N	N	N	N	N	N	N	N	N
Brazil	N	N			(-)	(-)	(-)	(-)	N	N	N	N
Malaysia	N	N	N	N			(+)	(+)	(+)	(+)	(+)	(+)
Thailand	N	N	N	N	(-)	(-)			N	N	N	N
Philippines	N	N	N	N	N	N	(+)	(+)			(+)	(+)
Korea	N	N	N	N	(-)	(-)	(+)	(+)	(+)	(+)		

Table 14: Currency crises' contagion

### 3.3.1.2. International and domestic variables

This methodology allows measuring the impact of international and domestic variables in the behaviour of the crisis variable, such as the EMP. In this case, where countries are set in pairs, the magnitude and sometimes the significance change depending on the country it is paired with. This could be addressed in a multi country setting, however this methodology still needs better development and problems of determinacy arise in the estimation of arise when the number of countries increases. Here we present some of the results that proven to be robust enough to indicate the possible significance of the parameters taken into account, the sign of the effect is between brackets and it includes only those effects significant at 10%.

<b>IMPACT ON THE EMP</b> <b>(contagion variable not included)</b> <b>(Threshold 1.65 SD)</b>						
	<b>Mexico</b>	<b>Brazil</b>	<b>Malaysia</b>	<b>Thailand</b>	<b>Philippines</b>	<b>Korea</b>
<b>International Variables</b>						
LIBOR	(+)			(+)	(+)	
World Inflation (WINF)				(-)		
World Industrial Production Growth (WIPG)		(+)	(-)	(-)	(-)	(-)
Oil prices (OILP)					(-)	
<b>Domestic Variables</b>						
Output Gap (OGAP)			(+)		(-)	(+)
Government position (GOV)		(+)	(-)		(-)	
Current account (CA)			(+)	(-)		
Money (M2)	(+)		(-)	(+)		
Financial crisis index (FIN)	(+)	(+)	(+)	(+)		(+)

Table 15: Impact on the EMP, international and domestic variables

Some of the conclusions that we can draw from are: i) international interest rates, such as the LIBOR, had a positive impact on the exchange rate market; ii) world inflation affected Thailand with a negative sign; iii) world industrial production growth affected positively Brazil and negatively Malaysia, Thailand, Philippines and Korea; iv) oil prices were significant in Philippines; v) output gap was significant for Malaysia, Korea and Philippines; vi) government budget position was significant in Philippines, Brazil and Malaysia; vii) M2 is significant in Mexico, Malaysia and Thailand; and, viii) financial crises are significant in all countries. One of the main features of these crises and is that there were seemingly strong fundamentals and ongoing structural reforms to liberalise financial markets and trade whilst controlling government deficits. In Mexico it is clear that the political turmoil during 1994 coupled with loss of confidence in the government's policy measures lead to the crisis in December<sup>28</sup>. In South East Asia, Chang and Velasco (1999) and Corsetti, Pesenti and Roubini (1998) coincide that the detonator of the crises was the devaluation of the Thai Baht, which spread to other countries sequentially. According to Chang and Velasco (1999) Thailand was the victim of severe mismanagement from the private sector that required backing from the government but more important, when the government was trying to bail out troubled firms, it discovered that reserves were less than required and opted for a devaluation of the currency. Korea suffered from contagion and the main factor that Chang and Velasco (1999) attribute to the crisis is the worsening of the current account which is confirmed by the estimated coefficients. Malaysia was the country that was facing a worsening in its fundamentals since 1995 and there were fears of the economy becoming overheated. Philippines had solid fundamentals according to Chang and Velasco (1999) and its crisis is more to blame on contagion.

<sup>28</sup> As it is discussed earlier.

### 3.3.2. Financial crises conditional on exchange market crises

We calculated the FMP series as we already discussed and we obtained the following series:

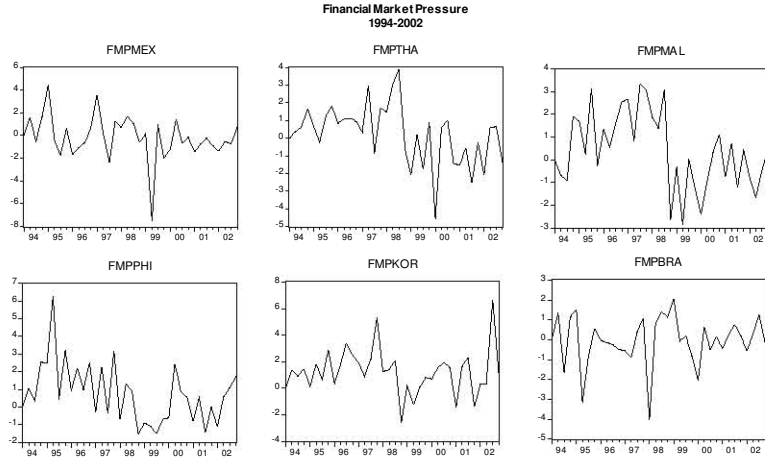


Figure 12: Financial Market Pressure, 1991-2002

#### 3.3.2.1. Contagion

The other possible channel for transmission of contagion is the financial system; we carried out the same test to find evidence of contagion but now the dependent variable is the financial market pressure index. We estimated the model<sup>29</sup>:

$$FMP_{it} = \delta_1 LIBOR_t + \delta_2 WINF_t + \delta_3 WIPG_t + \delta_4 OILP_t + \alpha_1 OGAP_{it} + \alpha_2 GOV_{it} + \alpha_3 CA_{it} + \alpha_4 M2_{it} + \alpha_5 CURR_{it} + \alpha_6 CURR_{it-1} + \beta_1 FIN_{jt} + \beta_2 FIN_{jt-1} + u_t$$

Where:

- FMP= Financial Market Pressure index
- LIBOR= London Inter-Bank Offer Rate
- WINF= World Inflation
- WIPG= Industrialised Countries' Production Growth
- OILP=Change in Oil Prices
- OGAP=Output Gap
- GOV=Government Deficit
- CA= Change in the Domestic Financial Account
- M2=Change in Money M2
- CURR= Exchange Market Crisis Dummy
- FIN= Financial Market Crisis Dummy

<sup>29</sup> Due to reasons of space we only present in annex A3.3 the complete procedure of estimation of the 2-SLS for one case, Mexico and Thailand.

We performed the same test as the previous section we estimated each of the equations of the 6 countries with the 5 contagion variables by OLS as the first stage of the 2-SLS. Again we are testing 5 different sets of instruments per country. In this case we found that Mexico, Malaysia Philippines and Korea have strong instruments regardless of which one is the other country. Brazil show relevant but weak instruments when paired with Brazil and improved with Philippines, with the rest of the countries they are weak. Thailand presents the strongest instruments when paired with Mexico and Malaysia, weaker with Philippines and Korea and the weakest with Brazil. We present the F-statistic probabilities of the first stage equations in the following table.<sup>30</sup>

Probability F-statistic Contagion between countries (Threshold 1.65 SD)						
From \ To	Mexico	Brazil	Malaysia	Thailand	Philippines	Korea
Mexico		0.1938	0.0070	0.0105	0.0000	0.1114
Brazil	0.0601		0.0150	0.3860	0.0343	0.0005
Malaysia	0.0327	0.5454		0.0985	0.0594	0.0083
Thailand	0.0923	0.5505	0.0059		0.0648	0.0052
Philippines	0.0532	0.1070	0.0032	0.1189		0.0004
Korea	0.0686	0.4309	0.0058	0.2164	0.1774	

Table 16: Strength of instruments FMP

In this case we found less evidence of contagion, being the most affected Malaysia which receives contagion from Thailand, Philippines and Korea. Brazil received positive contagion from Thailand; and Philippines received positive contagion from Korea. In the next table we show those countries where contagion was significant either with a (+) or (-) sign in its effect, at a given level of significance; (N) denotes that it is non-significant at that level.

Direction of financial contagion during the 1990's Contagion effect sign with different levels of significance (Threshold 1.65 SD)												
From \ To	Mexico		Brazil		Malaysia		Thailand		Philippines		Korea	
	5%	10%	5%	10%	5%	10%	5%	10%	5%	10%	5%	10%
Mexico			N	N	N	N	N	N	N	N	N	N
Brazil	N	N			N	N	N	N	N	N	N	N
Malaysia	N	N	N	N			N	N	N	N	N	N
Thailand	N	N	(-)	(-)	(+)	(+)			N	N	N	N
Philippines	N	N	N	N	(+)	(+)	N	N			N	N
Korea	N	N	N	N	(+)	(+)	N	N	(-)	(-)		

Table 17: Financial crises' contagion

### 3.3.2.2. International and domestic variables

As in the case of the EMP, we present here the estimated parameters of international and domestic variables on the financial market pressure index. Here we present some of the results that proven to be robust enough to indicate the possible significance of the parameters taken into

<sup>30</sup> Probabilities for each country are shown in columns while each row represents the source of contagion.

account, the sign of the effect is between brackets and it includes only those effects significant at the 10%.

IMPACT ON THE FMP 5% SIGNIFICANCE (contagion variable not included) (Threshold 1.65 SD)						
	Mexico	Brazil	Malaysia	Thailand	Philippines	Korea
<b>International Variables</b>						
LIBOR						
World Inflation (WINF)	(+)	(+)			(+)	
World Industrial Production Growth (WIPG)	(+)					
Oil prices (OILP)	(-)		(-)	(-)		
<b>Domestic Variables</b>						
Output Gap (OGAP)			(+)		(-)	(+)
Government position (GOV)			(-)	(-)	(-)	
Current account (CA)	(+)			(-)		(-)
Money (M2)						
Currency crisis (CURR)	(+)	(+)	(+)	(+)		(+)

Table 18: Impact on the FMP, international and domestic variables

In this case we found that: i) world inflation affects Mexico, Brazil and Philippines; ii) an increase in oil prices benefit Mexico, Malaysia and Thailand; iii) increases in the output gap pressures on the FMP in Malaysia and Korea; iii) a public deficit affects Malaysia, Thailand and Philippines; iv) increases in the current account pressures the FMP in Mexico, the effect has a negative sign in Thailand and Korea; and, v) currency crises consistently spread to financial crisis. Chang and Velasco (1999) recount of the currency crises in South East Asia argue that the currency crises uncovered and made evident the weakness in financial sectors once they were well underway and the economy was receding. This does not generalise to say that financial crises are easier to predict, according to Hillebrand (2004) the probability of the crash of Wall Street occurring in 1987 was only of 7%.

### 3.3.3. Relaxing the definition of a crisis: robustness

As an additional exercise we compare the results with the ones corresponding to the 10% threshold (that is a crisis happens when an observation exceeds 1.28 times the standard deviation from the mean) Regarding the EMP the countries that have significant changes (i.e. new period crises appear) are Philippines, Korea and Brazil; Mexico increases the length of the 1994 crisis in one quarter while Thailand and Malaysia are unaltered. With respect to the FMP, only Malaysia and Philippines show new crisis periods and the rest of the countries are unaltered.

#### 3.3.3.1. Currency crises conditional on financial market crises

As we can see, the strength of the instruments is not greatly affected; the main differences are to be found in the strength of instruments when Philippines and Malaysia are involved. The

reason why instruments are not affected is because the number of financial “crises” (which are used as instruments) only increases in Malaysia and Philippines as we lower the threshold. This is clear in our example of the pair Mexico and Thailand (see annex A3.3) the results of the first stage are identical because when lowering the threshold for the financial crisis there is no change in the number nor the length of the crisis signals in either country.

Probability F-statistic Contagion between countries (Threshold 1.28 SD)						
From \ To	Mexico	Brazil	Malaysia	Thailand	Philippines	Korea
Mexico		0.0438	0.0093	0.0714	0.0700	0.2777
Brazil	0.0438		0.0004	0.1825	0.0974	0.0775
Malaysia	0.0118	0.1023		0.0695	0.0022	0.3016
Thailand	0.0608	0.2830	0.0040		0.0542	0.1513
Philippines	0.1987	0.0380	0.0069	0.0295		0.2591
Korea	0.0780	0.0070	0.0092	0.2602	0.1260	

Table 19: Strength of instruments EMP (threshold 1.28 SD)

When calculating the second stage, the results differ greatly because the lower threshold allows for more currency crisis periods when applying the filter to the fitted series obtained in the first stage; if we compare the number of “crises” signalled we can see that there is a significant difference (see annex sections A3.3.1 and A3.3.2). When comparing the contagion effect with different thresholds we can see that we lose all contagion effects that Thailand receives (except the one received from Korea); Philippines does not show contagion from any country when the threshold is lowered; Malaysia now receives contagion from Philippines and there is positive contagion with Mexico; Mexico receives contagion from Brazil at 10% significance; Brazil receives contagion from Malaysia; Korea receives contagion only from Philippines and there is positive contagion from Brazil and Mexico at 10%. The reason of these differences is that with a lower threshold we are now including periods other than the ones corresponding to the main crises of interest and possible contagion effects are being measured with respect to those other “crises” as well.

Direction of currency contagion during the 1990's Contagion effect sign with different levels of significance (Threshold 1.28 SD)												
From \ To	Mexico		Brazil		Malaysia		Thailand		Philippines		Korea	
	5%	10%	5%	10%	5%	10%	5%	10%	5%	10%	5%	10%
Mexico			N	N	(-)	(-)	N	N	N	N	N	(-)
Brazil	N	(+)			N	N	N	N	N	N	N	(-)
Malaysia	N	N	(+)	(+)			N	N	N	N	N	N
Thailand	N	N	N	N	N	N			N	N	N	N
Philippines	N	N	N	N	(+)	(+)	N	N			(+)	(+)
Korea	N	N	N	N	N	N	(+)	(+)	N	N		

Table 20: Currency crises' contagion (threshold 1.28 SD)

As we can see, the countries where the effect of other variables on the EMP changes, are those where the new threshold introduces new “crises”, an example of this is the effect of WIPG on the Philippines' EMP.

IMPACT ON THE EMP (contagion variable not included) (Threshold 1.28 SD)						
	Mexico	Brazil	Malaysia	Thailand	Philippines	Korea
<b>International Variables</b>						
LIBOR	(+)	(-)		(+)		(+)
World Inflation (WINF)		(-)		(-)		(+)
World Industrial Production Growth (WIPG)		(+)	(-)		(+)	(-)
Oil prices (OILP)		(+)	(-)	(-)	(-)	
<b>Domestic Variables</b>						
Output Gap (OGAP)			(+)	(+)	(-)	(+)
Government position (GOV)		(+)	(-)		(-)	
Current account (CA)			(+)	(-)		
Money (M2)	(+)		(-)	(+)		(-)
Financial crisis (FIN)	(+)	(+)	(+)	(+)		(+)

Table 21: Impact on the EMP, international and domestic variables (threshold 1.28 SD)

### 3.3.3.2. Financial crises conditional on currency market crises

When doing the same exercise on financial crises, we obtained that with respect to the strength of the instruments, we can see that it is more affected than in the case of the EMP because the number of currency “crises” (which is an instrument in this stage) is higher in Philippines, Korea and Brazil and in Mexico the length of the crisis increases as well. In this case our example of Thailand and Mexico shows differences from the first stage because of the changed CURR series for Mexico.

Probability F-statistic Contagion between countries (Threshold 1.28 SD)						
From \ To	Mexico	Brazil	Malaysia	Thailand	Philippines	Korea
Mexico		0.0797	0.0314	0.1328	0.0001	0.0423
Brazil	0.1618		0.0355	0.3812	0.0151	0.0670
Malaysia	0.2071	0.3927		0.2584	0.0001	0.0131
Thailand	0.1740	0.3775	0.0167		0.0002	0.0039
Philippines	0.1354	0.0801	0.0144	0.0968		0.0002
Korea	0.3539	0.5868	0.0222	0.2021	0.0276	

Table 22: Strength of instruments FMP (threshold 1.28 SD)

We can see that the second stage results differ as well because of the increase in the number of crisis signals when filtering the fitted FMP obtained during the first stage (see annex A3.3.3 and A3.3.4). We have now positive contagion from Malaysia to Mexico and from Philippines to Brazil while the one from Thailand to Brazil disappears; in Malaysia, only the contagion from Philippines remains significant; Thailand now shows contagion at 10% significance from Philippines and Brazil; Philippines shows contagion only from Mexico; and, Korea now receives contagion from Brazil and Thailand.

Direction of financial contagion during the 1990's Contagion effect sign with different levels of significance (Threshold 1.28 SD)												
From \ To	Mexico		Brazil		Malaysia		Thailand		Philippines		Korea	
	5%	10%	5%	10%	5%	10%	5%	10%	5%	10%	5%	10%
Mexico			N	N	N	N	N	N	(+)	(+)	N	N
Brazil	N	N			N	N	N	(+)	N	N	(+)	(+)
Malaysia	(-)	(-)	N	N			N	N	N	N	N	N
Thailand	N	N	N	N	N	N			N	N	(+)	(+)
Philippines	N	N	(-)	(-)	(+)	(+)	N	(+)			N	N
Korea	N	N	N	N	N	N	N	N	N	N		

Table 23: Financial crises' contagion (threshold 1.28 SD)

In this case, the effect of international and domestic variables change mainly in Philippines where the results are completely different, in other countries they remain similar.

IMPACT ON THE FMP 5% SIGNIFICANCE (contagion variable not included) (Threshold 1.28 SD)						
	Mexico	Brazil	Malaysia	Thailand	Philippines	Korea
<b>International Variables</b>						
LIBOR						
World Inflation (WINF)						
World Industrial Production Growth (WIPG)	(+)					(+)
Oil prices (OILP)	(-)		(-)	(-)		
<b>Domestic Variables</b>						
Output Gap (OGAP)			(+)			(+)
Government position (GOV)			(-)	(-)	(-)	
Current account (CA)	(+)		(+)	(-)		(-)
Money (M2)				(+)		
Financial Market Pressure (FMP)	(+)	(+)		(+)	(+)	(+)

Table 24: Impact on the FMP, international and domestic variables (threshold 1.28 SD)

### 3.4. Conclusions of the chapter

An important discussion is how to define contagion: different studies have different definitions of contagion. Using the distinction that Pesaran and Pick (2005) make between interdependence and contagion, we propose a reclassification of existing studies by taking into account the type of linkage that they focus on. As a result we can see that most of them either mix both linkages into the definition of "contagion" they use or they omit pure contagion effects and focus on interdependence. Once the type of linkage is made clear, we can see that incorporating the distinction is not difficult and could improve the estimation of this phenomena, at the very least it would provide with a unified definition of which one is the phenomenon under study.

We applied the Pesaran and Pick (2005) methodology in order to look for evidence of contagion. A variable often disregarded in the study of currency crises is that linked to financial markets performance; we propose the Financial Market Pressure index that includes the role of



domestic credit, capital account and stock market index as a measure of this variable. The FMP allows not only to measure contagion on the currency market but provides with an index of the financial market that allows measuring the performance of financial markets as a macroeconomic indicator and define a financial crisis and apply the same contagion methodology as with the EMP.

We found the following sources of contagion, both for financial and currency crises.

Source of contagion	CURRENCY MARKET Affected countries	FINANCIAL MARKET Affected countries
<b>Mexico</b>	Philippines (-)	
<b>Brazil</b>	Malaysia (-) Thailand (-) Philippines (-)	
<b>Malaysia</b>	Thailand (+) Philippines (+) Korea (+)	
<b>Thailand</b>	Malaysia (+) Philippines (+)	Brazil (-) Malaysia (+)
<b>Philippines</b>	Thailand (+) Korea (+)	Malaysia (+)
<b>Korea</b>	Malaysia (-) Thailand (+) Philippines (+)	Malaysia (+) Philippines (-)

Table 25: Currency and Financial markets contagion

With regard to currency crises, the results of sources of contagion together with the figures from Brazil being a source of positive contagion suggest that the South East Asian and Latin American regions are to some extent immune to each other's crises.

Regarding the role of domestic variables in the behaviour of the EMP, we found that they were consistent with the findings of Chang and Velasco (1999) in their study about the South East Asian crisis and with the Bank of Mexico analysis of the Mexican crisis. That is, in some cases fundamentals were not at the hub of the all the currency attacks that these countries suffered. On the other hand, fundamentals are more successful explaining the behaviour of the FMP. If we think about the characteristics and the timeline of the crises, Chang and Velasco (1999) and Corsetti et al. (1998) document that financial crises followed the currency crises and financial imbalances in the private and bankruptcies were made evident after the crises occurred. As Morgan-Witts (1979) argues: "there are the same number of fraud and financial problems in calm times than in crisis times, the difference is that in a crisis there are no mechanisms to cover possible losses and failure is more frequent".

## Chapter 4: Impact on welfare; what about the consumer?

*“The more there is of mine, the less is of yours”*  
Alice’s Adventures in Wonderland,  
Lewis Carroll (1865)

Most of the available studies that address the costs of crises are concerned with the impact of sudden fluctuations in the exchange rates in output in OECD<sup>31</sup> countries. These fluctuations can be accounted as currency crises but in neither case the impact on GDP or consumption are comparable to those observed in emerging markets. Almost all studies about financial crises address the events and causes that lead an apparently successful country to a financial and currency meltdown and a subsequent contraction of income. All this literature has produced several methodologies to predict a crisis, although not all of them successfully. Some other studies have focused on the measurement of costs associated with these periods. However, costs have been associated mostly with variables such as the level of international reserves; public debt; fiscal deficits and the loss of output. The effects on welfare have been less studied and only in the case of Indonesia Frankenberg, Thomas and Beegle, (1999) conducted an in-depth survey to determine the effects of a crisis at the microeconomic level. We are going to measure welfare costs following Lucas’ (1987) framework in order to measure the impact of crises on both, utility and consumption and hence this will allow us to have a proper measure of these events’ impact on welfare.

As we will discuss in the following section, almost none of previous empirical studies have focused on measuring the costs of welfare but only in how much do output varies and/or its growth rate and how much of these variations can be explained by a crisis. As well there is no clear relationship between output losses incurred during crises and the fiscal costs of resolution associated with it. On the one hand, the larger the banking crisis the larger would be expected to be both the output losses and the fiscal costs; there could be a positive association between these costs but not clear causation. On the other hand, to the extent that fiscal costs are a good proxy for effective crisis resolution, the more spent by the authorities in resolving a given banking crisis the lower perhaps would be the output losses incurred during the crisis period. In order to fill this gap in the literature, we follow Hoggarth et al. (2002) recommendation about measuring the welfare cost rather than the change in output and consumption<sup>32</sup> by using Lucas (1987) measures of welfare cost when the consumption process suffers an alteration in its parameters.

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<sup>31</sup> Organization for Economic Cooperation and Development.

<sup>32</sup> This is discussed more in-depth in section 4.1.

Lucas (1987) developed two simple measures to determine the cost of permanent changes in the average growth rate and on the variability of real consumption. These tools provide: first, a measurement of the required increase in consumption at all dates that is necessary for consumers to accept voluntarily a reduction in the growth rate; and secondly, the required increase in consumption that would make consumers indifferent between a perfectly smooth consumption path and a process with some instability. Lucas (1987) used US parameters in order to estimate the costs of some hypothetical changes in the growth rate and in the variability of consumption with different risk aversions. However, there are some caveats in this methodology; Lucas (1987) did not include the effect of a change in the level of the trend of the consumption path and the costs are calculated separately which means that there is not a measure for the total cost of an event that changes simultaneously all these parameters.

**We expanded the calculations of the cost to include the combined effect of a change in the level, growth and variance of consumption; additionally, we adjust the calculation of the cost associated to increased variability to measure only the additional variability that can be attributed to the crisis and we do not assume, as Lucas (1987) does, that the initial state is one without variability. We apply this welfare measure to the observed parameters before and after the crisis period in some of the most relevant countries that have suffered a crisis during the 1990's and we will try to determine the cost these crises in terms of loss of real consumption. The countries to study are Mexico, Thailand Philippines, Malaysia, Korea and Brazil.**

When comparing the costs obtained with the Lucas' (1987) methodology with the adjusted methodology we observe that these costs increase significantly. With both methodologies we calculate the compensation in consumption required to leave the consumer indifferent between the pre and the post crisis periods, a positive number imply a required increase in post-crisis consumption (therefore a loss with respect to the pre-crisis period) while a negative number implies a gain in consumption after the crisis such that the consumer has to pay to be left indifferent to the pre-crisis period.

#### **4.1. Empirical evidence on costs after financial and currency crises**

Some of the studies that address the performance of emerging economies after a crisis are those of Caballero and Hammour (2000), Dornbusch (2001) and Tornell (2001), who conclude that recurrent crises in developing economies have large welfare consequences. Some of these are immediately apparent, while others manifest their damage over time and thus are often overlooked. A potentially major impact of the latter type is the disruptive effect that crises may have on restructuring and reform processes. The Costs that have been addressed by empirical studies can be grouped as follow:

1. *Increase in public debt associated with crises:* according to Dornbusch (2001) this phenomenon is observed because the government has the compromise to bail out banks and often bankrupting companies and while acquiring the necessary resources to do this, the public debt increases substantially. The period of high interest rates in the run-up to the crisis and in the stabilisation phase, and the fall in output and hence tax revenue, further contribute to the deterioration in public finances. Finally the increase in debt may itself contribute to a future crisis if it occurs in a situation in which the government is unable to meet the higher debt service burden through taxation or a reduction in spending.

2. *Economic disruption and loss of output:* Caballero and Hammour (2000) found evidence that lead to conjecture that crises slow down the restructuring process of the economy; if this is so, then crises are even more costly than their temporary impact on unemployment and other aggregate indicators may suggest. Their interpretation is that the main underlying factors that drive crises are financial constraints. While liquidations and the open failure of bankrupt firms make the news and may be regarded as the triggers of a crisis, recessions also deplete the financial resources needed to create new and more advanced production units. As the latter takes place, the competitive pressure from new production units slows down and low-productivity units can survive more easily. The scarcity of financial resources during the recovery limits the socially useful transfer of resources from low to high productivity units.

Although Caballero and Hammour (2000) do not have data available to assess the impact on recent crises in emerging markets it is likely that in general, crises constitute major obstacles to a well-functioning restructuring process, and that this disruption is closely associated with problems in financial markets. The result is a productivity-based social cost of economic crises that is incurred in addition to the traditional cost based on under-employment and the under-utilisation of other resources. Therefore, the cost of crises in terms of restructuring is twofold: i)

crises are likely to result in a significant amount of privately inefficient liquidations, leading to large costs of job loss and liquidations of organisational capital; and, ii) crises are likely to result in a freezing of the restructuring process and years of productivity stagnation; Dornbusch (2001) adds that there is also a large loss of reserves, which are depleted while defending the currency. If they are captured by the private sector, they merely amount to a transfer within the economy. However, when the counterparts are foreign investors, these reserves are actually transferred out of the economy which is a net loss. To the extent that a crisis experience deteriorates a country's credit rating, there is also a lasting cost in terms of a higher cost of accessing international capital.

3. *Redistribution of income and wealth*: in terms of income distribution, a currency crisis redistributes both, wealth and income. Dornbusch (2001) points out that, emerging market crises enrich those who are able to quickly convert their assets into foreign policy or to get the government to assume their debt while retaining their assets and almost always there is a dramatic fall in real wages and employment and bankruptcy of small debtors. In consequence, periods of recurrent currency crises translate into poor growth performance, short horizons, and slow increases in the standard of living, a deteriorating social and economic infrastructure that ultimately medium term growth rates, far from reflecting catch-up, reflect the costs of persistently poor finance.

4. *Measuring the impact on households, a microeconomic indicators approach*: an exception to the usual approach of identifying stylised facts is the analysis that Frankenberg, Thomas and Beegle (1999) do of the Indonesian crisis of 1998. The authors analysed the costs of the Indonesian crisis using the Indonesia Family Life Surveys (IFLS) corresponding to 1997 and to 1998; the objective of their study was to answer three main questions: i) which was the population sector most affected by the crisis; ii) how were they affected; and, iii) how they responded to it in terms of adjusting consumption patterns. The IFLS is an on-going longitudinal survey of individuals, households, families and communities in Indonesia. The data provide unambiguous evidence that the crisis had a far-reaching effect on the purchasing power of all respondents, regardless of their position in the income distribution. This first result is not surprising since the resulting inflation after the currency crisis of 1998. When one considers changes not in overall levels of spending, but in the allocation of this spending, the results suggest that the poorest households have been most affected. The share of the household budget spent on food has increased significantly and these increases are largest for the poorest. On the other hand, non-food expenditures have declined significantly, especially among the poorest. However, short and medium term effects are likely to differ across sub-groups of the population. This is true especially because expenditures on health and education since there

were significant declines in enrolment rates for young children from poor households and the use of government health clinics and community health posts has declined sharply.

The linkage between currency and bank crises (twin crises phenomenon) has been addressed more recently in theoretical literature. Most third generation currency crisis models with some combination of corporate credit flows, balance sheet currency mismatches (as in dollarisation of liabilities), bank runs into foreign assets, international illiquidity or international financial transaction costs raise the possibility of a twin crisis with adverse effects on the real economy. This joint occurrence may reflect a response to common factors or spill-over effects running from currency to financial crises and vice versa. According to Hutchinson and Noy (2002) the cost on the real economy associated with a twin crisis may be measured separately as the additive effects of independent currency and banking crises. However, there may be some other channels of transmission that increase the impact on output. In other words, twin crises may be associated with disproportionately large output costs such that the sum of the parts is indeed greater than either of the two types of crises acting alone.

According to Hoggarth et al. (2002) a crisis in the banking sector may impose several costs on the economy: i) stakeholders in the failed bank will be directly affected; ii) taxpayers may incur direct costs as a result of public sector crisis resolution. Costs affecting particular sectors of the economy may just reflect a redistribution of wealth, but under certain conditions banking crises may also reduce income and wealth in the economy as a whole. Caprio and Klingebiel (1999) and Barth et al. (2000) estimate fiscal costs incurred in the resolution of 24 major banking crises over the past two decades. These fiscal costs reflect the expenditure that governments incur when trying to rehabilitate or bail out the financial system; this can include bank recapitalisation, payments made to depositors either implicitly or explicitly and acquisition of banks' debt by the government in bail out schemes; in order to finance the support to the financial system, governments use fiscal resources and in some cases, as in Mexico, an increase in tax rates was used to: i) finance the cost of rescuing banks; and, ii) to slow down consumption and contain inflation. The average resolution cost for a twin crisis is 23% of annual GDP compared with 4.5% for a banking crisis alone. Moreover, all countries that had fiscal costs of more than 10% of annual GDP had an accompanying currency crisis.

Fiscal and Quasi-Fiscal Costs			
Country	Years	Non-performing loans (% of total loans)	Fiscal and quasi-fiscal costs/GDP
High income countries			
FINLAND	1991-1993	9.0	11.0
JAPAN	1992-1998	13.0	8.0
KOREA	1997-	30-40	34.0
NORWAY	1988-1992	9.0	8.0
SPAIN	1977-1985	N/A	16.8
SWEDEN	1991	11.0	4.0
UNITED STATES	1984-1991	4.0	3.2
AVERAGE		13.5	12.1
Medium and low income countries			
ARGENTINA	1980-1982	9.0	55.3
ARGENTINA	1995	N/A	1.6
BRAZIL	1994-1996	15.0	5-10
CHILE	1981-1983	19.0	41.2
COLOMBIA	1982-1987	25.0	5.0
GHANA	1982-1989	N/A	6.0
INDONESIA	1994	N/A	1.8
INDONESIA	1997-	65-75	50-55
MALAYSIA	1985-1988	33.0	4.7
MEXICO	1994-1995	11.0	20.0
PHILIPPINES	1981-1987	N/A	3.0
SRI LANKA	1989-1993	35.0	5.0
THAILAND	1983-1987	15.0	1.5
THAILAND	1997-	46.0	42.3
TURKEY	1994	N/A	1.1
URUGUAY	1981-1984	N/A	31.2
VENEZUELA	1994-1995	N/A	20.0
AVERAGE		27.8	16.0
Average all countries		17.7	4.6

Table 26: Non-performing loans and fiscal costs in Barth et al. (2000)

According to Hoggarth et al (2002), resolution costs may not always be a good measure of the costs of crises to the economy, but rather a transfer cost. Also, large fiscal costs may be incurred to forestall a banking crisis or, to limit its effect. In this case, the overall costs to the economy at large may be small. On the other hand, the government may incur only small fiscal costs and the effect on the overall economy of a banking crisis may be greater and longer. In sum, high fiscal costs may imply low welfare costs for households while low fiscal costs may imply high welfare costs for households. There is an additional element that has not been considered and is the financing of these costs in the long run, whether by debt, monetary expansion or higher taxes this is likely to have an indirect impact in consumption. Because of these two features of fiscal costs, they are not a reliable indicator of the impact that a crisis may have over the economy and in welfare. Similarly, Kaminsky and Reinhart (1999) find that bail-out costs in countries which experienced a twin crisis were much larger (13% of GDP), on average, than those which had a banking crisis alone (5%). The cumulative resolution costs of banking crises appear to be larger in emerging economies (on average 17.7% of annual GDP) than in developed ones (12.1%). The difference may be due to the fact that developed countries face smaller shocks to their banking systems; some data suggests that non-performing loans have been much larger in emerging market crises. Alternatively, both the banking system and

the real economy may have been better able to withstand a given shock because of more robust banking and regulatory systems. Chang and Velasco (2000) emphasize the interaction between banking crises and real exchange rate movements (currency crises) in a model with a banking sector and tradable and non-tradable goods producers. A crisis of one type may occur with or without the other occurring but that increases the likelihood of a twin crisis occurring with additional output costs to the economy. Self-fulfilling international bank runs are possible when short-term bank assets are large relative to central-bank reserves, but may also be induced by the refusal of domestic and foreign investors to roll over other short-term assets. Alternatively, a banking crisis may be exacerbated if a currency crisis occurs concurrently- in the way of a sharp devaluation at the time when many banks are on the edge of bankruptcy and a currency crisis may push them into bankruptcy.

According to Hutchinson and Noy (2002) there is little empirical literature systematically testing the extent to which financial crises impact output growth. Some of the literature reviewed by these authors concentrates in the effect of a single type of crisis in output. One example is McDill (2000) who investigates the effect of banking crises on a panel data set comprising industrial, emerging and developing economies; in this study the approach consists in regressing output growth on contemporaneous banking crises and several control variables (such as lagged exchange rate depreciation, real interest rate, lagged money growth and lagged change in stock price). This study finds that banking crises are associated with 1.2-1.8% point decline in output growth during each year of the banking crisis. Demirgüç-Kunt et al (2001) consider a cross section of 36 banking crises, investigating macroeconomic developments before, during and after a crisis; they find that a banking crisis is associated with a 4-percentage point decline in output growth. Barro (2001) and Bordo et al. (2001) measure the output costs of a currency crisis and a banking crisis in the same model. Barro (2001) considers the pattern of 5-year average output growth in a broad panel covering industrial, emerging and developing economies; this study regresses 5 year output growth averages on conventional control variables (per capita GDP, schooling, life expectancy) and contemporaneous and lagged currency banking crises. The crisis variable measures a (1,0) dummy for a crisis anytime during the focal 5 year period; a currency (banking) crisis is associated with a 1.3% point decline (0.6% decline) in average output growth over the 5 year period, when a combination of crises occurs reduces current growth by about 2% per year. Bordo et al. (2001) study a sample from 1973 to 1997; they find that the cumulative output loss for a twin crisis over and above the average recession is 16% of GDP. This effect is measured separately from the 13% cumulative output loss that is found to be combined effect of a banking (4.4%) and currency crisis (8.7%). Hutchinson and Noy (2002) focus on the output costs associated with twin crises in emerging market economies. Their objective is to examine separately the effects of a currency and of a banking crisis and



their joint effects. The main finding is that crises are very costly; currency crises reducing by about 5-8%, while banking crises do so in 8-10% over a two-four year period. Overall, they are able to explain 35-50% of the variation in annual GDP growth in emerging markets during 1975-1997. The combined effect of the two crises occurring simultaneously is therefore about 13-18% of output. However, twin crises do not appear to contribute additional negative impact on output growth above and beyond the combined effect of the two crises. In table 27 Hutchinson and Noy (2002) present the behaviour in average of some selected indicators for the countries they studied.

Impact of crises on selected indicators Hutchinson and Noy (2002)						
		t-2	t-1	t	t+1	t+2
<b>A. Currency crises</b>						
Real GDP growth rate (%)	Currency	4.0	2.7	1.4	1.7	3.6
	Currency (no banking)	3.6	2.4	1.9	1.7	3.6
	Twin crisis	4.3	4.9	0.7	1.0	2.1
Change in budget surplus (%)	Currency	-1.2	-1.4	-1.1	-1.0	-1.1
	Currency (no banking)	-0.9	-1.1	-1.2	-1.2	-1.2
	Twin crisis	-1.4	-2.1	-1.1	-1.9	-0.5
Inflation rate (%)	Currency	30.5	31.6	31.6	43.4	42.0
	Currency (no banking)	28.1	25.9	23.8	33.0	35.0
	Twin crisis	43.2	53.2	67.9	57.6	50.1
RER overvaluation measure	Currency	8.0	14.7	1.6	-6.8	-4.3
	Currency (no banking)	12.1	18.1	4.1	-6.7	-4.8
	Twin crisis	-0.4	7.4	3.0	4.0	-2.8
<b>B. Banking crises</b>						
Real GDP growth rate (%)		5.1	5.1	1.0	5.9	6.5
Change in budget surplus (%)		-0.5	-1.3	-0.8	-0.4	-0.2
Inflation rate (%)		29.7	32.5	33.6	29.0	26.5
RER overvaluation measure		1.5	8.3	4.1	-6.5	-3.7

Table 27: Impact of crises on selected indicators

With regard to output losses, Hoggarth et al. (2002) say that cross-country comparisons of the broader welfare losses to the economy associated with a banking crisis are usually proxied by losses in GDP comparing GDP during the crisis period with some estimate of potential output. **According to Hoggarth et al. (2002) welfare costs should ideally reflect losses to individuals' current and discounted future consumption over their lifetime; and, changes in the level of income may have more impact in individuals' utility at lower income levels than higher ones.** These authors describe three methods to estimate output losses: i) GAP1, the sum of the differences between the growth in potential and actual output (IMF, 1998b), potential growth is defined as the arithmetic average of GDP growth in the three years period prior to the crisis; ii) GAP2, the cumulative difference between the level of potential output and actual output over the crisis period (Caprio and Klingebiel, 1996 and 1999) output potential is measured using a Hodrick-Prescott filter; and, iii) GAP3, this method measures output losses as the cumulative difference between the counterfactual and the level of actual output during the (exogenously defined) crisis period The counterfactual is based on the forecast of GDP growth during the crisis period made before the outset of the crisis rather than potential or trend GDP.

Taking the sample of 47 countries the average estimates of GAP1 losses is 14.5%; the mean average losses using GAP2 are in the order of 16.5%. Hoggarth et al. (2002) used the GAP3 only in OECD countries so there are no comparisons available for emerging economies. However, for those OECD countries GAP3 estimates are higher than those of GAP1. In contrast there are marked variations, in both sign and magnitude, between GAP3 and GAP2 estimates.

Accumulated Output Losses				
Country	Years	GAP1	GAP2	GAP3
High income countries				
Australia	1989-1990	0.0	-1.4	0.0
Canada	1983-1985	0.0	-10.5	0.0
Denmark	1987-1992	22.3	31.9	47.5
Finland	1991-1993	22.4	44.9	24.6
France	1994-1995	0.0	0.7	0.0
Hong Kong	1982-1983	23.1	9.8	
Hong Kong	1983-1986	1.1	4.3	
Hong Kong	1998	9.6	9.0	
Italy	1990-1995	18.2	24.6	36.1
Japan	1992-1998	24.1	71.7	30.7
Korea	1997-	16.7	12.8	15.7
New Zealand	1987-1990	16.0	16.3	4.5
Norway	1988-1992	9.8	27.1	11.2
Spain	1977-1985	15.1	122.2	
Sweden	1991	11.8	3.8	2.5
United Kingdom	1974-1976	34.6	26.5	31.1
United States	1984-1991	0.0	-41.9	56.0
Average		13.2	20.7	
Medium and low income countries				
Argentina	1980-1982	20.7	25.9	
Argentina	1985	7.9	7.1	
Argentina	1989-1990	14.0	16.1	
Argentina	1995	11.4	5.8	
Bolivia	1986-1987	0.6	0.4	
Bolivia	1994	0.0	-26.8	
Brazil	1994-1996	0.0	-12.7	
Chile	1981-1983	41.4	24.3	
Colombia	1982-1987	6.7	31.4	
Egypt	1991-1995	1.0	22.8	
El Salvador	1989	0.6	-1.3	
Ghana	1982-1989	5.5	-47.4	
India	1993-	0.0	-41.1	
Indonesia	1994	0.0	-2.2	
Indonesia	1997-	24.5	20.1	
Madagascar	1988	0.0	-3.1	
Malaysia	1985-1988	14.5	39.2	
Mexico	1981-1982	110.4	-0.2	
Mexico	1994-1995	9.5	5.4	
Nigeria	1997	0.0	0.1	
Peru	1983-1990	12.5	94.0	
Philippines	1981-1987	35.2	111.7	
Sri Lanka	1989-1993	0.6	-10.0	
Thailand	1983-1987	0.0	-2.8	
Thailand	1997-	25.9	28.1	
Turkey	1994	10.4	9.2	
Uruguay	1981-1984	42.0	64.1	
Venezuela	1980-1983	27.6	52.2	
Venezuela	1994-1995	14.7	10.6	
Zimbabwe	1995-	0.4	-3.3	
Average		15.0	13.9	
Average all countries		14.4	16.4	

Table 28: Accumulated output losses in Barth et al. (2000)

## 4.2. Structural change in consumption

In order to check for stationarity, we performed two unit root tests; one over the complete sample and the other following Perron on the residuals of the de-trended series. According to Enders (1995) one econometric procedure to test for unit roots in the presence of a structural break involves splitting the sample into two parts and using the Dickey-Fuller test on each part. The problem with this procedure is that the degrees of freedom for each of the resulting regressions are diminished; it is preferable to have a single test based on the full sample. We used a Perron specification to estimate alternative representations of structural change with the use of the full sample.

$$c_t = \gamma_0 + \gamma_2 \cdot t + \gamma_3 \cdot D_L + a_4 \cdot t \cdot D_L + \varepsilon_t \quad (4.1)$$

Where  $c_t$  is a trend stationary process with a one time jump in the intercept and change in the slope of the trend and  $D_L$  represents a level dummy variable such that  $D_L = 1$  if  $t > \tau$  and zero otherwise. The implementation of Perron's technique is summarised by Enders (1995) as follow:

Step 1: de-trend the data by estimating the model above and calling the residuals  $\varepsilon_t$

Step 2: estimate the regression  $\varepsilon_t = a_1 \varepsilon_{t-1} + v_t$ . Under the null hypothesis of a unit root, the theoretical value of  $a_1$  is unity. Perron (1989) shows that when the residuals are i.i.d., the distribution of  $a_1$  depends on the proportion of observations occurring prior to the break. Denote this proportion by  $\lambda = t/T$  where  $T$ =total number of observations.

Step 3: perform diagnostic checks to determine if the residuals from Step 2 are serially uncorrelated. If there is serial correlation, use the augmented form of the regression:

$$\varepsilon_t = a_1 \varepsilon_{t-1} + \sum_{i=1}^k a_i \varepsilon_{t-i} + v_t$$

Step 4: calculate the t-statistic for the null hypothesis. This statistic in absolute terms can be compared to the critical values calculated by Perron. If a t-statistic greater than the critical value calculated by Perron is found it is possible to reject the null hypothesis of a unit root; this critical values tend to reject the null hypothesis more than the McKinnon critical value, in other words it may be the case that McKinnon may not reject while Perron does, but not vice versa.

	Mexico	Thailand	Malaysia	Philippines	Korea	Brazil
<b>UNIT ROOT TEST OVER THE WHOLE SAMPLE</b>						
<b>Augmented D-F test</b>	-2.3557	-2.2776	-2.1961	-2.5996	-2.2631	-1.8788
<b>McKinnon critical value 5%</b>	-3.5162	-3.5426	-3.5162	-3.5162	-3.5066	-3.5614
<b>PERRON TEST</b>						
<b>Augmented D-F test</b>	-3.3635	-2.5330	-3.3450	-2.2400	-2.9339	-2.8660
<b>McKinnon critical value 5%</b>	-1.9486	-1.9507	-1.9486	-1.9488	-1.9478	-1.9526

Table 29: Unit root test results consumption series

Perron (1989) used his analysis of structural change to challenge the findings of Nelson and Plosser (1982). With the same variables used, Perron's results indicate that most macroeconomic variables are not characterised by unit root processes. Instead the variables appear to be trend stationary processes coupled with structural breaks. In every case, it was possible to reject the null hypothesis of a Unit-Root with the Perron test specification. As we can see, when we test over the whole sample we cannot reject the null hypothesis for unit roots; however, when de-trending the series and including a structural breakpoint, we found that the series become stationary and we can reject the null hypothesis of a unit root. We estimated three possible breakpoints for each country around the quarter in where the crisis occurred in each of these countries<sup>33</sup>.

