Stockholm University

The Forgotten Twin Crises

Determinants of Banking and Sovereign Debt Crises in Emerging Markets

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Executive Summary

This thesis is probably the first to investigate common determinants of twin banking and sovereign debt crises, where such a combination is treated as a specific kind of crisis. By means of multinomial logit analysis, determinants of banking crises, sovereign defaults and twin banking and debt crises in emerging countries, are identified and related to theory. Twin banking and debt crises are found to be different from pure banking and pure sovereign debt crises, not only in their determinants, but also their superior predictive ability. Empirical evidence in this thesis suggests that twin banking and debt crises should be treated as a specific kind of crisis. In addition, a surge in capital inflows (capital flow bonanza) is found to be an important indicator prior to both pure banking and pure sovereign debt crises but not for twin crises. Finally, a deterioration of the trade balance (relative to GDP) is found to be important in the run up to twin banking and debt crises.

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Introduction

"Why did nobody notice it?" asked the Queen of England when she visited London School of Economics in the fall of 2008. The "it", to which the Queen referred, was the Second Great Contraction[1]. Shortly after, a three-page missive was sent to Her Majesty signed by Professor Tim Besley and the historian Peter Hennessy, summarizing the main conclusions and views from participants at a forum convened by the British Academy in June 2009 (Pierce, 2008).

"Many people did foresee the crisis. However, the exact form that it would take and the timing of its onset and ferocity were foreseen by nobody. What matters in such circumstances is not just to predict the nature of the problem but also its timing. And there is also finding the will to act and being sure that authorities have as part of their powers the right instruments to bring to bear on the problem. […] So in summary, Your Majesty, the failure to foresee the timing, extent and severity of the crisis and to head it off, while it had many causes, was principally a failure of the collective imagination of many bright people, both in this country and internationally, to understand the risks to the system as a whole. (Besley and Hennessy, 2009)"

In an interview in August 2011, the president of ECB Jean-Claude Trichet proclaimed that: "It is the worst crisis since the Second World War, and it might have been the worst since the First World War if those in charge had not taken very robust decisions, […] (Evans-Pritchard, 2011)". Eichengreen and O'Rourke (2010) provide empirical support presented in figure 1 & 2 for Trichet's view. It seems as if the world's industrial production was almost equally adversely affected during the first 10 month of both contractions (figure 1). However, the impact on international trade was considerably worse during the first year of the Second Great Contraction compared to the Great Depression (figure 1).

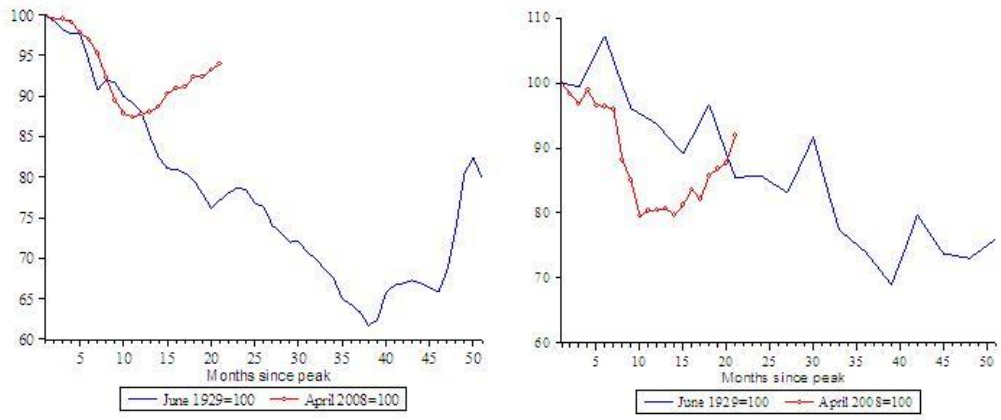

Figure 1. World industrial production (left) and world trade (right) during the First and the Second (dotted line) Great Contraction (Eichengreen and O'Rourke, 2010).

Is it possible that policy responses might explain the rebound in industrial production, international trade and equity markets after the first year of the Second Great Contraction? Figure 2 shows that compared to the Great Depression, both monetary and fiscal policy were significantly more expansionary during the Second Great Contraction.

[1] According to Kenneth Rogoff is the Second Great Contraction (2008-) a more appropriate terminology than the Great Recession (subprime crisis). A normal recession applies only to employment and output while a contraction also comprises credit and debt. The First Great Contraction was the Great Depression 1929-1938 (Rogoff, 2011).

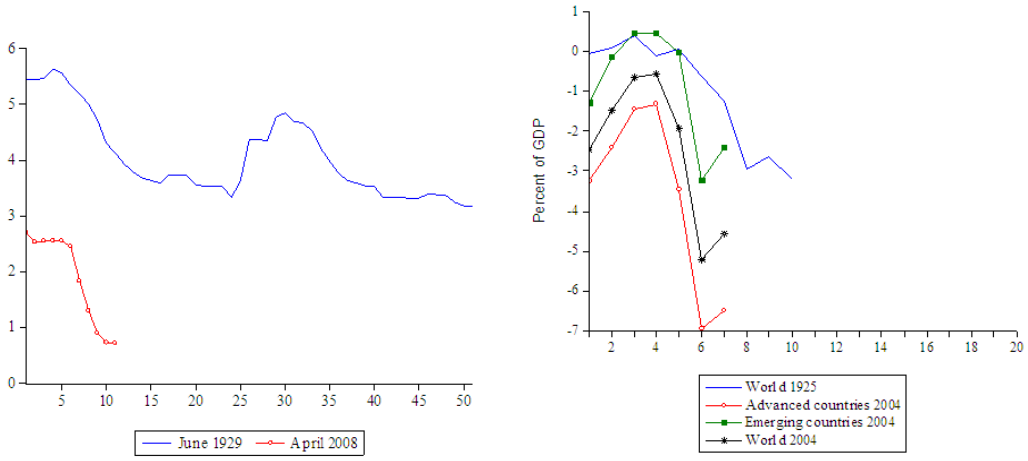

Figure 2. Central Bank Discount Rates (left) and Government Budget Surpluses (right) during the First and Second (dotted line) Great Contraction (Eichengreen and O'Rourke, 2010).

As economic conditions worsened drastically after the failure of Lehman Brothers in September 2008, the immediate response from G-20 was to establish a joint Early Warning Exercise (EWE) between the International Monetary Fund (IMF) and Financial Stability Board (FSB). A G-20 communiqué had the following statement:

"The IMF, in collaboration with the expanded FSB and other bodies, should work to better identify vulnerabilities, anticipate potential stresses, and act swiftly to play a key role in crisis response (G20 Communiqué, November 15, 2008)".

The aim of this joint EWE was not to predict the timing of crisis, but rather to identify underlying vulnerabilities and potential triggers that predispose a financial system to a certain type of crisis (IMF, 2010). In IMF's efforts to improve its surveillance capabilities, EWEs are planned to play an important role for analysis of economic, fiscal and financial risks. As soon as the global economy has returned to a more stable phase, EWEs will be conducted semi-annually in close collaboration with the FSB as a forward-looking exercise (IMF, 2011a). The initiative to conduct EWEs at regular intervals is not the first practice that has emerged as a consequence of a financial crisis. A number of practices, for example central banks' function as lender-of-last-resort and deposit insurance, as well as international institutions such as the IMF, have mainly evolved in response to different economic crises throughout history (IMF, 2010). A relevant question is if we really need these Early Warning Exercises to address national and global vulnerabilities, as the world economy sooner or later will return to more stable conditions. Even if a global financial crisis has negative economic consequences it seems as if it is a highly improbable event.

The frequency of banking, currency and debt crises from the 1970s until the beginning of the subprime crisis for advanced and emerging countries is shown in figure 3. From this dataset it is obvious that banking and debt crises are more common in emerging countries compared to advanced countries. The frequency of banking and sovereign debt crises is 4 and 2 percent respectively when crisis episodes are measured as a percentage of the total number of years for each emerging country (Ghosh et al., 2009).

Another picture of the frequency of banking and debt crises emerges in table 1 for 28 emerging countries between 1980 and 2002. All countries except the Dominican Republic and Pakistan experienced a banking crisis during the period and as much as one third of all

countries experienced two or more banking crises. Moreover, all countries except Hungary and Malaysia defaulted on their external debt and once again more than a third experienced two or more debt crises. Importantly, this empirical finding is roughly the same for the supplementary dataset with different definitions of banking and debt crises (see table 30 in appendix 9). In addition, more than a third of all countries experienced what seems to be a highly improbable event, characterized by a simultaneous banking, currency and sovereign debt crisis within a two-year period[2] (table 11 in appendix 1).

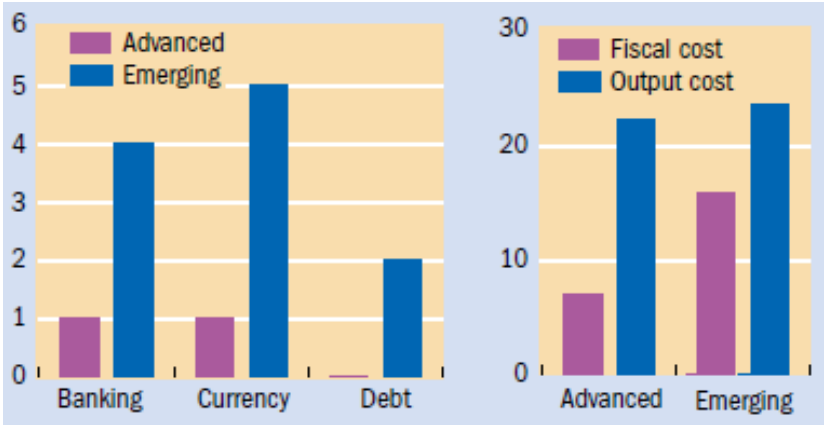

Figure 3. Frequency of crises and average cost of banking crises in percent 1970-2007 (Ghosh et al., 2009)

It is important to note that Ghosh et al. (2009) only look at the period from 1970 when they estimate the frequency of crises. Reinhart and Rogoff (2008a) on the other hand find that even if most advanced countries have graduated from serial default on sovereign debt and very high inflation, this is not the case for banking crises. In their extensive empirical investigation they conclude: "Whether the calculations are done from 1800 […] or from 1945 […], on average there are no significant differences in either the incidence or number of banking crises between advanced and emerging economies - banking crises are an equal opportunity menace (Reinhart & Rogoff, p. 17, 2008a)".