We chose the optimal breakpoint using the adjusted R-squared, the Akaike and the Schwarz information criterions. The adjusted R-squared measures the proportion of the sample variation in  $c_t$  that is explained by the set of regressors; while the Akaike and Schwarz criterions are used to compare between different specifications of the model when economic theory provides no guidance on selecting the appropriate model (i.e. they are used to choose the most parsimonious model in terms of information provided) they provide evidence that support the conclusions of R-squared and adjusted R-squared (Verbeek, 2000). The results are shown in table 30<sup>34</sup>. In most, of these cases, consumption was affected only in the quarter of the year where the crisis happened except in Philippines where slowdown in consumption happened one quarter earlier, and in Brazil that had a lagged effect; however, in Philippines the effect on consumption was not as strongly adverse as in other countries and in Brazil it may be due to the crisis happened towards the end of the quarter. But in all cases, we do not have evidence of slowdown as an indicator of a crisis expectation.

<sup>33</sup> See annex A4.1 for the unit root tests for the other breakpoints.

<sup>34</sup> For complete results see annex A4.2.

<b>Mexico</b>	<b>R-squared</b>	<b>Adjusted R-squared</b>	<b>Akaike info criterion</b>	<b>Schwarz criterion</b>
1994/12	0.8981	0.8912	-3.5640	-3.4081
<b>1995/01</b>	<b>0.9139</b>	<b>0.9080</b>	<b>-3.7327</b>	<b>-3.5767</b>
1995/02	0.8928	0.8853	-3.5920	-3.4346
<b>Thailand</b>	<b>R-squared</b>	<b>Adjusted R-squared</b>	<b>Akaike info criterion</b>	<b>Schwarz criterion</b>
1997/03	0.8499	0.8370	-4.1365	-3.9659
<b>1997/04</b>	<b>0.8894</b>	<b>0.8802</b>	<b>-4.3528</b>	<b>-4.1840</b>
1998/01	0.8218	0.8065	-3.9173	-3.7467
<b>Malaysia</b>	<b>R-squared</b>	<b>Adjusted R-squared</b>	<b>Akaike info criterion</b>	<b>Schwarz criterion</b>
1997/04	0.9542	0.9510	-3.8434	-3.6859
<b>1998/01</b>	<b>0.9652</b>	<b>0.9628</b>	<b>-4.0808</b>	<b>-3.9249</b>
1998/02	0.9452	0.9414	-3.6587	-3.5013
<b>Philippines</b>	<b>R-squared</b>	<b>Adjusted R-squared</b>	<b>Akaike info criterion</b>	<b>Schwarz criterion</b>
<b>1997/04</b>	<b>0.9966</b>	<b>0.9964</b>	<b>-7.0532</b>	<b>-6.8958</b>
1998/01	0.9961	0.9958	-6.8822	-6.7263
1998/02	0.9960	0.9957	-6.9040	-6.7465
<b>Korea</b>	<b>R-squared</b>	<b>Adjusted R-squared</b>	<b>Akaike info criterion</b>	<b>Schwarz criterion</b>
1997/04	0.9767	0.9752	-3.6998	-3.5482
<b>1998/01</b>	<b>0.9928</b>	<b>0.9924</b>	<b>-4.8150</b>	<b>-4.6649</b>
1998/02	0.9874	0.9866	-4.2680	-4.1165
<b>Brazil</b>	<b>R-squared</b>	<b>Adjusted R-squared</b>	<b>Akaike info criterion</b>	<b>Schwarz criterion</b>
1997/04	0.9061	0.8971	-4.0227	-3.8450
1998/01	0.9262	0.9192	-4.0345	-3.8586
<b>1998/02</b>	<b>0.9332</b>	<b>0.9267</b>	<b>-4.1240</b>	<b>-3.9462</b>

Table 30: Optimal crises' breakpoints in consumption

Thus, the pre and post-crisis periods are, defined as follows:

	<b>Pre-crisis</b>	<b>Post-crisis</b>
<b>Mexico</b>	1991:1 to 1994:4	1995:1 to 2002:4
<b>Thailand</b>	1993:1 to 1997:3	1997:4 to 2002:4
<b>Malaysia</b>	1991:1 to 1997:4	1998:1 to 2002:4
<b>Philippines</b>	1991:1 to 1997:3	1997:4 to 2002:4
<b>Korea</b>	1990:1 to 1997:4	1998:1 to 2002:4
<b>Brazil</b>	1994:1 to 1998:1	1998:2 to 2002:4

Table 31: Pre and post-crisis periods in consumption

In the graphs below we show the log of real consumption for each of the selected countries, the observed path, the trend and the de-trended series.

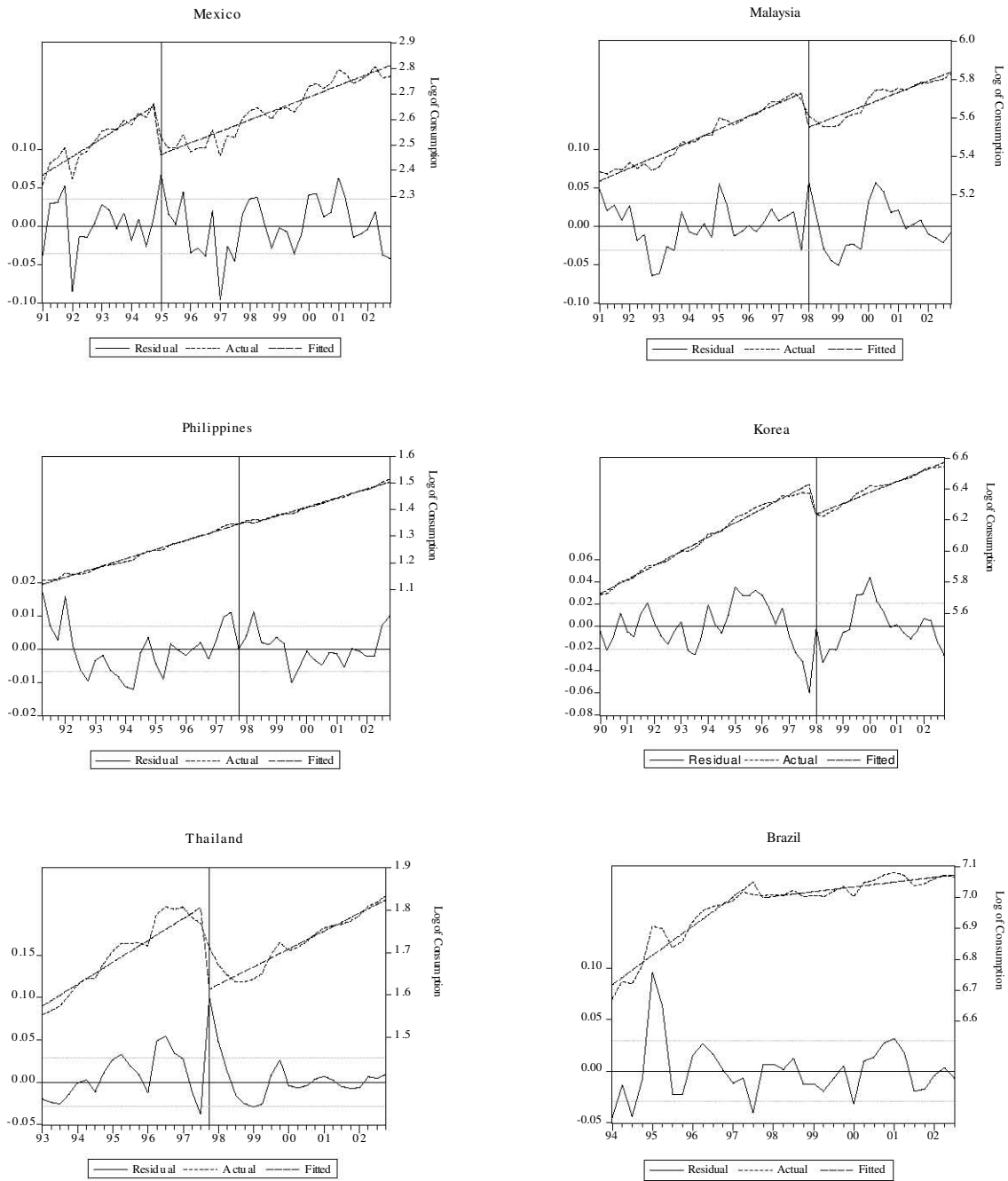


Figure 13: Consumption in Mexico, Malaysia, Thailand, Philippines, Korea and Brazil: Actual, trend and residual

We now need to check if the residuals are auto correlated. We estimated the process:

$$\varepsilon_t = a_0 \cdot \varepsilon_{t-1} + v_t$$

We found evidence of autocorrelation in all cases except for Mexico.

	Coefficient	t-Statistic	Prob.
<b>Mexico</b>	0.163628	1.121572	0.2679
<b>Thailand</b>	0.305841	1.991737	0.0536
<b>Malaysia</b>	0.456692	3.608860	0.0008
<b>Philippines</b>	0.491935	4.069068	0.0002
<b>Korea</b>	0.645734	5.822002	0.0000
<b>Brazil</b>	0.318821	2.019411	0.0516

Table 32: Consumption autocorrelation in Mexico, Philippines Malaysia, Thailand, Korea and Brazil.

### 4.3. Lucas's (1987) methodology

Lucas (1987) introduces consumer preferences in the context of business cycles theory and develops some measures on the welfare loss caused by deviations from the average growth rate of consumption and from increased instability, as we can see in diagram 8.

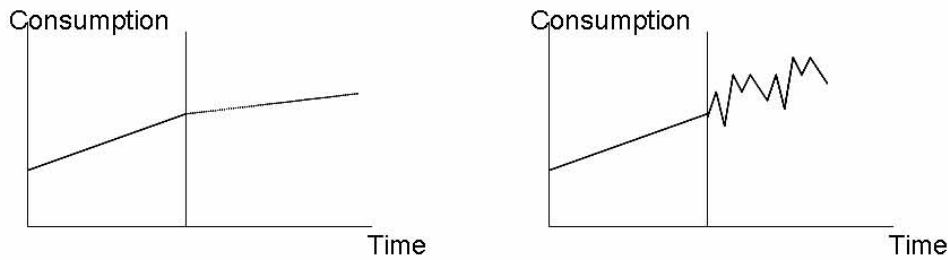


Diagram 8: changes in the consumption pattern, Lucas (1987)

In order to do this, Lucas (1987) uses a simple model of intertemporal consumption where a typical household consumes a collection  $c_t$  of goods at date  $t$ , possibly contingent on probabilistically determined events between dates zero and  $t$ , and will evaluate a process  $\{c_t\}$  of consumption with a utility function such as:

$$U(C) = E \left\{ \sum_{t=0}^{\infty} \beta^t U(c_t) \right\} \quad (4.2)$$

Where  $\beta \in (0,1)$  is a constant discount factor. Lucas (1987) identifies  $c_t$  as the real consumption at time  $t$ ; we will continue the analysis using a utility function of the form

$$U(c_t) = \frac{1}{1-\rho} (c_t^{1-\rho}) \quad (4.3)$$

Therefore, the intertemporal utility function takes the specific form:

$$U(C) = E \left\{ \sum_{t=0}^{\infty} \beta^t \frac{1}{1-\rho} (c_t^{1-\rho}) \right\} \quad (4.4)$$

where  $\rho > 0$  is the constant coefficient of relative risk aversion.

In order to examine the attitude towards different consumption fluctuations, it is necessary to define a particular consumption process. The proposed consumption process contains a deterministic stationary<sup>35</sup> ‘trend’ and a ‘cycle’ components and takes the form:

$$c_t^{1-\rho} = C_0^{1-\rho} (1+g)^{(1-\rho)t} \left[ \exp\left(\varepsilon_t - \frac{1}{2}Var(\varepsilon)\right) \right]^{1-\rho} \quad (4.5)$$

Lucas (1987) derives two instruments to measure the possible welfare costs of a decrease in consumption growth and of an increase of consumption instability (In annex A4.2 we verify and present the complete solution of the model). With these two measurements we can assess the impact that financial crises have had in welfare. On the one hand, the function

$$\tau_g = \left( \frac{1 - \beta(1+g_1)^{1-\rho}}{1 - \beta(1+g_0)^{1-\rho}} \right)^{1/1-\rho} - 1 \quad (4.6)$$

will allow us to measure the costs of a reduction in the growth rate; on the other hand, the function

$$\tau_{var} = \exp\left(\frac{1}{2}\rho(1-\rho)Var(\varepsilon)\right)^{\frac{1}{1-\rho}} - 1 \quad (4.7)$$

is an indicator of the costs of increased variability in consumption instead of having a stable and smooth consumption path.

#### **4.4. Deriving alternative measures of welfare costs**

As we already discussed, the Lucas (1987) methodology only deals with changes in different parameters caeteris paribus, that is, it does not address the possibility of simultaneous changes in the growth rate and variance of consumption. As well, because these measures are designed to be applied in the context of business cycles and smooth changes in parameters rather than catastrophic meltdowns of the economy, they do not include the possibility of permanent changes in the level of the consumption trend. In order to address these problems in the following sections we develop several alternatives of calculating the cost of an event where

<sup>35</sup> Lucas (1987) discusses the importance of this assumption since a perfectly predictable deterministic trend has implications to this model. In particular, Nelson and Plosser (1981) argue that most year-to-year variability in the US can be attributed to a random walk or stochastic trend. However, Cochrane (1986) argue that these authors overstate the importance of a random walk component.



the level, the growth rate and the variance around the trend are affected simultaneously. As well we will introduce habit formation in preferences and will explore the implications of the existence of autocorrelation and uncertainty. The permanent utility function we will use takes the form given by equation 4.4.

#### 4.4.1. Loss in lifetime utility

With this specification, the permanent utility of projected consumption with the parameters before the crisis ( $u_0$ ) and the observed consumption parameters after the crisis ( $u_1$ ) can be reduced to the following expressions (as we did earlier, the infinity sum can be simplified easily to derive a direct calculation):

$$U_0 = \frac{\bar{C}_0^{1-\rho}}{1-\rho} \frac{1}{1-\beta(1+g_0)^{1-\rho}} \exp\left(-\frac{1}{2}\rho(1-\rho)Var_0\right) \quad (4.8)$$

$$U_1 = \frac{\bar{C}_1^{1-\rho}}{1-\rho} \frac{1}{1-\beta(1+g_1)^{1-\rho}} \exp\left(-\frac{1}{2}\rho(1-\rho)Var_1\right)$$

With these two utility functions, the first proposed measure of the cost is simple to calculate the percentage change in utility:

$$\Delta U = \frac{U_1 - U_0}{U_0} = \frac{U_1}{U_0} - 1 \quad (4.9)$$

Which simplifying yields the expression:

$$\Delta U = \left[ \frac{\bar{C}_1}{\bar{C}_0} \right]^{1-\rho} \left[ \frac{1-\beta(1+g_0)^{1-\rho}}{1-\beta(1+g_1)^{1-\rho}} \right] \left[ \exp\left(\frac{1}{2}\rho(1-\rho)(Var_0 - Var_1)\right) \right] - 1 \quad (4.10)$$

This equation represents the total change in utility; we can calculate the effect of separate changes in the growth rate, the level and the variance of consumption.

Change in level, when  $g_0 = g_1$  and  $Var_0 = Var_1$

$$\Delta U = \left[ \frac{\bar{C}_1}{\bar{C}_0} \right]^{1-\rho} - 1 \quad (4.11)$$

Change in growth rate, when  $C_0 = C_1$  and  $Var_0 = Var_1$

$$\Delta U = \left[ \frac{1-\beta(1+g_0)^{1-\rho}}{1-\beta(1+g_1)^{1-\rho}} \right] - 1 \quad (4.12)$$

Change in variance, when  $C_0 = C_1$  and  $g_0 = g_1$

$$\Delta U = \left[ \exp\left(\frac{1}{2}\rho(1-\rho)(Var_0 - Var_1)\right) \right] - 1 \quad (4.13)$$

#### 4.4.2. Compensation required due to changes in utility after a crisis: A comprehensive welfare loss measure (WLM)

The above measure provides with the total costs incurred because of a crisis, however it does not measure how much is the compensation that will leave the individuals indifferent before and after a crisis as Lucas (1987) does. Hence, we now turn to derive a similar measure but including not only a change in the growth rate and in the variance, but also a change in the level of consumption and a measure of the total cost of these parameters changing together as diagram 9 shows.

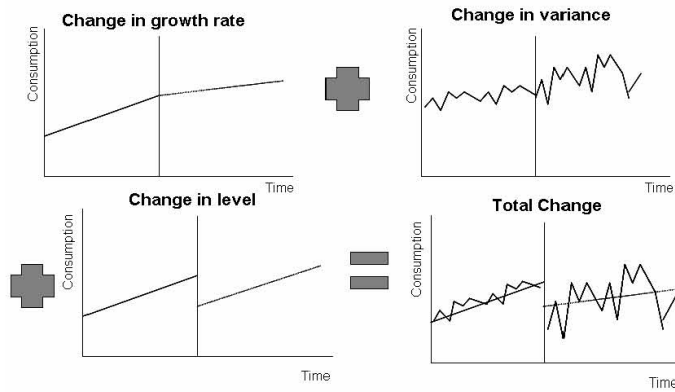


Diagram 9: changes in the consumption pattern, WLM

In order to do that, we use the same utility and the same consumption process as in the above section. And define the indifference as:

$$U_1\{(1+\tau)\bar{C}_1\} = U_0\{\bar{C}_0\} \quad (4.14)$$

When we substitute the utility functions we have:

$$\frac{\left((1+\tau)\bar{C}_1\right)^{1-\rho}}{1-\rho} \frac{1}{1-\beta(1+g_1)^{1-\rho}} \exp\left(-\frac{1}{2}\rho(1-\rho)Var_1\right) = \frac{\bar{C}_0^{1-\rho}}{1-\rho} \frac{1}{1-\beta(1+g_0)^{1-\rho}} \exp\left(-\frac{1}{2}\rho(1-\rho)Var_0\right)$$

Solving for  $\tau$  we obtain:

$$\tau = \left(\frac{\bar{C}_0}{\bar{C}_1}\right) \left[ \frac{1-\beta(1+g_1)^{1-\rho}}{1-\beta(1+g_0)^{1-\rho}} \exp\left(-\frac{1}{2}\rho(1-\rho)(Var_0 - Var_1)\right) \right]^{\frac{1}{1-\rho}} - 1 \quad (4.15)$$

We can now obtain the effect of separate changes in the growth rate, the level and the variance of consumption.

Compensation for changes in growth when  $C_0=C_1$  and  $Var_0=Var_1$ .

$$\tau_g = \left[ \frac{1 - \beta(1 + g_1)^{1-\rho}}{1 - \beta(1 + g_0)^{1-\rho}} \right]^{\frac{1}{1-\rho}} - 1 \quad (4.16)$$

Compensation for changes in growth when  $g_0=g_1$  and  $Var_0=Var_1$ .

$$\tau_L = \left( \frac{\bar{C}_0}{C_1} \right) - 1 \quad (4.17)$$

Compensation for changes in growth when  $C_0=C_1$  and  $g_0=g_1$ .

$$\tau_{Var} = \left[ \exp\left(-\frac{1}{2}\rho(1-\rho)(Var_0 - Var_1)\right) \right]^{\frac{1}{1-\rho}} - 1 \quad (4.18)$$

As in the original version,  $\tau$  represents the compensation that the individual needs to receive to be indifferent between the new and the previous consumption process. As we can see, we now have two new measures that Lucas (1987) did not include in his estimations, a change in level and the total compensation needed. We can now identify the costs of the 1990's crises both in absolute terms, as loss of permanent utility, and relative to the consumption process before a crisis.

## 4.5. Habit formation in preferences

According to Dynan (2000), many studies have used household panel data on consumption to examine behaviour when preferences are assumed to be time separable. More recently there has been growing interest in the implications of preferences that are not time separable. One specific class of time non-separable preferences are those which exhibit habit formation; in this kind of preferences, current utility depends not only on current expenditures, but also on a habit

stock formed by lagged expenditures. For a given level of current expenditure, a larger habit stock lowers utility. Habit formation may be modelled by assuming that consumers' current utility is determined by current consumption relative to a reference level of consumption. Habit forming consumers dislike large and rapid cuts in consumption. As a result, the premium that they will require to hold risky assets that might force a rapid cut in consumption will be large relative to that implied by the time separable utility model (Furher, 2000).

Among its potentially important empirical implications, habit formation causes consumers to adjust slowly to shocks to permanent income. According to Chetty and Szeidl (2004), representative consumer habit formation models have attracted much interest in many areas of economics. In asset pricing, Campbell and Cochrane (1999) use habit formation to understand the mean equity premium and the joint dynamics of equity returns and aggregate consumption. In monetary economics, habit preferences are used to match the hump-shaped response of consumption to interest rate shocks, including Fuhrer (2000). There are two important features of habit formation preferences that distinguish this theory from previous models:

1. *Habit affects risk preferences:* A higher level of habit implies that marginal utility is more sensitive to consumption shocks, making the representative consumer more risk averse.
2. *Habit is a slowly adjusting state variable:* shocks can therefore have lasting effects on future consumption.

Chetty and Szeidl (2004) show that consumption commitments -goods such as houses, cars, furniture and service contracts whose consumption cannot be freely adjusted in the short run- amplify household's risk aversion and make total consumption respond slowly to shocks. In an economy populated with agents with heterogeneous commitments, the aggregate dynamics of portfolios and total consumption coincide precisely with those that arise from a representative consumer model with habit formation preferences. Hence, consumption commitments provide neoclassical foundations for habit in the aggregates. Other implications are that consumption goods that are easier to adjust -such as food- should exhibit weaker evidence of habit formation in the aggregate than more broadly defined categories of consumption. Campbell and Cochrane (1999) use a difference model of habit consumption which displays time varying risk aversion such as:

$$U = \frac{(C_{t+1} - \delta C_t)^{1-\rho}}{1-\rho} \quad (4.19)$$

The parameter  $\delta$  measures the strength of habit formation; when  $\delta$  is larger, the consumer receives less lifetime utility from a given amount of expenditure.

With this utility function, the lifetime utility stream is as follows:

$$U = \sum_{t=0}^{\infty} \beta^t \frac{(C_{t+1} - \delta C_t)^{1-\rho}}{1-\rho} \quad (4.20)$$

Consumption follows the process<sup>36</sup>  $c_t = C_0 (1+g)^t \left[ \exp\left(\varepsilon_t - \frac{1}{2} \text{Var}(\varepsilon)\right) \right]$  where  $\varepsilon_t$  is an uncorrelated stationary stochastic process with a stationary distribution given by  $\varepsilon \sim N(0, \text{Var}(\varepsilon))$ . The discounted lifetime utility stream takes the form:

$$E_t U = \frac{(C_0 - \delta C)^{1-\rho}}{1-\rho} + \frac{C_0^{1-\rho}}{1-\rho} \exp\left(-\frac{1}{2}(1-\rho)\text{Var}(\varepsilon)\right) \frac{1}{(1+g-\delta)^\rho} \left[ \frac{(1+g-\delta) + \frac{(1-\rho)\text{Var}(\varepsilon)}{2(1+g-\delta)}}{\left((1-\rho)((1+g)^2 + \delta^2) - 2\delta(1+g)\right)} \right] \frac{\beta(1+g)^{(1-\rho)}}{1-\beta(1+g)^{(1-\rho)}} \quad (4.21)$$

Where the term  $\frac{(C_0 - \delta C)^{1-\rho}}{1-\rho}$  represents the utility at the period immediately after the breakpoint and  $C$  is the consumption prior to the breakpoint; in other words the infinite sum captures the utility from tomorrow onwards (that depends on today's consumption) while this term captures the utility today that depends on yesterday's consumption and it captures an additional effect on utility of a change in level due to the existence of habit.

#### 4.5.1. Lucas (1987) with habit formation

In this section we solve the Lucas model substituting the time separable preferences assumption for the one of habit formation. The percentage change in consumption ( $\tau_g$ ) uniform across all dates and values of the shocks, required to leave the consumer indifferent between the growth rates  $g$  and  $g_0$  is the solution to the equality:

<sup>36</sup> See annex A4.3 for complete solution.

$$\begin{aligned} & \frac{\left((1+\tau_g)C_0 - \delta C\right)^{1-\rho}}{1-\rho} + \frac{\left(1+\tau_g\right)^{1-\rho} C_0^{1-\rho}}{1-\rho} \exp\left(-\frac{1}{2}(1-\rho)\text{Var}(\varepsilon)\right) \frac{1}{(1+g_1-\delta)^\rho} \left[ \frac{(1+g_1-\delta) + \frac{(1-\rho)\text{Var}(\varepsilon)}{2(1+g_1-\delta)} \times}{\left((1-\rho)\left((1+g_1)^2 + \delta^2\right) - 2\delta(1+g_1)\right)} \right] \frac{\beta(1+g_1)^{(1-\rho)}}{1-\beta(1+g_1)^{(1-\rho)}} = \\ & \frac{\left(C_0 - \delta C\right)^{1-\rho}}{1-\rho} + \frac{C_0^{1-\rho}}{1-\rho} \exp\left(-\frac{1}{2}(1-\rho)\text{Var}(\varepsilon)\right) \frac{1}{(1+g_0-\delta)^\rho} \left[ \frac{(1+g_0-\delta) + \frac{(1-\rho)\text{Var}(\varepsilon)}{2(1+g_0-\delta)} \times}{\left((1-\rho)\left((1+g_0)^2 + \delta^2\right) - 2\delta(1+g_0)\right)} \right] \frac{\beta(1+g_0)^{(1-\rho)}}{1-\beta(1+g_0)^{(1-\rho)}} \end{aligned} \quad (4.22)$$

The costs of economic instability (increased variance in real consumption), can be measured in conceptually identical way as before. This implies solving for  $\tau_{Var}$  the equation:

$$\begin{aligned} & \frac{\left((1+\tau_{Var})C_0 - \delta C\right)^{1-\rho}}{1-\rho} + \frac{\left(1+\tau_{Var}\right)^{1-\rho} C_0^{1-\rho}}{1-\rho} \exp\left(-\frac{1}{2}(1-\rho)\text{Var}_1(\varepsilon)\right) \frac{1}{(1+g_0-\delta)^\rho} \left[ \frac{(1+g_0-\delta) + \frac{1}{2}(1-\rho)\text{Var}_1(\varepsilon) \times}{\left((1-\rho)\left((1+g_0)^2 + \delta^2\right) - 2\delta(1+g_0)\right)} \right] \frac{\beta(1+g_0)^{(1-\rho)}}{1-\beta(1+g_0)^{(1-\rho)}} = \\ & \frac{\left(C_0 - \delta C\right)^{1-\rho}}{1-\rho} \frac{C_0^{1-\rho}}{1-\rho} \frac{\beta(1+g_0)^{(1-\rho)}}{1-\beta(1+g_0)^{(1-\rho)}} (1+g_0-\delta)^{1-\rho} \end{aligned} \quad (4.23)$$

#### 4.5.2. Loss in lifetime utility with habit formation

With this specification, the permanent utility of projected consumption with the parameters before the crisis ( $U_0$ ) and the observed consumption parameters after the crisis ( $U_1$ ):

$$\begin{aligned} U_1 &= \frac{1}{1-\rho} \left[ \left(C_1 - \delta C\right)^{1-\rho} + C_1^{1-\rho} \exp\left(-\frac{1}{2}(1-\rho)\text{Var}_1\right) \frac{1}{(1+g_1-\delta)^\rho} \left[ \frac{(1+g_1-\delta) + \frac{1}{2}(1-\rho)\text{Var}_1 \times}{\left((1-\rho)\left((1+g_1)^2 + \delta^2\right) - 2\delta(1+g_1)\right)} \right] \frac{\beta(1+g_1)^{(1-\rho)}}{1-\beta(1+g_1)^{(1-\rho)}} \right] \\ U_0 &= \frac{1}{1-\rho} \left[ \left(C_0 - \delta C\right)^{1-\rho} + C_0^{1-\rho} \exp\left(-\frac{1}{2}(1-\rho)\text{Var}_0\right) \frac{1}{(1+g_0-\delta)^\rho} \left[ \frac{(1+g_0-\delta) + \frac{1}{2}(1-\rho)\text{Var}_0 \times}{\left((1-\rho)\left((1+g_0)^2 + \delta^2\right) - 2\delta(1+g_0)\right)} \right] \frac{\beta(1+g_0)^{(1-\rho)}}{1-\beta(1+g_0)^{(1-\rho)}} \right] \end{aligned} \quad (4.24)$$

With these two utility functions we calculate the percentage change in utility as in equation 4.9. Which simplifying yields the expression:

$$\Delta U = \frac{\left[ \begin{array}{c} (1-\beta(1+g_1)^{(1-\rho)})(1+g_1-\delta)^\rho (C_1-\delta C)^{1-\rho} + C_1^{1-\rho} \exp\left(-\frac{1}{2}(1-\rho)Var_1\right) \\ \left( \begin{array}{c} (1+g_1-\delta)+ \\ \frac{1}{2}(1-\rho)Var_1 \times \\ \left( (1-\rho)\left((1+g_1)^2 + \delta^2\right) \right) \\ -2\delta(1+g_1) \end{array} \right) \end{array} \right]}{\left[ \begin{array}{c} (1-\beta(1+g_0)^{(1-\rho)})(1+g_0-\delta)^\rho (C_0-\delta C)^{1-\rho} + C_0^{1-\rho} \exp\left(-\frac{1}{2}(1-\rho)Var_0\right) \\ \left( \begin{array}{c} (1+g_0-\delta)+ \\ \frac{1}{2}(1-\rho)Var_0 \times \\ \left( (1-\rho)\left((1+g_0)^2 + \delta^2\right) \right) \\ -2\delta(1+g_0) \end{array} \right) \end{array} \right]} \frac{\beta(1+g_1)^{(1-\rho)} \left( \frac{(1+g_0-\delta)^\rho}{(1+g_1-\delta)^\rho} \right)^{\rho-1}}{\beta(1+g_0)^{(1-\rho)} \left( \frac{(1+g_0-\delta)^\rho}{(1+g_1-\delta)^\rho} \right)^{\rho-1}} \quad (4.25)$$

Using this expression for the total change, we can calculate the effect of separate changes in the growth rate, the level and the variance of consumption.

Change in level, when  $g_0=g_1$ , and  $Var_0=Var_1$ .

$$\Delta U = \frac{\left[ \begin{array}{c} (1-\beta(1+g_0)^{(1-\rho)})(1+g_0-\delta)^\rho \left( (C_1-\delta C)^{1-\rho} - (C_0-\delta C)^{1-\rho} \right) + (C_1^{1-\rho} - C_0^{1-\rho}) \exp\left(-\frac{1}{2}(1-\rho)Var_0\right) \\ \left( \begin{array}{c} (1+g_0-\delta)+ \\ \frac{1}{2}(1-\rho)Var_0 \times \\ \left( (1-\rho)\left((1+g_0)^2 + \delta^2\right) \right) \\ -2\delta(1+g_0) \end{array} \right) \end{array} \right]}{\left[ \begin{array}{c} (1-\beta(1+g_0)^{(1-\rho)})(1+g_0-\delta)^\rho (C_0-\delta C)^{1-\rho} + C_0^{1-\rho} \exp\left(-\frac{1}{2}(1-\rho)Var_0\right) \\ \left( \begin{array}{c} (1+g_0-\delta)+ \\ \frac{1}{2}(1-\rho)Var_0 \times \\ \left( (1-\rho)\left((1+g_0)^2 + \delta^2\right) \right) \\ -2\delta(1+g_0) \end{array} \right) \end{array} \right]} \quad (4.26)$$

Change in growth, when  $C_0=C_1$ , and  $Var_0=Var_1$ .

$$\Delta U = \frac{\left[ \begin{array}{c} (1-\beta(1+g_1)^{(1-\rho)})(1+g_1-\delta)^\rho (C_0-\delta C)^{1-\rho} + C_0^{1-\rho} \exp\left(-\frac{1}{2}(1-\rho)Var_0\right) \\ \left( \begin{array}{c} (1+g_1-\delta)+ \\ \frac{1}{2}(1-\rho)Var_0 \times \\ \left( (1-\rho)\left((1+g_0)^2 + \delta^2\right) \right) \\ -2\delta(1+g_0) \end{array} \right) \end{array} \right]}{\left[ \begin{array}{c} (1-\beta(1+g_0)^{(1-\rho)})(1+g_0-\delta)^\rho (C_0-\delta C)^{1-\rho} + C_0^{1-\rho} \exp\left(-\frac{1}{2}(1-\rho)Var_0\right) \\ \left( \begin{array}{c} (1+g_0-\delta)+ \\ \frac{1}{2}(1-\rho)Var_0 \times \\ \left( (1-\rho)\left((1+g_0)^2 + \delta^2\right) \right) \\ -2\delta(1+g_0) \end{array} \right) \end{array} \right]} \frac{\beta(1+g_1)^{(1-\rho)} \left( \frac{(1-\beta(1+g_0)^{(1-\rho)})(1+g_0-\delta)^\rho}{(1-\beta(1+g_1)^{(1-\rho)})(1+g_1-\delta)^\rho} \right)^{\rho-1}}{\beta(1+g_0)^{(1-\rho)} \left( \frac{(1-\beta(1+g_0)^{(1-\rho)})(1+g_0-\delta)^\rho}{(1-\beta(1+g_1)^{(1-\rho)})(1+g_1-\delta)^\rho} \right)^{\rho-1}} \quad (4.27)$$

Change in variance, when  $g_0=g_1$ , and  $C_0=C_1$ .

$$\Delta U = \frac{\left[ \begin{array}{l} (1 - \beta(1 + g_0)^{(1-\rho)})(1 + g_0 - \delta)^\rho (C_0 - \delta C)^{1-\rho} + C_0^{1-\rho} \exp\left(-\frac{1}{2}(1-\rho)Var_1\right) \\ \left( \begin{array}{l} (1 + g_0 - \delta) + \\ \frac{1}{2}(1-\rho)Var_1 \times \\ \left( (1-\rho)((1 + g_0)^2 + \delta^2) \right) \\ -2\delta(1 + g_0) \end{array} \right) \end{array} \right]}{\left[ \begin{array}{l} (1 - \beta(1 + g_0)^{(1-\rho)})(1 + g_0 - \delta)^\rho (C_0 - \delta C)^{1-\rho} + C_0^{1-\rho} \exp\left(-\frac{1}{2}(1-\rho)Var_0\right) \\ \left( \begin{array}{l} (1 + g_0 - \delta) + \\ \frac{1}{2}(1-\rho)Var_0 \times \\ \left( (1-\rho)((1 + g_0)^2 + \delta^2) \right) \\ -2\delta(1 + g_0) \end{array} \right) \end{array} \right]} - 1 \quad (4.28)$$

### 4.5.3. Compensation required due to changes in utility after a crisis: the WLM with habit formation

We now turn to calculate the WLM with the assumption of habit formation instead of time separable preferences, we proceed in the same way as Lucas (1987) in order to find the compensation in consumption required to be indifferent between periods as in equation 4.14. When substituting the utility functions we have that the total compensation in consumption after the crisis will be the solution of  $\tau$  for:

$$\frac{((1 + \tau)C_1 - \delta C)^{1-\rho}}{1-\rho} + \frac{(1 + \tau)^{1-\rho} C_1^{1-\rho}}{1-\rho} \exp\left(-\frac{1}{2}(1-\rho)Var_1(\varepsilon)\right) \frac{1}{(1 + g_1 - \delta)^\rho} \left[ \begin{array}{l} (1 + g_1 - \delta) + \frac{1}{2}(1-\rho)Var_1(\varepsilon) \times \\ \left( (1-\rho)((1 + g_1)^2 + \delta^2) \right) \\ -2\delta(1 + g_1) \end{array} \right] \frac{\beta(1 + g_1)^{(1-\rho)}}{1 - \beta(1 + g_1)^{(1-\rho)}} =$$

$$\frac{(C_0 - \delta C)^{1-\rho}}{1-\rho} + \frac{C_0^{1-\rho}}{1-\rho} \exp\left(-\frac{1}{2}(1-\rho)Var_0(\varepsilon)\right) \frac{1}{(1 + g_0 - \delta)^\rho} \left[ \begin{array}{l} (1 + g_0 - \delta) + \frac{1}{2}(1-\rho)Var_0(\varepsilon) \times \\ \left( (1-\rho)((1 + g_0)^2 + \delta^2) \right) \\ -2\delta(1 + g_0) \end{array} \right] \frac{\beta(1 + g_0)^{(1-\rho)}}{1 - \beta(1 + g_0)^{(1-\rho)}} \quad (4.29)$$

The effect of separate changes in the growth rate, the level and variance of consumption can be derived as follows:

Compensation for changes in growth, when  $C_0=C_1$ , and  $Var_0=Var_1$ .



$$\begin{aligned}
 & \left( (1+\tau_s)C_0 - \delta C \right)^{1-\rho} + (1+\tau_s)^{1-\rho} C_0^{1-\rho} \exp\left(-\frac{1}{2}(1-\rho)Var_0(\varepsilon)\right) \frac{1}{(1+g_1-\delta)^\rho} \left[ \frac{(1+g_1-\delta) + \frac{1}{2}(1-\rho)Var_0(\varepsilon) \times}{(1-\rho)((1+g_1)^2 + \delta^2)} \right] \frac{\beta(1+g_1)^{(1-\rho)}}{1-\beta(1+g_1)^{(1-\rho)}} = \\
 & (C_0 - \delta C)^{1-\rho} + C_0^{1-\rho} \exp\left(-\frac{1}{2}(1-\rho)Var_0(\varepsilon)\right) \frac{1}{(1+g_0-\delta)^\rho} \left[ \frac{(1+g_0-\delta) + \frac{1}{2}(1-\rho)Var_0(\varepsilon) \times}{(1-\rho)((1+g_0)^2 + \delta^2)} \right] \frac{\beta(1+g_0)^{(1-\rho)}}{1-\beta(1+g_0)^{(1-\rho)}}
 \end{aligned} \tag{4.30}$$

Compensation for changes in level, when  $g_0=g_1$ , and  $Var_0=Var_1$ .

$$\begin{aligned}
 & \left( (1+\tau_i)C_1 - \delta C \right)^{1-\rho} + (1+\tau_i)^{1-\rho} C_1^{1-\rho} \exp\left(-\frac{1}{2}(1-\rho)Var_0(\varepsilon)\right) \frac{1}{(1+g_0-\delta)^\rho} \left[ \frac{(1+g_0-\delta) + \frac{1}{2}(1-\rho)Var_0(\varepsilon) \times}{(1-\rho)((1+g_0)^2 + \delta^2)} \right] \frac{\beta(1+g_0)^{(1-\rho)}}{1-\beta(1+g_0)^{(1-\rho)}} = \\
 & (C_0 - \delta C)^{1-\rho} + C_0^{1-\rho} \exp\left(-\frac{1}{2}(1-\rho)Var_0(\varepsilon)\right) \frac{1}{(1+g_0-\delta)^\rho} \left[ \frac{(1+g_0-\delta) + \frac{1}{2}(1-\rho)Var_0(\varepsilon) \times}{(1-\rho)((1+g_0)^2 + \delta^2)} \right] \frac{\beta(1+g_0)^{(1-\rho)}}{1-\beta(1+g_0)^{(1-\rho)}}
 \end{aligned} \tag{4.31}$$

Compensation for changes in variance, when  $C_0=C_1$ , and  $Var_0=Var_1$ .

$$\begin{aligned}
 & \left( (1+\tau_{var})C_0 - \delta C \right)^{1-\rho} + (1+\tau_{var})^{1-\rho} C_0^{1-\rho} \exp\left(-\frac{1}{2}(1-\rho)Var_1(\varepsilon)\right) \frac{1}{(1+g_0-\delta)^\rho} \left[ \frac{(1+g_0-\delta) + \frac{1}{2}(1-\rho)Var_1(\varepsilon) \times}{(1-\rho)((1+g_0)^2 + \delta^2)} \right] \frac{\beta(1+g_0)^{(1-\rho)}}{1-\beta(1+g_0)^{(1-\rho)}} = \\
 & (C_0 - \delta C)^{1-\rho} + C_0^{1-\rho} \exp\left(-\frac{1}{2}(1-\rho)Var_0(\varepsilon)\right) \frac{1}{(1+g_0-\delta)^\rho} \left[ \frac{(1+g_0-\delta) + \frac{1}{2}(1-\rho)Var_0(\varepsilon) \times}{(1-\rho)((1+g_0)^2 + \delta^2)} \right] \frac{\beta(1+g_0)^{(1-\rho)}}{1-\beta(1+g_0)^{(1-\rho)}}
 \end{aligned} \tag{4.32}$$

## 4.6. Autocorrelation in the consumption process

In some cases we can find that the random error  $\varepsilon$  of the de-trended consumption series does not follow a white noise process but instead shows serial correlation and follows a process such as:

$$\mathcal{E}_{t+1} = a\mathcal{E}_t + v_t \text{ where } v_t \text{ is a white noise process with distribution } v \sim N(0, Var(v)).$$

At this point by calculating the expected value of the auto correlated errors at time t allows us to state that the conditional distribution given the information at date 0 of  $\varepsilon_t$  is:

$$\varepsilon_t \sim N(\varepsilon_0 a^t, \text{Var}(\varepsilon_t | I_0))^{37}.$$

The consumption process is now described by:

$$c_t^{1-\rho} = C_0^{1-\rho} (1+g)^{(1-\rho)t} \left[ \exp\left(\varepsilon_0 a^t + \sum_{i=1}^t a^{t-i} v_i - \frac{1}{2} \text{Var}(\varepsilon)\right) \right]^{1-\rho} \quad (4.33)$$

The discounted lifetime utility stream for this process is therefore<sup>38</sup>:

$$E_t U = \frac{C_0^{1-\rho}}{1-\rho} \sum_{t=0}^{\infty} \beta^t (1+g)^{(1-\rho)t} \exp\left((1-\rho) \left( a^t \varepsilon_0 - (\rho + (1-\rho) a^{2(t+1)}) \frac{\text{Var}(\varepsilon)}{2} \right)\right) \quad (4.34)$$

In order to derive the corresponding WLM with autocorrelation we proceed as before starting with equation 4.14. When substituting the utility functions we obtain:

$$\begin{aligned} & \frac{\left((1+\tau)\bar{C}_1\right)^{1-\rho}}{1-\rho} \sum_{t=0}^{\infty} \beta^t (1+g_1)^{(1-\rho)t} \exp\left((1-\rho) \left( a^t \varepsilon_0 - (\rho + (1-\rho) a^{2(t+1)}) \frac{\text{Var}_1(\varepsilon)}{2} \right)\right) \\ &= \frac{C_0^{1-\rho}}{1-\rho} \sum_{t=0}^{\infty} \beta^t (1+g_0)^{(1-\rho)t} \exp\left((1-\rho) \left( a^t \varepsilon_0 - (\rho + (1-\rho) a^{2(t+1)}) \frac{\text{Var}_0(\varepsilon)}{2} \right)\right) \end{aligned} \quad (4.35)$$

Solving for  $\tau$ :

$$\tau = \frac{\bar{C}_0}{\bar{C}_1} \left[ \frac{\sum_{t=0}^{\infty} \beta^t (1+g_0)^{(1-\rho)t} \exp\left((1-\rho) \left( a^t \varepsilon_0 - (\rho + (1-\rho) a^{2(t+1)}) \frac{\text{Var}_0(\varepsilon)}{2} \right)\right)}{\sum_{t=0}^{\infty} \beta^t (1+g_1)^{(1-\rho)t} \exp\left((1-\rho) \left( a^t \varepsilon_0 - (\rho + (1-\rho) a^{2(t+1)}) \frac{\text{Var}_1(\varepsilon)}{2} \right)\right)} \right]^{1-\rho} - 1 \quad (4.36)$$

We can obtain the effect of separate changes in the growth rate, the level and the variance of consumption.

Compensation for changes in growth, when  $C_0=C_1$  and  $\text{Var}_0=\text{Var}_1$ .

<sup>37</sup> The demonstration of the expected value of autocorrelated errors is in annex A4.4.