If financial crises are not highly improbable then what are the possible consequences of a severe financial crisis. Reinhart and Rogoff (2009) provide three characteristics of the economic consequences of financial crises. First, both real estate and equity markets typically collapse with a deeper (56 %) but shorter fall (3½ years) in equity compared to the drop in the price of real estate (35%) which is more prolonged (6 years). Second, the drop in output is considerable (9%) but relatively short on average (2 years) compared to the increase in unemployment (7%) which is a more protracted event (4 years). This is consistent with Ghosh et al. (2009) who claim that banking crises are very costly in terms of lost output for both advanced and emerging countries (figure 3). Third, government debt seems to explode with an average increase of 86% in real terms chiefly due to a fall in tax revenue when output collapses.

However, financial crises do not only have economic consequences but also severe social impacts on countries. During a financial crisis both short-term and long-term unemployment typically increases, where the latter is more problematic as skills tend to depreciate and the unemployed gradually lose their motivation for searching for work. The impact of higher

[2] It is not only the emerging world that has experienced triple crises during the 1980s and 1990s. Today "Europe is suffering from simultaneous sovereign-debt, banking, and currency crises (Boskin, 2011)".

unemployment during the Asian crisis was considerably worse for youth, which in turn led to social problems as for example drug addiction and prostitution as well as political instability. The surge in crime and violence was striking in most affected countries, where for example Malaysia reported an increase of 31 percent in the overall index of crime in 1998 compared to the previous year. Moreover, income inequality and poverty rates increased in general after the Asian crisis in e.g. Korea where the poverty rate more than doubled[3,4]. Another important effect of the Asian crisis was deep budget cuts for both education and public health in many countries with potential long-term negative effects for human capital (Knowles et al., 1999). The economic and social consequences from financial crises are very problematic but perhaps the political impact might be even bigger.

A positive example of this can be found in American history. In 1783 when America's states gained independence from Britain, a majority of states were either unwilling or unable to repay the Revolutionary War debts. At the time, the country did not have a taxing authority and could be described as a loose confederation similar to the European Union of today. The purpose of the Philadelphia Convention in 1787 was to address the problems of governing the United States of America and to resolve the predicament of recurring debt crises. The Philadelphia convention resulted in the US Constitution which at the time was mainly a debt-repayment mechanism. President George Washington and Alexander Hamilton, who was America's first treasury secretary, were both convinced that only if the United States were fiscally strong could it defend itself against foreign powers. To become a fiscally responsible nation, Hamilton urged Congress' approval of the federal government's assumption and repayment of states' defaulted debt. In a grand compromise between Hamilton and the southern leaders Jefferson and Madison, who initially opposed the assumption plan, a fiscally responsible nation emerged. In short, the creation of the United States of America took place during and mainly because of America's first debt crisis (Roe, 2011).

However, not all debt crises lead to peaceful compromises. Britain invaded Egypt in 1882 and occupied Istanbul when Turkey defaulted on its external debt in 1876. Moreover, the U.S occupation of Haiti in 1915 was explained chiefly by the necessity of collecting debt. In addition, the once independent nation of Newfoundland lost its sovereignty and became a part of Canada in the 1930s as a consequence of debt servicing difficulties (Reinhart and Rogoff, 2009). The question is if all these events were special and something that belongs to the past, or do financial crises (not only sovereign defaults) make war more likely?

Cinquegrana (2011) finds that financial crises in the post-WWII period increase the likelihood of war onset with 85 percent. Moreover, it seems as if debt and banking crises are particularly troublesome since they have persistent effects. Even after five years from the beginning of a sovereign default or banking crisis the odds ratio multipliers are 1.36 and 1.16 respectively while the effect disappears for currency and inflation crises.

In the 1980s, emerging countries in Latin America were bailed out by advanced countries through so-called Brady bonds which enabled Brazil among others to recover. Today the tables have turned when the BRICs[5] are to some extent expected to rescue the PIIGS[6] by

[3] Importantly, a surge in crime and poverty rates in the aftermath of financial crises is not a phenomenon isolated to emerging countries. During the current crisis the number of robberies in Greece increased with about 60 percent between 2005 and 2009 (Stoukas, 2010).

[4] The Second Great Contraction has had a considerable impact on poverty in the U.S. as 46.2 million people in 2010 were living below the official poverty line, and this is the highest number in over a half century (Tavernise, 2011).

[5] The so-called BRIC countries comprise Brazil, Russia, India and China.

purchasing massive quantities of European debt and thus mitigate the Eurozone debt crisis (La Monica, 2011). Does this mean that emerging countries play a bigger role in the global economy today than just a couple of decades ago? Emerging countries reached an important milestone in 2005, as their combined GDP measured at purchasing-power parity accounted for more than half the share of the global economy (chart 2 in figure 4). Moreover, emerging countries have today a significant influence on advanced countries' wages, profits, inflation and interest rates. The gradual integration of emerging markets in the global economy, will be the greatest stimulus in history because the population in emerging countries account for more than 80 percent (chart 1 in figure 4) of the global population (The Economist, 2006).

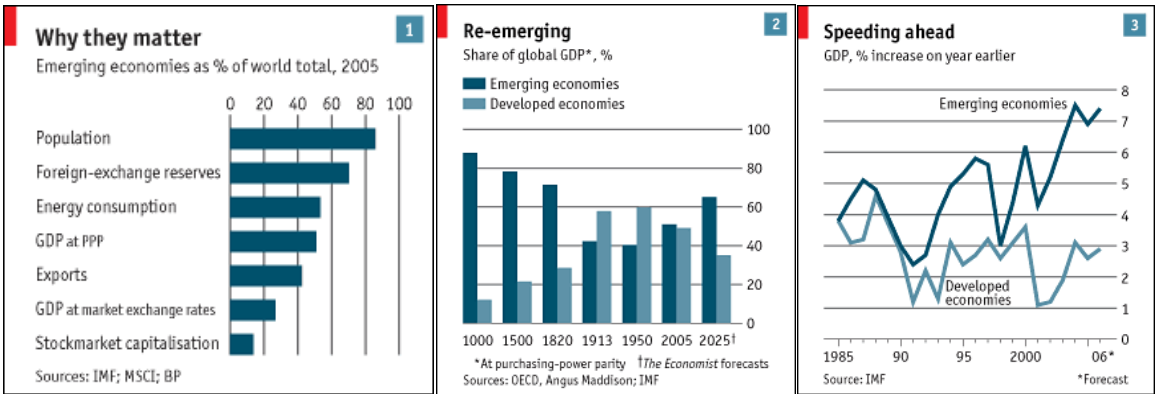

Figure 4. Emerging markets importance for the global economy (The Economist, Sep 14, 2006)

Emerging markets share of world exports has more than doubled since 1970 from 20% to 43% and they accounted in 2005 for half the demand for the worlds' energy (chart 1 in figure 4). In addition, the importance of emerging markets for advanced countries has been increasing due to a widening of the average growth rate shown in chart 3 in figure 4 (The Economist, 2006). The initiation of the Group of Twenty (G-20) in 1999 was perhaps the most important sign of how the rise of emerging countries will affect the global economy. A recent report jointly prepared by the Asian Development Bank and the Peterson Institute for International Economics concluded that:

"The new global economic governance structure will need to be based on representative institutions [G-20] that reflect the changing economic weight of emerging economies in the global economy. Asia should and will play a greater role on the global stage (ADB, p. 58, 2011)"

However, if emerging countries are becoming more integrated into the global economy this implies higher interdependence between the financial systems of emerging and developed countries. Consequently, this means that a severe banking or sovereign debt crisis in a large emerging country (or group of countries) poses unprecedented risks of contagion to the global financial system. The need to identify underlying vulnerabilities in emerging economies has never been as important as today; not only for the affected countries but for the world economy.

The Second Great Contraction started in the U.S. where the subprime market collapsed and this was not because of contagion from an emerging country. Since emerging and developed countries are fundamentally different, the question is if investigating determinants of past

[6] The PIIGS are highly indebted European countries and encompass Portugal, Italy, Ireland, Greece and Spain.

financial crises in emerging countries can provide anything more than indicators that, at best, are only relevant for emerging countries. Nouriel Roubini a professor at New York University and the co-founder of Roubini Global Economics was one of very few that already in 2006 correctly predicted the subprime crisis and its aftermath. According to the RGE website, Roubini applied the lessons from the Asian crisis in the 1990s to the United States, and drew the conclusion that the U.S. in 2006 had a similar behavior to that of a big emerging country (Roubini Global Economics). Reinhart and Rogoff (2009) introduce real housing prices in previous studies on early warning indicators of banking crises for developing countries. Surprisingly, real housing prices was found to be the second best indicator.

De Grauwe (2011) rejects the idea that members of the EMU are fundamentally different from emerging countries. When a country that is a member of a monetary union issues debt in a currency it no longer can control, it becomes highly exposed to the confidence of investors. The volatility of market sentiments can lead to a "sudden stop" and member states are for that reason reduced to the status of an emerging country. De Grauwe concludes that: "A monetary union can only function if there is a collective mechanism of mutual support and control. Such a collective mechanism exists in a political union (De Grauwe, p. 19, 2011).

Financial crises can be characterized as "a specific trigger superimposed on an underlying vulnerability (Ghosh et al., p 36, 2009)". Historically, common underlying vulnerabilities have been, for example, asset or real estate bubbles, large capital inflows, credit booms and balance sheet mismatches. Triggers, on the other hand, can be almost any possible event: for example financial contagion from other countries, terms of trade shocks, political turmoil, natural disasters, a collapse of the real estate market or a stock market crash. This characterization of financial crises has two important implications. First, since the trigger of a financial crisis is unpredictable, it is almost impossible to accurately predict the timing of the onset of crisis. Second, as the onset of crisis is unpredictable it is difficult to persuade policymakers to take immediate measures that often are economically costly to prevent crises. The purpose of an early warning system is to identify underlying vulnerabilities and then adopt policies that gradually can address these vulnerabilities (Ghosh et al., 2009).

To sum up, we are in the midst of the worst economic crisis since World War II and we have no idea what the situation will be like one year from today. Financial crises are quite common events in emerging economies. For a relatively small sample comprising only 28 emerging countries during 22 years, the total number of crises is more than 120 (!) categorized into banking, currency and sovereign debt crises (table 11 in appendix 1). Emerging countries are the engine of the global economy at present, and advanced countries, in particular the highly indebted Eurozone countries, depend on them[7]. Financial crises have severe economic, social and political impacts on both emerging and developed countries. The need to identify vulnerabilities in emerging and developed economies is critical at the moment as is the need to adopt appropriate policies to address these vulnerabilities.

The purpose of this thesis is threefold. First, the most important aim is to identify determinants (vulnerability indicators) for banking crises, sovereign defaults and twin crises[8] in emerging countries (figure 5). A second aim is to investigate if possible determinants differ between the various types of crisis. Third, an additional aim is to examine if identified determinants for each type of crisis can be applied to effectively signal a crisis in advance.

[7] "So the fact that emerging markets have provided about half of global growth has been a very important contributor to the nature of the recovery (Zoellick, 2011)."

[8] A twin crisis is defined as a banking crisis that is preceded or succeeded by a debt crisis within two years.

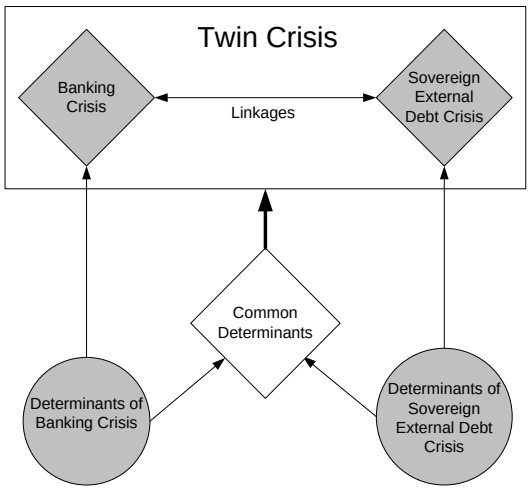

Figure 5. Determinants of banking crises, sovereign defaults and twin crises

Literature review

After the Mexican and Asian crises in the 1990s a growing body of research has emerged on the causes of financial crises. Scholars and policymakers began to emphasize the importance of research on empirical regularities around past crises in order to improve their ability to predict future crises. As a consequence, Early Warning Systems (EWS), partially derived from empirical regularities during crisis periods, were adopted by an increasing number of International Financial Institutions and central banks, among others, for surveillance of vulnerabilities in the economy (IMF, 2002).

The assumption that financial crises are associated with a common pattern, is consistent with the following observation by Kindleberger (1978, p.14) "For historians each event is unique. Economics, however, maintains that forces in society and nature behave in repetitive ways. History is particular; economics is general". Furthermore, Kindleberger's observation is closely related to the statement by Reinhart and Rogoff (2010), that policymakers' and investors' illusions of "this time is different" was a fundamental cause for the failure to anticipate the Second Great Contraction. The illusion of "this time is different" comprises a belief among most people that financial crises happen at other times in history, to other people in other countries, and that we are more sophisticated today as we have learned our lesson from crises in the past (Reinhart and Rogoff, 2010).

The main surveillance purpose of EWS is to accurately predict the probability of a certain kind of crisis in the near future, typically on the basis of country-specific fundamentals and global factors. A forecast horizon of one to two years is necessary because of long reporting lags for important variables and long lags before policies take effect. In addition, the trade-off between successfully predicting a crisis and the probability of issuing a false alarm has to be accounted for when calibrating the EWS model. Finally, the chief benefit of an EWS model is that it offers an objective and consistent method for prediction of crises, unbiased from analysts' and policymakers' illusions of "this time is different" (IMF, 2002).

The empirical approach on Early Warning Systems for prediction of banking and sovereign debt crises can be classified into non-parametric and parametric models. In a seminal paper by Kaminsky et al. (1999), a non-parametric signal extraction EWS on banking crises is applied on individual time series. The signal approach developed by Kaminsky et al. (1999) examines the behavior of macroeconomic variables and classifies an indicator to be either signaling a crisis or a normal period. If an indicator signaling a crisis (normal) period is not followed by a crisis (normal) event within a reasonable time frame it is a false alarm. The threshold value for issuing a signal is selected on the basis of minimizing the noise-to-signal ratio for each variable separately. Furthermore, Fioramanti (2008) estimated a non-parametric model with artificial neural networks (ANN) on sovereign debt crises that under certain circumstances outperforms traditional EWS models.

Analogous to the empirical approach in this thesis, Demirguc-Kunt and Detragiache (2005) and Ciarlone and Trebeschi (2004) estimated parametric EWS for banking crises and sovereign debt crises respectively using a (multinomial) logit model. In contrast to the indicator-by-indicator approach in the signal model, a parametric logit or probit account for interdependencies among variables that combined might increase the probability of a crisis (Davis and Karim, 2007). Many international financial institutions combine different kinds of

EWS models: for example the IMF applies a dual-core EWS consisting of both a parametric probit and non-parametric signal model for crisis prediction (IMF, 2002).

In the EWS literature it has become a standard procedure to distinguish between pure currency, banking or sovereign debt crises and combined ("twin") crises. In a seminal paper by Kaminsky and Reinhart (1999), the causes of combined banking and balance-of-payments crises are investigated using a signal approach. One important finding in their study is that vulnerability in the banking sector undermines the currency and increases the need for devaluation. As a consequence of devaluating the currency, banking sector problems worsen even further and a vicious circle is activated. A theoretical and empirical differentiation should be made when assessing the determinants of twin currency and banking crises (Kaminsky & Reinhart, 1999). Falcetti and Tudela (2008) confirm as well that banking and currency crises are intertwined and driven by common fundamentals. Additionally, state dependence for banking crises is found in the data, which suggests that countries that have experienced a banking crisis before are more vulnerable in the future (Falcetti and Tudela 2008). Finally, a recent working paper by Candelon et al. (2011) confirms the interaction between currency and banking crises, reported by Glick and Hutchinson (1999) and consequently support the twin crisis phenomenon empirically for a large sample of emerging countries.

According to a recent study by Bauer et al. (2007), a similar differentiation should be made with twin currency and sovereign debt crises. The authors find that pure sovereign defaults and currency crises differ from twin currency and debt crises not only in their determinants but also their economic consequences. Each kind of crisis seems to have a unique set of macroeconomic causes and if twin crises are not treated as a specific type of crisis, this may lead to biased estimates. However, a study by Dreher et al. (2006) only provides weak evidence for common factors behind currency and sovereign debt crises. Moreover, the authors find support for the fact that currency crises raise the probability of contemporaneous sovereign debt crises and vice versa (Dreher et al. 2006).

Single and twin crises also seem to differ when it comes to costs in terms of lost output. Borensztein and Panizza (2008) find that on average a sovereign default implies a decrease in the growth rate of 1.2 percentage points per year. However, it seems as if the effects of default are only short-term since no effects are found after two years, which is consistent with the belief that credit markets tend to "forgive and forget". Furthermore, a country defaulting on its debt has a cost in terms of lost reputation measured in lower credit ratings and probably a small negative effect on trade. On the other hand, the political implications of defaults are considerable since the probability of a change in political leadership doubles around the year of default[9] (Borensztein and Panizza, 2008). In contrast, a recent study by Cruces and Trebesch (2011) provides evidence for considerable adverse consequences in the medium term for governments. It seems as if high creditor losses are correlated with considerably higher post-restructuring spreads and extended periods of exclusion from credit markets. Cruces and Trebesch suggest that there might be a trade-off between short-term benefits after debt relief at the cost of worse borrowing conditions in the medium term (Cruces & Trebesch, 2011).

Hutchison and Noy (2005) find that the growth rate after a currency crisis decreases with 5%-8% and after a banking crisis with 8%-10% over a period of 2-4 years. However, after a twin

[9] Local and regional elections in Spain during the spring 2011 were a sign of the political implications from austerity measures to prevent a sovereign default.

currency and banking crisis the growth rate declines with 13%-18% over the same period. Kaminsky and Reinhart (1999) find additional support of higher cost for twin crises as the bailout costs for twin currency and banking crises are more than twice as large compared to single banking crises. Furthermore, the empirical finding that twin crises are more costly than single crises is consistent with twin banking and debt crises as well. Chuan and Sturzenegger (2005) find that after a sovereign default there is a reduction in growth of about 0.6 percentage points. However, the drop in growth is 2.2 percentage points when a default coincides with a banking crisis. To sum up, previous studies have investigated determinants of twin currency and banking crises as well as twin currency and sovereign debt crises and found twin crises to be more costly in terms of lost output than pure crises.