<sup>38</sup> The complete derivation can be found in annex A4.6.

$$\tau_g = \left[ \frac{\sum_{t=0}^{\infty} \beta^t (1+g_0)^{(1-\rho)t} \exp\left((1-\rho)\left(a^t \varepsilon_0 - (\rho + (1-\rho)a^{2(t+1)}) \frac{Var_0(\varepsilon)}{2}\right)\right)}{\sum_{t=0}^{\infty} \beta^t (1+g_1)^{(1-\rho)t} \exp\left((1-\rho)\left(a^t \varepsilon_0 - (\rho + (1-\rho)a^{2(t+1)}) \frac{Var_0(\varepsilon)}{2}\right)\right)} \right]^{\frac{1}{1-\rho}} - 1 \quad (4.37)$$

Compensation for changes in level, when  $g_0=g_1$  and  $Var_0=Var_1$ .

$$\tau_l = \left( \frac{\bar{C}_0}{\bar{C}_1} \right) - 1 \quad (4.38)$$

Compensation for changes in variance, when  $C_0=C_1$  and  $Var_0=Var_1$ .

$$\tau_{Var} = \left[ \frac{\sum_{t=0}^{\infty} \beta^t (1+g_0)^{(1-\rho)t} \exp\left((1-\rho)\left(a^t \varepsilon_0 - (\rho + (1-\rho)a^{2(t+1)}) \frac{Var_0(\varepsilon)}{2}\right)\right)}{\sum_{t=0}^{\infty} \beta^t (1+g_0)^{(1-\rho)t} \exp\left((1-\rho)\left(a^t \varepsilon_0 - (\rho + (1-\rho)a^{2(t+1)}) \frac{Var_1(\varepsilon)}{2}\right)\right)} \right]^{\frac{1}{1-\rho}} - 1 \quad (4.39)$$

## 4.7. Welfare loss under uncertainty

So far we have dealt with an ex-post measure of the effects of a crisis over welfare. We now can turn to develop an ex-ante measure taken into account the probability of a crisis occurring.

### 4.7.1. WLM with time separable preferences under uncertainty

In order to introduce uncertainty to this model we can calculate the expected consumption path under the probability of having a crisis  $p_c$  and not having a crisis  $p_{nc}$ .

$$c_t^{1-\rho} = p_{nc} (1+g)^{(1-\rho)t} C_0^{1-\rho} \exp(\varepsilon_t - 1/2 Var_0(\varepsilon))^{1-\rho} + p_c (1+g_1)^{(1-\rho)t} C_1^{1-\rho} \exp(\varepsilon_t - 1/2 Var_1(\varepsilon))^{1-\rho} \quad (4.40)$$

If we calculate the expected consumption as before, we obtain the following expression:

$$E(c_t^{1-\rho}) = p_{nc} C_0^{1-\rho} (1+g_0)^{(1-\rho)t} \exp\left(-\frac{1}{2} Var_0(\varepsilon) \rho(1-\rho)\right) + p_c C_1^{1-\rho} (1+g_1)^{(1-\rho)t} \exp\left(-\frac{1}{2} Var_1(\varepsilon) \rho(1-\rho)\right) \quad (4.41)$$

We can calculate the discounted lifetime utility stream:

$$\begin{aligned} \beta E_t U_{t+1} &= \frac{1}{1-\rho} \sum_{t=0}^{\infty} \beta^t \left[ \begin{aligned} & p_{nc} C_0^{1-\rho} (1+g_0)^{(1-\rho)^t} \exp\left(-\frac{1}{2} \text{Var}_0(\varepsilon) \rho(1-\rho)\right) + \\ & p_c C_1^{1-\rho} (1+g_1)^{(1-\rho)^t} \exp\left(-\frac{1}{2} \text{Var}_1(\varepsilon) \rho(1-\rho)\right) \end{aligned} \right] \\ &= \frac{1}{1-\rho} \left\{ \begin{aligned} & \sum_{t=0}^{\infty} \beta^t \left[ p_{nc} C_0^{1-\rho} (1+g_0)^{(1-\rho)^t} \exp\left(-\frac{1}{2} \text{Var}_0(\varepsilon) \rho(1-\rho)\right) \right] + \\ & \sum_{t=0}^{\infty} \beta^t \left[ p_c C_1^{1-\rho} (1+g_1)^{(1-\rho)^t} \exp\left(-\frac{1}{2} \text{Var}_1(\varepsilon) \rho(1-\rho)\right) \right] \end{aligned} \right\} \end{aligned} \quad (4.42)$$

Simplifying:

$$\beta E_t U_{t+1} = \frac{1}{1-\rho} \left[ \begin{aligned} & p_{nc} C_0^{1-\rho} \cdot \frac{1}{1-\beta(1+g_0)^{1-\rho}} \exp\left(-\frac{1}{2} \rho(1-\rho) \text{Var}_0(\varepsilon)\right) + \\ & p_c C_1^{1-\rho} \cdot \frac{1}{1-\beta(1+g_1)^{1-\rho}} \exp\left(-\frac{1}{2} \rho(1-\rho) \text{Var}_1(\varepsilon)\right) \end{aligned} \right] \quad (4.43)$$

In order to obtain the required compensation for being indifferent between the current path of consumption and the consumption with uncertainty we use the modified equation 4.14a:

$U_1\{\bar{C}_u\} = U_0\{(1+\tau)\bar{C}_0\}$  where  $\bar{C}_u$  is consumption under uncertainty and now we are calculating how much do we have to take away from current consumption to be indifferent between consumption with uncertainty and the actual path of consumption. When substituting the utility function we obtain:

$$\begin{aligned} & \left[ \begin{aligned} & \frac{p_c (\bar{C}_1)^{1-\rho}}{1-\rho} \frac{1}{1-\beta(1+g_1)^{1-\rho}} \exp\left(-\frac{1}{2} \rho(1-\rho) \text{Var}_1\right) + \\ & \frac{p_{nc} (\bar{C}_0)^{1-\rho}}{1-\rho} \frac{1}{1-\beta(1+g_0)^{1-\rho}} \exp\left(-\frac{1}{2} \rho(1-\rho) \text{Var}_0\right) \end{aligned} \right] = \frac{((1+\tau)\bar{C}_0)^{1-\rho}}{1-\rho} \frac{1}{1-\beta(1+g_0)^{1-\rho}} \exp\left(-\frac{1}{2} \rho(1-\rho) \text{Var}_0\right) \\ & p_c \frac{(\bar{C}_1)^{1-\rho}}{1-\rho} \frac{1}{1-\beta(1+g_1)^{1-\rho}} \exp\left(-\frac{1}{2} \rho(1-\rho) \text{Var}_1\right) = \frac{\bar{C}_0^{1-\rho}}{1-\rho} \frac{1}{1-\beta(1+g_0)^{1-\rho}} \exp\left(-\frac{1}{2} \rho(1-\rho) \text{Var}_0\right) \left[ (1+\tau)^{1-\rho} - p_{nc} \right] \end{aligned} \quad (4.44)$$

Solving for  $\tau$ :

$$\tau = \left( p_c \left( \frac{\bar{C}_1}{\bar{C}_0} \right)^{1-\rho} \frac{1-\beta(1+g_0)^{1-\rho}}{1-\beta(1+g_1)^{1-\rho}} \exp\left(-\frac{1}{2} \rho(1-\rho) (\text{Var}_0 - \text{Var}_1)\right) + p_{nc} \right)^{\frac{1}{1-\rho}} - 1 \quad (4.45)$$

The effect of separate changes in the growth rate, level and variance of consumption can be derived from this equation.

Compensation for changes in growth when  $C_0=C_1$  and  $Var_0=Var_1$ .

$$\tau_g = \left( p_c \frac{1 - \beta(1 + g_0)^{1-\rho}}{1 - \beta(1 + g_1)^{1-\rho}} + p_{nc} \right)^{\frac{1}{1-\rho}} - 1 \quad (4.46)$$

Compensation for changes in level when  $g_0=g_1$  and  $Var_0=Var_1$ .

$$\tau_l = \left( p_c \left( \frac{\bar{C}_1}{\bar{C}_0} \right)^{1-\rho} + p_{nc} \right)^{\frac{1}{1-\rho}} - 1 \quad (4.47)$$

Compensation for changes in level when  $C_0=C_1$  and  $g_0=g_1$ .

$$\tau_{Var} = \left( p_c \exp\left(-\frac{1}{2}\rho(1-\rho)(Var_0 - Var_1)\right) + p_{nc} \right)^{\frac{1}{1-\rho}} - 1 \quad (4.48)$$

#### 4.7.2. WLM with habit formation preferences under uncertainty

The ex-ante probability measure of utility can be expressed as:

$$U_{ea} = p_{nc} \left( \frac{(C_0 - \delta C)^{1-\rho}}{1-\rho} + \frac{C_0^{1-\rho}}{1-\rho} \exp\left(-\frac{1}{2}Var_0(\varepsilon)\right)^{1-\rho} \frac{1}{(1+g_0-\delta)^\rho} \begin{bmatrix} (1+g_0-\delta) \\ +\frac{1}{2}(1-\rho)Var_0(\varepsilon) \times \\ \left[ (1-\rho)\left((1+g_0)^2 + \delta^2\right) \right] \\ -2\delta(1+g_0) \end{bmatrix} \frac{\beta(1+g_0)^{(1-\rho)}}{1-\beta(1+g_0)^{(1-\rho)}} \right) \\ + p_c \left( \frac{(C_1 - \delta C)^{1-\rho}}{1-\rho} + \frac{C_1^{1-\rho}}{1-\rho} \exp\left(-\frac{1}{2}Var_1(\varepsilon)\right)^{1-\rho} \frac{1}{(1+g_1-\delta)^\rho} \begin{bmatrix} (1+g_1-\delta) \\ +\frac{1}{2}(1-\rho)Var_1(\varepsilon) \times \\ \left[ (1-\rho)\left((1+g_1)^2 + \delta^2\right) \right] \\ -2\delta(1+g_1) \end{bmatrix} \frac{\beta(1+g_1)^{(1-\rho)}}{1-\beta(1+g_1)^{(1-\rho)}} \right) \quad (4.49)$$

In order to obtain the required compensation ( $\tau$ ) for being indifferent between the current path of consumption and the consumption with uncertainty we can use the modified equation 4.14a. Total compensation can be calculated as the solution for  $\tau$  in the following equation:

$$\begin{aligned}
 & \left[ \begin{array}{l} p_{nc} \left( \frac{(C_0 - \delta C)^{1-\rho}}{1-\rho} + \frac{C_0^{1-\rho}}{1-\rho} \exp\left(-\frac{1}{2} \text{Var}_0(\varepsilon)\right)^{1-\rho} \frac{1}{(1+g_0-\delta)^\rho} \begin{bmatrix} (1+g_0-\delta) \\ +\frac{1}{2}(1-\rho)\text{Var}_0(\varepsilon) \times \\ \left( (1-\rho)\left((1+g_0)^2 + \delta^2\right) \right) \\ -2\delta(1+g_0) \end{bmatrix} \frac{\beta(1+g_0)^{(1-\rho)}}{1-\beta(1+g_0)^{(1-\rho)}} \right) + \\ p_{ec} \left( \frac{(C_1 - \delta C)^{1-\rho}}{1-\rho} + \frac{C_1^{1-\rho}}{1-\rho} \exp\left(-\frac{1}{2} \text{Var}_1(\varepsilon)\right)^{1-\rho} \frac{1}{(1+g_1-\delta)^\rho} \begin{bmatrix} (1+g_1-\delta) \\ +\frac{1}{2}(1-\rho)\text{Var}_1(\varepsilon) \times \\ \left( (1-\rho)\left((1+g_1)^2 + \delta^2\right) \right) \\ -2\delta(1+g_1) \end{bmatrix} \frac{\beta(1+g_1)^{(1-\rho)}}{1-\beta(1+g_1)^{(1-\rho)}} \right) \end{array} \right] \\
 & = \frac{\left((1+\tau)C_0 - \delta C\right)^{1-\rho}}{1-\rho} + \frac{\left((1+\tau)C_0\right)^{1-\rho}}{1-\rho} \exp\left(-\frac{1}{2} \text{Var}_0(\varepsilon)\right)^{1-\rho} \frac{1}{(1+g_0-\delta)^\rho} \begin{bmatrix} (1+g_0-\delta) \\ +\frac{1}{2}(1-\rho)\text{Var}_0(\varepsilon) \times \\ \left( (1-\rho)\left((1+g_0)^2 + \delta^2\right) \right) \\ -2\delta(1+g_0) \end{bmatrix} \frac{\beta(1+g_0)^{(1-\rho)}}{1-\beta(1+g_0)^{(1-\rho)}} \\
 & \hspace{20em} (4.50)
 \end{aligned}$$

The effect of separate changes in the growth rate, level and variance of consumption is the solution for individual  $\tau$  in each of the following equations.

Compensation for changes in growth when  $C_0=C_1$  and  $\text{Var}_0=\text{Var}_1$

$$\begin{aligned}
 & \left[ \begin{array}{l} p_{nc} \left( \frac{(C_0 - \delta C)^{1-\rho}}{1-\rho} + \frac{C_0^{1-\rho}}{1-\rho} \exp\left(-\frac{1}{2} \text{Var}_0(\varepsilon)\right)^{1-\rho} \frac{1}{(1+g_0-\delta)^\rho} \begin{bmatrix} (1+g_0-\delta) \\ +\frac{1}{2}(1-\rho)\text{Var}_0(\varepsilon) \times \\ \left( (1-\rho)\left((1+g_0)^2 + \delta^2\right) \right) \\ -2\delta(1+g_0) \end{bmatrix} \frac{\beta(1+g_0)^{(1-\rho)}}{1-\beta(1+g_0)^{(1-\rho)}} \right) + \\ p_{ec} \left( \frac{(C_0 - \delta C)^{1-\rho}}{1-\rho} + \frac{C_0^{1-\rho}}{1-\rho} \exp\left(-\frac{1}{2} \text{Var}_0(\varepsilon)\right)^{1-\rho} \frac{1}{(1+g_1-\delta)^\rho} \begin{bmatrix} (1+g_1-\delta) \\ +\frac{1}{2}(1-\rho)\text{Var}_0(\varepsilon) \times \\ \left( (1-\rho)\left((1+g_1)^2 + \delta^2\right) \right) \\ -2\delta(1+g_1) \end{bmatrix} \frac{\beta(1+g_1)^{(1-\rho)}}{1-\beta(1+g_1)^{(1-\rho)}} \right) \end{array} \right] \\
 & = \frac{\left((1+\tau_g)C_0 - \delta C\right)^{1-\rho}}{1-\rho} + \frac{\left((1+\tau_g)C_0\right)^{1-\rho}}{1-\rho} \exp\left(-\frac{1}{2} \text{Var}_0(\varepsilon)\right)^{1-\rho} \frac{1}{(1+g_0-\delta)^\rho} \begin{bmatrix} (1+g_0-\delta) \\ +\frac{1}{2}(1-\rho)\text{Var}_0(\varepsilon) \times \\ \left( (1-\rho)\left((1+g_0)^2 + \delta^2\right) \right) \\ -2\delta(1+g_0) \end{bmatrix} \frac{\beta(1+g_0)^{(1-\rho)}}{1-\beta(1+g_0)^{(1-\rho)}} \\
 & \hspace{20em} (4.51)
 \end{aligned}$$

Compensation for changes in level when  $g_0=g_1$  and  $Var_0=Var_1$

$$\begin{aligned}
 & \left[ \left( p_{nc} \left( \frac{(C_0 - \delta C)^{1-\rho}}{1-\rho} + \frac{C_0^{1-\rho}}{1-\rho} \exp\left(-\frac{1}{2}Var_0(\varepsilon)\right)^{1-\rho} \frac{1}{(1+g_0-\delta)^\rho} + \frac{1}{2}(1-\rho)Var_0(\varepsilon) \times \frac{\beta(1+g_0)^{(1-\rho)}}{1-\beta(1+g_0)^{(1-\rho)}} \right) + \right. \right. \\
 & \left. \left. \left( p_c \left( \frac{(C_1 - \delta C)^{1-\rho}}{1-\rho} + \frac{C_1^{1-\rho}}{1-\rho} \exp\left(-\frac{1}{2}Var_0(\varepsilon)\right)^{1-\rho} \frac{1}{(1+g_0-\delta)^\rho} + \frac{1}{2}(1-\rho)Var_0(\varepsilon) \times \frac{\beta(1+g_0)^{(1-\rho)}}{1-\beta(1+g_0)^{(1-\rho)}} \right) \right) \right] \\
 & = \frac{((1+\tau_l)C_0 - \delta C)^{1-\rho}}{1-\rho} + \frac{((1+\tau_l)C_0)^{1-\rho}}{1-\rho} \exp\left(-\frac{1}{2}Var_0(\varepsilon)\right)^{1-\rho} \frac{1}{(1+g_0-\delta)^\rho} + \frac{1}{2}(1-\rho)Var_0(\varepsilon) \times \frac{\beta(1+g_0)^{(1-\rho)}}{1-\beta(1+g_0)^{(1-\rho)}} \\
 & \qquad \qquad \qquad \left[ \begin{array}{c} (1+g_0-\delta) \\ (1-\rho)((1+g_0)^2 + \delta^2) \\ -2\delta(1+g_0) \end{array} \right] \\
 & \qquad \qquad \qquad (4.52)
 \end{aligned}$$

Compensation for changes in variance when  $C_0=C_1$  and  $g_0=g_1$

$$\begin{aligned}
 & \left[ \left( p_{nc} \left( \frac{(C_0 - \delta C)^{1-\rho}}{1-\rho} + \frac{C_0^{1-\rho}}{1-\rho} \exp\left(-\frac{1}{2}Var_0(\varepsilon)\right)^{1-\rho} \frac{1}{(1+g_0-\delta)^\rho} + \frac{1}{2}(1-\rho)Var_0(\varepsilon) \times \frac{\beta(1+g_0)^{(1-\rho)}}{1-\beta(1+g_0)^{(1-\rho)}} \right) + \right. \right. \\
 & \left. \left. \left( p_c \left( \frac{(C_0 - \delta C)^{1-\rho}}{1-\rho} + \frac{C_0^{1-\rho}}{1-\rho} \exp\left(-\frac{1}{2}Var_1(\varepsilon)\right)^{1-\rho} \frac{1}{(1+g_0-\delta)^\rho} + \frac{1}{2}(1-\rho)Var_1(\varepsilon) \times \frac{\beta(1+g_0)^{(1-\rho)}}{1-\beta(1+g_0)^{(1-\rho)}} \right) \right) \right] \\
 & = \frac{((1+\tau_{var})C_0 - \delta C)^{1-\rho}}{1-\rho} + \frac{((1+\tau_{var})C_0)^{1-\rho}}{1-\rho} \exp\left(-\frac{1}{2}Var_0(\varepsilon)\right)^{1-\rho} \frac{1}{(1+g_0-\delta)^\rho} + \frac{1}{2}(1-\rho)Var_0(\varepsilon) \times \frac{\beta(1+g_0)^{(1-\rho)}}{1-\beta(1+g_0)^{(1-\rho)}} \\
 & \qquad \qquad \qquad \left[ \begin{array}{c} (1+g_0-\delta) \\ (1-\rho)((1+g_0)^2 + \delta^2) \\ -2\delta(1+g_0) \end{array} \right] \\
 & \qquad \qquad \qquad (4.53)
 \end{aligned}$$

## 4.8. Impact on Emerging Markets' Consumption

The data used is from the International Monetary Fund, consumption data was deflated with the consumer's price index for each country. We use low frequency (quarterly) data for two main reasons: i) the effects of the currency and financial crises are shown in the short-term; and, ii) the time span in years for each of these crisis is only around 10 years since we used 1990's data (starting from the 1st quarter of 1991 to the 4th quarter of 2002). The period of 10 years was chosen because this allows to isolate from the effects of 1980's liquidity crises and because prior to the events under study. The countries chosen (Mexico, Brazil, Korea, Malaysia, Thailand and Philippines) share the same fundamental characteristics, they were receiving international resources for investment and going major economic reforms, all were regarded as successful emerging economies just before all faced a sudden stop and reversal of capital flows. Lucas (1987) analyses the welfare cost when there is a change in the growth rate of consumption, we do the same assuming that the crisis is the exogenous shock which is responsible for the most of changes in the consumption pattern; this allows to have a clear-cut division between periods needed calculate the welfare loss due to the occurrence of each of these crises. We will discuss some of the properties of the consumption series in order to support this assumption.

### 4.8.1. Estimation of welfare losses

#### 4.8.1.1. Time separable preferences

First we applied the change in permanent utility approach and estimated the welfare loss that these crises implied. We calculated the utility associated with the projected trend as if there was no crisis ( $U_0$ , maintaining the same level, variance and growth rate before each one of the crises) and the one associated to the observed trend after the crisis ( $U_1$ ). The pre-crisis period in all cases does not include the quarter in which the crisis occurred while the post-crisis period is taken from the quarter that includes the crisis; the effects of crises can be seen already in this first quarter. The assumptions that we make and that will be relaxed further on include: i) following Hoggarth et al. (2002) welfare is measured by the discounted lifetime utility; ii) a discount rate  $\beta=0.99$  constant across countries and time invariant; iii) a constant risk aversion  $\rho=0.8$  across countries and along time; and, iv) the instantaneous utility function takes the form:

$$U(c) = \frac{C^{1-\rho}}{1-\rho} \text{ for any } \rho \neq 1 ; \text{ and the lifetime utility function:}$$

$$E \left\{ \sum_{t=0}^{\infty} \beta^t U(c_t) \right\} = \frac{C_0^{1-\rho}}{1-\rho} \cdot \frac{1}{1-\beta(1+g)^{1-\rho}} \exp \left( -\frac{1}{2} \rho(1-\rho) \text{Var}(\varepsilon) \right)$$



The summary of the parameters<sup>39</sup> describing the consumption process is shown in table 33.

	C	C <sub>0</sub>	C <sub>1</sub>	g <sub>0</sub>	g <sub>1</sub>	Var <sub>0</sub>	Var <sub>1</sub>	a	ε <sub>0</sub>
<b>Mexico</b>	2.6509	2.6984	2.4621	1.79%	1.12%	0.00109	0.00131	--	0.0663
<b>Thailand</b>	1.8059	1.8293	1.6135	1.29%	1.05%	0.00064	0.00083	0.491935	0.0997
<b>Philippines</b>	1.3362	1.3479	1.3449	0.87%	0.85%	0.00006	0.00003	0.456692	0.0000
<b>Malaysia</b>	5.7282	5.8250	5.5527	1.69%	1.50%	0.00078	0.00100	0.305841	0.0586
<b>Korea</b>	6.4307	6.5773	6.2368	2.28%	1.76%	0.00045	0.00039	0.645734	-0.0020
<b>Brazil</b>	7.0032	7.1692	7.0071	2.37%	0.39%	0.00134	0.00029	0.318821	0.0013

Table 33: Consumption process parameters

As expected, when taken separately, almost all countries suffered a welfare loss because of lower levels of consumption, a reduction in the growth rate, and an increase in the variance; Philippines, Korea and Brazil are the exceptions because in these three countries the variance actually was reduced after the crisis event so, *caeteris paribus*, due to this factor they had an increase in lifetime utility (as can be seen in table 34). However, the total change in utility was negative for all countries because of the impact on level and growth. Mexico had a welfare loss of 18.34%; Thailand 8.27%; Philippines 0.52%; Malaysia 6.17%; Korea 16.39%; Brazil 42.28%. In the all cases, the major changes were due to the decline in growth rates: Mexico loss 16.83% because of this factor; Thailand 5.94%; Philippines, 0.47%; Malaysia 5.27%; Korea, 15.49%; and, Brazil 42.02%.

Change in permanent utility with time separable preferences						
	U <sub>0</sub>	U <sub>1</sub>	Total change	Changes associated with		
				Level	Growth	Variance
<b>Mexico</b>	940.84	768.29	-18.34%	-1.82%	-16.83%	-0.00176%
<b>Thailand</b>	756.36	693.81	-8.27%	-2.48%	-5.94%	-0.00153%
<b>Philippines</b>	640.76	637.46	-0.52%	-0.04%	-0.47%	0.00027%
<b>Malaysia</b>	1065.30	999.52	-6.17%	-0.95%	-5.27%	-0.00172%
<b>Korea</b>	1318.67	1102.57	-16.39%	-1.06%	-15.49%	0.00047%
<b>Brazil</b>	1385.36	799.67	-42.28%	-0.46%	-42.02%	0.00835%

Table 34: Change in permanent utility with time separable preferences

We then applied the cost measures proposed by Lucas (1987) and calculated the compensation required by individuals, as percentage of new consumption process, to be indifferent between the pre and the post crisis periods. We found that because of the change in the growth rate Mexico requires a 151.27% of increase in consumption; Thailand 35.80%; Philippines just 2.40%; Malaysia 31.09%; Korea 132.05%; and, Brazil 1425.78%. When calculating the requirement due to the variance, this goes between 0.0024% for Philippines to 0.0535% for Brazil; it is important to note that the compensation is positive in all cases even

<sup>39</sup> Where C<sub>0</sub>, g<sub>0</sub> and Var<sub>0</sub> are the level, growth rate and variance of consumption without crisis; C<sub>1</sub>, g<sub>1</sub> and Var<sub>1</sub> are the level, growth rate and variance of consumption after a crisis; the parameters *a* and ε<sub>0</sub> are the autocorrelation parameter and the initial error to estimate the error process.

though there are some countries that actually reduced the variance after the crisis, such as Philippines and Korea. This is because Lucas (1987) assumes that volatility goes from zero to a non-zero value.

<b>Compensation required due to changes in consumption parameters: Lucas (1987)</b>		
	<i>Compensation associated with</i>	
	<i>Growth</i>	<i>Variance</i>
<b>Mexico</b>	151.27%	0.0436%
<b>Thailand</b>	35.80%	0.0255%
<b>Philippines</b>	2.40%	0.0024%
<b>Malaysia</b>	31.09%	0.0314%
<b>Korea</b>	132.05%	0.0178%
<b>Brazil</b>	1425.78%	0.0535%

Table 35: Compensation required, Lucas (1987)

When we apply the extension of Lucas (1987) we can see that: i) the costs associated with the variance change with respect to the original measure; ii) when we included the cost associated to a change in level and calculated the total compensation required, we observed that the Lucas (1987) approach can be underestimating significantly if the drop in level is significant; the latter is the case for Mexico, where the cost raises from 151.26% to up to 175.39%; Thailand, where the cost goes up from 35.79% to 53.92%; in Malaysia, where it goes from 31.08% to 37.49%; in Korea, it goes from 132.04% to 144.71%; in Brazil it goes from 1425.78% up to 1460.44%. In Philippines the change is marginal and increases only from 2.39% to 2.61%; and, iii) changes associated with cost are similar to those of Lucas, even when adjusted by autocorrelation.

<b>Compensation in consumption required due to changes parameters: WLM</b>				
	<i>Total compensation</i>	<i>Compensation associated with</i>		
		<i>Level</i>	<i>Growth</i>	<i>Variance</i>
<b>Mexico</b>	175.3986%	9.5930%	151.2699%	0.0088%
Adjusted for autocorrelation		No adjustment necessary		
<b>Thailand</b>	53.9781%	13.3747%	35.8032%	0.0077%
Adjusted for autocorrelation	53.9224%	13.3747%	35.7940%	-0.0218%
<b>Philippines</b>	2.6161%	0.2156%	2.3967%	0.0003%
Adjusted for autocorrelation	2.6168%	0.2156%	2.3967%	-0.0006%
<b>Malaysia</b>	37.5314%	4.9020%	31.0933%	0.0086%
Adjusted for autocorrelation	37.4915%	4.9020%	31.0881%	-0.0164%
<b>Korea</b>	144.7096%	5.4595%	132.0467%	-0.0024%
Adjusted for autocorrelation	144.7189%	5.4595%	132.0480%	0.0009%
<b>Brazil</b>	1460.4256%	2.3134%	1425.7801%	-0.0417%
Adjusted for autocorrelation	1460.4478%	2.3134%	1460.4478%	-0.0396%

Table 36: Compensation required, WLM

### 4.8.1.2. Habit formation preferences

We now turn to the case where individuals have habit formation preferences and calculate the cost with non-separable utility functions. As we already discussed, the utility function takes the form:

$$U(c_{t+1}) = \frac{(c_{t+1} - \delta c_t)^{1-\rho}}{1-\rho} \text{ for any } \rho \neq 1; \text{ and the lifetime utility function:}$$

$$E \left\{ \sum_{t=0}^{\infty} \beta^t U(c_t) \right\} = \frac{C_0^{1-\rho}}{1-\rho} \cdot \frac{(1+g-\delta)^{1-\rho}}{1-\beta(1+g)^{1-\rho}} \exp \left( -\frac{1}{2} \rho (1-\rho) \text{Var}(\varepsilon) \right)$$

We assumed the same parameters as in the case of time separable preferences, that is  $\beta=0.99$ ,  $\rho=0.8$ . Additionally, we set  $\delta=0.9$  to be consistent with Deaton (1987) who shows,  $\delta$  must equal 0.78 to fully explain the “excess smoothness” of aggregate consumption; Carroll and Weil (1994) calculate that  $\delta$  would have to exceed 0.95 to explain the observed relationship between high aggregate income growth and subsequent periods of high aggregate saving; and Constantinides (1990) argues that  $\delta$  must be approximately 0.80 to explain the historical equity premium.

As we can see, with this new utility specification almost all countries suffered a welfare loss because of lower levels of consumption, a reduction in the growth rate, and an increase in the variance; again Philippines, Korea and Brazil had an increase in the utility if we only take into account the change in the variance. However, the total change in utility was negative for all countries because of the impact on level and growth. Mexico had a welfare loss of 19.46%; Thailand 9.83%; Philippines 0.55%; Malaysia 6.57%; Korea 17.15%; Brazil 44.19%. The major changes were due to the decline in growth rates: Mexico loss 17.80% because of this factor; Thailand, 6.34%; Philippines, 0.51%; Malaysia 5.58%; Korea, 16.22%; and, Brazil 44.00%.

	Change in permanent utility with habit formation $\delta=0.5$					
	$U_0$	$U_1$	Total change	Changes associated with		
				Level	Growth	Variance
<b>Mexico</b>	612.66	493.44	-19.46%	-1.96%	-17.80%	-0.0294%
<b>Thailand</b>	488.54	440.50	-9.83%	-3.63%	-6.34%	-0.0264%
<b>Philippines</b>	411.05	408.79	-0.55%	-0.05%	-0.51%	0.0047%
<b>Malaysia</b>	692.78	647.29	-6.57%	-1.01%	-5.58%	-0.0289%
<b>Korea</b>	866.42	717.81	-17.15%	-1.11%	-16.22%	0.0076%
<b>Brazil</b>	910.60	508.20	-44.19%	-0.48%	-44.00%	0.1340%

Table 37: Change in permanent utility with habit formation preferences

When applying the cost measures proposed by Lucas (1987) and assuming  $\delta=0.8$ , we have that the compensation required by individuals, as percentage of new consumption process, to be indifferent between the pre and the post crisis periods, because of the change in the growth

rate, Mexico requires 162.06% of increase in consumption; Thailand 37.32%; Philippines 2.43%; Malaysia 32.15%; Korea 139.16%; and, Brazil 1672.55%.

<b>Compensation in consumption required for changes in parameters: Lucas (1987) approach with habit formation <math>\delta=0.8</math></b>		
	<i>Compensation associated with</i>	
	<i>Growth</i>	<i>Variance</i>
<b>Mexico</b>	162.06%	0.1402%
<b>Thailand</b>	37.32%	0.1249%
<b>Philippines</b>	2.43%	-0.0221%
<b>Malaysia</b>	32.15%	0.1375%
<b>Korea</b>	139.16%	-0.0366%
<b>Brazil</b>	1672.55%	-0.6420%

Table 38: Compensation required, Lucas (1987) with habit formation preferences

Again, when we included the cost associated to a change in level and calculated the total compensation required, we observed that the Lucas (1987) approach can be underestimating significantly if the drop in level is significant; the latter is the case for Mexico, where the cost raises from 162.06% to up to 187.20%; Thailand, where the cost increases from 37.32% to 55.38%; in Philippines it goes up from 2.43% to 2.61%; in Malaysia, where it goes from 32.15% to 38.67%; in Korea, it goes from 139.16% to 151.92%; and in Brazil increases from 1672.55% to 1699.10%.

<b>Compensation in consumption required for changes in parameters: WLM with habit formation <math>\delta=0.8</math></b>				
	<i>Total compensation</i>	<i>Compensation associated with</i>		
		<i>Level</i>	<i>Growth</i>	<i>Variance</i>
<b>Mexico</b>	187.20%	9.15%	162.06%	0.1402%
<b>Thailand</b>	55.38%	12.68%	37.32%	0.1249%
<b>Philippines</b>	2.61%	0.20%	2.43%	-0.0221%
<b>Malaysia</b>	38.67%	4.65%	32.15%	0.1375%
<b>Korea</b>	151.92%	5.24%	139.16%	-0.0366%
<b>Brazil</b>	1699.10%	2.22%	1672.55%	-0.6420%

Table 39: Compensation required, WLM with habit formation preferences

When we compare the results obtained with different specifications of preferences, we can see in the first place that utility is less when we use habit formation preferences. As well the change in utility and in the compensation required from the pre-crisis to the post-crisis period are bigger in the three measures, in other words, the losses are bigger when we have habit formation preferences irrespective of the measure we are using. On the other hand, when changes in each factor are taken individually (level, growth and variance) we can see that the only source of change is in the growth measures for welfare loss in the three cases under study; costs associated with changes in variance and in level are not affected.

Comparison between the different measures of welfare costs								
	Preferences	Utility		Total	Costs associated with changes in			
		Before crisis	After crisis		Level	Growth	Variance	
Mexico	Lucas (1987)	Time separable	-	-	-	-	151.27%	0.0524%
		Habit formation	-	-	-	-	163.95%	0.8363%
	Change in permanent utility	Time separable	940.84	768.29	-18.34%	-1.82%	-16.83%	-0.0018%
		Habit formation	612.6577	493.4379	-19.46%	-1.96%	-17.80%	-0.0294%
	WLM	Time separable	-	-	175.40%	9.59%	151.27%	0.0088%
		Habit formation	-	-	187.20%	9.15%	162.06%	0.1402%
Thailand	Lucas (1987)	Time separable	-	-	-	-	35.80%	0.0332%
		Habit formation	-	-	-	-	37.91%	0.5423%
	Change in permanent utility	Time separable	756.36	693.81	-8.27%	-2.48%	-5.94%	-0.0015%
		Habit formation	488.5417	440.5002	-9.83%	-3.63%	-6.34%	-0.0264%
	WLM	Time separable	-	-	55.90%	13.37%	37.54%	-0.0218%
		Habit formation	-	-	55.38%	12.68%	37.32%	0.1249%
Philippines	Lucas (1987)	Time separable	-	-	-	-	2.40%	0.0010%
		Habit formation	-	-	-	-	2.47%	0.0174%
	Change in permanent utility	Time separable	640.76	637.46	-0.52%	-0.04%	-0.47%	0.0003%
		Habit formation	411.0529	408.7920	-0.55%	-0.05%	-0.51%	0.0047%
	WLM	Time separable	-	-	2.72%	0.22%	2.50%	-0.0006%
		Habit formation	-	-	2.61%	0.20%	2.43%	-0.0221%
Malaysia	Lucas (1987)	Time separable	-	-	-	-	31.09%	0.0400%
		Habit formation	-	-	-	-	32.84%	0.6410%
	Change in permanent utility	Time separable	1065.30	999.52	-6.17%	-0.95%	-5.27%	-0.0017%
		Habit formation	692.7812	647.2902	-6.57%	-1.01%	-5.58%	-0.0289%
	WLM	Time separable	-	-	38.99%	4.90%	32.52%	-0.0164%
		Habit formation	-	-	38.67%	4.65%	32.15%	0.1375%
Korea	Lucas (1987)	Time separable	-	-	-	-	132.05%	0.0155%
		Habit formation	-	-	-	-	139.84%	0.2401%
	Change in permanent utility	Time separable	1318.67	1102.57	-16.39%	-1.06%	-15.49%	0.0005%
		Habit formation	866.4245	717.8126	-17.15%	-1.11%	-16.22%	0.0076%
	WLM	Time separable	-	-	152.64%	5.46%	139.56%	0.0009%
		Habit formation	-	-	151.92%	5.24%	139.16%	-0.0366%
Brazil	Lucas (1987)	Time separable	-	-	-	-	1425.78%	0.0117%
		Habit formation	-	-	-	-	1687.81%	0.1811%
	Change in permanent utility	Time separable	1385.36	799.67	-42.28%	-0.46%	-42.02%	0.0083%
		Habit formation	910.5967	508.1965	-44.19%	-0.48%	-44.00%	0.1340%
	WLM	Time separable	-	-	1640.92%	2.31%	1602.23%	-0.0396%
		Habit formation	-	-	1699.10%	2.22%	1672.55%	-0.6420%

Table 40: Comparison between different measures and preferences

## 4.8.2. Variation in parameters: robustness

We can vary the value of the parameters to see the sensibility of the costs. We will only calculate  $\rho=5$  since the costs tend to diminish the higher the value of  $\rho$ . The total change in utility was negative for all countries because of the impact on level and growth.

### 4.8.2.1. Time separable preferences

Mexico had a welfare loss of 111.73%; Thailand 94.92%; Philippines a gain in utility of 2.61%; Malaysia 33.91%; Korea 53.64%; Brazil 322.48%. In the majority of cases, the major changes were due to the decline in growth rates: Mexico loss 46.45% because of this factor; Philippines, 1.77%; Korea, 24.28%; and, Brazil 289.59%. Thailand and Malaysia major changes were due to changes in level 65.22% and 21.10% respectively.

Change in permanent utility with time separable preferences						
	$U_0$	$U_1$	Total change	Changes associated with		
				Level	Growth	Variance
<b>Mexico</b>	-0.0613	-0.1297	-111.73%	-44.26%	-46.45%	-0.22%
<b>Thailand</b>	-0.3778	-0.7363	-94.92%	-65.22%	-17.75%	-0.19%
<b>Philippines</b>	-1.7335	-1.7788	-2.61%	-0.87%	-1.77%	0.03%
<b>Malaysia</b>	-0.0030	-0.0040	-33.91%	-21.10%	-10.34%	-0.22%
<b>Korea</b>	-0.0014	-0.0022	-53.64%	-23.69%	-24.28%	0.06%
<b>Brazil</b>	-0.0010	-0.0041	-322.48%	-9.58%	-289.59%	1.04%

Table 41: Change in permanent utility with time separable preferences and  $\rho=5$

With Lucas (1987) we found that because of the change in the growth rate Mexico requires a 10.01% of increase in consumption; Thailand 4.17%; Philippines just 0.44%; Malaysia 2.49%; Korea 5.59%; and, Brazil 40.49%. When calculating the requirement due to the variance, this goes between 0.0148% for Philippines to 0.3347% for Brazil.

Compensation in consumption required due to changes parameters: Lucas (1987)		
	Compensation associated with	
	Growth	Variance
<b>Mexico</b>	10.01%	0.2726%
<b>Thailand</b>	4.17%	0.1596%
<b>Philippines</b>	0.44%	0.0148%
<b>Malaysia</b>	2.49%	0.1964%
<b>Korea</b>	5.59%	0.1115%
<b>Brazil</b>	40.49%	0.3347%

Table 42: Compensation required, Lucas (1987) with  $\rho=5$

When we apply the extension of Lucas (1987) we can see that we still have the same conclusions: i) the costs associated to the variance change with respect to the original measure; ii) when we included the cost associated to a change in level and calculated the total compensation required, we observed that the Lucas (1987) approach may be underestimating costs significantly if the drop in level is significant; the latter is the case for Mexico, where the cost raises from 10 % to up to 20.62%; Thailand, where the cost goes up from 4.28% to 18.07%; in Malaysia, where it goes from 2.55% to 7.47%; in Korea, it goes from 5.57% to 11.34%; in Brazil it goes from 40.51% up to 43.40%. In Philippines the change is marginal and increases only from 0.43% to 0.64%; and, iii) changes associated with cost are similar to those of Lucas, even when adjusted by autocorrelation.

<b>Compensation in consumption required due to changes parameters: WLM</b>				
	<i>Total compensation</i>	<i>Compensation associated with</i>		
		<i>Level</i>	<i>Growth</i>	<i>Variance</i>
<b>Mexico</b>	20.6279%	9.5930%	10.0083%	0.0551%
Adjusted for autocorrelation		No adjustment necessary		
<b>Thailand</b>	18.1590%	13.3747%	4.1700%	0.0479%
Adjusted for autocorrelation	18.0702%	13.3747%	4.2831%	-0.1356%
<b>Philippines</b>	0.6469%	0.2156%	0.4387%	-0.0083%
Adjusted for autocorrelation	0.6515%	0.2156%	0.4387%	-0.0037%
<b>Malaysia</b>	7.5721%	4.9020%	2.4902%	0.0538%
Adjusted for autocorrelation	7.4737%	4.9020%	2.5552%	-0.1010%
<b>Korea</b>	11.3331%	5.4595%	5.5851%	-0.0148%
Adjusted for autocorrelation	11.3478%	5.4595%	5.5779%	0.0052%
<b>Brazil</b>	43.3674%	2.3134%	40.4918%	-0.2605%
Adjusted for autocorrelation	43.4095%	2.3134%	40.5132%	-0.2449%

Table 43: Compensation required, WLM with  $\rho=5$

#### 4.8.2.2. Habit formation preferences

As we can see, with this new utility specification almost all countries suffered a welfare loss because of lower levels of consumption, a reduction in the growth rate, and an increase in the variance. In some cases, the measure of loss associated with changes the level of consumption becomes extremely large making it difficult to get a solid conclusion with this method. This is because of the shape of the utility function when  $\rho$  takes values greater than zero; small changes in consumption will yield big changes in utility as the function becomes asymptotical to infinity with small values of consumption.

	Change in permanent utility with habit formation $\delta=0.9$					
	U <sub>0</sub>	U <sub>1</sub>	Total change	Change associated with		
				Level	Growth	Variance
<b>Mexico</b>	-365.34	-8307.71	-21.74	-2043.45%	-84.92%	-2.78%
<b>Thailand</b>	-2545.67	-12472016.65	-4898.30	-489777.57%	-28.08%	-2.70%
<b>Philippines</b>	-12548.60	-12944.71	-0.03	-1.20%	-2.49%	0.53%
<b>Malaysia</b>	-17.57	-34.26	-0.95	-69.56%	-17.55%	-2.84%
<b>Korea</b>	-6.60	-17.17	-1.60	-104.76%	-46.19%	0.76%
<b>Brazil</b>	-4.89	-37.08	-6.58	-20.41%	-699.91%	12.02%

Table 44: Change in permanent utility with habit formation preferences and  $\rho=5$

When applying the cost measures proposed by Lucas (1987), we have that the compensation required by individuals, as percentage of new consumption process, to be indifferent between the pre and the post crisis periods, because of the change in the growth rate, Mexico requires 19.84% of increase in consumption; Thailand 7.88%; Philippines 0.65%; Malaysia 5.77%; Korea 9.95%; and, Brazil 74.85%.

	Compensation required for changes in consumption: Lucas (1987) approach with habit formation $\delta=0.5$	
	Compensation associated with	
	Growth	Variance
<b>Mexico</b>	19.84%	3.37%
<b>Thailand</b>	7.88%	2.35%
<b>Philippines</b>	0.65%	0.08%
<b>Malaysia</b>	5.77%	2.58%
<b>Korea</b>	9.95%	0.80%
<b>Brazil</b>	74.85%	0.58%

Table 45: Compensation required, Lucas (1987) with habit formation preferences and  $\rho=5$

Again, when we included the cost associated to a change in level and calculated the total compensation required, we observed that the Lucas (1987) approach can be underestimating significantly if the drop in level is significant; the latter is the case for Mexico, where the cost raises from 15.54% to up to 27.54%; Thailand, where the cost increases from 5.49% to 20.14%; in Philippines it goes up from 0.46% to 0.52%; in Malaysia, where it goes from 3.21% to 8.58%; in Korea, it goes from 8.40% to 13.86%; but not for Brazil where decreases from 67.70% to 64.77%.