But where is the twin banking and sovereign debt crisis? There seems to be a void in the (EWS) literature on financial crises, when it comes to modeling simultaneous banking and sovereign debt crises as a separate kind of twin crisis. Reinhart and Rogoff (2010) find that the simultaneous (or in close proximity) occurrence of banking and sovereign debt crises is relatively common especially in emerging countries. This is consistent with the datasets compiled in this thesis (table 1 and table 30 in appendix 9). The datasets for emerging countries between 1980 and 2002 suggests that roughly half the number of banking crises is either preceded or succeeded by a sovereign default within a two-year period. Recent developments in Europe (PIIGS) indicate that advanced countries are not immune to simultaneous banking and sovereign debt crisis either (Candelon & Palm, 2010a).

This thesis is probably the first attempt to fill this void by applying a parametric Early Warning System to twin banking and sovereign debt crises, where such a combination is treated as a specific kind of crisis. The relatively high frequency and nontrivial costs associated with this kind of twin crisis, spur the need for investigating common determinants of banking crises and sovereign defaults in the midst of the Second Great Contraction.

Theory of Banking crises and Sovereign Defaults

Determinants of Banking Crises

A bank's balance sheet consists of liabilities, assets and bank capital. Liabilities are mainly in the form of short-term deposits while assets consist primarily of short- and long-term loans to the private sector and the difference between assets and liabilities is a bank's capital. A bank becomes insolvent when the value of its assets is lower than the value of its liabilities. Accordingly, a bank's capital as a percentage of its assets is typically required to be sufficiently high to avoid distress in the banking sector. If borrowers are not able or not willing to service their debt, credit risk increases and the bank is exposed to a higher probability of default. Another reason for fluctuations in asset value might be a drop in the value of borrowers' collateral. A systemic banking crisis arises when a significant number of banks have loan losses that exceed its capital (Demirguc-Kunt and Detragiache, 1998).

According to theory all shocks adversely affecting banks solvency should have a positive correlation with the frequency of banking crises. Additionally, banking systems that are highly capitalized should be less vulnerable to macroeconomic shocks. The literature on banking crises encompasses a broad set of indicators that can be used as proxies for adverse shocks increasing vulnerability in the banking sector (Demirguc-Kunt and Detragiache, 1998). Duttagupta and Cashin (2008) emphasize that an economic downturn, proxied by real GDP growth, increase banks' vulnerability by reducing the quality of its assets and weaken prospects for lending to the private sector.

Furthermore, a surge in inflation reduces the real return on banks assets and makes it harder for banks to screen out borrowers with low ability or willingness to service their debt, thus increasing the risk of adverse selection. A high inflation rate might also be considered as a proxy for macroeconomic mismanagement (Demirguc-Kunt and Detragiache 1998). In addition, English (1996) shows that a stabilization of the inflation rate for countries previously experiencing high inflation might increase vulnerability in the banking sector. High inflation rates for an extended period of time, as for example in Brazil during the 1980s, induces financial institutions to profit from the float of payments. A tighter monetary policy leads to a reduction in the inflation rate and banks can no longer profit from this source of revenue (English, 1996).

Maturity transformation is a function that may increase the vulnerability of the banking system under certain conditions. If a bank's rate of return on its assets falls below the rate it must pay to its depositors, the balance sheet deteriorates, with a higher risk of banking crisis. Since banks assets typically are long-term with a fixed interest rate, an increase in the short-term interest rate implies that the interest rate on deposits must rise as well and profits go down. Even if the bank is able to pass on the increase in real interest rate to borrowers and homeowners this results in more nonperforming loans (Demirguc-Kunt and Detragiache, 1998). This is consistent with the empirical finding that higher and more volatile real interest rates during the last two decades of the twentieth century coincided with a relatively high number of banking crises (Demirguc-Kunt and Detragiache, 2005). In addition, higher international interest rates (e.g. for US Treasury Bill Rate) increase vulnerability in emerging markets through the asset substitution channel, i.e. capital outflows, a weakening of borrower's creditworthiness in emerging countries and adverse selection with information problems in credit markets (IMF, 2000).

Another predicament surfaces when banks lend in domestic currency and borrow in foreign currency. If the currency suddenly depreciates, this might be a threat to banks profitability as the value of bank assets drop below the value of banks liabilities (Demirguc-Kunt and Detragiache, 1998). Kaminsky and Reinhart (1999) show empirically that the real exchange rate on the eve of banking crises is overvalued relative to its tranquil average. Interestingly, datasets compiled in this thesis show that a majority of banking crises are either preceded or succeeded by a currency crisis within two years (table 9 in appendix 1). In addition, a low level of international reserves (relative to short-term external debt) has been found to be an important measure of how vulnerable the economy is to external shocks and speculative attacks due to a limited amount of foreign exchange (Calafell & Del Bosque, 2002).

Reinhart and Reinhart (2008) show that a higher incidence of banking, currency and inflation crises is associated with capital inflow bonanzas. The authors' definition of a capital flow bonanza is a revised version of Milesi-Ferreti and Razin (2000), which encompasses a reduction in the current account balance of at least 3 percentage points of GDP over a period of three years. To incorporate cross-country variation of the current account, the threshold chosen is the 20^{th} percentile. Capital flow bonanzas are mainly debt-creating flows and as the inflows continue (private and public) leverage increases over time. Policymakers often see a capital flow bonanza as a permanent phenomenon even though episodes frequently end with a sudden stop à la Calvo (Reinhart and Reinhart, 2008). In addition, Kaminsky et al. (2004) support the phenomenon of "when it rains, it pours" i.e. GDP, capital inflow and fiscal policy all show a procyclical pattern during times of a capital flow bonanza in emerging markets. A study by Mendoza and Terrones (2008) support the notion that capital flow bonanzas were found to frequently precede credit booms in emerging countries.

A common finding in the literature on financial crises is that lending booms (i.e. a surge in the ratio of domestic credit from the banking sector to GDP) is correlated with a higher incidence of banking crises. One possible reason for this might be that banks ability to discriminate marginal projects decreases during times of rapid credit. As a result, the number of non-performing loans increases if the economy is hit by an adverse shock. Furthermore, inefficient regulation of the financial system and poor supervision combined with state guarantees induce moral hazard and excessive risk taking by financial institutions (IMF, 2000). Domestic credit provided by the banking sector (as a percentage of GDP) has also been found to be a relatively important determinant of housing prices. There seems to be a mutually enforcing mechanism between housing prices and bank credit that differs between countries, where the strength of this mechanism depend on how much weight mortgage lenders put on collateral valuation (Tsatsaronis and Zhu, 2004).

Duttagupta and Cashin (2008) suggest that a sufficiently high level of export growth is necessary not only for a country's economic performance in general, but also the ability of banks to generate profits from intermediating credit to exporters. A lower export growth thus increases vulnerability in the banking sector through two separate channels. Kaminsky and Reinhart (1999) find that both export growth and import growth fall prior to a banking crisis; yet the drop in imports might be accounted for by the general worsening of economic performance. Finally, empirical international linkages between banking crises emanating from financial centers (UK or US) and banking crises in emerging markets have been found to have empirical support in a recent study by Reinhart and Rogoff (2010).

Determinants of Sovereign Debt Crises

In a majority of previous empirical studies, a country is assumed to default on its debt either because it is unable to repay the debt or lacks the willingness to do so. A country's inability to repay its debt generally stems from insolvency or illiquidity in the years preceding a crisis episode. According to Manasse et al. (2009), a sovereign state is considered to be solvent only if "the discounted value of future primary balances is greater or equal to the current public stock (Manasse et al., p. 6, 2009)". Empirically, a classification of illiquidity and insolvency is necessary for appropriate pre-emptive policy measures. A solvent country with large stocks of short-term debt may face a liquidity crisis in the near future. On the contrary, a country with unsustainable accumulation of long-term debt could default even if it doesn't have any liquidity constraints (Manasse & Roubini, 2009).

For a country's ability to repay its debt, different measures of solvency and liquidity are considered as key indicators of vulnerability. Measures of solvency generally include ratios of external debt relative to the capacity to pay, e.g. total external debt to GDP. Liquidity measures on the other hand, typically comprise short term external debt and service on external debt in relation to reserves or exports. According to a study by Manasse et al. (2003), a deterioration of solvency and illiquidity ratios increases the probability of entering and being in sovereign default. In addition, Cohen and Valadier (2011) investigate sovereign debt crises in 127 countries since 1970 and find that roughly half the risk factor depends on the indebtedness of the countries.

In a study by Reinhart (2002), debt crises are preceded by a currency crisis in 84 percent of the cases in her sample, thus providing a reason for incorporating common indicators from the EWS literature on currency crises[10]. A high frequency of simultaneous currency and sovereign debt crises is consistent with the dataset compiled in this thesis (table 10 in appendix 1). Important indicators applied in EWS models for currency crises involve e.g. international reserves, ratio of M2 to reserves, international and national interest rates (Kaminsky & Reinhart, 1999). According to Bauer et al. (2007) currency devaluation might directly cause a debt crisis since the real value of debt denominated in foreign currency will increase; a phenomenon referred to as 'original sin'. Currency devaluation might also lead to a credit rate downgrade triggering a rise in the interest rate risk premium (Bauer, 2007).