	Compensation required for changes in consumption: WLM with habit formation $\delta=0.8$			
	Total compensation	Compensation associated with		
		Level	Growth	Variance
<b>Mexico</b>	27.54%	7.82%	15.54%	0.4604%
<b>Thailand</b>	20.14%	11.82%	5.49%	0.4750%
<b>Philippines</b>	0.52%	0.15%	0.46%	-0.0968%
<b>Malaysia</b>	8.58%	3.61%	3.21%	0.4726%
<b>Korea</b>	13.86%	3.67%	8.40%	-0.1106%
<b>Brazil</b>	64.77%	1.42%	67.70%	-1.5811%

Table 46: Compensation required, WLM with habit formation preferences and  $\rho=5$



Comparison between the different measures of welfare costs								
		Preferences	Utility		Total	Costs associated with changes in		
			Before crisis	After crisis		Level	Growth	Variance
Mexico	Lucas (1987)	Time separable	-	-	-	-	10.01%	0.3279%
		Habit formation	-	-	-	-	19.84%	3.3691%
	Change in permanent utility	Time separable	-0.06	-0.13	-111.73%	-44.26%	-46.45%	-0.2206%
		Habit formation	-365.3413	-8307.7073	-2173.96%	-2043.45%	-84.92%	-2.7751%
	WLM	Time separable	-	-	20.63%	9.59%	10.01%	0.0551%
		Habit formation	-	-	27.54%	7.82%	15.54%	0.4604%
Thailand	Lucas (1987)	Time separable	-	-	-	-	4.17%	0.2076%
		Habit formation	-	-	-	-	7.88%	2.3528%
	Change in permanent utility	Time separable	-0.38	-0.74	-94.92%	-65.22%	-17.75%	-0.1917%
		Habit formation	-2545.67	12472016.64	489829.84%	-489777.57%	-28.08%	-2.6953%
	WLM	Time separable	-	-	17.68%	13.37%	3.94%	-0.1356%
		Habit formation	-	-	20.14%	11.82%	5.49%	0.4750%
Philippines	Lucas (1987)	Time separable	-	-	-	-	0.44%	0.0065%
		Habit formation	-	-	-	-	0.65%	0.0773%
	Change in permanent utility	Time separable	-1.73	-1.78	-2.61%	-0.87%	-1.77%	0.0332%
		Habit formation	-12548.59	-12944.70	-3.16%	-1.20%	-2.49%	0.5335%
	WLM	Time separable	-	-	0.62%	0.22%	0.41%	-0.0037%
		Habit formation	-	-	0.52%	0.15%	0.46%	-0.0968%
Malaysia	Lucas (1987)	Time separable	-	-	-	-	2.49%	0.2503%
		Habit formation	-	-	-	-	5.77%	2.5779%
	Change in permanent utility	Time separable	0.00	0.00	-33.91%	-21.10%	-10.34%	-0.2153%
		Habit formation	-17.5733	-34.2599	-94.95%	-69.56%	-17.55%	-2.8425%
	WLM	Time separable	-	-	7.26%	4.90%	2.35%	-0.1009%
		Habit formation	-	-	8.58%	3.61%	3.21%	0.4726%
Korea	Lucas (1987)	Time separable	-	-	-	-	5.59%	0.0967%
		Habit formation	-	-	-	-	9.95%	0.7956%
	Change in permanent utility	Time separable	0.00	0.00	-53.64%	-23.69%	-24.28%	0.0591%
		Habit formation	-6.5952	-17.1745	-160.41%	-104.76%	-46.19%	0.7645%
	WLM	Time separable	-	-	10.93%	5.46%	5.18%	0.0052%
		Habit formation	-	-	13.86%	3.67%	8.40%	-0.1106%
Brazil	Lucas (1987)	Time separable	-	-	-	-	40.49%	0.0733%
		Habit formation	-	-	-	-	74.85%	0.5819%
	Change in permanent utility	Time separable	0.00	0.00	-322.48%	-9.58%	-289.59%	1.0380%
		Habit formation	-4.8940	-37.0835	-657.73%	-20.41%	-699.91%	12.0170%
	WLM	Time separable	-	-	40.59%	2.31%	37.75%	-0.2448%
		Habit formation	-	-	64.77%	1.42%	67.70%	-1.5811%

Table 47: Comparison between different measures and preferences with  $\rho=5$

## **4.9. Conclusions of the chapter**

By studying the consumption behaviour in countries affected by major financial and currency crises during the 1990's we can derive some interesting conclusions about the impact that these crises had on welfare. The impact of crises on consumption was important, except in the case of Philippines, the least affected country in the South East Asian crisis.

We used three methodologies in order to calculate the welfare cost of the crises, one was the original developed by Lucas (1987) that proved to underestimate the costs associated to a crisis because:

1. It only measures separately the cost of changes in the growth rate and in variance; therefore it does not offer a measure of the total cost.
2. It only considers the case where the variance goes from zero to a non-zero level and not changes from an initial situation with some volatility in consumption to another with a different volatility.
3. It does not consider the case of changes in the level of consumption and therefore it is not appropriate to determine the costs of catastrophic events where the level itself is decreased.

We introduced a simple measure comparing the utility between consumption processes. This measure however, lacks the feature of capturing the required compensation in terms of consumption (not utility) that would make an individual indifferent across all periods. With this in mind:

1. We propose a comprehensive welfare loss measure (WLM) in order to calculate the cost associated with the change in level and to get a measure of the excess variability due to the occurrence of a crisis.
2. An additional adjustment has to be made in the presence of autocorrelation, however this proved to be negligible.
3. We derived an ex-ante measure with uncertainty that involves the probability of a crisis happening.
4. We dropped the assumption of time separable preferences and introduced habit formation.

The main results of applying the WLM in its different versions are:

1. We observed that the associated cost of a decrease in the growth rate is more important than the cost associated to changes in the variance of real consumption.
2. When introducing the effect on the level of consumption, results can vary as to almost double the costs after a crisis.
3. When we compare the results obtained with different specifications of preferences, we can see in the first place that utility is less when we use habit formation preferences. As well the change in utility and in the compensation required from the pre-crisis to the post-crisis period are bigger in the three measures, in other words, the losses are bigger when we have habit formation preferences irrespective of the measure we are using.
4. When changes in each factor are taken individually (level, growth and variance) we can see that the only source of change is in the growth measures for welfare loss in the three cases under study; costs associated with changes in variance and in level are not affected.

As we have determined, the level effect has an important contribution to welfare costs in the short run; this effect arises the question: why does consumption fall? The purpose of chapter 5 is to answer this question. As we will discuss, existing theories of consumer behaviour do not have a straightforward answer and some of them have predictions contradicting observed data. We explore different theoretical frameworks which model consumption behaviour and decided to re-examine the intertemporal consumption framework which provides a simple specification for allocating resources across time not only by participating in the banking system but also it allows examining other asset markets such as stock markets.

## Chapter 5: Impact on welfare; evaluating policy options while solving some puzzles

*Be prepared to re-examine your reasoning*  
Robert S. McNamara Lesson #8 in Errol Morris' Fog of War (2003)

First and second generation models of exchange rate crises assume that the monetary authorities may react to defend fixed exchange regimes when an attack is under way and they do it so by using monetary policy and international reserves until the latter deplete and the peg has to be abandoned. During the 1990s most of the countries that faced a crisis intervened before the collapse of their exchange regimes through the money market increasing interest rates. An extreme case of this policy is Mexico where this process was accompanied by the substitution of debt denominated and payable in pesos by short term debt nominally denominated in pesos but coupons and principal payable in dollars at maturity at the spot exchange rate fixed at the date of issuance<sup>40</sup>. Brazil and South East Asian countries followed defensive policies with different variations. This kind of defence is designed to keep and even increase the incentives of maintaining capital inflows and to curtail the possibility of a currency crisis occurring. However, none of these countries were able to stop the reversal in capital flows and most of them suffered large welfare losses because of sheer drops in consumption levels.

Just after the collapse of the Exchange Rate Mechanism Ozkan and Sutherland (1995) developed a simple model to analyse possible policy responses to avoid a currency crisis; however, these authors did not address the use of the interest rate as an instrument that can be used for defending the exchange rate. More recently Lahiri and Vegh (2000) developed a model of balance of payment crises to analyse the case where interest rate increases at the time when the crisis occurs rather than a pre-emptive measure. The focus of this model is on the effect on fiscal imbalances and the timing on the crisis but effects on consumption are not included as part of the main analysis. Braggion, Christiano and Roldos (2005) focus in the apparent contradiction of an increase of interest rates before and at the moment of the crises and reductions of interest rates following the crises; they argue that this behaviour is optimal because of the effects that this policy has a positive effect on intermediate goods that translates

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<sup>40</sup> These are the Ajustabonos, to understand the mechanism we need to think it as a contract to buy dollars in the future but fixing today's exchange rate  $S_0$  pesos/USD. If today we pay 10 pesos, when the contract is due at date  $t$  the bearer receives  $10*(1+r)/S_0$  USD rather than  $10*(1+r)/S_t$  USD. This mechanism allows profits if the exchange rate Peso/USD depreciates.

in an increase of production of traded goods. A first problem we found when comparing the conclusions in these studies is that welfare implications are far from consistent; Lahiri and Vegh (2000) analysis find negative welfare effects when consumption depends on interest rates; however, this negative effect does not imply adjustments in consumption as severe as the ones observed in emerging countries. Braggion et al. (2005) find that the optimal response in terms of maximising welfare is to raise interest rates and then reduce them sharply; while Ozkan and Sutherland (1995) assume that interest rates have a negative effect on production and therefore on welfare. We found that real income in those affected countries where information was available had an identical behaviour than the one of consumption; in other words, in countries where real income fell sharply, the same happened to consumption. This is consistent with Carroll's (2002) findings but still has no theoretical explanation from the point of view of intertemporal consumption. There is a large branch of the empirical research based on intertemporal maximisation of consumption which focuses on the estimation of the Euler equation for consumption:

$$\Delta c_t = \alpha_1 + \alpha_2(1 + r_t) + e_t \quad (5.1)$$

However, this literature has not found a consistent relationship between real interest rates and consumption growth. Moreover, Canzoneri, Cumby and Diba (2003) define the challenge for monetary policy to explain why consumption falls for several quarters after there is an increase in interest rates, this result is inconsistent with the implications of the standard Euler equation. Favero (2005) expresses his "surprise"<sup>41</sup> that the first order condition and the budget restriction are not used together to find an optimal solution to the maximisation problem and to evaluate it empirically.

**The main question to ask is if the standard intertemporal approach can link consumption to shocks in real income regardless their origin. In other words, can we explain why real income shocks during a crisis transmit to consumption without recurring to "special case" assumptions.** Therefore we focus on the standard intertemporal choice problem to understand the consumer's behaviour and why some observed puzzles may be relevant when considering any policy options. When analysing the standard model we derive an optimal path solution for consumption behaviour based not only on real interest rates but on real income as well we need two simple assumptions in order to depart from the Euler equation result which are:

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<sup>41</sup> Sic in the original.

1. The maximisation of consumption is done over a lengthy period of time subject to a budget constraint rather than assuming that the planning horizon consists of sequential 2-period problems.
2. Once a period has passed it is not possible to adjust consumption; there is no time travelling.

With this result we present some exercises to analyse the behaviour of consumption when:

1. There is perfect information ex-ante about real income shocks and interest rates.
2. There is an unexpected shock in real income and the interest rate policy.
3. There is an expected shock in real income and the interest rate policy but rigidities in the consumption path.
4. There are liquidity constraints as consequence of a financial crisis.

These scenarios will allow us to analyse theoretically, the behaviour of real consumption under different conditions. We also derive a modified version of the Euler equation that includes income effects and which can be estimated empirically. One of the findings is that there is a limit to the use of monetary policy to offset drops in consumption associated with falls in real income; this limitation is because surprise changes in real interest rates have a negative impact on the level of consumption.

First, we examine the implications of monetary policy for the consumption decision. An important result is that when the planning horizon is longer than one period, a surprise increase in the risk-free interest can reduce consumption when it happens. This result arises from the same reason than in the loanable funds market, the individual cannot adjust decisions in periods that already passed and the wealth available for consumption decreases, this time through lower asset prices. We then apply this model to some issues in financial markets; following Emmons and Schmid (2000) we assume that the participants in the market are either noise traders (investors with a misperception of the real value of the asset) or informed investors (those who know the real value of the asset). We found that the existence of noise traders can have externalities on informed investors. We then turn to analyse some of the possible sources of financial turmoil such as slowdown of the economy, rational bubbles and crashes. As a third section of this chapter we present a possible timeline of events in a crisis which takes into account the results of intertemporal optimisation and a second generation model structure based on the UIP discussed in early chapters. Finally, we present the conclusions of the chapter.

## **5.1. Consumer's behaviour: how do we explain welfare costs?**

In this section we review the available models of consumption that may be useful to explain its behaviour after emerging markets crises. The first option we look at regards to the ability of the economy to insure against fluctuations of consumption via international capital markets. This ability for smoothing consumption is lost when the country is excluded (or chooses self-exclusion) from international capital markets. We will examine if the conditions and costs involved really describe what we observed were the facts during the crises under study. As a second option we discuss the Euler equation approach which relates the interest rate with consumption growth giving an explicit policy instrument that could be used to evaluate policy decisions and their impact on consumption.

### **5.1.1. International capital market exclusion**

According to Obstfeld (1995), global trade in financial assets has clear potential benefits. Individuals gain the opportunity to smooth consumption by borrowing or diversifying abroad and world savings are directed to the world's most productive opportunities. However, the size of these gains and the extent to which they are being attained in practice remain uncertain. Capital mobility allows countries to trade differential consumption risks; the effect is to provide mutual insurance against purely idiosyncratic national consumption fluctuations. In practice, consumption insurance is provided by trade in a wide array of contingent and non-contingent securities. The insurance function of international capital markets is illustrated by assuming that countries can trade a set of Arrow-Debreu securities, one of which entitles its owner to a specified payment on a particular date if and only if a determinate state of nature occurs. Backus, Kehoe and Kydland (1992) argue that the distinguishing feature of an open economy is that it can borrow and lend in international markets by running trade surpluses and deficits. The trade balance can vary systematically over the cycle. Its cyclical properties are determined by the balance of two forces: the desire and ability of agents to smooth consumption using international markets and the additional cyclical variability of investment that international capital flows permit. Tesar (1995) argues that this kind of assessment of welfare gains from international risk-sharing may be an underestimate of the true gains for several reasons. First, representative agent models do a poor job of pricing risky assets. As a consequence, the models generally imply that the gains from reducing all uncertainty are small. Second, in each of the models, the variance output is assumed to be finite. If output follows a random walk, the uncertainty facing individuals is obviously much larger, and the resulting gains from risk-

sharing substantially greater. Whether output is in fact non-stationary and whether countries can effectively insure permanent country-specific shocks to income remain open questions.

Yet, there is a possibility of disruption in this international insurance process. Obstfeld and Rogoff (1999) analyse the case in which a defaulting country faces the possibility of a long-term cut-off from foreign capital markets. This is a reputation model that identifies the implicit costs in the threat of a forced withdrawal from international capital markets. The measurement of the costs associated to fluctuations in GDP follow Lucas (1987) but in an open economy context. Some estimates were previously made for eight countries with data from the period comprised between 1950 and 1992. However, the results yielded some high costs that would make it difficult for such countries as Mexico and Brazil to opt for a macroeconomic adjustment. It is important to notice that this model captures the cost of complete loss of access to international capital markets; however, in all cases an IMF package of rescue was set up for these economies, which in practice means that the deterrent incentive is not as strong as it should be. In practice, there is no loss of access to foreign resources and therefore the threat of cutting the funds is not a credible one, which makes easier the decision for the country to default. These authors discuss Lucas (1987) study and point out that it would be possible to conclude that if the gain from eliminating unpredictable consumption variability is as small as suggested in this study, then the gain from perfect international pooling of risks must be even smaller.

Cole and Obstfeld (1991) use an underlying consumer-preference model and the stochastic properties of industrial country output growth, related to one that Lucas (1987) uses to estimate the cost of post-war United States consumption variability, and find small gains from international risk sharing. However, they do so incorporating the effect of output shocks on the relative prices at which international commodity trade occurs, which is absent from Lucas's (1987) framework. The authors found that fluctuations in international terms of trade can play an important role in automatically pooling risks. Indeed, the models used have the property that for certain parameter choices terms-of-trade responses provide perfect insurance against output shocks, in this extreme case, gains from international portfolio diversification are nil. Tesar (1995) tries to bring the theory of international risk-sharing into line with the empirical evidence by considering alternative models of the real and financial linkages between countries. In order to do so, the author develops a benchmark model which assumes that individuals in different countries consume a homogeneous, internationally-traded good and can write contracts contingent on all states of nature. In the pooled equilibrium, investors hold a market portfolio of domestic and foreign securities.



Tesar's (1995) main conclusions are: i) that gains from risk-sharing for the large country are less than one-half of one percent of lifetime consumption across all experiments. In a small country, the utility gains range from zero to two percent of lifetime consumption depending on the household's degree of risk aversion and the type of uncertainty; ii) when shocks are highly persistent and the set of financial assets is limited to non-contingent bonds, the fraction of uncertainty that can be eliminated by trading on international markets falls dramatically; iii) when households receive an uncertain endowment of a non-traded good, the utility gains are larger than in the one-good model when traded and non-traded goods are complements in consumption; and, iv) the results from the production economy suggest that when countries can smooth consumption domestically through investment, the added benefit of trading on world financial markets is minimal. Global markets allow countries to allocate investment more efficiently across markets and can help offset fluctuations in leisure. However, the costs of self insurance through adjusting domestic saving and investment appear to be significant.

When we measured the welfare loss with the modified Lucas (1987) methodology, we concluded that: i) volatility did not play an important role; ii); that the bulk of the loss was related to a sudden adjustment of consumption level; and, iii) in some cases there were gains in welfare because the impact on volatility was negligible, and the growth rate of consumption actually increased after the shock enough to offset the effect of a lower consumption level in the short run. Based on Lucas (1987), Obstfeld and Rogoff (1999) developed a model to measure the welfare loss of self-exclusion of international capital markets that emphasises the loss of the ability of insuring volatility as the source of welfare losses. These authors calculate the cost associated with the loss of credibility in international capital markets. The derivation of this cost follows exactly the same intuition than that of Lucas (1987), but while this study tries to establish the compensation in permanent consumption across all dates that the consumer needs to be indifferent between the pre and the post crisis period, Obstfeld and Rogoff (1999) calculate the same amount in terms of present output. Two measures can be derived from this context; the first one is the total cost of reputation loss as a ratio to current mean output. That ratio can be measured by the solution for  $\kappa$  of the equation:

$$u\left[(1 + \kappa)\bar{Y}\right] - u\left(\bar{Y}\right) = U^{\text{FI}} - U^{\text{A}} \quad (5.2)$$

For countries where  $\kappa \rightarrow \infty$ , that is where the cost as a proportion on current output tends to get higher, a full insurance is sustainable by reputation. The other measure is the cost per year, which reports the permanent fractional increase in GDP equivalent to access to full insurance. This is the same measure of cost of volatility as in Lucas (1987) and is given by:

$$\tau_{\text{var}} = \left\{ e^{\frac{1}{2}(1-\rho)\rho \text{Var}(\varepsilon)} \right\}^{\frac{1}{1-\rho}} - 1 \quad (5.3)$$

The assumption of this model that the volatility is the main cost of a crisis is at odds with the stylised facts of 1990's crises which are the ones we are interested in. Although is a useful approach for analysing self-exclusion for capital markets, this volatility cost is a feature more related of the debt crises during the 1980s. Trying to modify this framework to measure the costs of emerging markets' crises follows the same reasoning than modifying Lucas's (1987) measures; however, it lacks of clear theoretical support:

1. There is no clear connection between self inflicted exclusion and a crisis taking place;
2. Sudden drops in consumption are not explained by the abandonment of a full insurance environment; and,
3. Although volatility of consumption is explained by this framework and it is a cost to measure, we found that costs associated to volatility were not important when using the modified Lucas (1987) measure.

In other words, the main source that we found for welfare losses has no explanation in this model. Therefore, we opted to follow a new line of research to understand consumption behaviour during a crisis and to develop a tool to evaluate monetary policy to respond to real shocks. In order to explain consumption behaviour and to provide a theoretical explanation to these adjustments in the level, we need to analyse the determinants of consumption. On the other hand we are interested as well in the impact of an active interest rate policy on consumption.

### 5.1.2. The Euler equation: an intertemporal consumption approach

A result of the intertemporal consumption problem (which we will develop in the following section) is the Euler equation for consumption. This result offers a simple relation between consumption and interest rate, this allows to measure the possible impact of real interest rate policy (by affecting the nominal interest rate given an inflation level the monetary authority can affect the real interest rate) which is the Euler equation for consumption that has been amply used empirically. The simple form of the Euler equation if we assume a relative risk aversion form of utility with parameters for relative risk aversion  $\rho$  and a subjective intertemporal discount  $\beta$  is:

$$c_{t+1} = (\beta(1+r_t))^{1/\rho} c_t \tag{5.4}$$

And an empirical log-linearised form is given by:

$$\Delta c = \frac{1}{\rho} \ln \beta + \frac{1}{\rho} \ln(1+r_t) + \varepsilon_t \tag{5.5}$$

This approach offers a simple explanation of consumption behaviour based on intertemporal preferences and the interest rate; however, Carroll (2001) and Favero (2005) coincide in pointing out that this approach has consistently obtained contradicting empirical results that are not compatible with the theoretical Euler equation. As a first exercise we applied directly this specification of the Euler equation to the countries in our sample to see if we can apply it to evaluate monetary policy and explain the drop in consumption:

	Mexico	Malaysia	Korea	Philippines	Thailand	Brazil
r	0.8476 (0.1044)	-1.3779 (0.1131)	0.3639 (0.3211)	-0.1637 (0.0888)	-1.1816 (0.0041)	-0.0615 (0.1266)
c	-0.0029 (0.7696)	1.4054 (0.1104)	0.0099 (0.1592)	0.1743 (0.0746)	0.0164 (0.0007)	0.0093 (0.0976)
R-squared	0.0575	0.0548	0.0218	0.0629	0.2016	0.0692

Table 48: Log-linear equation results

Fitted Values from Euler Equations

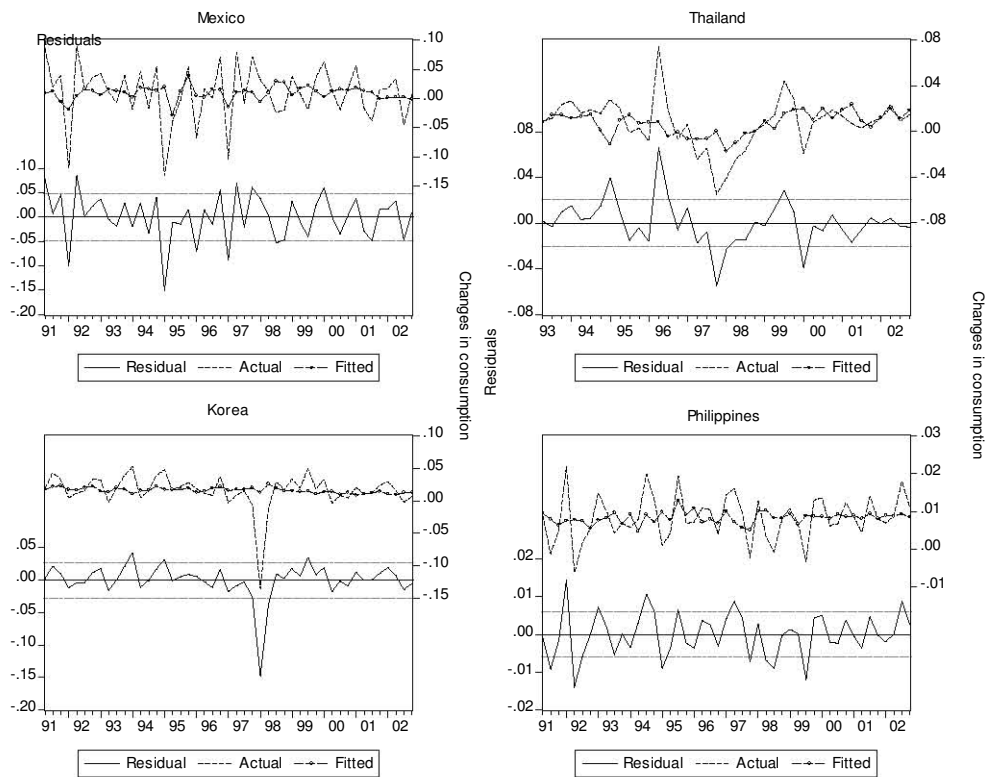


Figure 14: Fitted values from the estimation of Euler equations

As we can see the coefficients are not significant, and when they are (Philippines and Thailand) the sign of the coefficient of the interest rate is at odds with the implied by this log-linear form of the FOC which should be positive.

Carroll (2001) and Canzoneri, Cumby and Diba (2003) explain the puzzle that these results imply: standard macroeconomic models assume that the money market interest rate is equal to the interest rate implied by a consumption Euler equation in which the interest rate is proportional to the expected growth rate of consumption. In other words, the consumption growth rate increases if the interest rate does. However, the empirical literature shows that a monetary tightening slows consumption growth for a few quarters; this decline in expected consumption growth is inconsistent with the real interest rate implied by the Euler equation. In order to solve this puzzle, Carroll (2001) attempts to find other effects different than the ones contained in the Euler equation; in order to do that, he explores the effects on wealth of different regressors :

	<b>Effect on wealth holding</b>	<b>Implied effect on consumption</b>
Interest rates	(+)	(-)
Permanent income	(-)	(+)
Income uncertainty	(+)	(-)
Risk aversion	(+)	(-)

Table 49: Effects on wealth and consumption from Carrol (2001)

The effect of these variables is not captured by the Euler equation as it is defined, and this omission constitutes the core of the caveats that we already mentioned. However, Carroll (2001) does not find a theoretical justification to include them and mentions the inclusion of these regressors just as a possible way to improve the estimation of consumption. Favero (2001) criticises the use of the first condition as a consumption function arguing that it is not the closed form solution to the intertemporal model which he derives but does not go further in the analysis of the implications of using the latter. Favero (2005) when trying to solve the puzzle of consumption growth and asset pricing fluctuations found two branches of the literature. One focused on the use of the traditional Euler equation and the other one on the budget constraint of the maximisation problem alone (by testing that the present value of income equals the present value of consumption). When combining both the first order conditions and the budget constraint this author found that the deviation of consumption from its long-run trend has some predictive power for long-run expected stock market returns; this is contrary to the result when using the Euler equation alone where there is no predictive power at all.

In order to analyse policy actions when there is a crisis we need to solve these puzzles and derive an applicable result that yield sound results. We do this by making just an additional

assumption to the 2-period model: any shock in period 1 is a surprise one and therefore there cannot be any adjustments to the consumption in the previous period. This allows us to explain the apparent inconsistency of the intertemporal approach when predicting the behaviour of consumption.

## 5.2. Consumer's behaviour: why consumption sank during the 1990s?

We already measured the costs in terms of consumption and welfare in the affected countries using Lucas (1987). We need to explain why consumption can suffer a severe adjustment not only in its growth or volatility but in its level. Burnside, Eichenbaum and Rebelo (1999) characterise the aftermath of 1990's crises in simple terms: when the fixed exchange rate is abandoned in favour of a crawling peg, banks go bankrupt, the domestic (nominal) interest rate rises, real wages fall, and output declines. As we can see, those countries where real wages fell sharply consumption fell as well. A currency crisis has a pass-through effect over prices, Calvo and Reinhart (2000) find in a 41 country sample that developed countries show less pass-through than emerging countries. These authors mention this as one of the reasons why emerging countries usually maintained pegged exchange rate regimes. When abandoning the pegged exchange rate regimes, inflation may come as an important consequence and Burnside et al. (1999) observations of fall in real wages can be justified. The question is, is there any theoretical support to these findings? From the Euler equation result of the intertemporal consumption problem it would seem like there is none; as well, Obstfeld and Rogoff's (1999) model does not allow for sudden changes in the level of consumption.

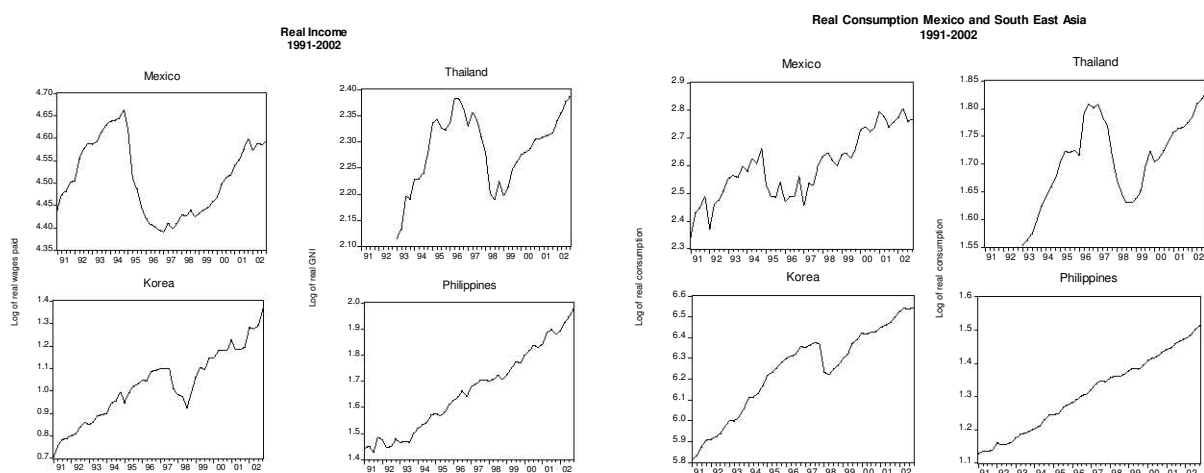


Figure 15: Real consumption and real income in selected countries

We can argue that a fall in real wages has a negative impact on consumption; however, none of the discussed approaches justify this theoretically. In order to determine the possible effect of

income on consumption we review the standard intertemporal model of consumption. We first solve the two-period version and obtain the first order conditions (FOC) and the optimal consumption of both periods. The FOC of this problem are an important result because it constitutes the empirical log-linearised Euler equation widely used in empirical research on consumption. We then proceed to solve a 3-period intertemporal problem and a longer 4-period model; this will allow us to discuss the importance of medium/long term planning of consumption schedules and how when taking this approach, together with the fact that there is a binding intertemporal constraint we depart from the result of the Euler equation and find predictions that describe better the observed behaviour of consumption.

The modelling of intertemporal consumption taking into account only the loanable funds market gives some answers to the puzzles found in empirical literature; however, it does not address all financial decisions taken by the individual. Moreover, it does not explain other types of financial crises such as frenzies, bubbles or asset mispricing. In order to address these important issues we solve an intertemporal consumption problem that incorporates a risky asset which follows a binomial stochastic behaviour. The modelling of capital markets using the intertemporal approach allows us to avoid the use of ad-hoc demands for the asset and to minimise the need of information-revealing structure to obtain results of when a crisis is optimal. This model by no means substitutes the decision to participate in the loanable funds market; it is however an important addition in the investment-consumption optimisation problem since an individual can diversify in different asset markets. A simplifying assumption is that there is an initial wealth (a stock) which is destined to the capital markets and it can only be transferred for future consumption through the value of the portfolio; on the other hand, income (a flow) can be transferred from future periods to present in the form of borrowing or transferred to the future in the form of lending. It is possible to combine income and wealth and calculate the optimal proportion destined to each market but doing this adds in complexity while the implications remain the same. Hence, for simplicity in the exposition we analyse what happens in each market separately.

### **5.2.1. The 2-period model of intertemporal consumption**

As we mentioned earlier the Euler equation is derived from the same maximisation problem we just described, it is in fact the relation between periods of first order conditions; however, it is not the solution of the problem at hand. In other words, it describes a condition that the optimum path has to fulfil, not the optimum path itself. In this model we assume that consumers have access to credit from the banking system and can transfer income between periods at a real interest rate  $r$ ; in other words, they can save and borrow at the same rate. For

this we assume that the consumer gets a disposable real endowment net of taxes ( $w_t = W_t - \tau_t$ ) at every date  $t$ . Agents cannot spend more of what they earn over time, that means that when they die they do it without debts or without savings in their bank account. Consumers will maximise the intertemporal utility:

$$\begin{aligned} \text{Max } U(c_0, c_1) &= u(c_0) + \beta u(c_1) \\ \text{Subject to: } c_0 + \frac{c_1}{(1+r)} &= w_0 + \frac{w_1}{(1+r)} \end{aligned}$$

Where  $\beta$  is the intertemporal preference discount rate and fulfils  $\beta \leq 1$  and  $w_t$  is the endowment at each period. This constraint indicates that the present value of consumption has to be equal to the present value of wealth. The mapping of this problem can be seen in the following diagram.

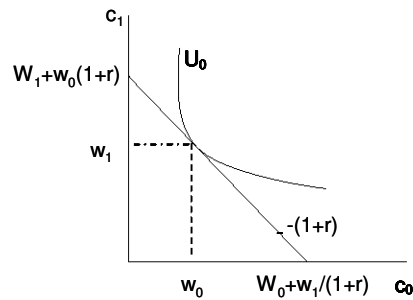


Diagram 10: Intertemporal consumption

The first step to find a solution is to substitute the consumption FOC in the budget restriction, by doing so we obtain the optimal consumption for both periods<sup>42</sup>:

$$c_0^* = \frac{(1+r)w_0 + w_1}{\left( (1+r) + (\beta(1+r))^{\frac{1}{\rho}} \right)} \quad (5.6)$$

And:

$$c_1^* = (\beta(1+r))^{\frac{1}{\rho}} \frac{(1+r)w_0 + w_1}{(1+r) + (\beta(1+r))^{\frac{1}{\rho}}} \quad (5.7)$$

Note that if we obtain the rate of change of consumption between periods we get back to the Euler equation approach. This is because we are adjusting  $c_0^*$  when there is a change

<sup>42</sup> The solution is on annex A5.1

either in income or in the interest rate. What happens when this is not possible? Let's assume that we decide our consumption schedule at the beginning of date 0, we consume at the beginning of date 0<sup>43</sup> (we take at the same time a savings decision either borrowing or lending) and then either the interest rate or the income at date 1 changes before making the decision and consuming at date 1. In this case, the optimal value derived before for consumption at date 1 is not anymore a feasible solution; since the present value of income changed the new present value of consumption has to fulfil the new intertemporal restriction:

$$PVW|_{I_{t=1}} = c_{0|I=0}^* + \frac{c_1^*}{(1+r)} \tag{5.8}$$

$$c_1^* = (1+r)(NPVW|_{I_{t=1}} - c_{0|I=0}^*)$$

This has important implications because now the Euler equation is not enough to describe the behaviour of consumption but we incorporate the current value of income and the expected income across the agent's lifetime.

Let's explore the behaviour of consumption under this solution of both net lenders and net borrowers. We first assume that there is a negative endogenous shock to income at period 1; this means that we move from endowment 0 to endowment 1 and given the existence of a financial market the budget constraint shifts in a parallel way. The common assumption of instant adjustment of date 0 consumption implies that lenders move from L0 to L1 and borrowers from B0 to B1. In both cases the ratio  $\frac{c_1^*}{c_0^*}$  remains constant in the equilibrium. Hence, the growth rate is neutral to changes in income when there is this perfect knowledge of the future.

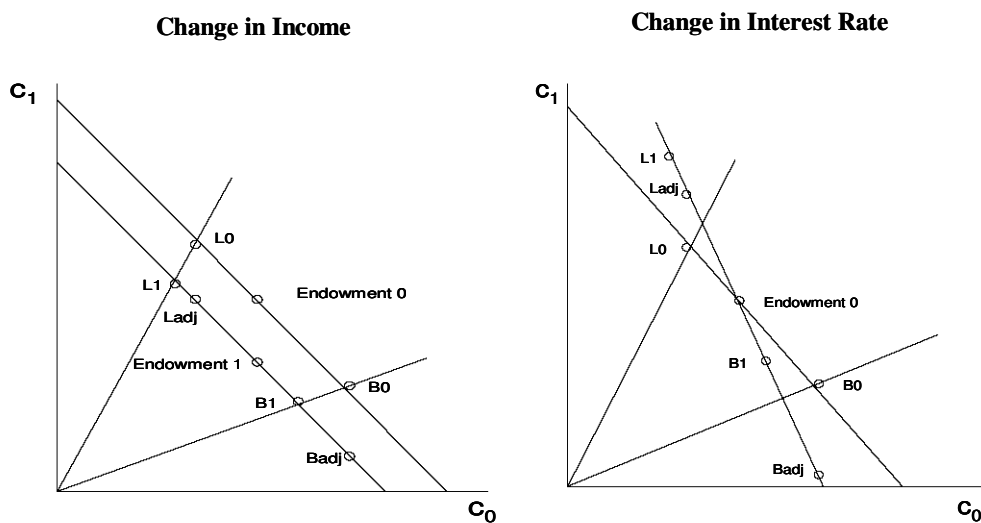


Diagram 11: Intertemporal consumption with time rigidities

<sup>43</sup> This assumption is perhaps grasped easier in a multiperiod setting when consumption has been taking place up to date t when there is an unexpected shock and previous consumption cannot be adjusted anymore, therefore there must be a level adjustment from date t onwards.



However, if we do not allow the adjustment of consumption at date 0, the new equilibrium is  $L_{adj}$  for lenders and  $B_{adj}$  for borrowers. The implications on welfare are: i) bigger losses for net borrowers than for net lenders; and, ii) these losses increase with the amount of debt. Therefore, a real income shock does have impact on consumption and we can explain now the behaviour after each one of the crises where there was a fall in real income and a fall in consumption.

Let's see how the conclusions change for a change in the interest rate. With perfect foresight and free adjustment an increase in the interest rate will increase consumption at date 1 and decrease consumption at date 0. Lenders will face a positive income effect while borrowers face a negative one. In both cases the growth rate of consumption increases, following the predictions of the Euler equation. Here is where the Canzoneri et al. (2003) puzzle comes into play, as we already mentioned, they observed that there is either a contraction or an unexpected slowdown of consumption following an increase in the interest rate. Again, if we assume non-free adjustment at date 0 we obtain a compatible result with these observations. In order to keep fulfilling the intertemporal budget constraint given that consumption at date 0 has been already committed we need to adjust consumption at date 1. For the lenders we will have that their future consumption will be less than it would have been at the new equilibrium  $L_1$  and they will consume at  $L_{adj}$  which is Pareto-inferior but preferred to  $L_0$  and the growth rate at this new solution point will be in-between the ones corresponding to  $L_0$  and  $L_1$ . However, the borrowers will be worse off in every sense, they don't only need to cut down on future consumption but the new growth is less than the ones at  $B_0$  and  $B_1$ . Therefore, we have further redistributive effects of interest rate policy between lenders and borrowers; for the first, the growth rate of consumption is not as high as it would be, but for the latter, not only is lower than the initial situation but the level of consumption falls as well. This effect limits the effectiveness of the monetary policy and can actually diminish welfare.

### **5.2.2. Intertemporal consumption with a surprise crisis: a 3 period solution**

We need now to model a crisis with this framework, in order to do so we have to assume a three period setting where date 0 is the pre-crisis period; at date 1 the crisis reveals and date 2 is the post-crisis period when the effects of the crisis and policy are already in place. Hence, in this setting there are two interest rates, the one between date 0 and date 1 ( $r_1$ ) which remains unchanged and the one from date 1 and date 2 ( $r_2$ ) which can be set by the monetary authority.

$$\begin{aligned} \text{Max } U(c) &= \sum_{t=0}^2 \beta^t u(c_t) \\ \text{Subject to } c_0 + \sum_{t=1}^2 \frac{c_t}{\prod_{k=1}^t (1+r_k)} &= w_0 + \sum_{t=1}^2 \frac{w_t}{\prod_{k=1}^t (1+r_k)} \end{aligned}$$

The solution for initial consumption is given by the equation<sup>44</sup>:

$$c_0^* = \frac{\left( w_0 + \sum_{t=1}^2 \frac{w_t}{\prod_{k=1}^t (1+r_k)} \right)}{\left( 1 + \sum_{t=1}^2 \frac{\left( \beta^t \prod_{k=1}^t (1+r_k) \right)^{\frac{1}{p}}}{\prod_{k=1}^t (1+r_k)} \right)} \quad (5.9)$$

And an optimal consumption path for consumption at date  $j=1, 2$ :

$$c_j^* = \left( \beta^j \prod_{k=1}^j (1+r_k) \right)^{\frac{1}{p}} \frac{\left( w_0 + \frac{w_1}{(1+r_1)} + \frac{w_2}{(1+r_1)(1+r_2)} \right)}{\left( 1 + \sum_{t=1}^2 \frac{\left( \beta^t \prod_{k=1}^t (1+r_k) \right)^{\frac{1}{p}}}{\prod_{k=1}^t (1+r_k)} \right)} \quad (5.10)$$

As we can see the model implies that current consumption will depend on income and on the interest rate. This is an important result because:

- i) It gives theoretical support to Carroll's (2001) findings about the relation of consumption and other variables;

<sup>44</sup> See annex A5.2.

- ii) It is possible to evaluate the effect of monetary policy in response to external shocks to income.
- iii) Consumption has no longer purely short term behaviour adaptive to the short term interest rate as the log-linear Euler equation would imply, but is the result of long term planning.
- iv) Regarding preference parameters:
  - An agent will be a net lender if  $(1-\beta) < r$ ; otherwise, he will be a net borrower.
  - For higher values of  $\rho$  (relative risk aversion) the discounted consumption path gets closer to the discounted income path.

Any change in the present value (due to a change in  $w_t$  or  $r_t$ ) will have effects on consumption depending if the shock is an expected or a surprise one. The standard assumption is to let consumption through the whole horizon to adjust the implications being:

1. A parallel shift of the optimal consumption schedule if  $w_t$  changes.
2. A change in the slope of the consumption path if  $r_t$  changes (Euler equation effect).

However, if we face a surprise shock which does not allow adjusting consumption at date 0 the new solution path has to fulfil the new budgetary restriction:

$$(\hat{c}^*_0 | I=0) + (PVc^*_{j=1,2} | I=1) - K = (PVw_{t=0,1,2} | I=1) \quad (5.11)$$

Where the present value of the adjustment needed at every period is given by  $K$  and the period-by-period cost is given by  $\kappa$ .

$$K = \frac{\kappa}{1+r_1} + \frac{\kappa}{(1+r_1)(1+r_2)} \quad (5.12)$$

The right hand side of the new budgetary restriction is the new present value of income given the information at date 1. The first term of the left hand side is the optimal consumption given the information at date 0; the second term is the present value of optimal consumption at dates 1 and 2 given the information at date 1; and, the third term ( $K$ ) is the present value of the adjustment ( $\kappa$ ) needed to fulfil the new budget restriction. If consumption at date 0 were allowed to adjust then this adjustment would be  $K=0$ . We can express the adjustment needed at dates 1 and 2 as:

$$\kappa = \frac{K}{\frac{1}{1+r_1} + \frac{1}{(1+r_1)(1+r_2)}} \quad (5.13)$$

Note that this adjustment is a parallel shift, and that after the shock, the optimal growth rate is not affected; in other words, the Euler equation is still being fulfilled after the short term adjustment. We now turn to analyse what happens when there is a surprise shock at date 1.

### 5.2.2.1. Income changes

At a first glance it is evident that a decrease in current income at date  $j$  will decrease consumption. The same will happen if there is a change in expected income at date 2 because the present value of income decreases. The mechanism of adjustment is as follows:

- i) The original optimum path without a expected crisis at date 1 is given by line AA'
- ii) The optimum path with an expected crisis with effects on real income is given by line BB'
- iii) If we start on point A and at date 1 when a crisis happens we change to line AB' then the adjustment is not enough since we are still violating the new budget constraint.
- iv) A further adjustment is needed and the new path is effectively the line AC'.

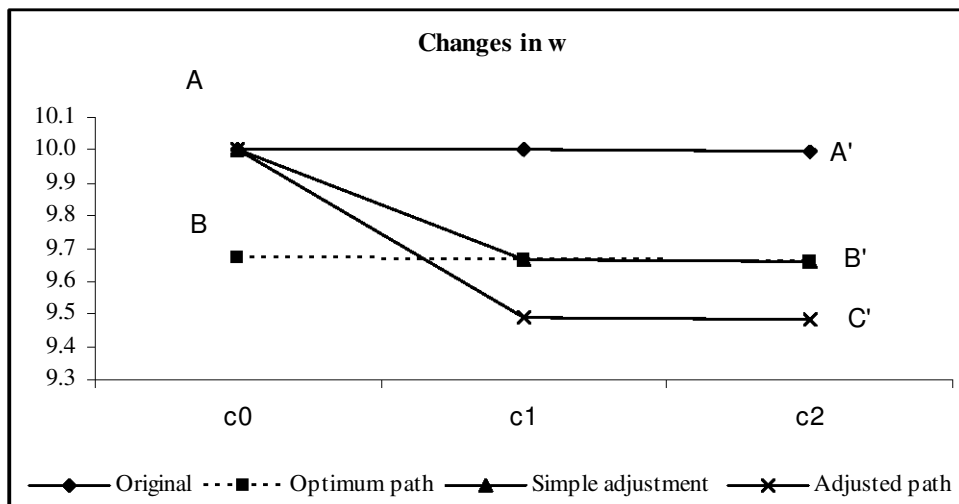


Diagram 12: Intertemporal consumption with time rigidities and changes in  $w$  (net borrowers)

We set a numerical example with the following assumptions of parameters and income with a crisis at date 1 that affects only the level of real income for one period. Preferences are

described for a borrower by the parameters  $\beta=0.95$  and  $\rho=5$ ; interest rates are constant  $r_1=r_2=5\%$  and real income follows the schedules: expected at date 0  $w_1=10$  and when information is revealed at date 1:  $w_0=w_2=10$  and  $w_1=9$ .

We can see that the present value of income reduces from 28.59 to 27.64; we can see that if there is a simple adjustment (path AB') then the present value of consumption (27.97) is still higher than the new restriction and the only path that fulfils the new restriction is if we adjust further and follow a path AC' which present value of consumption is 27.64.

Consumption schedule, changes in w Net borrowers				
	Original path AA'	Optimum path BB'	Simple adjustment AB'	Observed adjusted path AC'
Present value of income (Information at date 0)	28.5941	--	--	--
Present value of income (new restriction)	--	27.6417	--	--
$c_0$	10.0048	9.6716	10.0048	10.0048
$c_1$	9.9998	9.6668	9.6668	9.4876
$c_2$	9.9948	9.6619	9.6619	9.4827
Present value consumption	28.5941	27.6417	27.9750	27.6417
$\kappa$	0.1792			

Table 50: Consumption schedule with changes in w, net borrowers 3 period model

We have the same effects even when we are dealing with a net lender; the only difference is that consumption will now tend to rise over time. In this case we only set  $\beta=0.99$  and the rest of information is left unchanged.

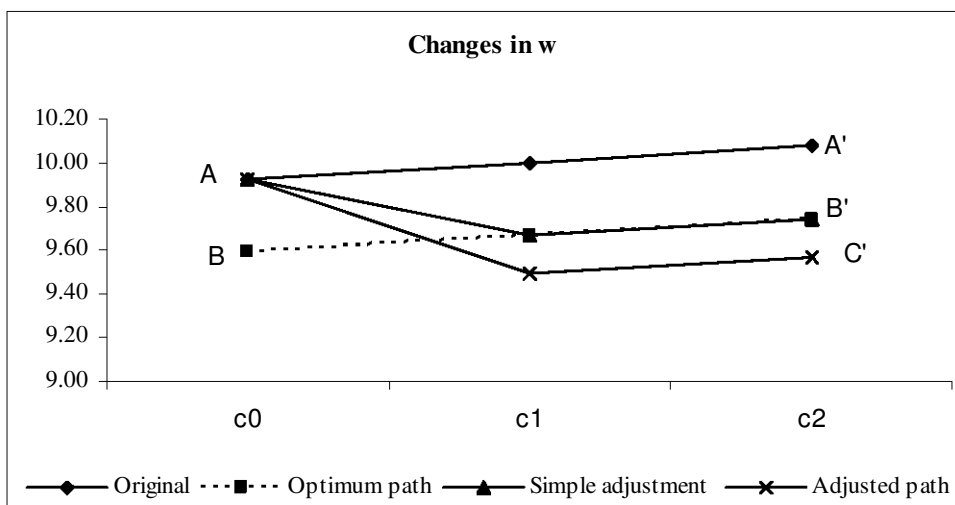


Diagram 13: Intertemporal consumption with time rigidities and changes in w (net lenders)

Consumption schedule, changes in w				
Net lenders				
	Original path AA'	Optimum path BB'	Simple adjustment AB'	Observed adjusted path AC'
Present value of income (Information at date 0)	28.5941	--	--	--
Present value of income (new restriction)	--	27.6417	--	--
$c_0$	9.9251	9.5945	9.9251	9.9251
$c_1$	10.0023	9.6692	9.6692	9.4914
$c_2$	10.0801	9.7444	9.7444	9.5666
Present value consumption	28.5941	27.6417	27.9723	27.6417
$\kappa$	0.1778			

Table 51: Consumption schedule with changes in w, net lenders 3 period model

### 5.2.2.2. Interest rates change

We start from an original situation which is given by the line AA'. To determine what happens when the interest rate increases is more complicated because involves two contrary effects:

1. The first one is an intertemporal substitution effect which will increase the slope of the consumption path because with a higher interest rate a consumer will increase the rate of consumption as the first order conditions imply. This is the effect described by the standard form of the Euler equation and it is shown in line BB'. Note that this result needs the rescheduling of consumption from date 0; in other words, if we calculate an optimal path as if the new interest rate scenario was known at date 0, we will notice that this new path has a greater slope from date 1 onwards and a lower intercept than the original AA'. Each consumption path is compatible with different present values of income being the original greater than the new one.

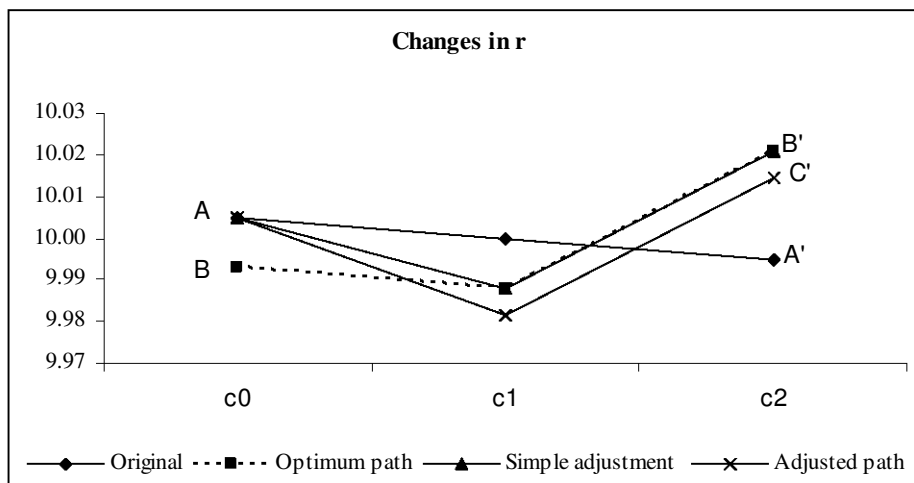


Diagram 14: Intertemporal consumption with time rigidities and changes in r (net borrowers)

2. However, there is a second effect which is the reduction of the present value of income. The question is: it is enough to move between paths after date 1 (that is to follow AB')? The answer is no, because even if we are in an infinite setting we have a binding constraint across the whole horizon not only from date 1 onwards; as we already followed the consumption path up to date 1, just increasing the rate of consumption has as consequence the violation of this constraint, the present value of consumption will be higher than the present value of the new income, therefore we need a further adjustment downwards to keep fulfilling the binding constraint, that is to follow the schedule AC'. In terms of our numerical example we have the following assumptions: preference parameters  $\beta=0.95$  and  $r=5$ ;  $w_0=w_1=w_2=10$ ; and, interest rates at date 0  $r_0=5\%$  and when information is revealed at date 1  $r_1=5\%$  and  $r_2=7\%$
  
3. As we can see, even if we keep the path AA' the present value of consumption (28.4247) with the new interest rates at date 1 is still slightly above the new present value of income (28.4246), hence for us to maintain the budget restriction need to adjust consumption to AC' and not simply to AB'. Note that this effect is not as big as if there is a contraction of real income but we have the result that a surprise change in the interest rates may have level effects on consumption limiting the effectiveness of monetary policy which is consistent with Canzoneri, Cumby and Diba's (2003) findings about higher interest rates and drops in consumption.

Consumption schedule, changes in r				
Net borrowers				
	Original path AA'	Optimum path BB'	Simple adjustment AB'	Observed adjusted path AC'
Present value of income (Information at date 0)	28.5941	--	--	--
Present value of income (new restriction)	--	28.4246	--	--
$c_0$	10.0048	9.9930	10.0048	10.0048
$c_1$	9.9998	9.9880	9.9880	9.9816
$c_2$	9.9948	10.0207	10.0207	10.0143
Present value consumption (Information at date 1)	28.4247	28.4246	28.4364	28.4246
$\kappa$	0.0064			

Table 52: Consumption schedule with changes in r, net borrowers 3 period model

In the case of a net lender ( $\beta=0.99$ ), the effect of interest rates on consumption has the same implications; at date 1, when the new interest rate is known consumption must adjust further relative to the full information schedule BB' and we end up in the path AC'.

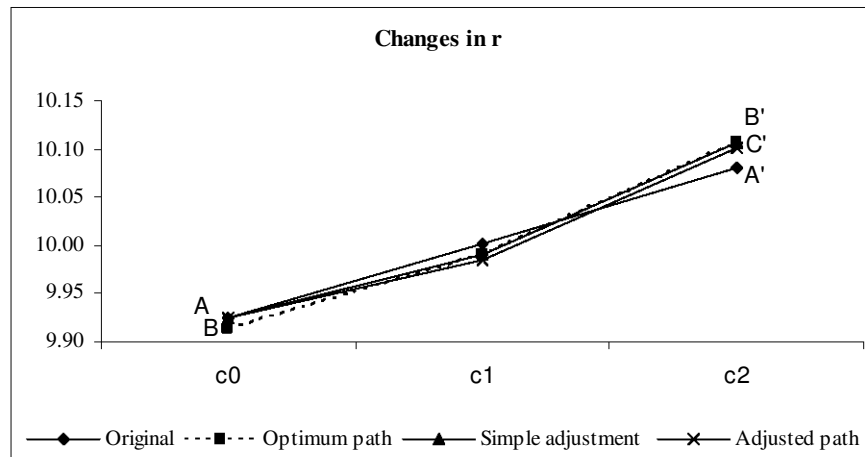


Diagram 15: Intertemporal consumption with time rigidities and changes in  $r$  (net lenders)

Consumption schedule, changes in $r$				
Net lenders				
	Original path AA'	Optimum path BB'	Simple adjustment AB'	Observed adjusted path AC'
Present value of income (Information at date 0)	28.5941	--	--	--
Present value of income (new restriction)	28.4246	--	--	--
$c_0$	9.9251	9.9138	9.9251	9.9251
$c_1$	10.0023	9.9909	9.9909	9.9847
$c_2$	10.0801	10.1067	10.1067	10.1005
Present value consumption (Information at date 1)	28.4232	28.4246	28.4359	28.4246
$\kappa$	0.0064			

Table 53: Consumption schedule with changes in  $r$ , net lenders 3 period model

### 5.2.2.3. A crisis in motion: monetary policy response

We now study what happens when there is a surprise crisis that diminishes real income and the monetary authority decides to intervene by changing  $r_2$ . Using the same assumptions as described above, we define a crisis as a fall in real income at period 1 so that  $w_1=9$ . We can observe that increasing the interest rate has a negative effect at date 1 (the higher the increase the greater the fall in  $c_1$ ) but at date 2 we can achieve a higher consumption when compared with the no-intervention case (maintaining  $r_2=5\%$ ). If the monetary authority opts for lowering the interest rate, then consumption at date 1 will be higher than without intervention because of a positive income effect, but at date 2, consumption will fall with respect to this latter case following the Euler equation effect.



Net Borrower Case					
	Original	Crisis $r_2=5\%$	Policy $r_2=7\%$	Policy $r_2=10\%$	Policy $r_2=2\%$
$c_0$	10.0048	10.0048	10.0048	10.0048	10.0048
$c_1$	9.9998	9.4876	9.4652	9.4330	9.5226
$c_2$	9.9948	9.4827	9.4968	9.5181	9.4618
Net Lender Case					
	Original	Crisis $r_2=5\%$	Policy $r_2=7\%$	Policy $r_2=10\%$	Policy $r_2=2\%$
$c_0$	9.9251	9.9251	9.9251	9.9251	9.9251
$c_1$	10.0023	9.4914	9.4697	9.4384	9.5254
$c_2$	10.0801	9.5666	9.5816	9.6042	9.5443

Table 54: Consumption schedule with policy responses 3 period model

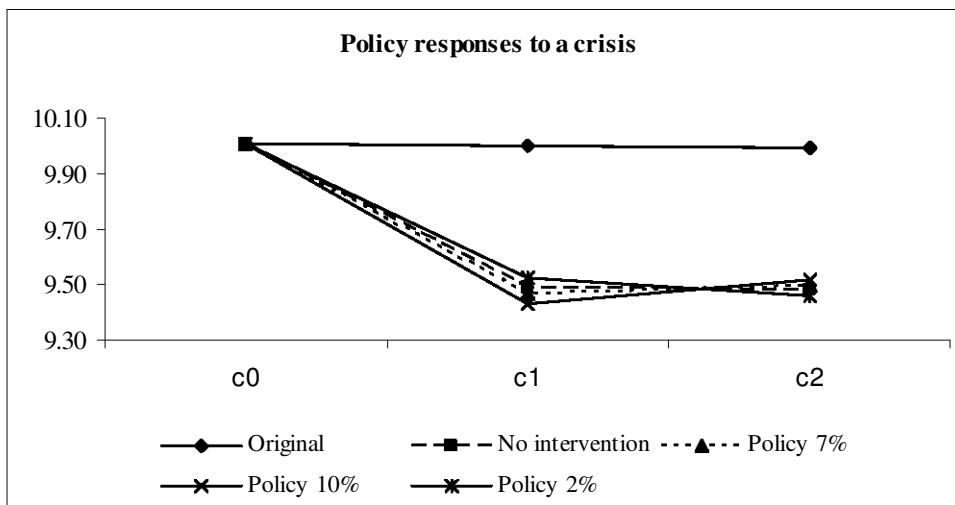


Diagram 16: Policy responses to a crisis

This analysis depends largely on the crisis being unexpected at date 0; however, this assumption does not reflect entirely the reality where a crisis can be anticipated and the monetary authority would react pre-emptively by rising interest rates. We could implement that kind of policy in this 3 period set up but that would imply that the consumer has different information than the authority implying an asymmetric information problem; on the other hand, removing the surprise component will leave us with the usual framework that relies on the Euler equation and again the behaviour of consumption would go again unexplained. Nonetheless, the main assumption we are doing can be used to expand the analysis to include an expected crisis and possible pre-emptive policies: the individuals engage in medium or long term planning and they have an intertemporal budget constraint to fulfil.

### 5.2.3. Intertemporal consumption with an expected crisis: long term planning horizons

The assumptions underlying the derivation of the Euler equation are that consumers maximise consumption as sequential 2-period problems and the optimising result is obtained by applying the envelope theorem. However, when we are dealing with longer planning periods and if we assume that past consumption is already realised, the Euler equation does not describe anymore the behaviour of consumption if there are unexpected shocks in the middle of the planning period. In other words, unexpected shocks within the planning period will require adjusting the optimal path to fulfil the new budget constraint and this implies a departure from the Euler equation approach as a solution. We will now assume that consumers have longer term planning horizons and they plan consumption for several periods ahead given some stability of the economy; this is not an unrealistic assumption since this planning can be done on a quarterly or monthly basis. This also allows for the government to engage in pre-emptive active policy before a crisis happens. We will assume that the crisis is inevitable and that this pre-emption has no effect on the decision to attack the currency peg.

There are four periods, the first one ( $t=0$ ) is a normal period when an optimal consumption path is obtained and the agent engages in consumption. During the second period ( $t=1$ ) it becomes evident that a crisis that could affect real income will happen at the third period ( $t=2$ ); both consumers and the monetary authority can react accordingly but cannot change past actions. At period three, there is a crisis that has a negative impact on real income; the monetary authority can react and consumers take this information into account. Given the structure of the assumptions we eliminate any element of surprise other than the knowledge of a crisis unveiling at date 1; in other words, the monetary authority discloses the policy it will follow before and after the crisis and consumers are able to take into account the decisions of the monetary authority at dates 1 and 2, this allow to evaluate the minimum cost scenario (introducing more surprise elements will increase the costs).

$$\text{Max } U(c) = \sum_{t=0}^3 \beta^t u(c_t)$$

$$\text{Subject to } c_0 + \sum_{t=1}^3 \frac{c_t}{\prod_{k=1}^t (1+r_k)} = w_0 + \sum_{t=1}^3 \frac{w_t}{\prod_{k=1}^t (1+r_k)}$$

With an optimal solution:

$$c_0^* = \frac{\left( w_0 + \sum_{t=1}^3 \frac{w_t}{\prod_{k=1}^t (1+r_k)} \right)}{\left( 1 + \sum_{t=1}^3 \frac{\left( \beta^t \prod_{k=1}^t (1+r_k) \right)^{\frac{1}{\rho}}}{\prod_{k=1}^t (1+r_k)} \right)} \quad (5.14)$$

$$c_j^* = \left( \beta^j \prod_{k=1}^j (1+r_k) \right)^{\frac{1}{\rho}} \frac{\left( w_0 + \sum_{t=1}^3 \frac{w_t}{\prod_{k=1}^t (1+r_k)} \right)}{\left( 1 + \sum_{t=1}^3 \frac{\left( \beta^t \prod_{k=1}^t (1+r_k) \right)^{\frac{1}{\rho}}}{\prod_{k=1}^t (1+r_k)} \right)} \quad (5.15)$$

Again, at date 1 when the coming real income shock is known the consumers will have to adjust their consumption to keep fulfilling the restriction:

$$\left( \hat{c}_0^* \mid I=0 \right) + \left( PVc_{j=1,2,3}^* \mid I=1 \right) - K = \left( PVw_{t=0,1,2,3} \mid I=1 \right) \quad (5.16)$$

### 5.2.3.1. Policy options against real consumption potholes

We can compare different policy options and compare the resulting consumption schedules. The initial assumptions are  $\beta=0.95$ ,  $\rho=5$ ,  $w_j=10$  and  $r_j=5\%$ . The crisis will result in  $w_2=9$ . As we can see, the results show that a no-intervention policy will leave us with the smaller consumption at date 3. However, in the short run at date 1, consumption ( $c_1$ ) is greater than when  $r_2$  is left unchanged or when it increases. Consumption at date 2 ( $c_2$ ) shows mixed behaviour depending on the policy followed before the crisis period.

Consumption under different policy options						
Net borrowers						
	Original	No intervention	Policy $r_3=10\%$	Policy $r_2=10\%$ $r_3=10\%$	Policy $r_2=2\%$ $r_3=10\%$	Policy $r_2=10\%$ $r_3=5\%$
$c_0$	10.0072	10.0072	10.0072	10.0072	10.0072	10.0072
$c_1$	10.0022	9.6690	9.6361	9.5843	9.6693	9.6162
$c_2$	9.9972	9.6641	9.6312	9.6701	9.6080	9.7022
$c_3$	9.9922	9.6592	9.7173	9.7567	9.6938	9.6973

Table 55: Consumption schedule with policy responses 4 period model, net borrowers

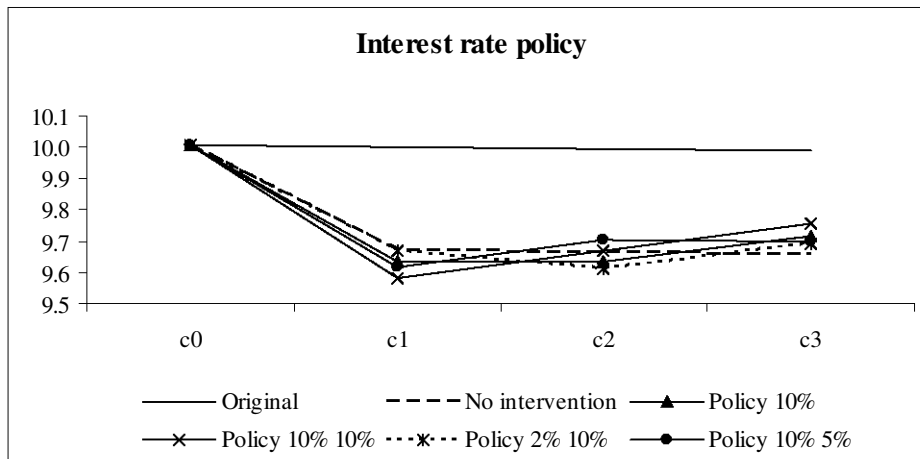


Diagram 17: Policy responses to a crisis 4-period model (net borrowers)

When we look at the case of a net lender we can see that in all cases, the no-intervention case is the worst for consumption at date 3. As well, decreasing the interest rate  $r_2$  increases consumption at date 1 while increasing it has the contrary effect. At date 2, in those scenarios where  $r_2$  increased, consumption increased.

Consumption under different policy options						
Net lenders						
	Original	No intervention	Policy $r_3=10\%$	Policy $r_2=10\%$ $r_3=10\%$	Policy $r_2=2\%$ $r_3=10\%$	Policy $r_2=10\%$ $r_3=5\%$
$c_0$	9.8888	9.8888	9.8888	9.8888	9.8888	9.8888
$c_1$	9.9657	9.6344	9.6032	9.5538	9.6349	9.5840
$c_2$	10.0432	9.7101	9.6786	9.7201	9.6539	9.7506
$c_3$	10.1213	9.7863	9.8468	9.8892	9.8214	9.8273

Table 56: Consumption schedule with policy responses 4 period model, net lenders

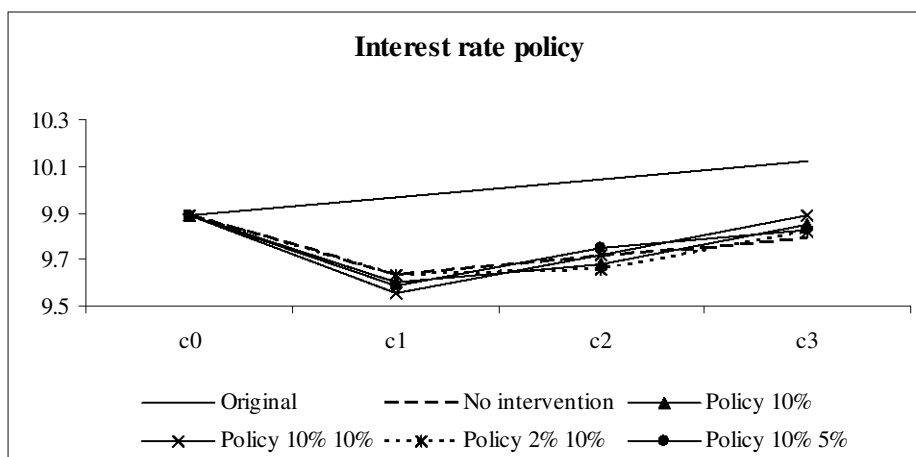


Diagram 18: Policy responses to a crisis 4-period model (net lenders)

### Liquidity constraints

One of the features of a financial crisis may involve the shrinking of credit by higher borrowing rates relative to lending rates. This differentiation in the terms of borrowing and lending is a common assumption that reflects stylised facts of the real functioning of debt

markets; loans and credit cards often ask for a higher interest rate than the one of the risk free asset. We now characterise a financial crisis as an increase in this risk premium; this can be due to a currency crisis that is expected to worsen the credit worthiness of borrowers (via reduced income and ability to pay) or by balance-sheet imbalances in the banking system (cost of liabilities increasing) what we are interested in is in the effect on consumption and precautionary savings.

Hence, we assume that there is no fall in real income but that this type of crisis is purely financial and that it affects the conditions of borrowing; in fact, this is equivalent to assume an increase in the interest rate payable where the borrower has to pay the higher rate:  $r_3^* = r_3 + r_{p3}$  where  $r_{p3}$  corresponds to a risk premium; we do not allow the credit market to disappear in which case the borrower will consume his initial endowment minus the accrued interest from previous loans (if collateral recovery can be enforced). As we can see with our example, introducing a risk premium as a consequence of an expected financial crisis will reduce consumption at dates 1 and 2 but increase it at date 3 (this is because of the increase in savings and their corresponding returns). The assumptions are again  $\rho=5$ ,  $\beta=0.95$ ,  $r_f=5\%$ ,  $r_{p3}=5\%$  and  $w_j=10$  and before the crisis there is no risk premium.

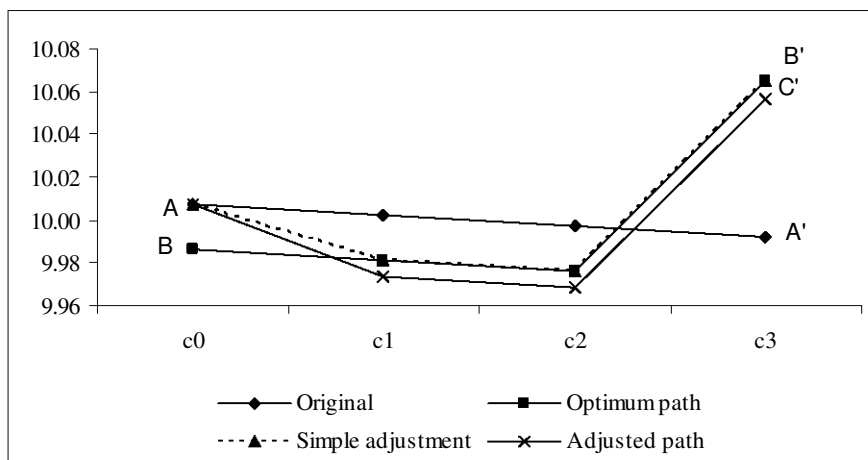


Diagram 19: Financial crisis with liquidity constraints

Again, we start from a schedule AA' and engage in consumption. At date 1 we learn that there is going to be a crisis that will increase the borrowing rate and we can adjust consumption from date 1 onwards but not date 0 consumption. The optimum path if we were allowed to adjust date 0 would be BB'. A simple jump between paths to follow the AB' schedule is not enough to fulfil the intertemporal budget restriction and we need a further adjustment to the path AC'.

Consumption schedule with liquidity constraints				
Net borrowers				
	Original path AA'	Optimum path BB'	Simple adjustment AB'	Observed adjusted path AC'
Present value of income (Information at date 0)	37.2325	--	--	--
Present value of income (new restriction)	--	36.8398	--	--
$c_0$	10.0072	9.9862	10.0072	10.0072
$c_1$	10.0022	9.9812	9.9812	9.9734
$c_2$	9.9972	9.9763	9.9763	9.9684
$c_3$	9.9922	10.0645	10.0645	10.0567
Present value consumption (Information at date 1)	36.8401	36.8398	36.8608	36.8398
$\kappa$	0.0113			

Table 57: Consumption schedule with liquidity constraints

### Debt defaults

Let's remember that in this framework we are allowing to transfer income between several periods; hence, a borrowing agent will be carrying through time these liabilities. This analysis suggests that an increase in real interest rates (such as those imposed by liquidity constraints) and a fall in real wages can tighten the budget constraint and may make it optimal for the borrowing agent to default on his debt. This becomes a transmission mechanism from a currency crisis that has a negative impact on real wages to the banking system that will see the value of its assets reduced if massive defaults occur (as it happened in Mexico during 1995).

In the absence of collateral, and assuming that the borrowing consumer faces the choice of repaying its debt or defaulting to consume his endowment, the consumer will find it optimal to default when the lifetime utility of not defaulting is less than the lifetime utility of defaulting  $U_{ND} < U_D$ . As an example, we can assume a borrowing agent with preference parameters  $\beta=0.9$ ,  $\rho=5$ ; an income of  $w_t=10$  and faces an interest rate  $r_t=5\%$  and it is a problem of 4 periods with  $t=0, \dots, 3$ . The individual borrows up to date  $n$  following the optimum consumption path and faces the choice at date  $n+1$  when he has to start repaying his debt; hence, he will default if the following condition is met:

$$\sum_{t=0}^3 \beta^t \frac{c_t^{*1-\rho}}{(1-\rho)} < \sum_{t=0}^n \beta^t \frac{c_t^{*1-\rho}}{(1-\rho)} + \sum_{t=n+1}^3 \beta^t \frac{w_t^{1-\rho}}{(1-\rho)}$$

Or similarly:

$$\sum_{t=n+1}^3 \beta^t \frac{c_t^{*1-\rho}}{(1-\rho)} < \sum_{t=n+1}^3 \beta^t \frac{w_t^{1-\rho}}{(1-\rho)} \quad (5.17)$$

A loan contract with collateral that eliminates the incentives to default should then comply with:

$$\sum_{t=n+1}^3 \beta^t \frac{c_t^{*1-\rho}}{(1-\rho)} = \sum_{t=n+1}^3 \beta^t \frac{w_t^{1-\rho}}{(1-\rho)} - \text{Collateral} \quad (5.18)$$

$$\text{Collateral} = \sum_{t=n+1}^3 \beta^t \frac{w_t^{1-\rho} - c_t^{*1-\rho}}{(1-\rho)}$$

An important assumption is that the threat of the bank of keeping the collateral is credible. If not, we can model the exposure of the bank in a simple way. The monetary authority is providing liquidity to the banking system. In this model there are 2 types of agents, net lenders (a) who deposit in the banking system and net borrowers (1-a), population is normalised to 1. The banking system obtains funding from two sources: the central bank and deposits. Banks lend to early consumers at an interest rate r and pay late consumers the rate  $r_p$  for their deposits. In either case, the present value of net savings at each date, for each consumer is:

$$NS_t = w_t - (c_t^*) \begin{cases} > 0 \text{ Lenders} \\ < 0 \text{ Borrowers} \end{cases}$$

And the bank's position with the central bank is denoted by the expression:

$$B_t = a(NS_t | type = a) + (1-a)(NS_t | type = 1-a)$$

When  $B > 0$  then the bank buys government bonds and when  $B < 0$  the bank borrows from the central bank. The restriction that always binds is  $\sum_{t=0}^T \frac{B_t}{(1+r_t)^t} = 0$ , the bank cannot overdraft

from the central bank and deposits are always paid. Therefore, when  $a=0$  the bank just invests in risk free bonds the savings from late consumers and pays off by redeeming those bonds from the central bank. When  $a=1$  then the bank borrows from the central bank and repays at rate r, the credits to the consumer are also at rate r. This simple expression implies that when there are defaults from some borrowers and when collateral is either not exercised or at a percentage of the value of the loan the loss is unrecoverable. Common solutions to this problem are to set minimum capital levels, requirements on deposits and lender of last resort arrangements. This availability of reserves (DR) has the effect of minimising the possible impact on the bank's position from defaults and hence the bank's position is now:

$$B_t = a(NS_t | type = a) + (1-a)(NS_t | type = 1-a) + DR \quad (5.19)$$

Depending on the source or the reserves, the bank will end up with a positive or a zero balance in its position B. If for example, it takes a fraction of deposits then the possibility of allocating credit will be restricted but the position will be self-financing and will take the form:

$$B_t = a(NS_t | type = a) + (1-a)(NS_t | type = 1-a)((\delta) + (1-\delta))$$

Where  $(1-a)(NS_t | type = 1-a)(1-\delta) = DR$  and  $(1-a)(NS_t | type = 1-a)\delta$  is the available amount to lend. On the other hand, if bank's own capital is paid then at the end there will be a positive balance depending of the size of defaults.

#### 5.2.4. Implications for consumption estimation: an infinite period solution

The previous analysis has important implications for the empirical estimation of consumption since it departs from the standard Euler equation. We can derive a new equation that is theoretically compatible with Carroll's (2001) findings regarding the importance of other variables to estimate consumption. In order to do that we will assume an infinite-lived consumer with the following problem:

$$\begin{aligned} \text{Max } U(c_0, c_1) &= \sum_{t=0}^{\infty} \beta^t u(c_t) \\ \text{Subject to } c_0 + \sum_{t=1}^{\infty} \frac{c_t}{\prod_{k=1}^t (1+r_k)} &= w_0 + \sum_{t=1}^{\infty} \frac{w_t}{\prod_{k=1}^t (1+r_k)} \end{aligned}$$

To calculate the present value of a given observation we need to compound the time variant interest rates of all the periods from date 0 up to date t. The assumptions on  $r_k$  are:

1. Every value of  $r_k$  is the interest rate prevailing between k and k-1.
2. Each  $r_k$  is not the rate of the term structure prevailing at date 0, it corresponds to the one period interest rate at date k.
3. The interest rate does not follow a stochastic process<sup>45</sup> but is a monetary policy instrument.

<sup>45</sup> Relaxing this assumption is necessary if we need to obtain an optimal portfolio where the available assets follow a martingale process, Pliska (1997).



In order to simplify the calculation, we can introduce the concept of equivalent interest rate which is the geometric mean<sup>46</sup> of all the discounting factors up to date  $t$  such

$$\text{that } \left( \prod_{k=1}^t (1 + r_k) \right)^{\frac{1}{t}} = (1 + \bar{r}_t).$$

The optimal consumption schedule with full information in terms of income is now:

$$c_0^* = \frac{\left( \sum_{t=0}^{\infty} \frac{w_t}{(1 + \bar{r}_t)^t} \right)}{\left( \sum_{t=0}^{\infty} \frac{\left( \beta(1 + \bar{r}_t) \right)^{\frac{t}{p}}}{(1 + \bar{r}_t)^t} \right)} \quad (5.20)$$

And an optimal consumption path:

$$c_j^* = \left( \beta(1 + \bar{r}_j) \right)^{\frac{j}{p}} \frac{\left( \frac{w_j}{(1 + \bar{r}_t)^j} + \frac{w_{j-1}}{(1 + \bar{r}_{j-1})^{j-1}} + \sum_{t=0, t \neq j, j-1}^{\infty} \frac{w_t}{(1 + \bar{r}_t)^t} \right)}{\left( \sum_{t=0}^{\infty} \frac{\left( \beta(1 + \bar{r}_t) \right)^{\frac{t}{p}}}{(1 + \bar{r}_t)^t} \right)} \quad (5.21)$$

Note that in order to have an interior solution we need that the present value of income must be a finite number and the denominator must converge as well. Hence, we need two assumptions:

1. Income cannot have a growth rate  $\varphi_t$  between periods that replicates exactly the observed interest rate process or that is permanently higher<sup>47</sup>. This to ensure that the discounted summation converges. Otherwise, consumption becomes infinite at

<sup>46</sup> This equivalent interest rate allows to discount each period with a single rate. For instance instead of having to calculate  $(1+0.05)*(1+0.07)*(1+0.08) = 1.21338$  we can calculate the geometric mean of these rates and obtain  $(1.06659353)^3 = 1.21388$  as the discount factor for date  $t=3$ .

<sup>47</sup> As an example, if the interest rate is fixed at a level  $r$  and we have a fixed income growth  $\varphi$  then it must be that  $\varphi < r$ .

every point in time. In the n-period model the finite present value of income is forced by the transversality condition.

- For the denominator to converge, one sufficient but not necessary condition is that  $\beta < 1$  which corresponds to an impatient agent with no restriction on the degree of relative risk aversion; another sufficient but not necessary condition is  $\rho > 1$ , which is an agent with high relative risk aversion coefficient with no restriction on the subjective preference discount, this means that convergence can be achieved if  $\beta = 1$  and  $\rho > 1$ , this corresponds to a patient agent with high relative risk aversion. In the case of a patient agent with low relative risk aversion ( $\beta = 1$  and  $\rho < 1$ ) the denominator does not converge and consumption collapses to zero at every point in time implying infinite savings.

If we want to determine the adjustment needed when there is an unexpected shock at date t we need to solve again for K:

$$\left( \text{PV} \hat{c}^*_{j=0, \dots, t-1} \mid I=0 \right) + \left( \text{PV} c^*_{j=t, \dots, \infty} \mid I=t \right) - K = \left( \text{PV} w_{t=0, \dots, \infty} \mid I=t \right) \quad (5.22)$$

#### 5.2.4.1. An equilibrium consumption path equation vs. the Euler equation

We can compare this result with the standard Euler equation. The solution with an infinite horizon, time variant real interest rates and time variant real income that we just derived can be rewritten as:

$$c^*_j = \left( \beta (1 + \bar{r}_j) \right)^{\frac{j}{\rho}} \left( \frac{\frac{w_j}{(1 + \bar{r}_j)^j} + \frac{w_{j-1}}{(1 + \bar{r}_{j-1})^{j-1}} + A_j}{B} \right) = \left( \beta (1 + \bar{r}_j) \right)^{\frac{j}{\rho}} \left( \frac{A_j}{B} + \frac{w_j}{B(1 + \bar{r}_j)^j} + \frac{w_{j-1}}{B(1 + \bar{r}_{j-1})^{j-1}} \right)$$

Where  $B \equiv \sum_{t=0}^{\infty} \left( \frac{\beta (1 + \bar{r}_t)^{\frac{t}{\rho}}}{(1 + \bar{r}_t)^t} \right)$  is a constant,  $A_j$  is the present value of income excluding

the observed income and any lags included explicitly, and applying logarithms to obtain the result:

$$\ln c^*_j = j \frac{\ln \beta}{\rho} + \frac{j}{\rho} \ln (1 + \bar{r}_j) + \ln \frac{1}{B} + \ln \left( A_j + \frac{1}{B} \left( \frac{w_j}{(1 + \bar{r}_j)^j} + \frac{w_{j-1}}{(1 + \bar{r}_{j-1})^{j-1}} \right) \right) \quad (5.23)$$

The first one of the new terms  $\left(\ln \frac{1}{B}\right)$  corresponds to the discounted growth rates of consumption at equilibrium which is required to be a constant for an interior solution. The second of the new terms can be described as a function of present income and permanent income. We found that there is a time index involved (which is denoted by  $j$ ) and its parameter is related to the value of time; this effect corresponds to the constant term  $\frac{1}{\rho} \ln \beta$  in the standard

Euler equation  $\ln c_t = \frac{1}{\rho} \ln \beta + \frac{1}{\rho} \ln(1 + r_t) + \ln c_{t-1}$ .

Effect from:	Standard Euler equation	Equilibrium consumption path equation
Value of time	$\frac{1}{\rho} \ln \beta$	$\frac{j}{\rho} \ln \beta$
Interest rate	$\frac{1}{\rho} \ln(1 + r_t)$	$\frac{j}{\rho} \ln(1 + \bar{r}_j)$
Current and permanent income.	Not considered	$\ln \left( A_j + \frac{1}{B} \left( \frac{w_j}{(1 + \bar{r}_j)^j} + \frac{w_{j-1}}{(1 + \bar{r}_{j-1})^{j-1}} \right) \right)$
Discounted growth rate of consumption	Not considered	$\ln \frac{1}{B}$

Table 58: Log-linear Euler equation vs. equilibrium consumption path

### 5.2.4.2. Empirical considerations

As we have seen the Euler equation comes from the same maximisation problem we just described, it is in fact the relation between periods of first order conditions; however, it is not the solution of the problem. In other words, it describes a condition that the optimum path has to fulfil, not the optimum path itself. When trying to apply this long run, full information and ex-ante relationship to obtain short run implications with uncertainty it is not surprising it performs badly. Why? Because the Euler equation is consistent with one and only one level of permanent real income, any unexpected change in interest rates and/or current income will alter the budget constraint and will affect consumption. The solution to the constrained problem takes the form of the standard Euler equation only in the case of full information where *income and interest rates are known, the interest rate is constant and there are no surprise changes* in any of these variables, then it is true that:

$$\frac{c_{j+1}^*}{c_j^*} = \frac{(\beta(1+r))^{\frac{j+1}{\rho}}}{(\beta(1+r))^{\frac{j}{\rho}}} = (\beta(1+r))^{\frac{1}{\rho}}$$

Applying the standard form of the Euler equation to a series that does not fulfil these conditions ignores the intertemporal budget constraint. It is important to note that there is no restriction on the interest rate sign since it is possible that there is a negative effect on income and consumption due to its impact on the present value. This is contrary to the standard form of the Euler equation which requires the parameter to have a positive sign to be considered a valid estimation. A related issue to interest rates is that consumption depends not only in current but past and future interest rates; this is the result of having a binding constraint. In other words, optimising intertemporal consumption means transferring real income from all over the planning horizon; this implies that the agent contracts debt or accumulates savings both which accrue an interest rate. Treating non-current interest rates as by-gone or not-yet-existing, effectively ignores the accrued interest that must be paid (or spent) in the future which in turn violates the binding constraint.

Empirical estimation of this function poses several problems though, as it can be seen we need a measure of the present value of income across the planning horizon (not only of future but of past income as well). We can separate the effect of current and lagged values of income but we are still kept with the problem to calculate future income. There are several proposed methods, ranging from simple approaches such as Graham, Eggers and Sukhtankar (2003) who consider the average income over two periods as a proxy for permanent income and any deviation as transitory income to more sophisticated and data-intensive ones such as Carrol (1994). However, under this specification this variable depends not only of future income alone but on its discounted value therefore it responds to expected interest rates as well (either if a shock is temporary or permanent) making it more difficult to find an appropriate proxy. Ignoring this variable may bias the estimations of the rest of the parameters are we would be omitting a relevant variable as Graham et al. (2003), Carrol (1994), DeJuan, Seater and Wirjanto (2004) and Shea (1995) have found that consumption responds to permanent income.

As a preliminary exercise, we followed the Graham et al. (2003) approach to permanent income. Under that approach, observations of current income contain all the information of both permanent and transitory income implicitly:

Current Income = Permanent income + Transitory income

$$(w_t) = \left( \frac{w_t + w_{t-1}}{2} \right) + \left( w_t - \frac{w_t + w_{t-1}}{2} \right) \quad (5.24)$$

Hence, we can include a regression with current and lagged observations and compare these results with the standard Euler equation approach. We regressed the equations:

$$c_t = \alpha_1 + \alpha_2 r_t + \alpha_3 c_{t-1} + \varepsilon_t \quad (5.25)$$

$$c_t = \gamma_1 + \gamma_2 t + \gamma_3 \bar{r}_t + \gamma_4 w_t + \gamma_5 w_{t-1} + \eta_t \quad (5.26)$$

In order to compare the results from the Euler equation in its extended form and the ones obtained from the optimal path equation. It is important to note that the interest rate used in the latter is the expected long term interest rate, in this case it was calculated as the ex-ante geometric average interest rate up to date t.

<b>Euler Equation Results</b>				
Coefficient (Probability)	<b>Mexico</b>	<b>Korea</b>	<b>Thailand</b>	<b>Philippines</b>
$\alpha_1$	0.3105 (0.0473)	0.2085 (0.1624)	0.1140 (0.1432)	0.0063 (0.5682)
$\alpha_2$	0.9000 (0.0755)	0.0493 (0.9092)	-1.1308 (0.0058)	-0.1561 (0.1142)
$\alpha_3$	0.8788 (0.0000)	0.9689 (0.0000)	0.9426 (0.0000)	1.0033 (0.0000)
Adjusted R-squared	0.8325	0.9821	0.9209	0.9972
Akaike info criterion	-3.2330	-4.3210	-4.8962	-7.3219
Schwarz criterion	-3.1149	-4.2029	-4.7683	-7.2038
<b>Optimal Path Equation Results</b>				
Coefficient (Probability)	<b>Mexico</b>	<b>Korea</b>	<b>Thailand</b>	<b>Philippines</b>
$\gamma_1$	-0.1060 (0.7057)	4.8399 (0.0000)	-0.3878 (0.0037)	1.0154 (0.0000)
$\gamma_2$	0.0065 (0.0000)	0.0057 (0.0000)	0.0020 (0.0000)	0.0069 (0.0000)
$\gamma_3$	6.8269 (0.0057)	7.5418 (0.0000)	-2.2678 (0.2774)	-2.2783 (0.0154)
$\gamma_4$	1.2808 (0.0000)	0.4314 (0.0067)	0.6231 (0.0000)	0.1012 (0.0437)
$\gamma_5$	-0.7349 (0.0009)	0.6872 (0.0000)	0.2805 (0.0211)	
Adjusted R-squared	0.9152	0.9766	0.9376	0.9968
Akaike info criterion	-3.8748	-4.0161	-5.0874	-7.1720
Schwarz criterion	-3.6780	-3.8193	-4.8741	-7.0146

Table 59: Comparison of results

As we can see, when estimating this version of the Euler equation, for Korea and Philippines the only significant coefficient is the one that corresponds to lagged consumption, the other two coefficients are not significant. For Mexico and Thailand we have that the coefficient associated with the interest rate  $\alpha_2$  is significant but not the one associated with preference parameters  $\alpha_1$ . When estimating the optimal path equation, we can see that all

coefficients are significant and that in most of the selected countries the adjusted R-squares improves. Regarding the information criterion, we see that for Mexico and Thailand both values show that the optimal path approach performs better than the traditional Euler equation. As opposed to the standard approach of the Euler equation in the optimum path approach it is more complicated to identify the values of the preference parameters  $\beta$  and  $\rho$  and to isolate the specific effects of each variable on consumption because of the non-linear form of the theoretical equation. That is the reason why the interest rate can have a negative sign, depending on which effect prevails, the effect on the slope (as in the Euler equation) or on the level via the present value of lifetime income (as in the new optimal path equation).

### **5.3. Intertemporal consumption and risky assets**

Past sections have focused on the lending-borrowing problem for transferring income between periods given access to a banking system and the money market. This is a partial explanation of what is going on within one market of the financial sector. The next question is: how does a planning horizon beyond 2 periods can affect an investor that participates in a risky asset market? In this section we will apply the approach we have adopted to solve the investment problem of an investor who faces uncertainty in the returns of his assets. This problem follows Pliska (1997) in the general specification of the model but differs in the approach to the solution by solving over the entire horizon rather than splitting the problem into a sequential 2-period modelling. Since this model is the standard approach to financial decision making it can be modified to address several issues in financial theory.