Furthermore, global factors have been emphasized to be important for emerging markets in several studies. Manasse and Roubini (2009) stress the importance of the US Treasury Bill Rate as a possible cause of debt servicing problems in emerging markets via a reduction in capital flows. Reinhart and Rogoff (2010) provide empirical support for an indirect causal link between banking crises in financial centers (UK or US) and sovereign debt crises in emerging markets. In addition, measures of volatility, e.g. the variability of inflation, have been found to rise in the years preceding a default. Empirical findings by Eichengreen and Mody (1998) support the notion of export variability, as a proxy for market participant's perception of interruptions to external debt service.

A capital flow bonanza does not only help to predict banking crises but also sovereign defaults, as discussed by Reinhart and Reinhart (2008). The temporal pattern depicted in figure 6 suggests that bonanzas precede sovereign defaults and this is formally tested with binomial logistic regressions. The main results are that lagged versions of a capital flow

[10] The author is grateful to Carmen M. Reinhart for providing her article via e-mail.

bonanza help to predict sovereign defaults[11]. This is consistent with Mendoza and Terrones (2008), who find that credit booms are associated with most debt crises in emerging markets.

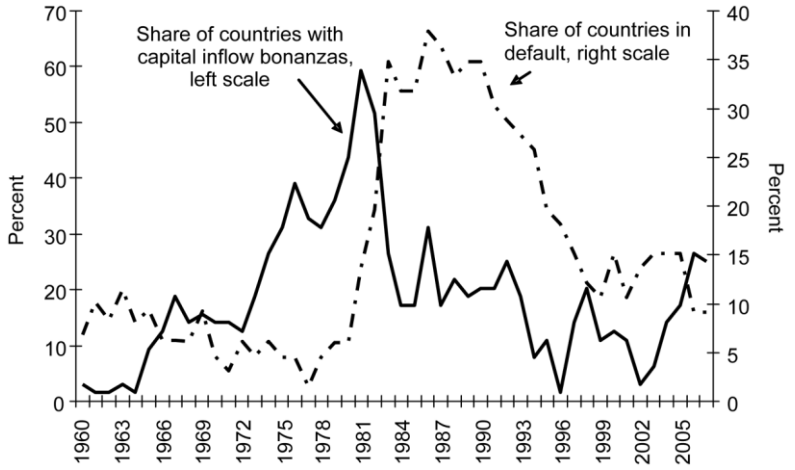

Figure 6. Capital flow bonanzas and sovereign default, 1960-2007 (Reinhart and Reinhart, p. 35, 2008)

Finally, macroeconomic variables, as for example real GDP growth, inflation and the real exchange rate, have been found to be important indicators for determining the probability of default. Figure 7 illustrates the relatively strong correlation between inflation crises (annual inflation rate above 20%) and sovereign defaults; especially since 1940 (0.75). This correlation should be expected since inflation can be considered as a partial default on government liabilities, which are not completely indexed to the exchange rate or to prices (Reinhart and Rogoff, 2009).

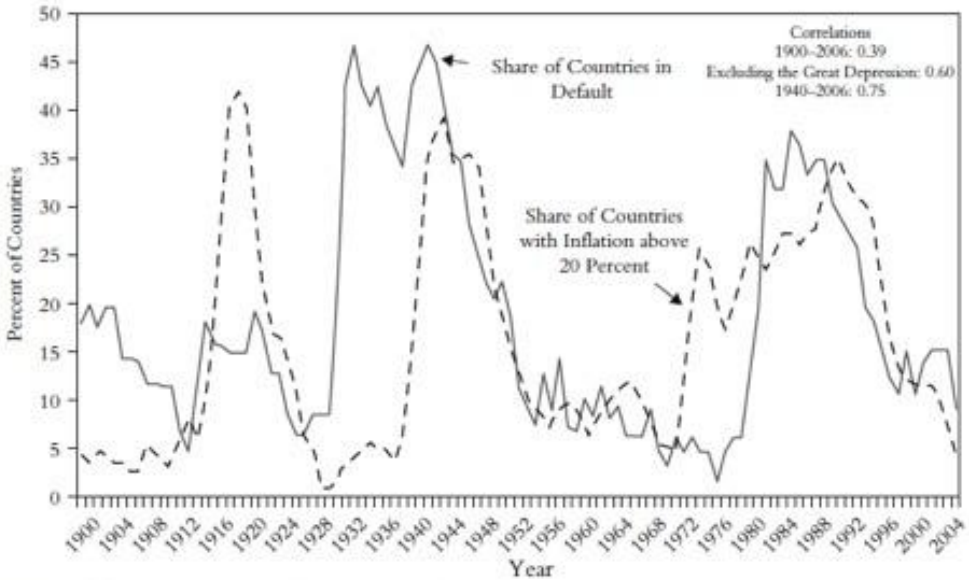

Figure 7. Inflation Crises and Sovereign Defaults 1900-2007 (Reinhart and Rogoff, p., 76, 2009)

[11] It seems as if capital flow bonanzas followed by sudden stops are the most important causes to the Eurozone debt crises in Portugal, Ireland, Greece and Spain as well. This finding contradicts the statement by Wolfgang Schäuble, among others, that excessive state spending was the main cause of unsustainable debt levels in PIGS (Kash, 2011; Krugman, 2011). Interestingly, this finding is consistent with De Grauwe (2011) and provides further support for the claim that underlying vulnerabilities are similar for emerging and advanced countries.

Linkages between Banking Crises and Sovereign Defaults

Reinhart and Rogoff (2009) provide compelling evidence that banking crises historically have been associated with a high incidence of sovereign defaults or periods of restructuring around the world. Spikes in the incidence of both debt and banking crises have occurred during the turbulent times of World War I, the Great Depression and World War II (figure 8). A tranquil period followed World War II until the occurrence of the "new" debt crises of the 1980s and 1990s in emerging markets. During the 1980s more than one third of all countries experienced a sovereign debt crisis or a period of restructuring[12].

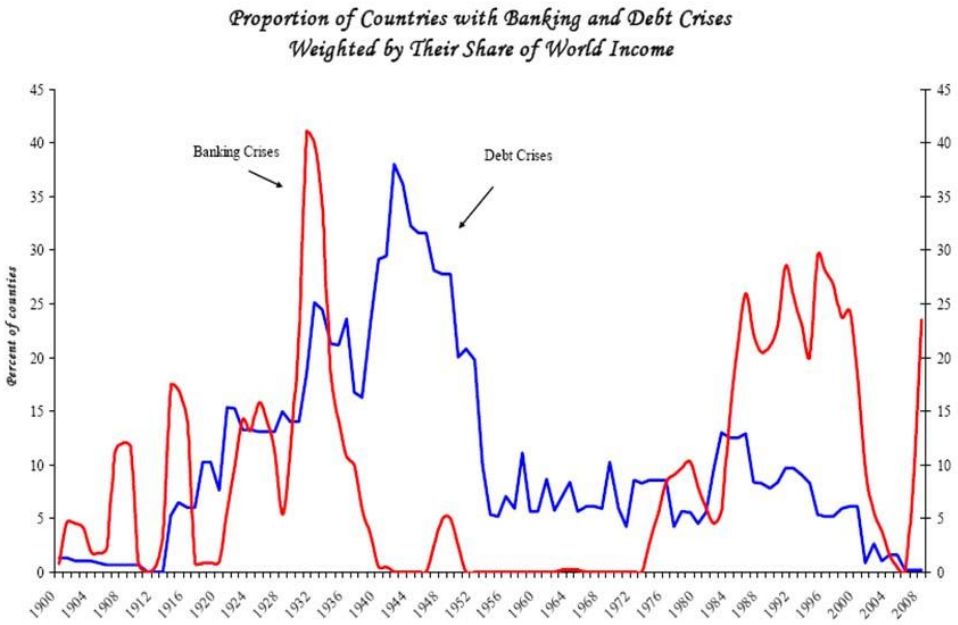

Figure 8. Historical evolution of sovereign debt and banking crises. (Reinhart & Rogoff, p. 74, 2008)

Several reasons exist for why banking crises often precede or coincide with sovereign defaults. Firstly, governments may take on massive debts in reaction to a banking crisis through bailouts, for example direct liquidity support. Furthermore, off-balance sheet support to financial institutions, such as government guarantees to commercial banks, increases the risk premium potential investors demand (Candelon & Palm, 2010). Diaz-Alejandro (1985) emphasizes the contingent liability story with huge amounts of hidden public debt that surfaces ex-post to a financial crisis. He argues that "foreign lenders take government announcements that it will not rescue local private debtors, especially banks, with non-guaranteed external (or domestic) liabilities even less seriously than depositors take the threat of a loss of their money (Diaz-Alejandro, 1985, p. 15)". This finding provides a rationale for not differentiating between private and public external debt for emerging countries, as private debts turn into public debts after the crisis. In addition to bailout costs from supporting banks and other financial intermediaries there are indirect costs associated with banking crises. Tax revenues drop as a consequence of higher unemployment and at the same time public spending increases due to higher costs of social security and countercyclical policy actions needed to stimulate demand (Diaz-Alejandro, 1985).

[12] The author is grateful to Carmen M. Reinhart for pointing this out.

According to Reinhart and Rogoff (2009), the increase in debt from direct and indirect fiscal costs, is on average 86 percent (in real terms) for the period after World War II and these fiscal costs are comparable for advanced and emerging countries. However, advanced countries have a stronger inclination to use fiscal stimulus as a countercyclical policy measure as well as more extensive automatic stabilizers. This is because public spending is higher in developed countries than in emerging markets. On the other hand, the drop in tax revenues is broadly similar for both groups of countries, although with a swifter recovery for emerging countries (Reinhart and Rogoff, 2009).

The Balance Sheet Approach[13] (BSA) is a theoretical model that can be applied to investigate linkages between sectors of the economy and transformations of one type of crisis into another kind of crisis. According to Rosenberg et al. (2005) the economy consists mainly of three different sectors: the private financial sector (comprising mainly banks), the nonfinancial sector (including households and corporations) and the government sector (including the central bank). All sectors of the economy have liabilities to and claims on each other which are netted out when all sectors are consolidated into a country balance sheet. The country balance sheet shows the external balance in relation to external (i.e. nonresident) entities (Rosenberg et al., 2005).

Rosenberg (2005) identifies three potential vulnerabilities that can be analyzed with the BSA: currency mismatches, maturity mismatches and capital structure mismatches. A borrower faces a currency mismatch when liabilities are denominated in foreign currency while assets are denominated in the domestic currency. If the currency suddenly depreciates, then borrowers are unable to repay their loans and creditors will suffer huge losses. The problem of currency mismatch might be even more accentuated by a long-term fixed exchange rate since that can mean that exchange rate risks are underestimated. Maturity mismatches arise when assets are short-term and liabilities are long-term, thus exposing borrowers to both rollover risk (i.e. failure to refinance maturing debt) and interest risks (i.e. movements in interest rates may have different impacts on long-term assets and short-term liabilities). Finally, capital structure mismatches (market risks) are present if debt, instead of equity, is used for financing investments. In contrast to debt payments which remain unchanged, equity can vary considerably, since dividends along with earnings may plummet during a financial crisis (Mathisen & Pellechio, 2006).

Candelon and Palm (2010) suggest that the BSA can be applied to detect sources of banking and sovereign debt crises (figure 9). If there is, for example, a boom in real housing prices in China, this might lead to both higher market risk (due to gradually higher exposure of the financial sector to real estate) and a maturity mismatch (i.e. the proportion of long-term loans in the form of mortgages is too high)[14]. Now if real housing prices begin to decline the financial (and external) sector's asset side will deteriorate exposing the banking sector's vulnerability to the real estate sector. As the financial sector's asset side contracts, demand for public bonds decline and the government now has to enter the foreign bond market. This will however lead to a deterioration of the external debt position increasing the probability of a sovereign debt crisis (Candelon and Palm, 2010a).

[13] The Balance Sheet Approach is applied in practice by both international organizations such as the IMF (Allen et al., 2002) and independent research firms as for example Roubini Global Economics (www.Roubini.com).
[14] Dreger and Zhang (2011) find strong indications of a house-price bubble in China where property prices are overvalued in general by about 20 percent and considerably more in the special economic zones.

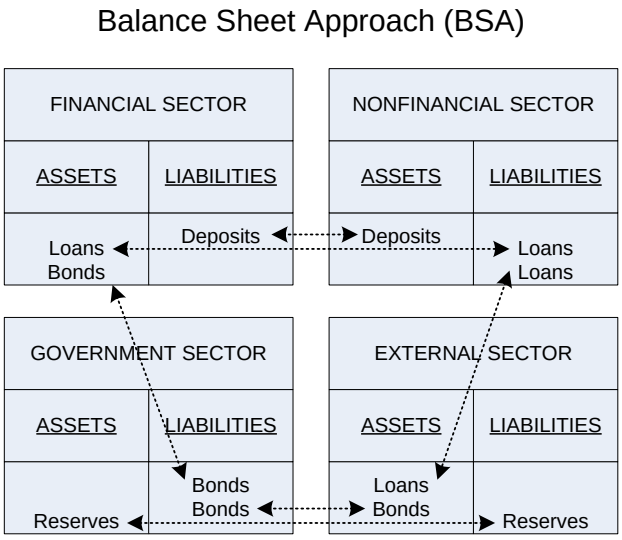

Figure 9. The Balance Sheet Approach (Source: Rosenberg et al., p. 5, 2005)

Reinhart and Rogoff (2009) sketch a prototype for how banking crises can transform into sovereign debt crises via a currency crash (figure 10). The temporal pattern from banking crisis to currency crisis is considerably more frequent than the reversed causality shown in table 9 (appendix 1). According to Diaz-Alejandro (1985) banking crises are often preceded by financial liberalization. There are mainly two reasons for why financial liberalization can trigger the beginning of a banking crisis: it simultaneously increases banks access to external credit and leads to a surge in risky lending domestically (Diaz-Alejandro, 1985). The subsequent lending and asset price boom after financial liberalization eventually leads to a weakening of banks balance sheets. Potential triggers of the banking crisis are that the stock or real estate market crashes. This is consistent with Kaminsky and Reinhart (1999) who find that financial liberalization helps predict banking crises.

As financial institutions experience problems, the central bank supports the financial sector by providing credit. The central bank faces an inconsistency between its role as a lender of last resort and supporting a heavily managed exchange rate. Often the central bank is reluctant to defend the currency by raising interest rates even if the lending to financial institutions is limited. A depreciation or devaluation of the exchange rate is problematic for three different reasons. Firstly, the problem related to currency mismatch, also emphasized in the BSA by Rosenberg (2005), is exacerbated. Secondly, inflation tends to pick up, especially in countries with a history of very high inflation. Thirdly, if the government has debt denominated in foreign currency this increases the probability of both external and domestic default. There are two alternatives to what might follow a significant depreciation or devaluation of the exchange rate. If there is no sovereign credit crisis the banking crisis peaks immediately after the currency crash. Otherwise it is postponed to after the external (and possibly domestic) default (Reinhart and Rogoff, 2009). Table 11 (appendix 1) shows that at least one third of all banking crises are either preceded or succeeded by both a currency crises and a sovereign default within two years. To sum up, crises often occur in close proximity, or, to quote Carmen M. Reinhart, "Disasters do tend to go hand in hand[15]".

[15] E-mail correspondence with Carmen M. Reinhart (2011-09-12).

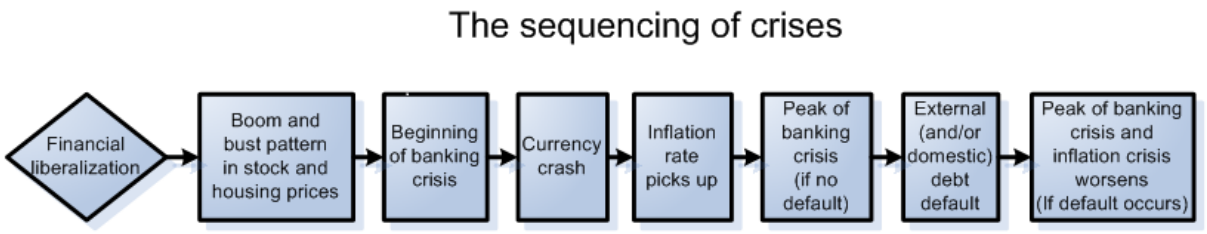

Figure 10. The Sequencing of Crises (Source: Reinhart and Rogoff., p. 271, 2009)

Reinhart and Rogoff (2010) provide empirical support for the temporal pattern that banking crises precede sovereign debt crises[16]. The authors test the causality of crises by using a standard vector autoregressive (VAR) model on both banking and debt crises as dichotomous variables for a sample comprising 70 countries. The results suggest that banking crises in financial centers (UK or US) predict domestic banking crises, which in turn help to predict sovereign debt crises (Reinhart and Rogoff, 2010).

In contrary to the aforementioned theories it is also possible that the causal chain run from sovereign debt crisis to banking crisis. Borensztein and Panizza (2008) have identified three types of links from sovereign default to banking crises. Firstly, a sovereign default can have a negative effect on the confidence of the domestic financial system, which in turn may lead to bank runs. Secondly, a default will have a negative impact on banks' balance sheet. If banks holdings of defaulted papers are large this will reduce the amount of credit banks are willing to supply. Thirdly, creditors' rights may weaken during a default which in turn leads to an even more conservative lending by banks (Borensztein & Panizza, 2008).

Moreover, according to Reinhart and Rogoff (2010) financial repression and international capital controls may induce the government to coerce banks to buy government debt, thus increasing vulnerability of the banking sector in the case of government default. In addition, sovereign default may have an impact on the "sovereign ceiling" i.e. corporate borrowers are not rated higher than the government by foreign investors, which in turn might lead to a 'sudden stop' and considerable problems for banks' solvency (Reinhart and Rogoff, 2010). Empirical support has been found by Borensztein and Panizza (2008) that the direction of causality runs from sovereign debt crises to banking crises. Statistically significant results indicate that the probability of a banking crisis conditional on default is 14 percent. However, the probability of sovereign default conditional on banking crisis is roughly 4 percent and not statistically significant at conventional levels (Borensztein and Panizza, 2008).

In conclusion, the literature suggests that there is both theoretical and empirical support for a causal direction from banking crises to sovereign debt crises and vice versa. Similarly, the country datasets compiled in this thesis are consistent with the empirical finding of mixed temporal patterns; under the assumption that a banking crisis is either preceded or succeeded by a sovereign debt crisis within two years. Since the literature and country datasets emphasize a two-way causal direction and a relatively high frequency of simultaneous banking and sovereign debt crises, this provides a rationale for investigating common determinants to twin crises.

[16] The author is grateful to Carmen M. Reinhart for suggesting this article.

Dataset and Descriptive Statistics

The Dataset

The country dataset was constructed from the JPMorgan EMBI Global Diversified with 31 emerging market economies. Since four countries (Bulgaria, Cote d'Ivoire, Lebanon and Ukraine) lacked comprehensive macroeconomic time series data they were dropped and South Korea was included instead. The final version of the dataset comprises 28 countries from Africa (5), Asia (7), Europe (4) and Latin America (12) during the period 1980-2002.