#### **5.3.1. Arbitrage-free pricing of contingent assets**

We start assuming that there is a risky asset which value depends on the realised state of nature, we can think of it as a stock share or even real state. Depending on the state in which the economy is found it will be its value; if the economy performs well then the final value of the asset is higher than with respect to other states of nature. For simplicity and manageability we assume that there are 3 periods and  $t=0, 1, 2$ . The risky asset follows a stochastic binomial behaviour with probability  $p^2$  to reach a final known value of  $S_{uu}$  after 3 periods; a probability  $2p(1-p)$  to reach a final known value of  $S_{ud}=S_{du}$ ; and, a probability  $(1-p)^2$  to reach a final known value of  $S_{dd}$ . Hence, at date 0 there is one observed state of nature, at date 1 there are 2 states of nature, at date 2 there are 3 states of nature. It is important to have clear from this point that higher prices of the asset at date 1 may constitute higher ex-post returns but the expected return is an inverse proportion of the price; to make this clearer let's assume that at date 1 the

price is 10 but the maximum possible real value of the asset at the best state of nature at the date 2 is 9, then the expected return is negative. The investor can sell and buy at any time without cost. There is a risk-free interest rate  $r$  (for simplicity we will assume it constant). We have a three period model where  $t=0, 1, 2$ . In an arbitrage-free valuation the value of any asset is given by the discounted expected value of future prices. The price  $H$  of the risky asset at each date at each node of the binomial tree will be:

Asset price at each date	
Date 0	$H_0 = \frac{1}{(1+r)} [pH_1^u + (1-p)H_1^d]$
Date 1	
State 1 (1 step up)	$H^u = \frac{1}{1+r} (pH_{uu} + (1-p)H_{ud})$
State 2 (1 step down)	$H^d = \frac{1}{1+r} (pH_{du} + (1-p)H_{dd})$
Date 2	
State 1 (2 steps up)	$H^{uu}$
State 2 (1 step up and 1 down) or (1 step down and 1 up)	$H^{ud} = H^{du}$
State 3 (2 steps down)	$H^{dd}$

Table 60: Asset price process

As we are assuming that the individual can only invest in the risky asset to allocate his initial wealth to consumption over time, we need to determine the proportion of initial wealth destined to consumption and to buy the asset at every point in time ( $s_t$ ). For simplicity we assume that preferences are given by  $U(c_t) = \ln(c_t)$ . In this case we need to maximise the expected utility subject to the restrictions: i) wealth has to be either destined to consumption or to investment; ii) consumption in 1 is the residual from the value of the initial portfolio minus the value of the new portfolio; and, iii) consumption at date 2 is equal to date 1 portfolio valued at date 2 prices. Note that  $s_1^*$  is being determined independently of the state of nature, this allows to simplify the algebraic treatment otherwise the problem becomes non-linear and intractable. This ensures that initial wealth is depleted at the end of the planning horizon and that there is no external financing.

$$\text{Max } U(c) = \sum_{t=0}^2 \beta^t E(u(c_t))$$

$$W = s_0 H_0 - P_0 c_0$$

$$\text{Subject to } c_1 = (s_0 - s_1) H_1 / P_1$$

$$c_2 = s_1 H_2 / P_2$$

Where  $P_t$  are the prices at date  $t$  of the consumption goods. Hence, the optimal solution<sup>48</sup> of this problem is given by:

$$\begin{aligned}
 c_0^* &= \frac{W}{P_0(1 + \beta + \beta^2)} & s_0^* &= \frac{W}{H_0} \left( 1 - \frac{1}{P_0(1 + \beta + \beta^2)} \right) \\
 c_1^* &= (s_0^* - s_1^*) \frac{H_1}{P_1} & s_1^* &= \frac{\beta^2}{H_0} \left( \frac{W}{1 + \beta + \beta^2} \right) \\
 c_2^* &= s_1^* \frac{H_2}{P_2}
 \end{aligned} \tag{5.27 to 5.31}$$

Note that  $c_1^*$  and  $c_2^*$  depend on the specific value taken by the asset price  $H_1 = \{u, d\}$  and  $H_2 = \{uu, ud, du, dd\}$ . Hence, with a risky asset consumption depends on the observed realisation of the states of nature and it is sensitive to fluctuations in the value of the portfolio as new information is being revealed disregarding unattainable nodes of the asset price tree.

### 5.3.2. Interest rate changes

Since we are interested in the effect of monetary policy on welfare when there are financial markets, we need to analyse the effects of changes in the interest rate on consumption. We are interested in the effect of changes in the interest rate on the optimal consumption path. We will assume that the interest rate can change; therefore we have that the interest rate prevailing between date 0 and date 1 is  $r_1$  and the one prevailing between date 1 and date 2 is  $r_2$ . The expressions for the real price of the asset at dates 0 and 1 are then given by:

Asset price at each date	
Date 0	$H_0 = \frac{1}{(1 + r_1)(1 + r_2)} (p^2 H_{uu} + 2p(1 - p) H_{ud} + (1 - p)^2 H_{dd})$
Date 1	
State 1 (1 step up)	$H^u = \frac{1}{1 + r_2} (p H_{uu} + (1 - p) H_{ud})$
State 2 (1 step down)	$H^d = \frac{1}{1 + r_2} (p H_{du} + (1 - p) H_{dd})$

Table 61: Asset price process with varying interest rates

#### 5.3.2.1. Expected changes in the interest rate

The first case we can consider is when the interest rates are equal  $r_1 = r_2$  and both change at the same time. To simplify the analysis, that  $P_t = 1$ . In this case we have the following<sup>49</sup>:

<sup>48</sup> The complete solution can be found in annex A5.3

<sup>49</sup> A demonstration can be found in annex A5.4



Effect of expected changes of interest rates			
	$r_1 = r_2 = r, \frac{dc_t^*}{dr}$	$r_1 \neq r_2, \frac{dc_t^*}{dr_2} = 0, \frac{dc_t^*}{dr_1} \neq 0$	$r_1 \neq r_2, \frac{dc_t^*}{dr_2} \neq 0, \frac{dc_t^*}{dr_1} = 0$
$c_0^*$	0		
$c_1^*$	>0	0	>0
$c_2^*$	>0	>0	>0

Table 62: Asset price changes with expected changes in interest rates

### 5.3.2.2. Surprise changes in the interest rate

We now turn to the case where the interest rate  $r_2$  changes at date 1 unexpectedly. This means that all decisions for date 0 are irreversible<sup>50</sup>. Consumption at date 0 and date 2 remains constant, the latter because the optimal investment remains unchanged as does the final price of the asset. But consumption at date 1 changes in the opposite direction of the interest rate because the investor cannot adjust the initial holdings of the asset  $s_0^*$ .

Effect of surprise changes of the interest rate at date 1	
	$r_1 \neq r_2, \frac{dc_t^*}{dr_2} = 0, \frac{dc_t^*}{dr_1} \neq 0$
$c_0^*$	0
$c_1^*$	<0
$c_2^*$	0

Table 63: Asset price changes with surprise changes in interest rates

### 5.3.3. A model of asymmetric information with informed investors and noise traders

Emmons and Schmid (2002) develop a model of arbitrage by professional traders who need-but lack wealth of their own to trade. Professional arbitrageurs must convince wealthy but uninformed investors to entrust them with investment capital in order to exploit mispricing perceptions in an asset and push the market back to its fundamental value. It is possible that assets become even more mispriced before reverting eventually to their fundamental value, having incurred in losses, the outside investors may demand their money back at this point even though the price will recover to its fundamental value. The results may depend on factors such as the ability of investors to wait, the use of performance rules (feedback rules) when assessing

<sup>50</sup> We can check if the investment strategy at date 1 is still optimal, the demonstration is found in annex A5.5.

the fund manager. In this model it is shown that the existence of professional arbitrageurs mitigates, but not eliminates, mispricing in asset markets. A timeline of the model that outlines the decisions taken at the three periods is presented by Emmons and Schmid (2002) as follows:

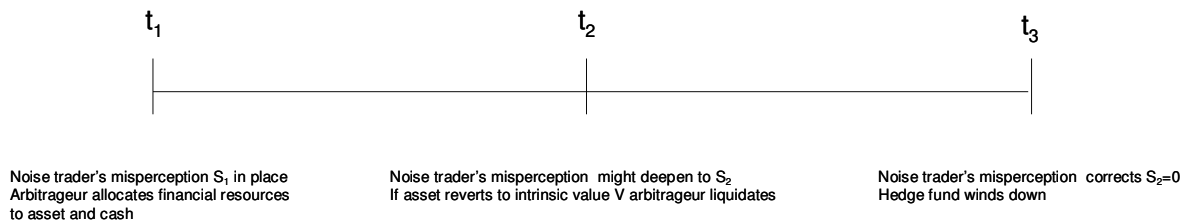


Diagram 20: Emmons and Schmid (2002) model timeline

There are three participants in the market: i) noise traders who have wealth but misperceive the intrinsic value of the financial asset; ii) investors who have wealth but not insight into the financial asset's intrinsic value; and, iii) arbitrageurs who know the intrinsic value but they don't have wealth of their own. All parties are risk neutral. We will assume that there is a mechanism that can align the investor's and the arbitrageur's interests so we treat them as one agent within the market (since we are not analysing the funds' market and fee structure we can simplify to two participants, informed investors and noise traders). Noise traders maximise expected utility as well but under a different perception of the asset price. The assumption of maximising utility will allow us to derive a demand for the asset building up on Emmons and Schmid (2002) and Schleifer (2000) approaches that assume ad-hoc demands for the asset. The timeline now becomes:

1. Participants are all buyers in the asset market and they need to set a market price. There is a proportion  $(a)$  of informed investors and  $(1-a)$  of noise traders. They set a market price of the asset given their different expectations and calculate the real consumption schedule.
2. At the second period participants decide whether or not the asset is still mispriced and if it is optimal to adapt their optimal portfolio calculated at date 0. As well, they determine a market price for the asset.
3. At the last period the asset reveals its true value and the agents consume the value of their portfolios.

Why can an asset be mispriced? Noise traders exist because pricing of an asset depends on expected returns that are not observable but in this model we are assuming that the final possible values of the asset are known. Another factor is that the probabilities of different states

on nature are not observable; this is the assumed source of error in our model, noise traders have their own estimation of these probabilities. At this point it is important to remind that an overpriced asset at date 1 will have a lower expected return at date 2, it effectively represents an exp-post higher return from date 0 to date 1 but the expected return diminishes with respect to the real price at date 1.

The maximisation problem is the one that we derived above; however, noise traders price the asset at date  $t$  as  $H_{NT} = H_t E_t$  where  $E_t$  is a proportion of the real price. We will assume additionally that the subjective probability of the noise traders can vary over time  $p_{t, NT}$  this will allow us to correct or deepen the misperception at date 1. Hence  $E_t$  is given by the expressions:

$$E_0 = \frac{p_{0,NT} p_{1,NT} H^{uu} + 2p_{0,NT} (1 - p_{1,NT}) H^{ud} + (1 - p_{0,NT}) (1 - p_{1,NT}) H^{dd}}{p^2 H^{uu} + 2p(1 - p) H^{ud} + (1 - p)^2 H^{dd}} \quad (5.32)$$

While  $E_1$  depends on the specific node we are at date 1 so it can take one of two possible values:

$$E_{1u} = \frac{p_{1,NT} H^{uu} + (1 - p_{1,NT}) H^{ud}}{p H^{uu} + (1 - p) H^{ud}}$$

or

$$E_{1d} = \frac{p_{1,NT} H^{du} + (1 - p_{1,NT}) H^{dd}}{p H^{du} + (1 - p) H^{dd}} \quad (5.33)$$

If  $E_t=1$  there is no mistake in the pricing process; if  $E_t < 1$  the probability of the value of the asset going up  $p_{NT}$  is less than the real probability  $p$  and the asset is under-priced; on the other hand, if  $E_t > 1$  then the probability  $p_{NT} > p$  and the asset is over-priced.

Noise traders maximise the same problem as in the previous section, but they have a misperception about the price. Hence, a noise trader optimal investment-consumption schedule is:

$$c_{0NT}^* = \frac{W}{P_0 (1 + \beta + \beta^2)} \quad s_{0NT}^* = \frac{W}{H_0 E_0} \left( 1 - \frac{1}{P_0 (1 + \beta + \beta^2)} \right)$$

$$c_{1NT}^* = (s_{0NT}^* - s_{1NT}^*) \frac{H_1 E_1}{P_1} \quad s_{1NT}^* = \frac{\beta^2}{H_0 E_0} \left( \frac{W}{1 + \beta + \beta^2} \right)$$

$$c_{2NT}^* = s_{1NT}^* \frac{H_2}{P_2}$$

We can solve for the market price by aggregating the demands for both types of consumers, we will normalise the supply of the asset at date 0 to  $S = a(s_0 | H_0) + (1+a)(s_0 | H_0 E_0)$ . By doing this we are in fact assuming that the market functions as a clearing house that provides the required liquidity being able to satisfy the demand. This pricing mechanism avoids distortions in prices that come from artificial liquidity shortages and prices only reflect the mix of informed and uninformed investors in the market. Since we are looking for a unique market price, the aggregate demand for the asset is given by:

$$D = a \frac{W}{H_{0M}} \left( 1 - \frac{1}{P_0 (1 + \beta + \beta^2)} \right) + (1-a) \frac{W}{H_{0M}} \left( 1 - \frac{1}{P_0 (1 + \beta + \beta^2)} \right) = \frac{W}{H_{0M}} \left( 1 - \frac{1}{P_0 (1 + \beta + \beta^2)} \right)$$

The market equilibrium will be then  $S=D$ :

$$S = \frac{W}{H_{0M}} \left( 1 - \frac{1}{P_0 (1 + \beta + \beta^2)} \right) \quad (5.34)$$

$$H_{0M} = \frac{W}{S} \left( 1 - \frac{1}{P_0 (1 + \beta + \beta^2)} \right)$$

If there is no mistake in the price  $E$ , then the market price at date 0 that clears the market is the real price; the same happens if  $a=1$ . If  $a=0$  then the prevailing price is the “wrong” price. For estimating the price at  $t=1$ , we have 2 markets again, this time the asset market is cleared and we need to clear the goods market. We assume that the supply of goods at date 1 is  $S_g = a(c_1 | H_1, P_1) + (1+a)(c_1 | H_1 E_1, P_1)$  for the same reasons as with the asset market at date 0. Since it is a 2-market model and the asset market clears at any price, we want that the price reflects the mix of investors rather than possible shortages in goods. This is an interesting result, when asset prices start increasing in real terms more than the real price and this is required because there is a slowdown in production then this will trigger a crisis in the financial sector,

because asset prices cannot rise indefinitely, prices meet a roof when  $H_t = \frac{H_T}{(1+r)^{T-t}}$  that is

when the value of one unit of the asset is equal to the discounted value of the maximum final price of the asset. In other words, the risky asset cannot pay fewer returns than the risk-free asset if that happens, then the optimal strategy will be a sell out of the holdings of the risky asset and buying the risk-free bond until prices fall enough to correct the mispricing. On the other hand the price has no floor since an under-priced asset below will always have greater returns than expected.

The demand for goods is given by:

$$D_g = a(s_0^* - s_1^*) \frac{H_1}{P_1} + (1-a)(s_{0NT}^* - s_{1NT}^*) \frac{H_1}{P_1} E_1$$

But because both agents have the same behaviour at date 0 and we are looking for a single market price of goods, then we can simplify to a representative agent that faces a single market price:

$$D_g = (s_0^* - s_1^*) \frac{H_{1M}}{P_1} \quad (5.35)$$

The market equilibrium  $S_g = D_g$  is then:

$$S_g = (s_0^* - s_1^*) \frac{H_{1M}}{P_1} \quad (5.36)$$

$$H_{1M} = \frac{P_1 S_g}{(s_0^* - s_1^*)} \quad \text{or} \quad P_1 = \frac{H_{1M} (s_0^* - s_1^*)}{S_g}$$

At date 2, goods market clears at the final price. Some implications of this model are:

1. When the asset is under priced informed investors will demand more of the risky asset at date 0 and date 1 than when the price is the real value. Noise traders demand less of the asset than if the price were the one they think is real. When the asset is over priced the contrary will take place.
2. An under priced asset will always increase the expected utility of informed investors with respect to the expected utility under no price errors.
3. An over priced asset will always decrease the expected utility of informed investors with respect to the expected utility under no price errors.

### **5.3.3.1. Financial crises: optimal breakdowns**

This model allows analysing some of the possible sources of instability other than the ones that can arise because of the asymmetric information that explains the existence of noise traders and informed investors. Since this is a model of financial decisions under constrained optimisation, it allows calculating the possible impact on welfare of different phenomena in the risky asset market. As well, financial decisions being the result of intertemporal maximisation allow us to avoid the use of ad-hoc asset demands commonly used when modelling financial markets. With little modifications, we can analyse other phenomena that has been widely covered in the literature such as frenzies and crashes. In this section, we briefly address these types of financial crises within this model.

### ***Real shocks***

As we have already mentioned, at date 1 in this model there is the possibility for a real shock such as a contraction in aggregate supply to transmit to the financial sector. When there is a slowdown in production, then the market price  $H_1$  asked for the asset that clears the market must go up, since portfolio holdings are the only source of income in this model. This creates an artificial bubble in the asset market which cannot be indefinite; the market crashes if the price goes beyond the roof imposed by the existence of the risk-free asset when it is a better strategy for the buyers giving liquidity to the market to stop trading the asset at that price. As we will see in the following section, if we allow for sequential trading (an agent has to sell his position in order to buy a new portfolio) there are some price-correction mechanisms.

### ***Bubbles and slumps***

Till now we have assumed that at date 1 all transactions are made at a single price, however the structure of the model points towards an interesting phenomenon: the appearance of a bid-ask gap. If we remember consumption at date 1 is given by  $c_1^* = (s_0^* - s_1^*) H_{1M} / P_1$ . If we add the assumption found in Chen (1999) which is that transactions are made in sequence, we can end up with an optimal frenzy followed by an optimal crash in the risky asset in the pursue of increasing consumption. Consumption at date one will now depend on a selling price (ask) and a buying price (bid)  $c_1^* = (s_0^* H_{1ask} - s_1^* H_{1bid}) / P_1$ .

Let assume that at date 1 the individuals need first to liquidate their portfolio and then buy a new portfolio. It can be argued that they need only to sell  $(s_0^* - s_1^*)$  at the observed price but that may be suboptimal if we can differentiate the selling and the buying price aiming for the golden rule in asset markets “buy low and sell high”. Hence, given that the market price is calculated taking into account the proportion of noise traders, it may be optimal for informed investors to manipulate the price by presenting themselves as noise traders and asking for the noise trader price.

When the turn comes to buy the asset, informed investors will behave as their true nature, since it will correct the price down; for noise traders is their turn to behave as informed investors will find it optimal to correct their price and the market price will correct to the true value of the asset. This self-correcting mechanism works if the over pricing is not big; however, if that is not the case, and if we accept that the source of error is not only the probability but the final value of the asset then we allow for bigger variations of the price. If this happens, it may

be optimal for informed investors to crowd in at the incorrect price at a buying frenzy and then dropping the market price when it is time to sell. The market can entirely disappear if holding the risk-free asset is a better strategy for the buyers giving liquidity to the market. If the monetary authority intervenes by increasing the interest rate  $r_2$  in an effort to reduce the market price then, as we have seen, the effect will be negative on consumption. A slump can happen at date 0, when informed investors find it optimal to lie about the price. If the under pricing is small, then we may find small deviations from the real value. However, this slump will always be corrected at date 1 when it is turn to sell the asset and the real value is revealed.

### 5.4. Financial and currency crises: twin crises in 3 stages

We can turn to the second generation model described in a previous chapter to analyse the interaction between financial, currency and goods markets. The UIP approach is a portfolio model where we have risk-free assets in 2 countries, a currency market and a goods market. We will introduce 2 features, a capital market in the small country with a risky asset that makes it attractive to diversify internationally the portfolio and intertemporal consumption in 2 periods. The implications of the existence of a risky asset can be derived intuitively given the mechanisms that we have already studied and we can outline a generic timeline of a financial crisis in the risky asset market that transmits to a currency crisis and feedbacks to a financial crisis but this time in the banking sector. We can turn to equation 1 to describe the expected devaluation given the interest rate parity:

$$\frac{S_{t+1}^e - S_t}{S_t} = (r_t^{cb} - r_t^{cb*}) + (\Delta p_{t+1}^e - \Delta p_{t+1}^e *)$$

We start from an equilibrium situation without inflation in any country and an expected devaluation of 0 which implies that the risk-free returns set by the central bank are  $r_t^{cb} = r_t^{cb*}$ . Consumers are participating in 3 markets: goods, loanable funds and capital markets. Taking into account the simplifying rule that income is transferred via loanable funds and wealth through risky asset; at this point we can imagine that a person may have income but not enough wealth to participate in share markets or to invest in real estate on the other hand a wealthy agent may prefer to invest in a riskier asset with higher returns. Given the characteristics of the countries of interest this is not an unrealistic assumption. We can characterise the risky asset as we have done before, 3 possible ending scenarios with different values of the asset ( $H_{uu}$ ,  $H_{ud}=H_{du}$  and  $H_{dd}$ ) and a probability  $p$  of going up

At date 0, every agent makes his decision of consumption and investment schedule. In the risky asset market there may be a mix of noise traders and informed investors and a market price for the risky asset is set. At date 1, it is possible that there is a bubble in the risky asset. As we have already discussed the size of the bubble may vary depending on the mispricing of the asset. We have 2 cases:

1. The bubble is small and the impact on prices in the goods sector is small and can be managed with a temporary increase in the real interest rate by the central bank to avoid devaluating the currency whilst the prices correct. Consumption falls or slowdowns in response to the increase in interest rates (the effect may be small or even negligible as we have discussed).
2. In the first stage, the bubble becomes frenzy and the impact on prices cannot be countered with increasing the interest rates and the abandonment of the peg follows. During the second stage the correction of the asset price translates into a market crash. Since there is an upsurge in prices real income falls and income-related consumption does it as well. Borrowers face higher interest rates on their loans and may decide to default.

At date 2, the true state of nature is revealed. Borrowers decrease consumption, lenders increase consumption. Some investors benefit from the selling at a higher price and leaving the market before the crash and moving towards the risk free asset denominated in foreign currency. Hence, a typical 1990's crisis can be explained as a result of speculative bubbles in otherwise "well-behaved" countries with strong fundamentals.

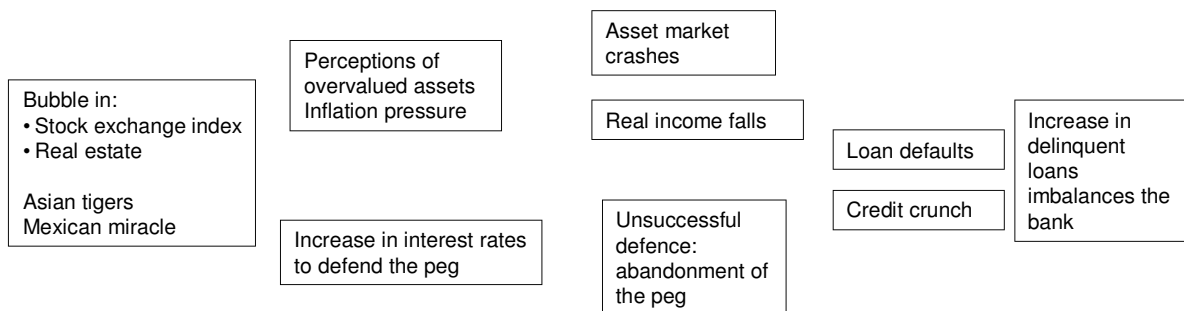


Diagram 21: Financial and currency crises timeline



## **5.5. Conclusions of the chapter**

The Lucas (1987) model provides a way of measuring the loss in lifetime utility after a shock; however, there is little room to test the possible effects of monetary policy (we are particularly interested on movements of the real interest rate) on real consumption. Obstfeld and Rogoff (1999) apply Lucas (1987) in the context of self-exclusion of international capital markets and identify the possible losses in terms of the loss of insurance capabilities against volatility in consumption. This model was developed to explain the effects of debt crises with default sovereign debt by countries; however, it does not explain the changes of the growth rate and of the level of consumption that countries in crises experienced in during the 1990s making it hard to evaluate the effects of policy to counter the negative effects of the crises.

The intertemporal maximisation problem provides a useful framework to explain the behaviour and determinants of consumption. However, the usual estimation of the Euler equation (which relates the real interest rate with consumption growth) is not enough to explain the behaviour of consumption because it overlooks the one-direction linearity of time by implicitly assuming that there is instantaneous adjustment along the planning period. This is more evident in analysis where there is a planning horizon longer than 2 periods and the Euler equation is still considered to be the relevant solution to the problem.

We need to solve the complete model and obtain the optimal path of consumption and obtain the true determinants of consumption at equilibrium. It is necessary to understand that this analysis is based solely on the effects on consumption and constitutes a partial equilibrium approach. However, we consider that understanding the consumer's behaviour is necessary to evaluate any policy response to an external shock. This allows us not only to address the specific case of the transmission mechanisms present during a crisis, but also to extend the analysis to stability periods and to improve consumption estimation. It turns out that consumption depends not only on the interest rate but on household income as well. We found that there is an intertemporal substitution effect of interest rates, which affects the slope of the optimal path and an income effect that may affect the level. In this context, interest rate increases may have a short-term negative impact on consumption that solves the puzzle observed by Canzoneri, et al. (2003), Carroll (2001) and Favero (2005). An additional benefit is that we were able to calculate implied interest rates compatible with the observed ones a puzzle that Favero (2005) addresses. It would seem that a policy which decreases the interest rate would be useful to increase consumption in the short run; however, this kind of policy implies a

trade off with the growth rate of consumption which would decrease and can have other effects on financial markets making unattractive investment in the country. It is the decision of the policy maker to balance the objectives of interest rate policy taking into account that there is no option with pure benefits but all of them imply a trade off.

**This approach to the solution provides an equilibrium consumption path equation that should incorporate real income, the behaviour of the stock exchange market (as wealth proxy) and the expected interest rate in order to explain consumption. If we compare this specification with the standard log-linear Euler equation, there are several omitted variables in the latter.** Unfortunately, because of limited and incomplete information we were not able to estimate a more complete empirical model to include the value of the stock exchange but we could incorporate a measure of real income which yields better results than the standard Euler equation.

The question is why the Euler equation does not capture these effects? This is because one of the assumptions from which it is derived is that consumers behave like they have sequential 2-period planning horizons. However, this result has been applied to cases where there are longer and finite horizons incorrectly disregarding the budget constraint as Favero (2001) points out. On the other hand we can think that the intertemporal consumption model is as well a financial model, the individual has the possibility not only to participate in the loanable funds market (through the banking system) but as well in the capital market (through risky assets) and his financial decisions are the ones that allow this consumer to transfer income and wealth between periods for consumption. When we allow longer planning periods, the intrinsic characteristic of time (it runs linearly and in one direction) imposes rigidities that make instantaneous adjustments along time limited to present and future consumption. It is because of these rigidities that surprise changes in financial markets may have the opposite effects than the expected ones when there is perfect foresight.

In economics, the intertemporal maximisation framework has been commonly used to explain consumption taking into account only the possibility of lending and borrowing in the banking system. By doing this, investment in wealth carrying assets has been completely left out of the explanation of consumption. On the other hand, in finance the same framework has been used to derive optimal portfolios for investment in financial markets without studying more in-depth the implications for consumption. We solve the portfolio optimisation problem for a single asset in a multi-period setting and we derive the optimal investment-consumption path for an investor with perfect information and for a noise trader. With these two types of investors we:

1. Build a shares market based on the model developed by Emmons and Schmid (2002) and derive the market price at all periods; this allows to derive the true demands for assets rather than to assume ad-hoc ones.
2. Explore the implications of monetary policy; interest rates movements have an immediate negative effect on consumption.
3. Derive the implications for the price of consumption goods; an overpriced financial market has an inflationary impact.
4. Derive the possibility of the existence of a bid-ask spread that depends on the uncertainty in the market; uncertainty is generated by the proportion of noise traders and the degree of mispricing of the asset; a higher distortion in the market price with respect with the true value increases the spread.

As we have demonstrated, financial crises can evolve into currency crises and feedback, even if the fundamentals of the economy do not point towards a currency crisis happening. This constitutes a problem for policy makers since intervention through interest rates alone may not be enough to correct the asset market but a more direct intervention. A precedent of this took place on August 1998 when the government of Hong Kong intervened directly in the stock market with the expressed purpose of drive out of the market currency speculators (Chan, Chan and Fong, 2000). Another issue to bear in mind is that we are not deriving an optimal policy package in the medium and the long run. This package would include the restructuring of the financial sector, adoption of other exchange rate regime, deepening of the economic reforms or even reversion of previously adopted reforms which would have further and possibly larger welfare effects.

## Final Remarks

The word crisis has its Greek root on *Krisis* that is derived from the verb *krinein* that means “to separate” or “to decide”. The modern conception applies “crisis” to a period of disruption of normal functioning and a time to decide. Chinese relate “crisis” to a period of danger but also to one of opportunity. Crises in asset markets have taken place along history and they may be an inherent part of the functioning of financial markets. These episodes may be perceived as oddities in economic functioning for developed economies where safeguards are in place and the economy is able to absorb external shocks; however, for a number of countries they are a harsh reality that cause not only temporary disruption in economic performance but large income and wealth redistributions (more often than not, with regressive consequences). For a time it has been the common assumption that the causes of economic instability were either a government with “bad” economic behaviour (as was the case of German hyperinflation or the debt crises during the 1980’s) or irrational market behaviour. However, the 1990’s crises made evident that even when there is economic adjustment and structural reforms it is still possible for a crisis to take place. We have reviewed the crises that emerging countries faced during the 1990’s in countries where the usual policy “mistakes” were not present; in other words, there were stabilisation programmes in place, opening to international commodities and financial markets and stabilisation of public deficits.

The openness of financial markets added an extra risk to consider when crises took place; regional contagion effects were an important source of instability in the South East Asian region. We estimated a leading indicators-contagion model of financial and currency crises using the standard measure for the Exchange Market Pressure and proposed a measure for the Financial Market Pressure in order to define periods with crisis. We found that financial and currency crises in the countries under study were closely intertwined, that contagion effects were important but that fundamentals were not sufficient explanation for triggering these crises.

The proposed measure by Lucas (1987) was a starting point to measure the impact of crises on welfare. We expanded this measure in order to incorporate the effect on the level of consumption and to derive a single measure that comprises changes in the growth rate, the variance and the level of consumption. As well we explored the results under different forms of preferences and modified assumptions to incorporate stochastic consumption and autocorrelation in consumption series. The main cost we found was a short term effect on the level of consumption; the change in growth rates after a crisis was in some cases positive

implying welfare gains; and, increase in consumption volatility was not an important source of welfare costs.

One of the striking features of consumption series was the sudden breakdown in the consumption path. Obstfeld and Rogoff (1999) assume that the main cost of international capital markets exclusion is volatility, which is contrary to the results we obtained, and moreover there is no available explanation the drop in the level of consumption. On the other hand the Euler equation result does not explain what happens either since it requires sudden and sharp drops of interest rates to explain observed consumption. However, the evidence of the adequacy of the Euler equation to describe consumption even in tranquil periods is under great debate because of its poor results. We decided to re-examine the intertemporal consumption model modifying some assumptions: i) that individuals solve sequential 2-period problems; ii) the intertemporal budget constraint always binds; and, iii) that past decisions cannot be adjusted.

The results explain the fall in consumption as consequence of a fall in real income and in the process we provided a solution to a puzzle in monetary policy: that an increase in interest rates have a negative impact in the short run, possibility which is not allowed by the Euler equation.

Since the intertemporal allocation of income addresses only the loanable funds market we expanded the analysis to a risky asset market. In this analysis we maximise the intertemporal utility of an initial wealth that has to be consumed along time. We demonstrated that consumption depends on the value of the asset after the initial period and that surprise changes of interest rates may have a negative effect on consumption. In order to explain what may cause a crisis we incorporated an asymmetric information structure in the market with noise traders and informed investors and derived the following results: i) that bubbles are possible as a rational strategy; ii) noise traders improve welfare of informed investors when the market price is under the real value of the asset; iii) an ask-bid spread arises naturally. When combining the results of the loanable funds market, the risky asset market and a second-generation model of exchange rate crises we can build a timeline that resembles the 1990's crises. That is a country with apparently strong fundamentals can face a financial crisis that results in a currency crisis and feedbacks into a banking crisis. In astrophysics, black holes (points in space so massive that laws of physics collapse) were considered to be an odd phenomenon of nature and their existence as fascinating as rare; recent discoveries have placed a black hole in the centre of every galaxy and linked them to their formation. It is necessary to go deeper in the causes of crises and economic disruption; it may be the case that these phenomena are linked to the formation and new developments in markets (not only as new assets appear but when new

institutional arrangements are made) and sudden adjustments need to take place at the limits of these innovations.

This continues to be a fascinating topic not only because it puts to test the limits of the understanding of economic theory but also because it has important consequences far beyond affecting economic performance and market efficiency. In economic terms, the disruption of the “normal” performance of the economy has further implications; severe crises diminish welfare and have redistributive effects between lenders and borrowers, between informed investors and non-informed ones, between the rich and the poor. On the other hand, the intertwining of economic, political and social functioning becomes even more evident during a period of instability. As crises affect welfare and distribution of wealth there has always been a reaction to modify social arrangements and create new institutions to counter the effect and to prevent their recurrence.

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## Annex to Chapter 3

### A3.1: Inconsistency of OLS estimators

In order to demonstrate the inconsistency of OLS estimators, we can assume the simplest form of the model, with only one exogenous country-specific regressor  $X_i$  that is stationary and independent of the error  $u_i$ . The model now looks like:

$$\begin{aligned} y_{1t} &= \alpha_1 x_{1t} + \beta_1 I(y_{2t} - c_2) + u_{1t} \\ y_{2t} &= \alpha_2 x_{2t} + \beta_2 I(y_{1t} - c_1) + u_{2t} \end{aligned}$$

With a distribution of errors  $u$  conditional to  $x_{it}$ , given by:

$$\begin{pmatrix} u_{1t} \\ u_{2t} \end{pmatrix} | x_{1,t}, x_{2,t} \sim N \left[ \begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_{u1}^2 & \rho \sigma_{u1} \sigma_{u2} \\ \rho \sigma_{u1} \sigma_{u2} & \sigma_{u2}^2 \end{pmatrix} \right]$$

As we can see, the correlation between  $(u_{1t}, u_{2t})$  is given by  $\rho \sigma_{u1} \sigma_{u2}$ . An approximation of the probability of a crisis can be calculated as a function of the observed values of the crisis variable  $I(\bullet)$  which gives an interior value of the probability, this is similar to the one calculated by Jeanne and Masson (2000). We can calculate the probability of the crisis such that:

$$\pi_i = \frac{1}{T} \sum_{t=1}^T I(y_{it} - c_i \sigma_{i,t-1}) \text{ for } i=1,2$$

As well, we have that:

$$\begin{aligned} \frac{1}{T} \sum_{t=1}^T x_{jt}^2 &\rightarrow \sigma_{xj}^2 \text{ and} \\ \frac{1}{T} \sum_{t=1}^T x_{jt} u_{it} &\rightarrow 0 \text{ for } i,j=1,2 \end{aligned}$$

Let's simplify the notation by defining a new variable  $d_{it} = I(y_{it} - c_i)$  and rewrite this system in matrix form as  $Y = XB + U$  where  $H$  is the partitioned matrix  $H = \begin{pmatrix} X_1 & D_2 \\ X_2 & D_1 \end{pmatrix}$  (the letters in upper case denote the matrix form of the variables) and  $B$  is the parameter matrix  $B = \begin{pmatrix} \alpha_1 & \alpha_2 \\ \beta_1 & \beta_2 \end{pmatrix}$ .

For each country we can write an equation  $y_i = H_i B_i + u_i$ . The OLS estimator for this model is given by:

$$B_i = (H_i' H_i)^{-1} H_i' y_i$$

Being  $Z_i$  a partitioned matrix of the form  $H_i = [X_i, D_j]$  then

$$(H_i' H_i) = \begin{pmatrix} X_i' X_i & X_i' D_j \\ D_j' X_i & D_j' D_j \end{pmatrix}^{51}.$$

The OLS estimator takes the partitioned form:

$$\begin{pmatrix} \alpha_i \\ \beta_i \end{pmatrix} = \begin{pmatrix} X_i' X_i & X_i' D_j \\ D_j' X_i & D_j' D_j \end{pmatrix}^{-1} \begin{pmatrix} X_i' y_i \\ D_j' y_i \end{pmatrix}$$

Taking any row and applying the general form of the inverse matrix we have the estimator for  $\beta_i$ <sup>52</sup>:

$$\hat{\beta}_i = (D_j' M_i D_j)^{-1} D_j' M_i y_i$$

<sup>51</sup> The inverse of this matrix takes the general form:

$A = \begin{pmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{pmatrix} \rightarrow A^{-1} = \begin{pmatrix} A_{11}^{-1} + A_{11}^{-1} A_{12} B_{22} A_{21} A_{11}^{-1} & -A_{11}^{-1} A_{12} B_{22} \\ -B_{22} A_{21} A_{11}^{-1} & B_{22} \end{pmatrix}$  where  $B_{22} = (A_{22} - A_{21} A_{11}^{-1} A_{12})^{-1}$ . In this particular case:  $B_{22} = (D_j' D_j - D_j' X_i (X_i' X_i)^{-1} X_i' D_j)^{-1} = (D_j' M_i D_j)^{-1}$  with  $M_i = I - X_i (X_i' X_i)^{-1} X_i'$ .

<sup>52</sup> See Johnston and DiNardo (1997) for a complete derivation of this result.

In order to check for consistency we need to calculate the plim of  $\hat{\beta}_i$  we first need to calculate the value of the component:

$$\frac{1}{T}(D_j' M_i D_j) = \frac{1}{T} \sum_{t=1}^T I(y_{jt} - c_j) - \frac{\left( \frac{1}{T} \sum_{t=1}^T I(y_{jt} - c_j) x_{it} \right)^2}{\frac{1}{T} \sum_{t=1}^T x_{it}^2}$$

Which tends to a non-zero

constant  $\varphi_j > 0$ ; a special case which is the simplest and allow as us to verify this convergence is when  $x_{it} = 1$  for all t. In that case, we have:

$$\frac{1}{T}(D_j' M_i D_j) = \frac{1}{T} \sum_{t=1}^T I(y_{jt} - c_j) - \left( \frac{1}{T} \sum_{t=1}^T I(y_{jt} - c_j) \right)^2$$

We already defined  $\pi_i$  for country i, for country j we can calculate the same probability as

$$\pi_j = \frac{1}{T} \sum_{t=1}^T I(y_{jt} - c_j) \quad \text{therefore in this particular case, } \varphi_j = \pi_j (1 - \pi_j)$$

Then continuing checking consistency:  $p \lim_{T \rightarrow \infty} (\hat{\beta}_i) = \beta_i + \frac{1}{\varphi_j} p \lim_{T \rightarrow \infty} \left( \frac{D_j' M_i U_i}{T} \right)$ .

$$\frac{D_j' M_i U_i}{T} = D_j' (I - X_i (X_i' X_i)^{-1} X_i') U_i = D_j' U_i - D_j' X_i (X_i' X_i)^{-1} X_i' U_i$$

$$p \lim_{T \rightarrow \infty} \left( \frac{D_j' M_i U_i}{T} \right) = p \lim_{T \rightarrow \infty} \left( \frac{D_j' U_i}{T} \right) - \frac{1}{\sigma_{xi}^2} p \lim_{T \rightarrow \infty} \left( \frac{D_j' X_i}{T} \right) p \lim_{T \rightarrow \infty} \left( \frac{X_i' U_i}{T} \right)$$

Because X is uncorrelated with U, then  $p \lim_{T \rightarrow \infty} \left( \frac{D_j' M_i U_i}{T} \right) = E(u_{it} I(y_{jt} - c_j))$  and

therefore:

$p \lim_{T \rightarrow \infty} (\hat{\beta}_i) = \beta_i + \frac{1}{\phi_j} E(u_{it} I(y_{jt} - c_j))$  Therefore,  $\hat{\beta}_i$  is inconsistent to the extent that  $E(u_{it} I(y_{jt} - c_j)) \neq 0$ .

In order to see different possibilities, let's assume that  $\beta_j = 0$ . Under normally distributed errors, we have  $u_{it} = \rho \frac{\sigma_{ui}}{\sigma_{uj}} u_{jt} + v_t$ , where  $x_{it}$ ,  $u_t$  and  $v_t$  are independently distributed and  $v_t \sim N(0, \sigma_v)$ . So we can express:

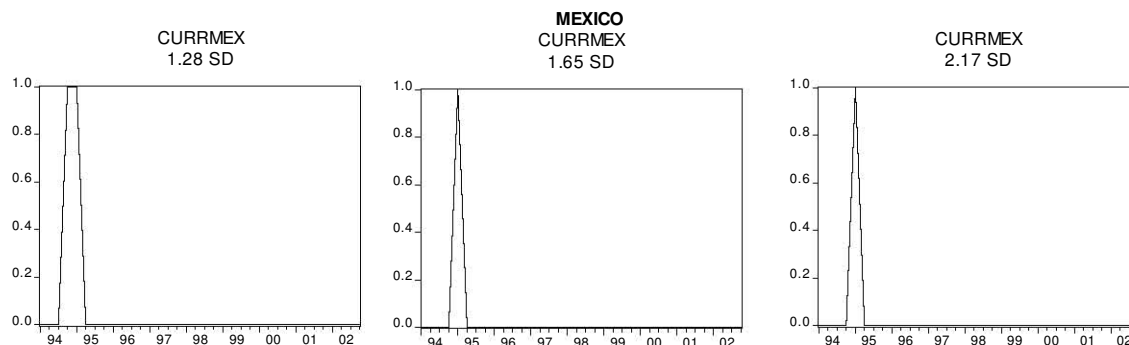
$$E(u_{it} I(y_{jt} - c_j)) = E(u_{it} I(\alpha_j x_{jt} + u_{jt} - c_j)) = \rho \frac{\sigma_{ui}}{\sigma_{uj}} E(u_{jt} I(\alpha_j x_{jt} + u_{jt} - c_j)) + E(v_t I(\alpha_j x_{jt} + u_{jt} - c_j))$$

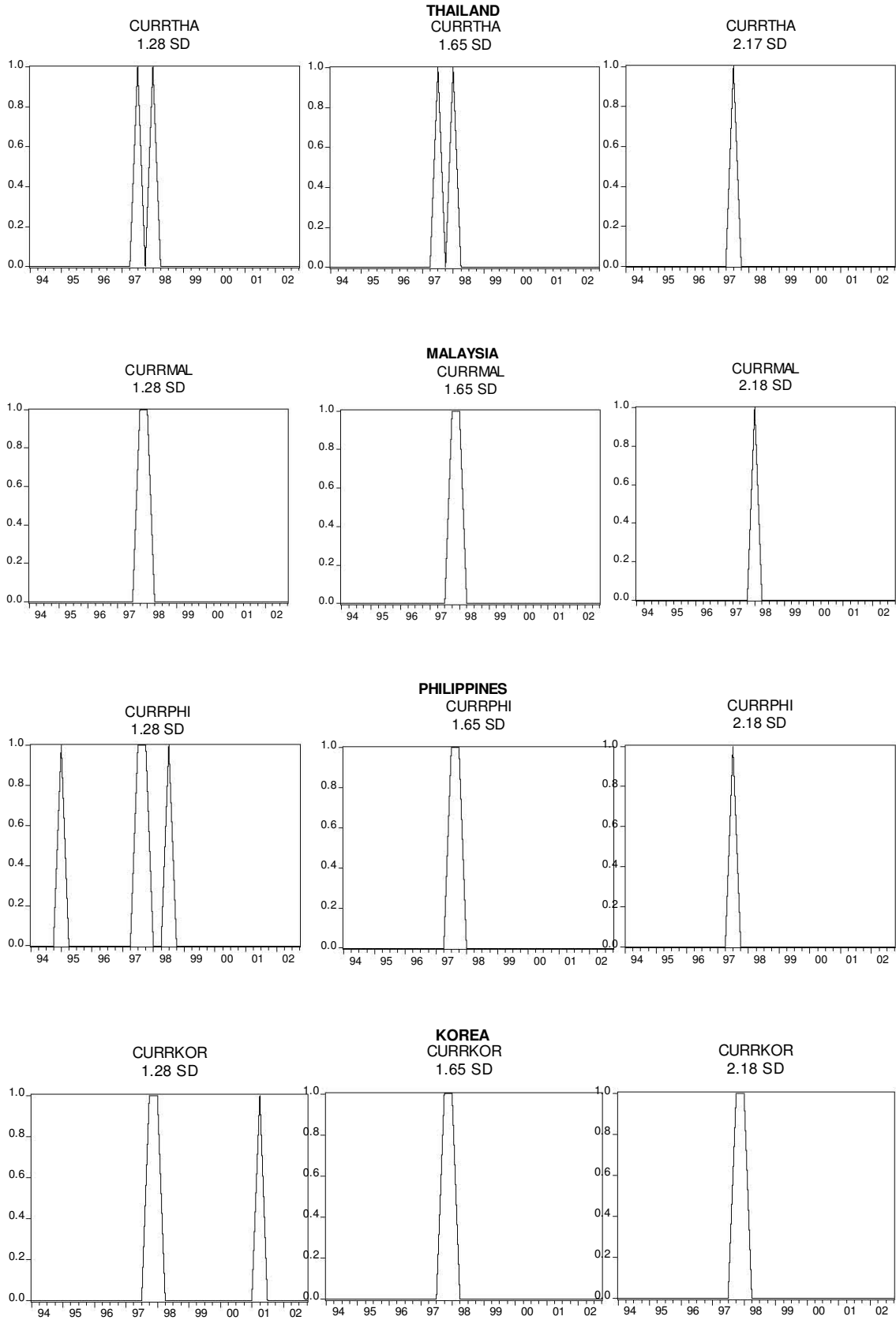
Given the independence between errors  $v_t$  and the rest of the variables, then we have that  $E(v_t I(\alpha_j x_{jt} + u_{jt} - c_j)) = 0$  and

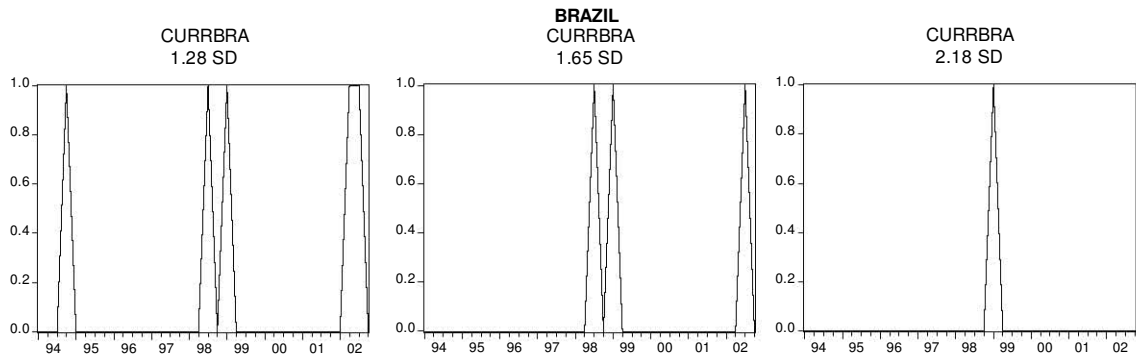
$$E(u_{it} I(y_{jt} - c_j)) = \rho \frac{\sigma_{ui}}{\sigma_{uj}} E(u_{jt} I(\alpha_j x_{jt} + u_{jt} - c_j)) \neq 0$$

## A3.2: Currency and financial dummy variables

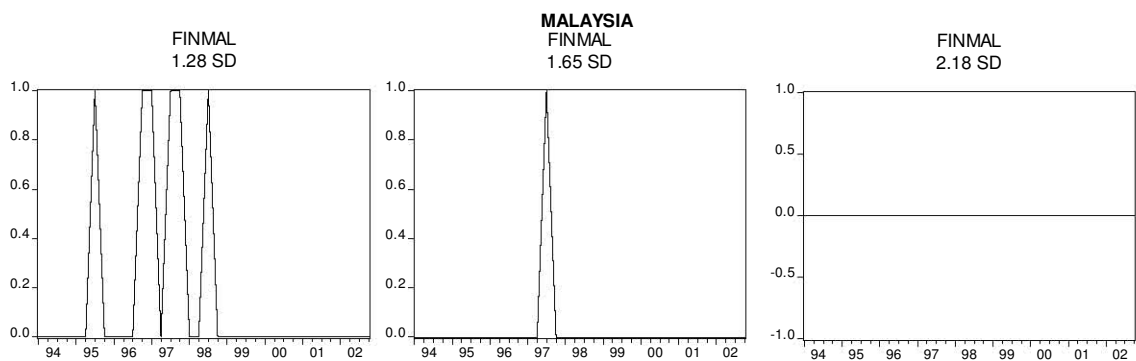
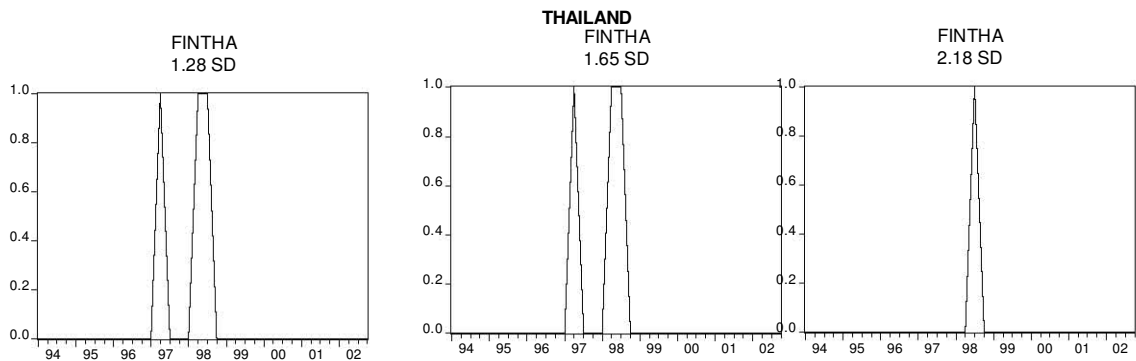
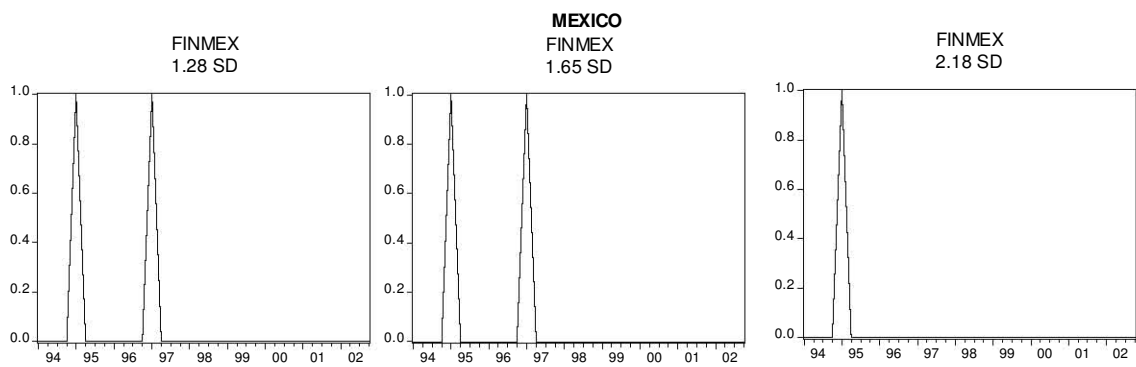
### A3.2.1. CURR series with different thresholds



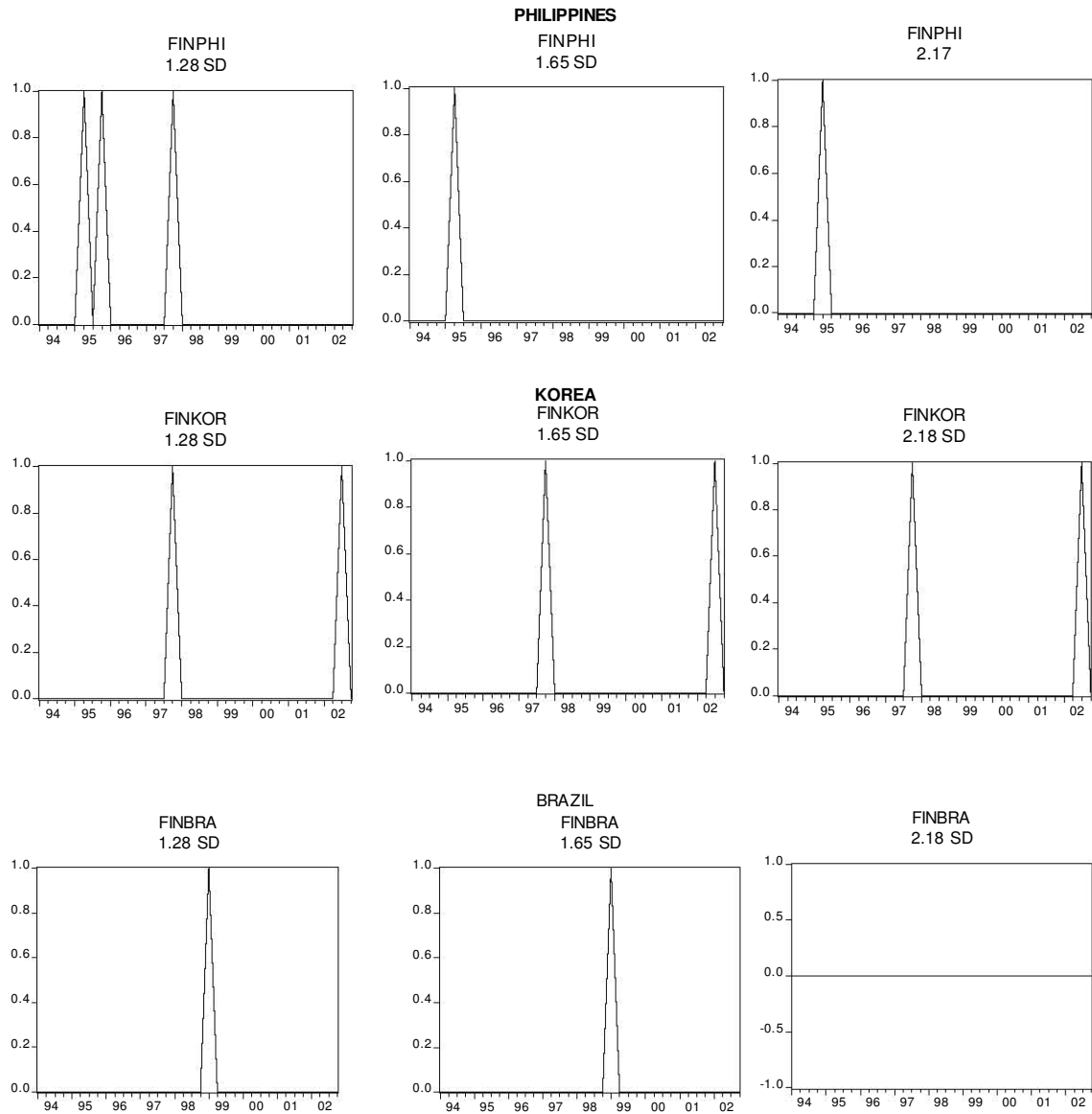




### A3.2.2. FIN series with different thresholds

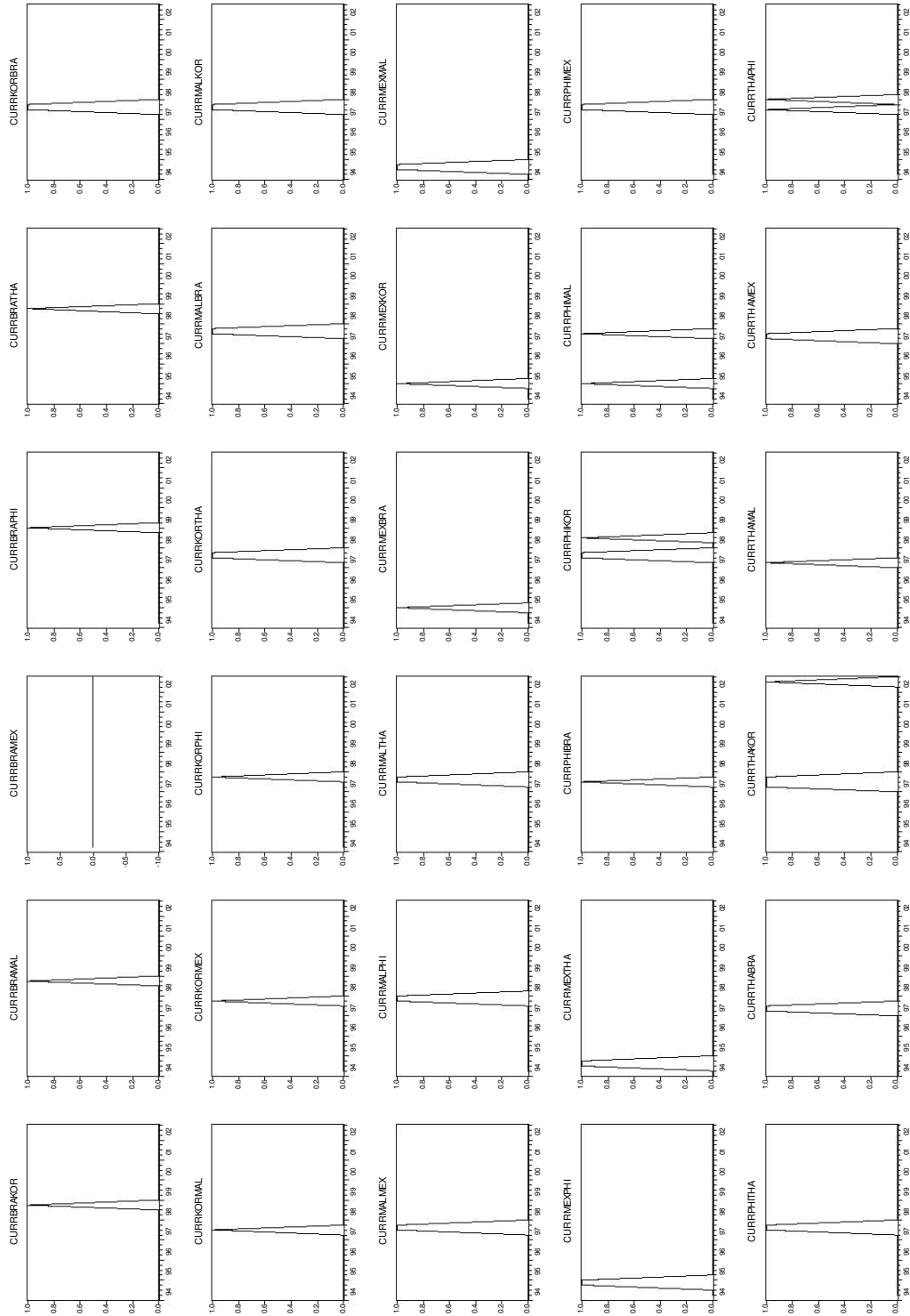






### A3.3: 2-SLS estimations

#### A3.3.1. Fitted conditional CURR series for all countries: threshold 1.65 SD



### A3.3.2. Currency crises conditional to financial crisis (threshold=1.28 SD)

We present the estimation of the Pesaran and Pick (2005) model for the EMP of Thailand and Mexico. We chose these two countries because they are representative of the 1990's crises. Thailand was the first country to suffer a crisis in South East Asia and Mexico in Latin America. As first stage we estimate with OLS the EMP for each separate equation and obtain the estimated EMP for Thailand and for Mexico.

Variable	Dependent Variable: EMPMEX		Dependent Variable: EMPTHA	
	Coefficient	Prob.	Coefficient	Prob.
LIBOR	18.4755	0.3066	26.9993	0.0929
WINF	7.998055	0.7976	-54.17457	0.0565
WIPG	8.740851	0.7994	-41.72428	0.1725
OILP	2.358198	0.6255	0.257538	0.9509
OGAPMEX	-3.139438	0.8495	20.91777	0.1562
GOVMEX	0.012365	0.7880	0.038721	0.3373
CAMEX	0.14303	0.7782	-0.689651	0.1288
M2MEX	-35.1637	0.0038	-5.25801	0.5766
FINMEX	2.947234	0.0985	0.000471	0.9997
FINMEX(-1)	-1.859297	0.3699	0.881819	0.6215
OGAPTHA	5.582366	0.7080	26.98553	0.0476
GOVTHA	-0.00532	0.9020	-0.000272	0.9942
CATHA	-0.003875	0.8330	0.001586	0.9207
M2THA	2.642778	0.6318	0.771733	0.8715
FINTHA	1.258857	0.4469	-1.10654	0.4411
FINTHA(-1)	0.85798	0.6146	0.240717	0.8703

Each of the fitted EMP series are renamed to denote the country they are conditional to; in other words, the estimated EMP for Mexico given the information of Thailand is labelled MEXTHAMEMP and the estimated EMP for Thailand given the information of Mexico is labelled MEXTHATEMP. Since the results are exactly the same for this threshold and the 1.65, the residuals have the same properties at this stage of the estimation.

We obtained the same strength of the instruments than when having a threshold of 1.68 SD.

F-statistic	Value	Probability
Equation: MEXTHAMEMP	2.1117	0.0608
Equation: MEXTHATEMP	2.0270	0.0714

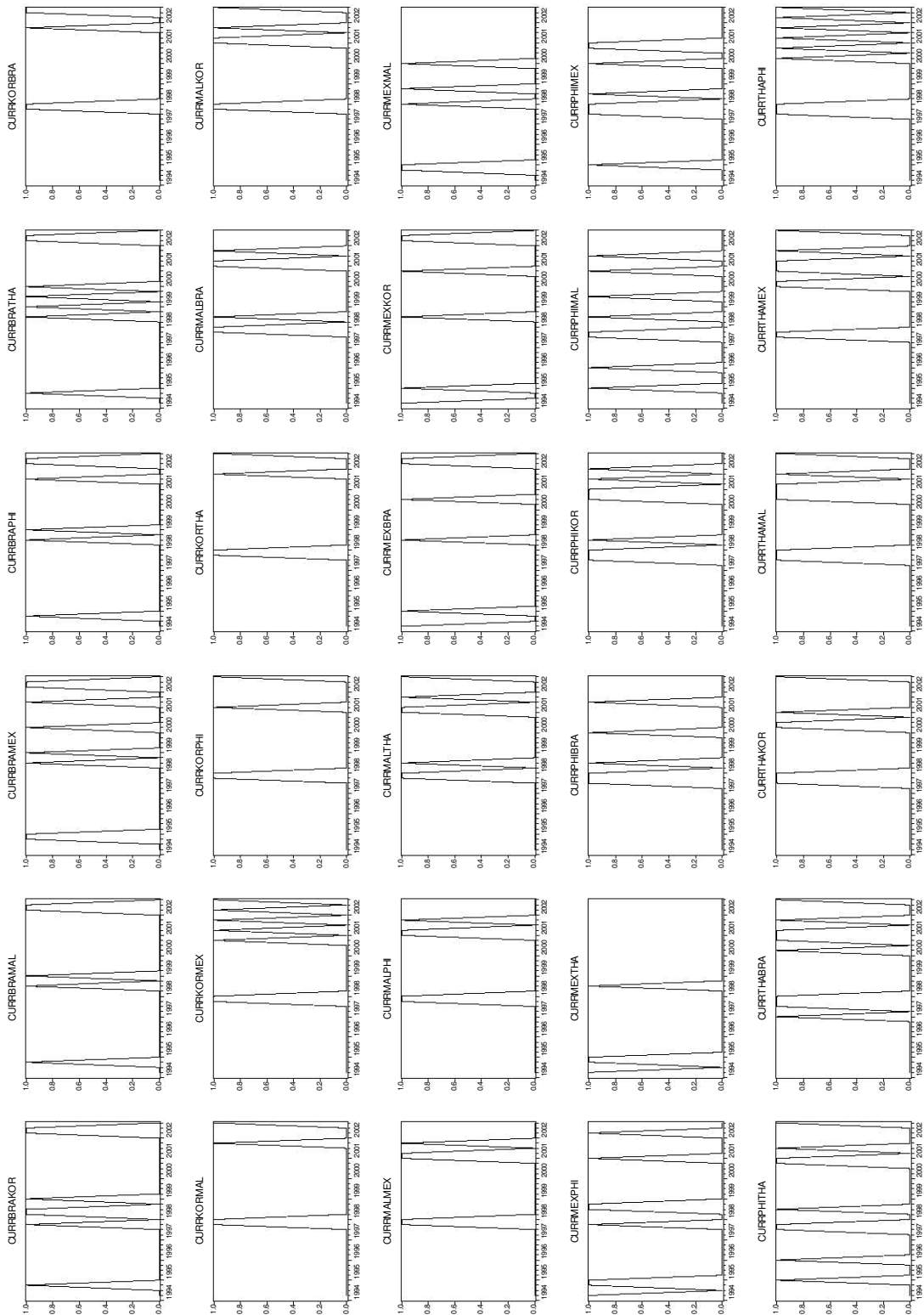
Again, with the fitted values of the EMP we obtain new series of the non-linear variables for a currency crisis. In this particular case these are labelled: CURRTHAMEX which is the currency crisis variable of Thailand given the information of Mexico; and, CURRMEXTHA for the currency crisis variable of Mexico given the information of Thailand.

Dependent Variable: EMPMEX			Dependent Variable: EMPTHA		
	Coefficient	Prob.		Coefficient	Prob.
LIBOR	30.5834	0.1204	LIBOR	35.9572	0.026
WINF	-12.9083	0.7963	WINF	-104.7045	0.0671
WIPG	0.3994	0.625	WIPG	-31.10766	0.2865
OILP	1.7449	0.7301	OILP	-4.794291	0.261
OGAPMEX	-4.4300	0.5881	OGAPTHA	18.06784	0.0584
GOVMEX	0.0186	0.6565	GOVTHA	0.001132	0.9732
CAMEX	-0.0408	0.6639	CATHA	0.003789	0.7531
M2MEX	-34.5547	0.0032	M2THA	0.811858	0.8635
FINMEX	2.9245	0.1095	FINTHA	-2.008532	0.1257
FINMEX(-1)	-0.8862	0.4593	FINTHA(-1)	0.6759	0.6098
CURRTHAMEX	-0.7018	0.5997	CURRMEXTHA	1.712533	0.2118
CURRTHAMEX(-1)	0.3253	0.5529	CURRMEXTHA(-1)	-0.255454	0.8652
R-squared	0.6083		R-squared	0.5096	
Adjusted R-squared	0.4125		Adjusted R-squared	0.2644	

In this stage the results change because the fitted CURR series for both countries change. We tested again for normality and autocorrelation of the residuals at this second stage. As we can see, there is no evidence to reject the null hypotheses of absence of autocorrelation and normality respectively.

	<i>EMPMEX</i> <i>RESIDUALS</i>	<i>EMPTHA</i> <i>RESIDUALS</i>
<i>BREUSCH-GODFREY</i>	<i>1.1607</i>	<i>0.2651</i>
<i>PROBABILITY</i>	<i>0.3335</i>	<i>0.7698</i>
<i>JARQUE-BERA</i>	<i>3.7720</i>	<i>1.3179</i>
<i>PROBABILITY</i>	<i>0.1517</i>	<i>0.5174</i>

Fitted conditional CURR series for all countries



### A3.3.3: Financial crises conditional to currency crises (threshold=1.65 SD)

In this annex we present the estimation of the Pesaran and Pick (2005) model for the FMP of Thailand and Mexico. We chose these two countries because they are representative of the 1990's crises. Thailand was the first country to suffer a crisis in South East Asia and Mexico in Latin America. As first stage we estimate with OLS the FMP for each separate equation and obtain the estimated FMP of Thailand and for Mexico.

Variable	Dependent Variable: FMPMEX		Dependent Variable: FMPTHA	
	Coefficient	Prob.	Coefficient	Prob.
LIBOR	-26.2224	0.1991	7.942162	0.5953
WINF	43.44143	0.1324	18.39553	0.3833
WIPG	50.21732	0.0866	24.13872	0.2587
OILP	-11.95832	0.0164	-2.049845	0.5524
OGAPMEX	11.5895	0.5208	-37.65053	0.0103
GOVMEX	-0.014007	0.7164	-0.02353	0.4166
CAMEX	0.845222	0.1148	1.258742	0.0038
M2MEX	12.80559	0.4219	-29.3623	0.0207
CURRMEX	6.904085	0.0531	0.040905	0.9871
CURRMEX(-1)	-0.730359	0.8038	-7.669816	0.0022
OGAPTHA	-4.430962	0.6844	9.967202	0.2284
GOVTHA	0.013173	0.8585	-0.187422	0.0027
CATHA	0.001985	0.9499	-0.077297	0.0035
M2THA	-4.015353	0.4138	10.81765	0.0071
CURRTHA	-0.866831	0.6700	3.682611	0.0234
CURRTHA(-1)	0.761017	0.8619	12.83301	0.0008

Each of the fitted FMP series are renamed to denote the country they are conditional to; in other words, the estimated FMP for Mexico given the information of Thailand is labelled MEXTHAMFMP and the estimated FMP for Thailand given the information of Mexico is labelled MEXTHATFMP. In this case we don't have evidence to reject the null hypotheses of normality and no serial correlation at 5% significance in the case of Mexico.

	<i>FMPMEX</i> <i>RESIDUALS</i>	<i>FMPTHA</i> <i>RESIDUALS</i>
<i>BREUSCH-GODFREY</i>	<i>3.5451</i>	<i>0.2534</i>
<i>PROBABILITY</i>	<i>0.0517</i>	<i>0.7790</i>
<i>JARQUE-BERA</i>	<i>0.3387</i>	<i>0.0013</i>
<i>PROBABILITY</i>	<i>0.8442</i>	<i>0.9993</i>

Again, the instruments are strong for this first stage.

F-statistic	Value	Probability
Equation: MEXTHATFMP	3.0875	0.0105
Equation: MEXTHAMFMP	1.8939	0.0923

With the fitted values of the FMP we obtain new series of the non-linear variables for a financial crisis. In this particular case these are labelled: FINTHAMEX which is the financial crisis variable of Thailand given the information of Mexico; and,

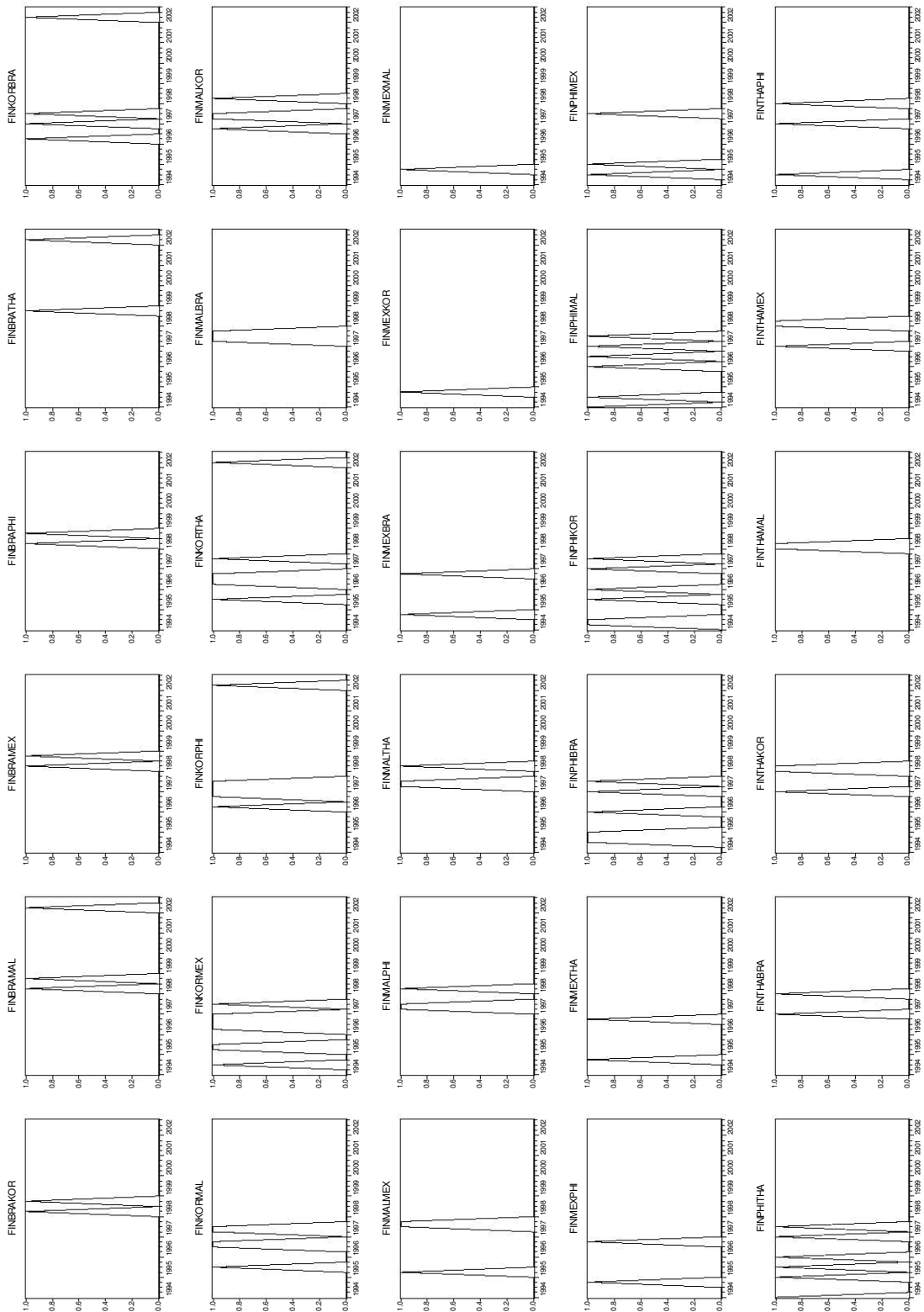
FINMEXTHA for the financial crisis variable of Mexico given the information of Thailand.

Dependent Variable: FMPMEX			Dependent Variable: FMPTHA		
	Coefficient	Prob.		Coefficient	Prob.
LIBOR	-15.7479	0.3245	LIBOR	-13.9238	0.1744
WINF	32.2874	0.1855	WINF	33.4138	0.1407
WIPG	45.8047	0.0761	WIPG	14.0531	0.5908
OILP	-10.4748	0.0072	OILP	-5.0739	0.2324
OGAPMEX	2.9884	0.8424	OGAPTHA	4.0292	0.5763
GOVMEX	-0.0067	0.8136	GOVTHA	-0.1150	0.0750
CAMEX	0.9964	0.0075	CATHA	-0.0451	0.0809
M2MEX	0.9479	0.9394	M2THA	6.6622	0.1173
CURRMEX	5.3748	0.0534	CURRTHA	-0.3379	0.8121
CURRMEX(-1)	-2.2764	0.3100	CURRTHA(-1)	8.9033	0.0248
FINTHAMEX	0.6247	0.6116	FINMEXTHA	0.7878	0.5278
FINTHAMEX(-1)	0.3569	0.7305	FINMEXTHA(-1)	0.8901	0.5419
R-squared	0.5852		R-squared	0.4288	
Adjusted R-squared	0.3868		Adjusted R-squared	0.1556	

In this case, we don't have evidence to reject the null hypotheses of no serial correlation and normality at 5% significance.

	<i>FMPMEX</i> <i>RESIDUALS</i>	<i>FMPTHA</i> <i>RESIDUALS</i>
<i>BREUSCH-GODFREY</i>	<i>2.3901</i>	<i>0.1937</i>
<i>PROBABILITY</i>	<i>0.0789</i>	<i>0.8254</i>
<i>JARQUE-BERA</i>	<i>0.5827</i>	<i>0.3467</i>
<i>PROBABILITY</i>	<i>0.7473</i>	<i>0.8409</i>

Fitted conditional FIN series for all countries





### A3.3.4: Financial crises conditional to currency crises (threshold=1.28 SD)

In this annex we present the estimation of the Pesaran and Pick (2005) model for the FMP of Thailand and Mexico. We chose these two countries because they are representative of the 1990's crises. Thailand was the first country to suffer a crisis in South East Asia and Mexico in Latin America. As first stage we estimate with OLS the FMP for each separate equation and obtain the estimated FMP of Thailand and for Mexico.

Variable	Dependent Variable: FMPMEX		Dependent Variable: FMPTHA	
	Coefficient	Prob.	Coefficient	Prob.
LIBOR	-37.5491	0.1550	16.4434	0.4585
WINF	41.4309	0.1751	7.4970	0.7694
WIPG	39.9765	0.2067	24.5994	0.3598
OILP	-12.4160	0.0182	-3.6014	0.3930
OGAPMEX	25.8723	0.2151	-32.7536	0.0736
GOVMEX	-0.0135	0.7443	-0.0079	0.8249
CAMEX	0.2872	0.5706	0.7669	0.0881
M2MEX	28.4609	0.1908	-30.1924	0.1095
CURRMEX	3.6596	0.1288	0.7888	0.6942
CURRMEX(-1)	3.6014	0.2291	-4.4450	0.0895
OGAPTHA	-7.6054	0.5196	9.7103	0.3407
GOVTHA	0.0507	0.4935	-0.1214	0.0660
CATHA	0.0196	0.5402	-0.0558	0.0519
M2THA	-6.6523	0.2207	9.8496	0.0414
CURRTHA	-2.4104	0.2379	2.0630	0.2386
CURRTHA(-1)	-1.1114	0.8020	9.1856	0.0240

Each of the fitted FMP series are renamed to denote the country they are conditional to; in other words, the estimated FMP for Mexico given the information of Thailand is labelled MEXTHAMFMP and the estimated FMP for Thailand given the information of Mexico is labelled MEXTHATFMP. Again we don't have evidence to reject the null hypotheses of no serial correlation and normality.

	<i>FMPMEX</i> <i>RESIDUALS</i>	<i>FMPTHA</i> <i>RESIDUALS</i>
<i>BREUSCH-GODFREY</i>	1.7122	0.7223
<i>PROBABILITY</i>	0.2102	0.5000
<i>JARQUE-BERA</i>	3.8352	0.7664
<i>PROBABILITY</i>	0.1470	0.6817

In this case the instruments are weaker but still relevant.

F-statistic	Value	Probability
Equation: MEXTHATFMP	1.5669	0.1740
Equation: MEXTHAMFMP	1.7060	0.1328

With the fitted values of the FMP we obtain new series of the non-linear variables for a financial crisis. In this particular case these are labelled: FINTHAMEX which is the financial

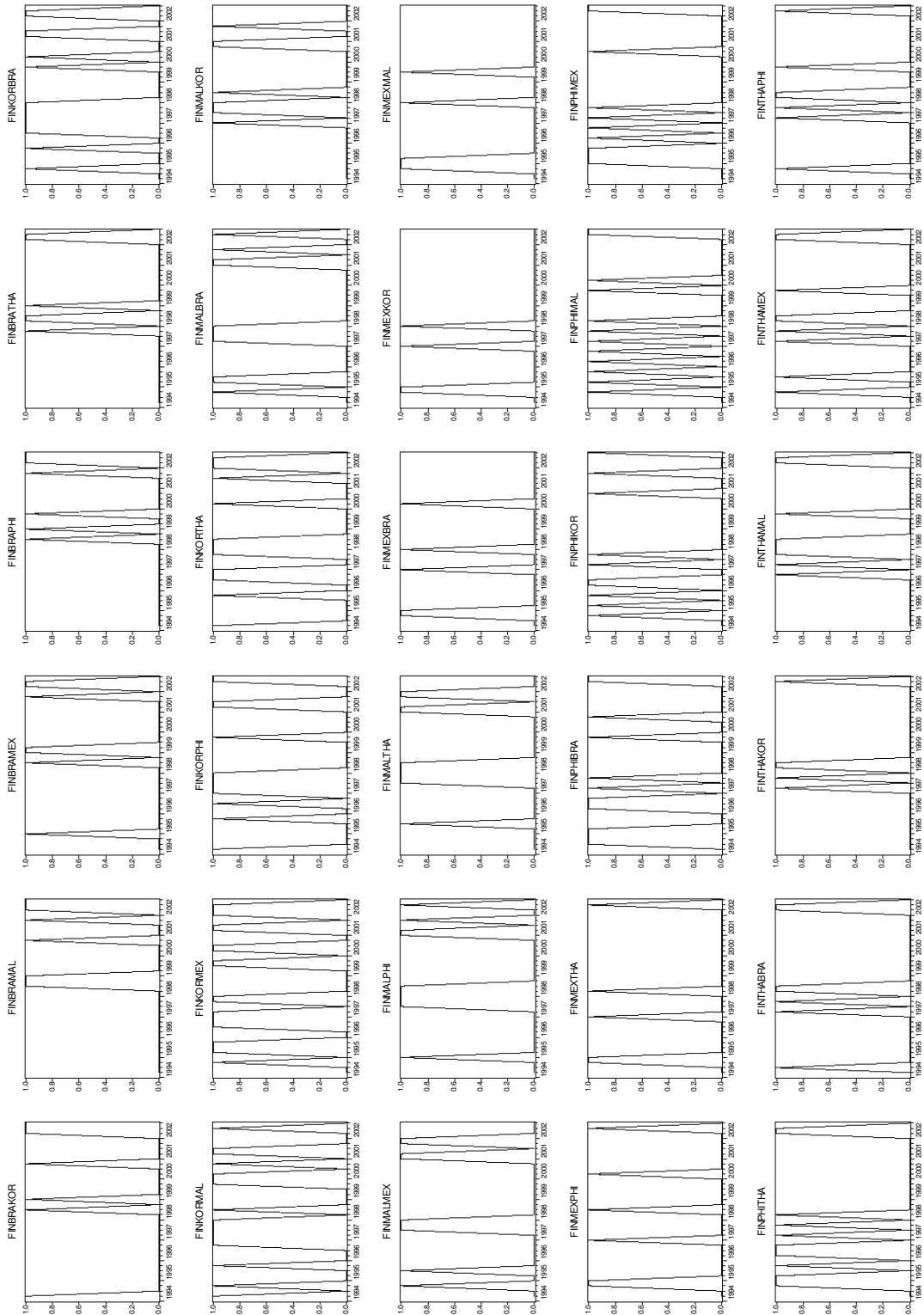
crisis variable of Thailand given the information of Mexico; and, FINMEXTHA for the financial crisis variable of Mexico given the information of Thailand.

Dependent Variable: FMPMEX			Dependent Variable: FMPTHA		
	Coefficient	Prob.		Coefficient	Prob.
LIBOR	3.4654	0.8666	LIBOR	-16.4572	0.1864
WINF	-33.4137	0.3829	WINF	41.6921	0.2418
WIPG	49.2814	0.0873	WIPG	23.1304	0.4319
OILP	-12.5348	0.0008	OILP	-4.9568	0.2704
OGAPMEX	-2.8774	0.8673	OGAPTHA	4.7878	0.5076
GOVMEX	0.0077	0.7993	GOVTHA	-0.0936	0.1497
CAMEX	1.1109	0.0047	CATHA	-0.0383	0.1181
M2MEX	0.6239	0.9651	M2THA	5.7079	0.1858
CURRMEX	4.2655	0.0368	CURRTHA	-0.3530	0.8072
CURRMEX(-1)	-0.2732	0.9003	CURRTHA(-1)	7.8211	0.0317
FINTHAMEX	-0.9182	0.2290	FINMEXTHA	0.1887	0.8658
FINTHAMEX(-1)	0.8328	0.2154	FINMEXTHA(-1)	0.6621	0.4396
R-squared	0.5728		R-squared	0.4403	
Adjusted R-squared	0.3592		Adjusted R-squared	0.1605	

In this case with a lower threshold we have evidence to reject the null hypothesis of serial correlation in Mexico at 5% significance. Regarding normality there is no evidence to reject the null hypothesis of normality in either country.

	FMPMEX residuals	FMPTHA residuals
Breusch-Godfrey	4.1628	0.3453
Probability	0.0308	0.7122
Jarque-Bera	3.1589	0.9835
Probability	0.2061	0.6116

Fitted conditional FIN series for all countries





## Annex to Chapter 4

### A4.1: Consumption behaviour

#### A4.1.1 Unit root tests

Mexico, breakpoint at 1995/02

ADF Test Statistic	-2.9040	1% Critical Value*	-2.6182
		5% Critical Value	-1.9488
		10% Critical Value	-1.6199

\*MacKinnon critical values for rejection of hypothesis of a unit root.

Mexico, breakpoint at 1994/04

ADF Test Statistic	-3.1430	1% Critical Value*	-2.6182
		5% Critical Value	-1.9488
		10% Critical Value	-1.6199

\*MacKinnon critical values for rejection of hypothesis of a unit root.

Korea, breakpoint at 1998/02

ADF Test Statistic	-3.3201	1% Critical Value*	-2.6132
		5% Critical Value	-1.9480
		10% Critical Value	-1.6195

\*MacKinnon critical values for rejection of hypothesis of a unit root.

Korea, breakpoint at 1997/04

ADF Test Statistic	-2.7496	1% Critical Value*	-2.6132
		5% Critical Value	-1.9480
		10% Critical Value	-1.6195

\*MacKinnon critical values for rejection of hypothesis of a unit root.

Malaysia, breakpoint at 1998/02

ADF Test Statistic	-3.5787	1% Critical Value*	-2.6182
		5% Critical Value	-1.9488
		10% Critical Value	-1.6199

\*MacKinnon critical values for rejection of hypothesis of a unit root.

Malaysia, breakpoint at 1997/04

ADF Test Statistic	-2.9436	1% Critical Value*	-2.6182
		5% Critical Value	-1.9488
		10% Critical Value	-1.6199

\*MacKinnon critical values for rejection of hypothesis of a unit root.

Philippines, breakpoint at 1998/02

ADF Test Statistic	-2.9604	1% Critical Value*	-2.6182
		5% Critical Value	-1.9488
		10% Critical Value	-1.6199

\*MacKinnon critical values for rejection of hypothesis of a unit root.

Philippines, breakpoint at 1998/01

ADF Test Statistic	-2.8055	1% Critical Value*	-2.6168
		5% Critical Value	-1.9486
		10% Critical Value	-1.6198

\*MacKinnon critical values for rejection of hypothesis of a unit root.

## Thailand, breakpoint at 1998/01

ADF Test Statistic	-2.1127	1% Critical Value*	-2.6321
		5% Critical Value	-1.9510
		10% Critical Value	-1.6209

\*MacKinnon critical values for rejection of hypothesis of a unit root.

## Thailand, breakpoint at 1997/03

ADF Test Statistic	-2.5144	1% Critical Value*	-2.6321
		5% Critical Value	-1.9510
		10% Critical Value	-1.6209

\*MacKinnon critical values for rejection of hypothesis of a unit root.

## Brazil, breakpoint at 1998/01

ADF Test Statistic	-2.6884	1% Critical Value*	-2.6395
		5% Critical Value	-1.9521
		10% Critical Value	-1.6214

\*MacKinnon critical values for rejection of hypothesis of a unit root.

## Brazil, breakpoint at 1997/04

ADF Test Statistic	-2.1767	1% Critical Value*	-2.6423
		5% Critical Value	-1.9526
		10% Critical Value	-1.6216

\*MacKinnon critical values for rejection of hypothesis of a unit root.