Table 1. Dataset of banking crises (Demirgüc-Kunt & Detragiache, 2005) and sovereign defaults (Ciarlone & Trebeschi, 2006) for 28 emerging countries between 1980 and 2002.

Country	Year of banking crisis (Demirgüc-Kunt)	No. of banking crises	Year of debt crisis (Ciarlone)	No. of debt crises	Year of twin crisis	No. of twin crises
Argentina	1980-82; 1989-90; 1995; 2001-…	4	1983-95; 2001-…	2	2001-…	1
Brazil	1990; 1994-1999	2	1983-93; 1998-…	2	-	-
Chile	1981-87	1	1983-90	1	1981-90	1
China	1997-99 (Caprio et al., 2003)	1	-	-	-	-
Colombia	1982-85; 1999-2000	2	1988	1	-	-
Dom. Republic	-	-	1982-99; 2002-…	2	-	-
Ecuador	1995-…	1	1983-2000	1	-	-
Egypt	1980-81 (Caprio et al., 2003)	1	1980-91; 1995	2	1980-91	1
El Salvador	1989	1	1984; 1989-92	2	1989-92	1
Hungary	1991-95 (Caprio et al., 2003)	1	-	-	-	-
Indonesia	1992-1995; 1997-…	2	1997-…	1	1997-…	1
Korea, Rep. Of	1997-2002…	1	1980-81; 1984; 1997-99	3	1997-2002…	1
Malaysia	1985-88; 1997-2001	2	-	-	-	-
Mexico	1982; 1994-97	2	1982-92; 1995-96	2	1982-92	1
Morocco	1983 (Caprio et al., 2003)	1	1983-92; 1999	2	1983-92	1
Nigeria	1991-95 (-97)	1	1986-…	1	-	-
Pakistan	-	-	1981-82; 1998-2000	2	-	-
Panama	1988-89	1	1983-95	1	-	-
Peru	1983-90	1	1980; 1983-96; 2000	3	1983-96	1
Philippines	1981-87; 1998-…	2	1984-91; 1994	2	-	-
Poland	1991-1994**	1	1981-93	1	-	-
Russia	1995; 1998-99 (Caprio et al., 2003)	2	1989-…	1	-	-
South Africa	1985	1	1985-89; 1993	2	1985-89	1
Thailand	1983-87; 1997-…	2	1981; 1997-99	2	1981-87; 1997-…	2
Tunisia	1991-95	1	1991	1	1991-95	1
Turkey	1982-85; 1991; 1994; 2000-…	4	1980-82; 2000-…	2	1980-85; 2000-…	2
Uruguay	1981-85; 2002-…	2	1983; 1986-88; 2002-…	3	1981-85; 2002-…	2
Venezuela	1993-97	1	1984-94; 1998	2	-	-
Total 28		**41**		**44**		**17**

**The end date of crisis is not certain but a four-year duration is assumed.

Twin crises are defined as episodes in which a banking crisis is preceded or succeeded by a sovereign debt crisis within two years. Thus, no assumption about the sequencing of crises is made in this thesis, although Reinhart and Rogoff (2011) have found that banking crises often precede debt crises.

The definition of debt crises and chronology of default episodes comes from a study by Ciarlone and Trebeschi (2005). Similarly, the information on banking crises is from Demirgüc-Kunt et al. (2005) and Caprio et al. (2003).

Definition of sovereign debt crisis according to Ciarlone and Trebeschi (2005)

A sovereign debt crisis is defined as the event when one or more of the following conditions occur:

1. A country has officially declared a moratorium on public or external debt payments;
2. A country has incurred a missed payment of interest and/or principal on external obligations towards official and commercial creditors which adds up to more than 5% of the debt service ratio paid by year-end;
3. A country has accumulated arrears of interest and/or principal on external obligations towards official and commercial creditors, which add up to more than 5% of the total external debt outstanding by year-end;
4. A country has signed a debt restructuring or rescheduling agreement with an official and/or commercial creditor;
5. A country has received a large assistance package from the IMF, where large is defined as access in excess of 100% of quota.

Definition of banking crisis according to Demirgüc-Kunt and Detragiache (2005)

A banking crisis is defined as the event when one or more of the following conditions occur:

1. The ratio of non-performing assets to total assets in the banking system exceeded 10 per cent.
2. The cost of the rescue operation was at least 2 percent of GDP.
3. Banking sector problems had led to large-scale nationalization of banks.
4. Extensive bank runs took place or emergency measures such as deposit freezes, prolonged bank holidays, or generalized deposit guarantees were enacted by the Government in response to the crisis.

Explanatory variables

The set of explanatory variables (table 2), is adopted mainly from the body of literature on banking and sovereign debt crises in emerging markets. Data on explanatory variables is taken from IMF International Financial Statistics (IFS), IMF World Economic Outlook (WEO), World Bank World Development Indicators (WDI) and other sources. Variables that exhibit kurtosis, skewness and outliers, have been corrected for by either taking the logarithm of the variable or discarding extreme observations.

Table 2. Explanatory variables

Explanatory variables	Indicator code	Type of crisis[17]	Prev. sig.[18]
Banking crisis in financial center (dummy)	BCrisisFC	Banking	Yes
Ratio of Current Account Balance to Short Term Debt[19]	CABSTD	Debt	Yes
Capital flow bonanza (dummy)	CapFlowBon	Banking / Debt	Yes
Current Account Balance growth[20]	CABGrowth		
Domestic credit provided by banking sector (% of GDP)	DomCredBSGDP	Banking / Debt	Yes
Export growth	ExGrowth	Banking / Debt	-
Export variability (logged)	ExVar_log	Banking / Debt	Yes
Foreign Direct Investment[21] (% of GDP)	FDIGDP	Banking / Debt	-
Import growth	ImGrowth	Banking / Debt	-
Inflation crisis, Inflation rate > 20% (dummy)	InfCrisis	Banking / Debt	Yes
Inflation rate (logged)	InfRate_log	Banking / Debt	Yes
Inflation variability (logged)	InfVar_log	Banking / Debt	Yes
International reserves growth[22]	IntResGrowth	Debt	-
Ratio of debt service on PNG external debt to GDP	DSerPNGEDGDP	Debt	-
Ratio of international reserves to imports	IntResIm	Debt	Yes
Ratio of international reserves to short-term external debt[23]	IntResSTED	Debt	-
Ratio of M2 to reserve money (logged)	M2ResMoney_log	Banking / Debt	-
Ratio of short-term external debt to international reserves (logged)	STEDIntRes_log	Debt	Yes
Ratio of total debt service on external debt to exports	DSerTEDEx	Debt	-
Ratio of total debt service on external debt to international reserves	DSerTEDIntRes	Debt	Yes
Ratio of total external debt to GDP (logged)	TEDGDP_log	Debt	Yes
Real Exchange Rate (logged)	RER_log	Banking / Debt	-
Real GDP growth	RGDPGrowth	Banking / Debt	Yes
Real interest rate	RIR	Banking	Yes
Severe recession, GDP growth < -5% (dummy)	SevRec	Banking / Debt	Yes
Trade (% of GDP)	TradeGDP	Banking / Debt	Yes
Trade balance (% of GDP)	TradeBalGDP	Banking / Debt	-
U.S. inflation	USInf	Debt	Yes
U.S. treasury bill rate	USTBR	Debt	-

[17] An explanatory variable has been used in previous research for a certain type of crisis.
[18] An explanatory variable has been found to be significant in previous research.
[19] Excluding Panama 2000 & 2001
[20] Excluding Russia 1999
[21] Excluding Panama 1987 & 1988
[22] Excluding Dominican Republic 1991
[23] Excluding Panama 2000

Descriptive statistics

Descriptive statistics with mean values for tranquil, pre-crisis and post-crisis regimes similar to that of Manasse et al. (2003) are presented in appendix 2. This is a simple and merely suggestive approach to investigate the behavior of explanatory variables between different regimes and types of crisis.

The ratio of domestic credit provided by the banking sector (to GDP) increases slightly in the run-up to a banking crisis and then continues to rise even further during the post-crisis period. Interestingly, a sovereign default is associated with the opposite pattern, while twin crises seem to balance between banking and debt crises, as the average of domestic credit provided by banking sector (to GDP) first fall during the pre-crisis period and later rise again. Real GDP growth drops significantly during pre-crisis and post-crisis periods for both banking and debt crises. However, twin crises experience first a higher GDP growth on the eve of crisis and later a pronounced fall in the post-crisis period. In addition, the behavior of GDP growth is analogous to that for credit provided by banking sector (to GDP) for banking and twin crises. Concerning the ratio of FDI to GDP, all three types of crisis experience a nontrivial drop in the pre-crisis period followed by a rebound for banking and debt crises on average.

The EWS literature suggests international reserves to be a key determinant for debt and currency crises in emerging markets. The growth rate of international reserves is only one third during the pre-crisis period compared to the tranquil mean for twin crises and even lower for sovereign defaults. In the post-crisis period the growth rate surges to a higher value than the tranquil mean for both crises. Interestingly, international reserves growth only drops considerably in the post-crisis phase for banking crises. All crises experience a substantial fall during the pre-crisis phase when it comes to international reserves (relative to short-term external debt).

Fluctuations in US inflation and the Treasury Bill Rate may have repercussions in emerging countries due to international linkages between economies. All types of crisis demonstrate a higher mean during the pre-crisis period followed by a fall during the post-crisis phase. The real interest rate increases prior to a banking or debt crisis and later falls on average, while twin crises only experience a gradual fall.