#### A4.1.2 Results of the estimation of crises' optimal breakpoints

Dependent Variable: MEXICO

Sample: 1991:1 2002:4

Variable	Coefficient	Prob.
C	2.3824	0.0000
@TREND	0.0179	0.0000
@TREND*MEX	-0.0067	0.0023
MEX	-0.0997	0.0010
R-squared	0.9139	
Adjusted R-squared	0.9080	
Akaike info criterion	-3.7327	
Schwarz criterion	-3.5767	

Dependent Variable: BRAZIL

Sample(adjusted): 1994:1 2002:3

Variable	Coefficient	Prob.
C	6.717314	0
@TREND	0.0237	0

@TREND*BRZ(+1)	-0.019804	0
BRZ(1)	0.22357	0

R-squared	0.933165
Adjusted R-squared	0.926697
Akaike info criterion	-4.123968
Schwarz criterion	-3.946214

Dependent Variable:  
PHILIPPINES  
Sample(adjusted): 1991:2 2002:4

Variable	Coefficient	Prob.
C	1.110235	0
@TREND	0.008694	0
@TREND*PHI(-1)	-0.000158	0.6314
PHI(-1)	-0.008097	0.4776
R-squared	0.996605	
Adjusted R-squared	0.996368	
Akaike info criterion	-7.053249	
Schwarz criterion	-6.895789	

Dependent Variable: KOREA  
Sample: 1990:1 2002:4

Variable	Coefficient	Prob.
C	5.725206	0
@TREND	0.022758	0
@TREND*KOR	-0.005169	0
KOR	-0.051246	0.1483
R-squared	0.99282	
Adjusted R-squared	0.992371	
Akaike info criterion	-4.814998	
Schwarz criterion	-4.664903	

Dependent Variable: THAILAND  
Sample: 1993:1 2002:4

Variable	Coefficient	Prob.
C	1.562055	0
@TREND	0.014787	0
@TREND*THAI	-0.005546	0.0005
THAI	-0.106427	0.0012

R-squared	0.889422
Adjusted R-squared	0.880208
Akaike info criterion	-4.352839
Schwarz criterion	-4.183951

Dependent Variable: MALAYSIA

Sample: 1991:1 2002:4

Variable	Coefficient	Prob.
C	5.272396	0
@TREND	0.016882	0
@TREND*MAL	-0.001869	0.179
MAL	-0.139997	0.0038
R-squared	0.965199	
Adjusted R-squared	0.962826	
Akaike info criterion	-4.080844	
Schwarz criterion	-3.924911	



## A4.2: Solution for Lucas (1987)

Assuming the consumption process we can verify the solution provided by Lucas (1987):

$$\begin{aligned}
 c_t^{1-\rho} &= C_0^{1-\rho} (1+g)^{(1-\rho)t} \left[ \exp\left(\varepsilon_t - \frac{1}{2}\text{Var}(\varepsilon)\right) \right]^{1-\rho} \\
 &= C_0^{1-\rho} (1+g)^{(1-\rho)t} \exp\left((1-\rho)\varepsilon_t - (1-\rho)\frac{1}{2}\text{Var}(\varepsilon)\right) \\
 &= C_0^{1-\rho} (1+g)^{(1-\rho)t} \exp((1-\rho)\varepsilon_t) \exp\left(- (1-\rho)\frac{1}{2}\text{Var}(\varepsilon)\right)
 \end{aligned}$$

Where  $\varepsilon_t$  is an uncorrelated stationary stochastic process with a stationary distribution given by  $\varepsilon \sim N(0, \text{Var}(\varepsilon))$  so that the expected utility of consumption in date  $t$  conditional on the information on date 0, can be calculated as:

$$\begin{aligned}
 E\left(\frac{c_t^{1-\rho}}{1-\rho} \mid I_0\right) &= E\left(\frac{C_0^{1-\rho} (1+g)^{(1-\rho)t} \exp\left(- (1-\rho)\frac{1}{2}\text{Var}(\varepsilon)\right) \exp((1-\rho)\varepsilon_t)}{1-\rho}\right) \\
 &= \frac{C_0^{1-\rho}}{1-\rho} (1+g)^{(1-\rho)t} \exp\left(- (1-\rho)\frac{1}{2}\text{Var}(\varepsilon)\right) E \exp((1-\rho)\varepsilon_t) \\
 &= \frac{C_0^{1-\rho}}{1-\rho} (1+g)^{(1-\rho)t} \exp\left(- (1-\rho)\frac{1}{2}\text{Var}(\varepsilon)\right) \exp\left((1-\rho)^2 \frac{1}{2}\text{Var}(\varepsilon)\right) \\
 &= \frac{C_0^{1-\rho}}{1-\rho} (1+g)^{(1-\rho)t} \exp\left((1-\rho)\frac{1}{2}\text{Var}(\varepsilon)((1-\rho)-1)\right) \\
 &= \frac{C_0^{1-\rho}}{1-\rho} (1+g)^{(1-\rho)t} \exp\left(-\frac{1}{2}\text{Var}(\varepsilon)\rho(1-\rho)\right)
 \end{aligned}$$

We can calculate the discounted lifetime expected utility stream:

$$\begin{aligned}
 U &= \frac{1}{1-\rho} \sum_{t=0}^{\infty} \beta^t \left( C_0^{1-\rho} (1+g)^{(1-\rho)t} \exp\left(-\frac{1}{2}\rho(1-\rho)\text{Var}(\varepsilon)\right) \right) \\
 &= \frac{C_0^{1-\rho} \exp\left(-\frac{1}{2}\rho(1-\rho)\text{Var}(\varepsilon)\right)}{1-\rho} \sum_{t=0}^{\infty} \beta^t (1+g)^{(1-\rho)t} \\
 &= \frac{C_0^{1-\rho}}{1-\rho} \cdot \frac{1}{1-\beta(1+g)^{1-\rho}} \exp\left(-\frac{1}{2}\rho(1-\rho)\text{Var}(\varepsilon)\right)
 \end{aligned}$$

The parameter  $\tau$  is the ‘compensation’ for variations in the parameters  $g$  and  $\text{Var}(\varepsilon)$ ; therefore, the parameter  $g$  is the average growth rate in total consumption and  $\text{Var}(\varepsilon)$  as the

variance of the log of consumption about trend. With these parameters we can describe the real consumption path as being a function of  $c_t(\tau, g, Var(\varepsilon))$  and a utility function  $U$  that depends on consumption.

Furthermore, we can obtain a measure of *compensating* variations in  $c_t$  to evaluate various levels of  $g$  and  $Var(\varepsilon)$ . To evaluate changes in the growth rate  $g$ , let us define  $\tau$  as a function  $\tau_g(g_0, g_1)$  such that:

$$u_1(\tau_g(g_0, g_1), g, Var(\varepsilon)) = u_0(0, g_0, Var(\varepsilon))$$

Where  $u_0$  is the utility before the change has occurred and  $u_1$  is the utility after the change. In this case,  $\tau_g(g_0, g_1)$  is the percentage change in consumption, uniform across all dates and values of the shocks, required to leave the consumer indifferent between the growth rates  $g_1$  and  $g_0$ ; in other words, is the cost of reducing consumption growth from  $g_0$  to  $g_1$ . Equating the lifetime utility streams we have:

$$\frac{((1+\tau_g)\bar{C}_0)^{1-\rho}}{1-\rho} \cdot \frac{1}{1-\beta(1+g_1)^{1-\rho}} \exp\left(-\frac{1}{2}\rho(1-\rho)Var(\varepsilon)\right) = \frac{\bar{C}_0^{1-\rho}}{1-\rho} \cdot \frac{1}{1-\beta(1+g_0)^{1-\rho}} \exp\left(-\frac{1}{2}\rho(1-\rho)Var(\varepsilon)\right)$$

And solving for  $\tau$  we have

$$(1+\tau_g)^{1-\rho} \frac{\bar{C}_0^{1-\rho}}{1-\rho} \cdot \frac{1}{1-\beta(1+g_1)^{1-\rho}} \exp\left(-\frac{1}{2}\rho(1-\rho)Var(\varepsilon)\right) = \frac{\bar{C}_0^{1-\rho}}{1-\rho} \cdot \frac{1}{1-\beta(1+g_0)^{1-\rho}} \exp\left(-\frac{1}{2}\rho(1-\rho)Var(\varepsilon)\right)$$

$$(1+\tau_g)^{1-\rho} \frac{1}{1-\beta(1+g_1)^{1-\rho}} = \frac{1}{1-\beta(1+g_0)^{1-\rho}}$$

Rearranging

$$(1+\tau_g)^{1-\rho} = \frac{1-\beta(1+g_1)^{1-\rho}}{1-\beta(1+g_0)^{1-\rho}} \Rightarrow$$

$$\tau_g = \left( \frac{1-\beta(1+g_1)^{1-\rho}}{1-\beta(1+g_0)^{1-\rho}} \right)^{1/1-\rho} - 1$$

The costs of economic instability (increased variance in real consumption), can be measured in conceptually identical way. Let's define the function  $\tau_{var}(Var(\varepsilon))$  as the percentage increase in consumption, uniform across all dates and values of the shocks, required to leave the consumer indifferent between consumption instability of  $Var(\varepsilon)$  and a perfectly

smooth consumption path; in other words, is the cost of real consumption instability. As before, the condition to be met is:

$$u_1(\tau_{Var}(Var(\varepsilon)), g_0, Var(\varepsilon)) = u_0(0, g_0, 0)$$

This implies:

$$\frac{((1 + \tau_{Var})\bar{C}_0)^{1-\rho}}{1-\rho} \cdot \frac{1}{1-\beta(1+g_0)^{1-\rho}} \exp\left(-\frac{1}{2}\rho(1-\rho)Var(\varepsilon)\right) = \frac{\bar{C}_0^{1-\rho}}{1-\rho} \cdot \frac{1}{1-\beta(1+g_0)^{1-\rho}}$$

And solving for  $\tau$  we have

$$(1 + \tau_{Var})^{1-\rho} \frac{\bar{C}_0^{1-\rho}}{1-\rho} \cdot \frac{1}{1-\beta(1+g_0)^{1-\rho}} \exp\left(-\frac{1}{2}\rho(1-\rho)Var(\varepsilon)\right) = \frac{\bar{C}_0^{1-\rho}}{1-\rho} \cdot \frac{1}{1-\beta(1+g_0)^{1-\rho}}$$

$$(1 + \tau_{Var})^{1-\rho} = \exp\left(\frac{1}{2}\rho(1-\rho)Var(\varepsilon)\right)$$

Rearranging

$$\tau_{Var} = \exp\left(\frac{1}{2}\rho(1-\rho)Var(\varepsilon)\right)^{\frac{1}{1-\rho}} - 1$$

### A4.3: Lifetime utility stream for habit formation in preferences

Consumption follows the same process as before:

$$c_t = C_0 (1+g)^t \left[ \exp\left(\varepsilon_t - \frac{1}{2} \text{Var}(\varepsilon)\right) \right]$$

$$(C_{t+1} - \delta C_t)^{1-\rho} = \left( C_0 (1+g)^{t+1} \left[ \exp\left(\varepsilon_{t+1} - \frac{1}{2} \text{Var}(\varepsilon)\right) \right] - \delta C_0 (1+g)^t \left[ \exp\left(\varepsilon_t - \frac{1}{2} \text{Var}(\varepsilon)\right) \right] \right)^{1-\rho}$$

$$= C_0^{1-\rho} (1+g)^{t(1-\rho)} \exp\left(-\frac{1}{2} \text{Var}(\varepsilon)\right)^{1-\rho} \left( (1+g) \left[ \exp(\varepsilon_{t+1}) \right] - \delta \left[ \exp(\varepsilon_t) \right] \right)^{1-\rho}$$

Where  $\varepsilon_t$  is an uncorrelated stationary stochastic process with a stationary distribution given by  $\varepsilon \sim N(0, \text{Var}(\varepsilon))$ . Taking expectations conditional on the information at date  $t$ :

$$E(C_{t+1} - \delta C_t | I_t)^{1-\rho} = C_0^{1-\rho} \exp\left(-\frac{1}{2}(1-\rho)\text{Var}(\varepsilon)\right) (1+g)^{t(1-\rho)} E\left(\left((1+g)\left[\exp(\varepsilon_{t+1})\right] - \delta\left[\exp(\varepsilon_t)\right]\right)^{1-\rho}\right)$$

In order to obtain the expected value we can use a second-order Taylor approximation of the function  $f(\varepsilon_{t+1}, \varepsilon_t) = \left((1+g)\left[\exp(\varepsilon_{t+1})\right] - \delta\left[\exp(\varepsilon_t)\right]\right)^{1-\rho}$ . A second-order Taylor approximation for two variables will take the form:

$$f(x, y) = f(x^0, y^0) + \sum_{i=1}^2 f_i h_i + \sum_{i=1}^2 \sum_{j=1}^2 \frac{f_{ij} h_{ij}}{2!}$$

$$\frac{\delta f}{\delta e_t} = - \frac{\left((1+g)\exp(e_{t+1}) - \delta \exp(e_t)\right)^{1-\rho} (1-\rho) \delta \exp(e_t)}{(1+g)\exp(e_{t+1}) - \delta \exp(e_t)}$$

$$= - \frac{(1-\rho) \delta \exp(e_t)}{\left((1+g)\exp(e_{t+1}) - \delta \exp(e_t)\right)^\rho}$$

$$\frac{\delta f}{\delta e_{t+1}} = \frac{\left((1+g)\exp(e_{t+1}) - \delta \exp(e_t)\right)^{1-\rho} (1-\rho) (1+g) \exp(e_{t+1})}{(1+g)\exp(e_{t+1}) - \delta \exp(e_t)}$$

$$= \frac{(1-\rho) (1+g) \exp(e_{t+1})}{\left((1+g)\exp(e_{t+1}) - \delta \exp(e_t)\right)^\rho}$$

$$\frac{\delta f}{\delta e_t \delta e_{t+1}} = - \frac{\left((1+g)\exp(e_{t+1}) - \delta \exp(e_t)\right)^{1-\rho} (1-\rho)^2 (1+g) \delta \exp(e_{t+1}) \exp(e_t)}{\left((1+g)\exp(e_{t+1}) - \delta \exp(e_t)\right)^2}$$

$$+ \frac{\left((1+g)\exp(e_{t+1}) - \delta \exp(e_t)\right)^{1-\rho} (1-\rho) (1+g) \delta \exp(e_{t+1}) \exp(e_t)}{\left((1+g)\exp(e_{t+1}) - \delta \exp(e_t)\right)^2}$$

$$= \frac{\left((1+g)\exp(e_{t+1}) - \delta \exp(e_t)\right)^{1-\rho} \rho (1-\rho) (1+g) \delta \exp(e_{t+1}) \exp(e_t)}{\left((1+g)\exp(e_{t+1}) - \delta \exp(e_t)\right)^2}$$

$$\begin{aligned}
\frac{\delta f}{\delta e_{t+1} \delta e_t} &= - \frac{((1+g)\exp(e_{t+1}) - \delta \exp(e_t))^{1-\rho} (1-\rho)^2 (1+g) \delta \exp(e_{t+1}) \exp(e_t)}{((1+g)\exp(e_{t+1}) - \delta \exp(e_t))^2} \\
&+ \frac{((1+g)\exp(e_{t+1}) - \delta \exp(e_t))^{1-\rho} (1-\rho)(1+g) \delta \exp(e_{t+1}) \exp(e_t)}{((1+g)\exp(e_{t+1}) - \delta \exp(e_t))^2} \\
&= \frac{((1+g)\exp(e_{t+1}) - \delta \exp(e_t))^{1-\rho} \rho(1-\rho)(1+g) \delta \exp(e_{t+1}) \exp(e_t)}{((1+g)\exp(e_{t+1}) - \delta \exp(e_t))^2} \\
\frac{\delta^2 f}{\delta e_t^2} &= \frac{((1+g)\exp(e_{t+1}) - \delta \exp(e_t))^{1-\rho} (1-\rho)^2 \delta^2 (\exp(e_t))^2}{((1+g)\exp(e_{t+1}) - \delta \exp(e_t))^2} - \frac{((1+g)\exp(e_{t+1}) - \delta \exp(e_t))^{1-\rho} (1-\rho) \delta (\exp(e_t))}{((1+g)\exp(e_{t+1}) - \delta \exp(e_t))} \\
&- \frac{((1+g)\exp(e_{t+1}) - \delta \exp(e_t))^{1-\rho} (1-\rho) \delta^2 (\exp(e_t))^2}{((1+g)\exp(e_{t+1}) - \delta \exp(e_t))^2} \\
&= \frac{(1-\rho)^2 \delta^2 (\exp(e_t))^2 - (1+g)(1-\rho) \delta (\exp(e_t)) \exp(e_{t+1}) + (1-\rho) \delta^2 (\exp(e_t))^2 - (1-\rho) \delta^2 (\exp(e_t))^2}{((1+g)\exp(e_{t+1}) - \delta \exp(e_t))^{1+\rho}} \\
&= \frac{(1-\rho) \delta \exp(e_t) ((1-\rho) \delta \exp(e_t) - (1+g) \exp(e_{t+1}))}{((1+g)\exp(e_{t+1}) - \delta \exp(e_t))^{1+\rho}} \\
\frac{\delta^2 f}{\delta e_{t+1}^2} &= \frac{((1+g)\exp(e_{t+1}) - \delta \exp(e_t))^{1-\rho} (1-\rho)^2 (1+g)^2 (\exp(e_{t+1}))^2}{((1+g)\exp(e_{t+1}) - \delta \exp(e_t))^2} + \frac{((1+g)\exp(e_{t+1}) - \delta \exp(e_t))^{1-\rho} (1-\rho)(1+g) (\exp(e_{t+1}))}{((1+g)\exp(e_{t+1}) - \delta \exp(e_t))} \\
&- \frac{((1+g)\exp(e_{t+1}) - \delta \exp(e_t))^{1-\rho} (1-\rho)(1+g)^2 (\exp(e_{t+1}))^2}{((1+g)\exp(e_{t+1}) - \delta \exp(e_t))^2} \\
&= \frac{(1-\rho)^2 (1+g)^2 (\exp(e_{t+1}))^2 + ((1+g)\exp(e_{t+1}) - \delta \exp(e_t))(1-\rho)(1+g) (\exp(e_{t+1})) - (1-\rho)(1+g)^2 (\exp(e_{t+1}))^2}{((1+g)\exp(e_{t+1}) - \delta \exp(e_t))^{1+\rho}} \\
&= \frac{(1-\rho)^2 (1+g)^2 (\exp(e_{t+1}))^2 + (1-\rho)(1+g)^2 (\exp(e_{t+1}))^2 - (1-\rho)(1+g) \delta (\exp(e_{t+1})) \exp(e_t) - (1-\rho)(1+g)^2 (\exp(e_{t+1}))^2}{((1+g)\exp(e_{t+1}) - \delta \exp(e_t))^{1+\rho}} \\
&= \frac{(1-\rho)(1+g) (\exp(e_{t+1})) ((1-\rho)(1+g) (\exp(e_{t+1})) - \delta \exp(e_t))}{((1+g)\exp(e_{t+1}) - \delta \exp(e_t))^{1+\rho}}
\end{aligned}$$

The second-order Taylor approximation can be expressed as:

$$\begin{aligned}
f(\overline{\varepsilon}_{t+1} = e^1, \overline{\varepsilon}_t = e^0) &+ \frac{\partial f}{\partial \varepsilon_t} (\varepsilon_t - e^0) + \frac{\partial f}{\partial \varepsilon_{t+1}} (\varepsilon_{t+1} - e^1) + \frac{1}{2} \frac{\partial^2 f}{\partial \varepsilon_t \partial \varepsilon_{t+1}} (\varepsilon_t - e^0) (\varepsilon_{t+1} - e^1) \\
&+ \frac{1}{2} \frac{\partial^2 f}{\partial \varepsilon_{t+1} \partial \varepsilon_t} (\varepsilon_{t+1} - e^1) (\varepsilon_t - e^0) + \frac{1}{2} \frac{\partial^2 f}{\partial \varepsilon_t^2} (\varepsilon_t - e^0)^2 + \frac{1}{2} \frac{\partial^2 f}{\partial \varepsilon_{t+1}^2} (\varepsilon_{t+1} - e^1)^2
\end{aligned}$$

If we substitute the partial derivatives we obtain the function:

$$\begin{aligned}
f(\overline{\varepsilon_{t+1}} = e^1, \overline{\varepsilon_t} = e^0) &= \left( (1+g)\exp(e^1) - \delta\exp(e^0) \right)^{1-\rho} \\
&- \frac{(1-\rho)\delta\exp(e^0)}{\left( (1+g)\exp(e^1) - \delta\exp(e^0) \right)^\rho} (\varepsilon_t - e^0) \\
&+ \frac{(1-\rho)(1+g)\exp(e^1)}{\left( (1+g)\exp(e^1) - \delta\exp(e^0) \right)^\rho} (\varepsilon_{t+1} - e^1) \\
&+ \frac{1}{2} \frac{\left( (1+g)\exp(e^1) - \delta\exp(e^0) \right)^{1-\rho} \rho(1-\rho)(1+g)\delta\exp(e^1)\exp(e^0)}{\left( (1+g)\exp(e^1) - \delta\exp(e^0) \right)^2} (\varepsilon_t - e^0)(\varepsilon_{t+1} - e^1) \\
&+ \frac{1}{2} \frac{\left( (1+g)\exp(e^1) - \delta\exp(e^0) \right)^{1-\rho} \rho(1-\rho)(1+g)\delta\exp(e^1)\exp(e^0)}{\left( (1+g)\exp(e^1) - \delta\exp(e^0) \right)^2} (\varepsilon_{t+1} - e^1)(\varepsilon_t - e^0) \\
&+ \frac{1}{2} \frac{(1-\rho)\delta\exp(e^0)\left( (1-\rho)\delta\exp(e^0) - (1+g)\exp(e^1) \right)}{\left( (1+g)\exp(e^1) - \delta\exp(e^0) \right)^{1+\rho}} (\varepsilon_t - e^0)^2 \\
&+ \frac{1}{2} \frac{(1-\rho)(1+g)\left( \exp(e^1) \right)\left( (1-\rho)(1+g)\left( \exp(e^1) \right) - \delta\exp(e^0) \right)}{\left( (1+g)\exp(e^1) - \delta\exp(e^0) \right)^{1+\rho}} (\varepsilon_{t+1} - e^1)^2
\end{aligned}$$

If we expand around the mean values of  $e^0 = e^1 = 0$  then we have:

$$\begin{aligned}
f(\varepsilon_{t+1}, \varepsilon_t) &= \left( (1+g) - \delta \right)^{1-\rho} - \frac{(1-\rho)\delta}{\left( (1+g) - \delta \right)^\rho} (\varepsilon_t) + \frac{(1-\rho)(1+g)}{\left( (1+g) - \delta \right)^\rho} (\varepsilon_{t+1}) \\
&+ \frac{\left( (1+g) - \delta \right)^{1-\rho} \rho(1-\rho)(1+g)\delta}{\left( (1+g) - \delta \right)^2} (\varepsilon_t)(\varepsilon_{t+1}) + \frac{1}{2} \frac{(1-\rho)\delta\left( (1-\rho)\delta - (1+g) \right)}{\left( (1+g) - \delta \right)^{1+\rho}} (\varepsilon_t)^2 \\
&+ \frac{1}{2} \frac{(1-\rho)(1+g)\left( (1-\rho)(1+g) - \delta \right)}{\left( (1+g) - \delta \right)^{1+\rho}} (\varepsilon_{t+1})^2
\end{aligned}$$

Taking expectations:

$$\begin{aligned}
E\left( (1+g)[\exp(\varepsilon_{t+1})] - \delta[\exp(\varepsilon_t)] \right)^{1-\rho} &= E \left[ \begin{aligned}
&\left( (1+g) - \delta \right)^{1-\rho} - \frac{(1-\rho)\delta}{\left( (1+g) - \delta \right)^\rho} (\varepsilon_t) + \frac{(1-\rho)(1+g)}{\left( (1+g) - \delta \right)^\rho} (\varepsilon_{t+1}) \\
&+ \frac{\left( (1+g) - \delta \right)^{1-\rho} \rho(1-\rho)(1+g)\delta}{\left( (1+g) - \delta \right)^2} (\varepsilon_t)(\varepsilon_{t+1}) - \frac{1}{2} \frac{(1-\rho)\delta\left( (1+g) - (1-\rho)\delta \right)}{\left( (1+g) - \delta \right)^{1+\rho}} (\varepsilon_t)^2 \\
&+ \frac{1}{2} \frac{(1-\rho)(1+g)\left( (1-\rho)(1+g) - \delta \right)}{\left( (1+g) - \delta \right)^{1+\rho}} (\varepsilon_{t+1})^2
\end{aligned} \right] \\
&= (1+g - \delta)^{1-\rho} + \frac{(1-\rho)\text{Var}(\varepsilon)}{2\left( (1+g) - \delta \right)^{1+\rho}} \left( (1-\rho)\left( (1+g)^2 + \delta^2 \right) - 2\delta(1+g) \right)
\end{aligned}$$

And therefore,

$$E(C_{t+1} - \delta C_t)^{1-\rho} = C_0^{1-\rho} \exp\left(-\frac{1}{2}(1-\rho)\text{Var}(\varepsilon)\right) (1+g)^{t(1-\rho)} \frac{1}{(1+g-\delta)^\rho} \left[ \frac{(1+g-\delta) + \frac{(1-\rho)\text{Var}(\varepsilon)}{2(1+g-\delta)} \times}{((1-\rho)((1+g)^2 + \delta^2) - 2\delta(1+g))} \right]$$

Now we can calculate the discounted lifetime utility stream:

$$\begin{aligned} E_t U &= \frac{(C_0 - \delta C)^{1-\rho}}{1-\rho} + \sum_{t=1}^{\infty} \left[ \beta^t (1+g)^{t(1-\rho)} \frac{C_0^{1-\rho}}{1-\rho} \exp\left(-\frac{1}{2}(1-\rho)\text{Var}(\varepsilon)\right) \frac{1}{(1+g-\delta)^\rho} \left[ \frac{(1+g-\delta) + \frac{(1-\rho)\text{Var}(\varepsilon)}{2(1+g-\delta)} \times}{((1-\rho)((1+g)^2 + \delta^2) - 2\delta(1+g))} \right] \right] \\ &= \frac{(C_0 - \delta C)^{1-\rho}}{1-\rho} + \frac{C_0^{1-\rho}}{1-\rho} \exp\left(-\frac{1}{2}(1-\rho)\text{Var}(\varepsilon)\right) \frac{1}{(1+g-\delta)^\rho} \left[ \frac{(1+g-\delta) + \frac{(1-\rho)\text{Var}(\varepsilon)}{2(1+g-\delta)} \times}{((1-\rho)((1+g)^2 + \delta^2) - 2\delta(1+g))} \right] \sum_{t=1}^{\infty} \beta^t (1+g)^{t(1-\rho)} \\ E_t U &= \frac{(C_0 - \delta C)^{1-\rho}}{1-\rho} + \frac{C_0^{1-\rho}}{1-\rho} \exp\left(-\frac{1}{2}(1-\rho)\text{Var}(\varepsilon)\right) \frac{1}{(1+g-\delta)^\rho} \left[ \frac{(1+g-\delta) + \frac{(1-\rho)\text{Var}(\varepsilon)}{2(1+g-\delta)} \times}{((1-\rho)((1+g)^2 + \delta^2) - 2\delta(1+g))} \right] \frac{\beta(1+g)^{(1-\rho)}}{1-\beta(1+g)^{(1-\rho)}} \end{aligned}$$

#### A4.4: Expected value of autocorrelated errors

Iterating forwards from  $\varepsilon_0$  which is known, and taking expectations at each point it is always true that:

$$\varepsilon_1 = a\varepsilon_0 + v_1$$

$$E(\varepsilon_1 | I_0) = a\varepsilon_0 + E(v_1 | I_0) \text{ and } E(v_1 | I_0) = E(v) = 0 \text{ thus } E(\varepsilon_1 | I_0) = a\varepsilon_0$$

$$\varepsilon_2 = a\varepsilon_1 + v_2 = a(a\varepsilon_0 + v_1) + v_2 = a^2\varepsilon_0 + av_1 + v_2$$

$$E(\varepsilon_2 | I_0) = aE(\varepsilon_1 | I_0) + E(v_2 | I_0) = a(a\varepsilon_0) = a^2\varepsilon_0$$

$$\varepsilon_3 = a\varepsilon_2 + v_3 = a(a^2\varepsilon_0 + av_1 + v_2) + v_3 = a^3\varepsilon_0 + a^2v_1 + av_2 + v_3$$

$$E(\varepsilon_3 | I_0) = aE(\varepsilon_2 | I_0) + E(v_3 | I_0) = a(a^2\varepsilon_0) = a^3\varepsilon_0$$

$$\varepsilon_4 = a\varepsilon_3 + v_4 = a(a^3\varepsilon_0 + a^2v_1 + av_2 + v_3) + v_4 = a^4\varepsilon_0 + a^3v_1 + a^2v_2 + av_3 + v_4$$

$$E(\varepsilon_4 | I_0) = aE(\varepsilon_3 | I_0) + E(v_4 | I_0) = a(a^3\varepsilon_0) = a^4\varepsilon_0$$

And we can generalise these results to:

$$\varepsilon_t = \varepsilon_0 a^t + \sum_{i=1}^t a^{t-i} v_i$$

$$E(\varepsilon_t | I_0) = E\left(\varepsilon_0 a^t + \sum_{i=1}^t a^{t-i} v_i | I_0\right) = \varepsilon_0 a^t$$

### A4.5: Derivation of the lifetime expected utility stream with autocorrelation

Given the consumption process with autocorrelation:

$$\begin{aligned} c_t^{1-\rho} &= C_0^{1-\rho} (1+g)^{(1-\rho)t} \left[ \exp \left( \varepsilon_0 a^t + \sum_{i=1}^t a^{t-i} v_i - \frac{1}{2} \text{Var}(\varepsilon) \right) \right]^{1-\rho} \\ &= C_0^{1-\rho} (1+g)^{(1-\rho)t} \exp \left( (1-\rho) a^t \varepsilon_0 + (1-\rho) \sum_{i=1}^t a^{t-i} v_i - (1-\rho) \frac{1}{2} \text{Var}(\varepsilon) \right) \\ &= C_0^{1-\rho} (1+g)^{(1-\rho)t} \exp \left( (1-\rho) \left( a^t \varepsilon_0 - \frac{1}{2} \text{Var}(\varepsilon) \right) \right) \exp \left( (1-\rho) \sum_{i=1}^t a^{t-i} v_i \right) \end{aligned}$$

Taking expectations:

$$E(c_t^{1-\rho} | I_0) = E \left( C_0^{1-\rho} (1+g)^{(1-\rho)t} \exp \left( (1-\rho) \left( a^t \varepsilon_0 - \frac{1}{2} \text{Var}(\varepsilon) \right) \right) \exp \left( (1-\rho) \sum_{i=1}^t a^{t-i} v_i \right) | I_0 \right)$$

The constants in this case are:

$$C_0^{1-\rho} (1+g)^{(1-\rho)t} \exp \left( (1-\rho) \left( a^t \varepsilon_0 - \frac{1}{2} \text{Var}(\varepsilon) \right) \right)$$

And we are left to calculate the expected value:

$$E \left( \text{Exp} \left( (1-\rho) \sum_{i=0}^t (a^{t-i} v_i) \right) | I_0 \right)$$

Calculating this expectation is a similar result to the moment generating function of a Normal variable say  $x \sim (\mu_x, \sigma_x^2)$ , which is:

$$E(\exp(ax)) = \exp \left( a\mu_x + \frac{a^2 \sigma_x^2}{2} \right)$$

$$\begin{aligned} E \left( \text{Exp} \left( (1-\rho) \sum_{i=0}^t (a^{t-i} v_i) \right) | I_0 \right) &= \text{Exp} \left( (1-\rho) E \left( \sum_{i=0}^t (a^{t-i} v_i) | I_0 \right) \right) \text{Exp} \left( \frac{(1-\rho)^2}{2} \text{Var} \left( \sum_{i=0}^t (a^{t-i} v_i) | I_0 \right) \right) \\ &= \text{Exp} \left( (1-\rho) \sum_{i=0}^t a^{t-i} E(v_i | I_0) \right) \text{Exp} \left( \frac{(1-\rho)^2}{2} (\text{Var}(v | I_0)) \sum_{i=0}^t a^{2(t-i)} \right) \end{aligned}$$



Since  $v_i$  are independently and normally distributed and with mean 0:

- i) there are no covariance terms; and,
- ii) the conditional expectation and conditional variance given the information at date 0, are equal to the unconditional mean and variance  $(0, Var(v))$ . Therefore:

$$\begin{aligned} E\left(\text{Exp}\left((1-\rho)\sum_{i=0}^t(a^{t-i}v_i)\right)\middle|I_0\right) &= \text{Exp}\left(\frac{(1-\rho)^2 Var(v)}{2}\sum_{i=0}^t a^{2(t-i)}\right) \\ &= \text{Exp}\left(\frac{(1-\rho)^2 Var(v)}{2}\frac{1-a^{2(t+1)}}{1-a^2}\right) \end{aligned}$$

$$E(c_t^{1-\rho} | I_0) = C_0^{1-\rho} (1+g)^{(1-\rho)t} \exp\left(\left((1-\rho)a^t \varepsilon_0 - \frac{1}{2}(1-\rho)Var(\varepsilon)\right)\right) \text{Exp}\left(\frac{(1-\rho)^2(1-a^{2(t+1)})}{2} \frac{Var(v)}{(1-a^2)}\right)$$

We know that the unconditional variances of  $\varepsilon_t$  and  $\varepsilon_{t+1}$  can be described as  $Var(\varepsilon_t) = Var(\varepsilon_{t+1}) = Var(\varepsilon)$  (Verbeek, 2000) and therefore, solving for  $Var(\varepsilon)$ , we can work out the following relationship:

$$Var(\varepsilon_{t+1}) = a^2 Var(\varepsilon_t) + Var(v_t)$$

$$Var(\varepsilon) = \frac{Var(v)}{1-a^2}$$

$$\begin{aligned} E(c_t^{1-\rho} | I_0) &= C_0^{1-\rho} (1+g)^{(1-\rho)t} \exp\left((1-\rho)a^t \varepsilon_0 - (1-\rho)\frac{1}{2}Var(\varepsilon)\right) \text{Exp}\left(\frac{(1-\rho)^2(1-a^{2(t+1)})}{2}Var(\varepsilon)\right) \\ &= C_0^{1-\rho} (1+g)^{(1-\rho)t} \exp\left((1-\rho)a^t \varepsilon_0 - (1-\rho)\frac{1}{2}Var(\varepsilon) + \frac{(1-\rho)^2(1-a^{2(t+1)})}{2}Var(\varepsilon)\right) \\ &= C_0^{1-\rho} (1+g)^{(1-\rho)t} \exp\left((1-\rho)\left(a^t \varepsilon_0 - (\rho + (1-\rho)a^{2(t+1)})\frac{Var(\varepsilon)}{2}\right)\right) \end{aligned}$$

We can calculate the discounted lifetime utility stream for this process:

$$\begin{aligned} E_t U &= \frac{1}{1-\rho} \sum_{t=0}^{\infty} \beta^t \left( C_0^{1-\rho} (1+g)^{(1-\rho)t} \exp\left((1-\rho)\left(a^t \varepsilon_0 - (\rho + (1-\rho)a^{2(t+1)})\frac{Var(\varepsilon)}{2}\right)\right) \right) \\ &= \frac{C_0^{1-\rho}}{1-\rho} \sum_{t=0}^{\infty} \beta^t (1+g)^{(1-\rho)t} \exp\left((1-\rho)\left(a^t \varepsilon_0 - (\rho + (1-\rho)a^{2(t+1)})\frac{Var(\varepsilon)}{2}\right)\right) \end{aligned}$$



## Annex to Chapter 5

### A5.1 Two-period intertemporal maximisation

The solution to this problem is straight forward:

$$\text{Max } L = u(c_0) + \beta u(c_1) + \lambda \left( w_0 - c_0 + \frac{w_1}{(1+r)} - \frac{c_1}{(1+r)} \right)$$

$$\frac{dL}{dc_0} = u'(c_0) - \lambda = 0$$

$$\frac{dL}{dc_1} = \beta u'(c_1) - \frac{\lambda}{(1+r)} = 0$$

$$\frac{dL}{d\lambda} = w_0 - c_0 + \frac{w_1}{(1+r)} - \frac{c_1}{(1+r)} = 0$$

FOC imply:

$$\frac{u'(c_0)}{u'(c_1)} = \beta(1+r)$$

If we assume a utility function of the form:  $u(c_t) = \frac{c_t^{1-\rho}}{1-\rho}$ , then the first order condition

becomes:

$$\frac{c_0^{-\rho}}{c_1^{-\rho}} = \beta(1+r)$$

This implies:

$$c_1 = (\beta(1+r))^{\frac{1}{\rho}} c_0$$

The first step to find a solution is to substitute the consumption FOC in the budget restriction, by doing so we obtain the optimal consumption for both periods:

$$c_0^* = \frac{(1+r)w_0 + w_1}{\left( (1+r) + (\beta(1+r))^{\frac{1}{\rho}} \right)}$$

And:

$$c_1^* = (\beta(1+r))^{\frac{1}{\rho}} \frac{(1+r)w_0 + w_1}{(1+r) + (\beta(1+r))^{\frac{1}{\rho}}}$$

### A5.2 Three-period intertemporal maximisation

$$\text{Max } U(c) = \sum_{t=0}^2 \beta^t u(c_t)$$

$$\text{Subject to } c_0 + \sum_{t=1}^2 \frac{c_t}{\prod_{k=1}^t (1+r_k)} = w_0 + \sum_{t=1}^2 \frac{w_t}{\prod_{k=1}^t (1+r_k)}$$

With FOC:

$$\frac{dL}{dc_0} = u'(c_0) - \lambda = 0$$

$$\frac{dL}{dc_j} = \beta^j u'(c_j) - \frac{\lambda}{\prod_{k=1}^j (1+r_k)} = 0 \quad \forall j = 1, 2$$

$$\frac{dL}{d\lambda} = w_0 + \sum_{t=1}^2 \frac{w_t}{\prod_{k=1}^t (1+r_k)} - c_0 - \sum_{t=1}^2 \frac{c_t}{\prod_{k=1}^t (1+r_k)} = 0$$

We assume that the utility function takes the usual form  $u(c_j) = \frac{c_j^{1-\rho}}{1-\rho}$ , therefore the

solution must satisfy:

$$c_{j+1} = \left( \beta(1+r_j) \right)^{\frac{1}{\rho}} c_j \text{ which implies } c_j = \left( \beta^j \prod_{k=1}^j (1+r_k) \right)^{\frac{1}{\rho}} c_0$$

And substituting into the budget constraint we obtain the optimal initial consumption in terms of income:

$$c_0^* = \frac{\left( w_0 + \sum_{t=1}^2 \frac{w_t}{\prod_{k=1}^t (1+r_k)} \right)}{\left( 1 + \sum_{t=1}^2 \frac{\left( \beta^t \prod_{k=1}^t (1+r_k) \right)^{\frac{1}{\rho}}}{\prod_{k=1}^t (1+r_k)} \right)}$$

$$c_j^* = \left( \beta^j \prod_{k=1}^j (1+r_k) \right)^{\frac{1}{\rho}} \frac{\left( w_0 + \frac{w_1}{(1+r_1)} + \frac{w_2}{(1+r_1)(1+r_2)} \right)}{\left( 1 + \sum_{t=1}^2 \frac{\left( \beta^t \prod_{k=1}^t (1+r_k) \right)^{\frac{1}{\rho}}}{\prod_{k=1}^t (1+r_k)} \right)}$$

### A5.3. Intertemporal maximisation in stock markets

$$\text{Max } U(c) = \sum_{t=0}^2 \beta^t E(u(c_t))$$

$$W = s_0 H_0 - P_0 c_0$$

$$\text{Subject to } c_1 = (s_0 - s_1) H_1 / P_1$$

$$c_2 = s_1 H_2 / P_2$$

This can be rewritten as:

$$\begin{aligned} \text{Max } U(c) = & \ln(c_0) + p\beta \ln\left(\left(\frac{(W - P_0 c_0)}{H_0} - s_1\right) \frac{H^u}{P_1}\right) + (1-p)\beta \ln\left(\left(\frac{(W - P_0 c_0)}{H_0} - s_1\right) \frac{H^d}{P_1}\right) + \\ & p^2 \beta^2 \ln\left(\frac{s_1 H^{uu}}{P_2}\right) + 2p(1-p)\beta^2 \ln\left(\frac{s_1 H^{ud}}{P_2}\right) + (1-p)\beta^2 \ln\left(\frac{s_1 H^{dd}}{P_2}\right) \end{aligned}$$

The FOC with respect to  $c_0$  and  $s_1$  imply:

$$c_0 = \frac{W - s_1 H_0}{P_0 (1 + \beta)}$$

$$s_1 = \frac{\beta (W - P_0 c_0)}{H_0 (1 + \beta)}$$

### A5.4. Expected changes of the interest rate

The first case we can consider is when the interest rates are equal  $r_1=r_2$  and both change at the same time. To simplify the analysis, that  $P_t=1$ . In this case we have the following:

$$\frac{dH_0}{dr} = -\frac{2}{(1+r)^3} (p^2 H_{uu} + 2p(1-p) H_{ud} + (1-p)^2 H_{dd}) = -\frac{2}{(1+r)} H_0 < 0$$

And  $H_{1i} = \frac{1}{1+r} (pH_2^u + (1-p)H_2^d)$  where  $H_2^u$  and  $H_2^d$  depend on the node  $i=u,d$  where we are.

$$\frac{dH_{1i}}{dr} = -\frac{1}{(1+r)^2} (pH_2^u + (1-p)H_2^d) = -\frac{H_{1i}}{(1+r)} < 0$$

Consumption at date 0 does not depend on the price of the asset, therefore it does not change. This is not true for consumption at date 1 and 2 as we demonstrate next. Substituting  $s_0^*$  and  $s_1^*$  into  $c_1^*$ :

$$c_{1i}^* = \left( W \left( 1 - \frac{1}{1 + \beta + \beta^2} \right) - \beta^2 \left( \frac{W}{1 + \beta + \beta^2} \right) \right) \frac{H_{1i}}{H_0}$$

$$\frac{dc_{1i}^*}{dr} = \left( W \left( 1 - \frac{1}{1 + \beta + \beta^2} \right) - \beta^2 \left( \frac{W}{1 + \beta + \beta^2} \right) \right) \frac{H_{1i}}{H_0 (1+r)} > 0$$

$$c_2^* = \frac{\beta^2}{H_0} \left( \frac{W}{1+\beta+\beta^2} \right) H_2$$

$$\frac{dc_2^*}{dr} = \frac{H_2}{H_0} \frac{2\beta^2}{(1+r)} \left( \frac{W}{1+\beta+\beta^2} \right) > 0$$

Another possibility is that  $r_1 \neq r_2$ , we will assume that the interest rate changes at  $r_2$ .

$$\frac{dH_0}{dr_2} = -\frac{1}{(1+r_1)(1+r_2)^2} (p^2 H_{uu} + 2p(1-p) H_{ud} + (1-p)^2 H_{dd}) = -\frac{H_0}{(1+r_2)} < 0$$

$H_{li} = \frac{1}{1+r_2} (pH_2^u + (1-p)H_2^d)$  where  $H_2^u$  and  $H_2^d$  depend on the node  $i=u, d$  where we

are.

$$\frac{dH_{li}}{dr_2} = -\frac{1}{(1+r_2)^2} (pH_2^u + (1-p)H_2^d) = -\frac{H_{li}}{(1+r_2)} < 0$$

$$c_{li}^* = \left( W \left( 1 - \frac{1}{1+\beta+\beta^2} \right) - \beta^2 \left( \frac{W}{1+\beta+\beta^2} \right) \right) \frac{H_{li}}{H_0}$$

$$\frac{dc_{li}^*}{dr_2} = \left( W \left( 1 - \frac{1}{1+\beta+\beta^2} \right) - \beta^2 \left( \frac{W}{1+\beta+\beta^2} \right) \right) \left( \frac{H_{li}}{H_0(1+r_2)} - \frac{1}{H_0} \frac{H_{li}}{(1+r_2)} \right) = 0$$

$$c_2^* = \frac{\beta^2}{H_0} \left( \frac{W}{1+\beta+\beta^2} \right) H_2$$

$$\frac{dc_2^*}{dr_2} = \frac{\beta^2 H_2}{H_0(1+r_2)} \left( \frac{W}{1+\beta+\beta^2} \right) > 0$$

Finally, the other possibility is that  $r_1 \neq r_2$ , and the interest rate  $r_1$  is the one that changes.

$$\frac{dH_0}{dr_1} = -\frac{1}{(1+r_1)^2(1+r_2)} (p^2 H_{uu} + 2p(1-p) H_{ud} + (1-p)^2 H_{dd}) = -\frac{H_0}{(1+r_1)} < 0$$

$$c_{li}^* = \left( W \left( 1 - \frac{1}{1+\beta+\beta^2} \right) - \beta^2 \left( \frac{W}{1+\beta+\beta^2} \right) \right) \frac{H_{li}}{H_0}$$

$$\frac{dc_{li}^*}{dr_1} = \left( W \left( 1 - \frac{1}{1+\beta+\beta^2} \right) - \beta^2 \left( \frac{W}{1+\beta+\beta^2} \right) \right) \frac{H_{li}}{(1+r_1)H_0} > 0$$

$$c_2^* = \frac{\beta^2}{H_0} \left( \frac{W}{1+\beta+\beta^2} \right) H_2$$

$$\frac{dc_2^*}{dr_1} = \frac{\beta^2 H_2}{H_0(1+r_1)} \left( \frac{W}{1+\beta+\beta^2} \right) > 0$$

### **A5.5 Surprise changes of the interest rate: optimal investment strategy**

We can check if the investment strategy at date 1 is still optimal. We now maximise the expected utility at date 1 as:

$$\text{Max } U(c) = \ln((s_0^* - s_1^*)H_1) + p\beta \ln(s_1^* H_{2uH_i}) + (1-p)\beta \ln(s_1^* H_{2dH_i})$$

Where  $H_{2uH_i}$  is the price up at date 2 given that  $H_1$  is at the node  $i$  and  $H_{2dH_i}$  is the price down at date 2 given that  $H_1$  is at the same node where  $i=u,d$ . The FOC with respect to  $s_1$  imply:

$$s_1 = \frac{\beta s_0^*}{(1 + \beta)}$$

If we substitute  $s_0^* = \frac{W}{H_0} \left(1 - \frac{1}{1 + \beta + \beta^2}\right)$  the optimal solution of this problem is given by the same expression we had before:

$$s_1^* = \frac{\beta^2}{H_0} \left( \frac{W}{1 + \beta + \beta^2} \right)$$

Hence, it is optimal to continue with the initial strategy calculated before the change in the interest rate. Substituting into the optimal consumption for date 1:

$$c_1^* = \left( s_0^* - \frac{\beta s_0^*}{(1 + \beta)} \right) H_1 = s_0^* \left( \frac{1}{(1 + \beta)} \right) H_1$$

$$\frac{dc_1^*}{dr_2} = -s_0^* \left( \frac{1}{(1 + \beta)} \right) \frac{H_1}{(1 + r_2)} < 0$$