Inflation has been found to be significant in predicting both banking crises and sovereign defaults. In the run-up to banking, debt or twin crises, the economy experiences a surge in the inflation rate which is later followed by a small drop for banking crises on average but still higher than the tranquil mean. In contrast, sovereign defaults and twin crises experience a continued increase during the post-crisis period. Inflation variability on the other hand depicts a different temporal pattern for all types of crises. Prior to banking or debt crises inflation variability rises and then falls somewhat during the post-crisis period for banking crises, while it continue to increase considerably for debt crises. A twin crisis on the other hand, experiences a large drop in inflation variability on average during the pre-crisis period and then a rebound back to a somewhat higher value compared to the tranquil mean.

A country's ability to generate revenue in foreign currency is dependent on international trade. The behavior of export and import growth displays a different pattern for all types of crisis. Whereas export and import growth rates rise prior to a banking crisis and then drop below the tranquil mean during the post-crisis period, the opposite pattern occurs in a sovereign default. Twin crises experience a divergent pattern as exports fall and imports

increase during the pre-crisis period. Interestingly, the variability of exports rises ahead of all types of crises on average and then drops during the post-crisis period. However, although export variability increases considerably prior to a banking crisis on average and later falls, the mean value is still higher than the tranquil mean in the post-crisis period. Sovereign debt and twin crises, on the other hand, have a considerably lower average in the post-crisis period compared to the tranquil mean. Furthermore, ratios of trade and trade balance (relative to GDP) have the same V-shaped pattern of for all crises, particularly pronounced in the run up to sovereign debt and twin crises.

Moreover, the literature on debt crises has identified current account balance (relative to short term debt) as a potentially important predictor. The average of current account balance (relative to short term debt), relative to the tranquil benchmark is higher in pre- and post-crisis periods for both banking and debt crises. On the contrary, twin crises display a lower than tranquil average for both crisis periods. Money and quasi money (M2) relative to reserves have been identified in previous research on early warning indicators to be a fairly good predictor of currency crises. The average level of M2 relative to reserves is higher than the tranquil mean in the run up and post-crisis period of a banking crisis; while the opposite is true for debt crises. Differently, twin crises exhibit a considerable increase during the pre-crisis period followed by a drop to a lower value than the tranquil average. The real exchange rate displays a similar pattern for banking and twin crises, as the exchange rate depreciates (devalues) on the eve of crisis and later appreciates (revalues). Debt crises on the other hand show a different pattern with a higher mean than the tranquil mean prior to and after a sovereign default.

One of the most frequently applied measures of a country's solvency is total external debt (relative to GDP). In the pre-crisis period for banking and twin crises the ratio falls below the tranquil mean, while it increases considerably prior to a sovereign default. In the post-crisis phase, all types of crises experience an increase to a level far higher than during tranquil periods on average.

Important measures of liquidity often include ratios of short-term external debt and external debt service (relative to exports, GDP or international reserves). The ratio of short-term external debt to international reserves ascend in the run-up to all crises and especially prior to sovereign defaults. In the post-crisis period it continues to increase for banking and debt crises but falls back somewhat in the aftermath of twin crises. Nevertheless it still remains above the tranquil average.

The ratio of total service on external debt to international reserves exhibits a similar pattern for debt and twin crises, with an increase in the pre-crisis period followed by a further rise in the post-crisis period on average. When the ratio of total service on external debt is relative to exports, it is considerably higher prior to sovereign defaults and twin crisis, yet falls back during the post-crisis period. Banking crises however display a completely different pattern for both ratios. Finally, debt service on PNG external debt (scaled to GDP) rises prior to all crises and rises even further during the post-crisis period for banking crises, while it falls back, on average, for debt and twin crises.

Empirical Analysis

Econometric Specification

A multinomial logit model with three different regimes is applied to data (appendix 4). The different regimes include a tranquil period, a pre-crisis event and a post-crisis phase during which the macroeconomic variables return to a more sustainable path. This methodology is applied to pure sovereign debt crises, pure banking crises and twin banking and sovereign debt crises respectively. In addition, a multinomial logit model normally performs better compared to the multinomial probit, when the dependent variable is unevenly distributed between all three outcomes (Manasse et al., 2003).

The purpose of using a multinomial logit model instead of a simple binomial logit to identify vulnerability indicators is to take into account what Bussiere and Fratzscher (2002) refer to as the post-crisis bias. In the run-up to a financial crisis the behavior of many macroeconomic variables differ from the behavior during the post-crisis phase and this might lead to biased coefficient estimates. There are two ways of solving the post-crisis bias. The first is to drop all observations of being in a crisis and then estimate a standard binomial model. A problem with this alternative is that it ignores data that might include valuable information. The second alternative, applied in this thesis, is a multinomial logit with three different regimes that solves the post-crisis bias without the need to drop any observations.

The three different regimes are defined according to table 3. A crisis period (table 1) is denoted 1 and a non-crisis period equals 0. If there is not a crisis period next year (t+1) or the subsequent year (t+2) the economy is in a tranquil period at time t and the dependent variable equals zero (Y=0). However, if the economy has a crisis episode next year or the subsequent year the economy is in a pre-crisis period at time t and the dependent variable is denoted one (Y=1). Finally, the economy experiences a post-crisis period at time t if there is a crisis in the current year (t) and either the next year (t+1) and/or the subsequent year (t+2), for which the dependent variable takes the value two (Y=2).

Table 3. Regimes of multinomial logit model (Ciarlone and Trebeschi, 2005)

Model at time t	t	t+1	t+2
Tranquil (Y=0)	0	0	0
	1	0	0
Pre-crisis (Y=1)	0	0	1
	0	1	0
	0	1	1
Post-crisis (Y=2)	1	1	0
	1	1	1
	1	0	1

With a two-year forecast horizon the model indicates a pre-crisis regime both one and two years ahead of the first year of crisis. The reason for choosing a two-year forecast horizon is to be able to apply the model as a policy tool. Due to publication lags of macroeconomic data and a policymaker's ability to take pre-emptive policy measures before the onset of crisis, the choice of a two-year forecast horizon can partly mitigate these concerns. However, there is a trade-off between the applicability of the model as an early warning system and the cost of higher forecast variance.

The multinomial model is estimated with maximum likelihood and the tranquil state is the benchmark to which the other regimes are compared. Since data at time t is applied for predicting crisis events at time t+1 and t+2 all variables in 2001 and 2002 are disregarded.

The main purpose of this thesis is to identify determinants (vulnerability indicators) for banking crises, sovereign defaults and twin banking and debt crises. To identify the determinants of each type of crisis, a general to specific approach is conducted in three steps with multinomial logit regressions. Subsequently, a comparison of possibly significant indicators for each type of crisis is performed and related to theory[24].

1. Independent multinomial logit regressions of each variable excluding all variables that are insignificant or have a counterintuitive sign in determining the pre-crisis or post-crisis phase. The descriptive statistics analysis (appendix 2) is applied to decide whether a variable has a counterintuitive sign or not.

2. Group-wise regressions of all variables that passed the first step after they have been grouped into families according to their nature. Only variables that are significant and have the correct sign are retained.

3. All variables that have passed the first and second step together with variables found significant in previous studies are included in a general multinomial logit regression. This is to take into account the effects of omitted variable bias, which might render coefficient estimates inefficient and biased, leading to the exclusion of variables that were omitted in the first or second step (Ciarlone & Trebeschi, 2005). Once again, only variables that are significant and have the correct sign are retained for each type of crisis in the final model (table 4, 5 & 6).

Finally, the marginal effect is estimated for each variable that passed the third step and for each type of crisis. Since the multinomial logit model is nonlinear, the marginal effect depends on the independent variables' specific values (Long & Freese, 2006). Marginal effects are calculated at sample means or for switch from zero to one for dummy variables.

[24] Results from all regressions are available from the author upon request.

Estimation results

Banking Crises

At the end of the general to specific approach, only nine vulnerability indicators remain that have significant marginal effects on the probability of entering and/or being in a crisis. Furthermore, the sign of all coefficients for significant variables are consistent with the pattern in the chapter on descriptive statistics. The ratio between international reserves and short term external debt is the only variable that has a significant negative probability of entering into crisis. This is consistent with Calafell & del Bosque (2002) and might be an indication of the empirical finding that a majority of banking crises coincide with currency crises (table 9 in appendix 1).

Domestic credit from the banking sector (relative to GDP) has a positive and significant probability of entering and being in a crisis. Since domestic credit from the banking sector and housing prices are correlated to some degree, this might be consistent with Reinhart and Rogoff (2009) result that real housing prices are the second best indicator of banking crises. A surge in capital inflow proxied by the dummy variable capital flow bonanza has a positive probability of entering into crisis. This is consistent with the empirical findings of Reinhart and Reinhart (2008). Export variability is another vulnerability indicator with a positive probability of entering and being in a crisis. Higher export variability as a proxy for a market participant's view of interruptions to service on external debt, should not be surprising as banking and debt crises often coincide.

Falls in the growth rates of international reserves and real GDP increases the probability of a country being in a post-crisis period. Furthermore, an inflation crisis (i.e. inflation rate above 20 percent) has a positive marginal effect of being in a post-crisis period, which is consistent with the sequencing of crises (figure 10) according to Reinhart and Rogoff (2009). Total external debt (relative to GDP) increases in the post-crisis period and might be indicative of a causal direction from banking to debt crises. Finally, a banking crisis in the UK or US is not significant in the pre-crisis period in contrast to Reinhart and Rogoff (2010).

Table 4. Final multinomial logit estimation for banking crises

Variable – banking crisis	Marginal Effect	Coefficient	Standard Error	Z-statistics	P-value
Pre-crisis period (Y=1)					
Constant		-5.5786	1.0267	-5.43	0.000
IntResSTED	-0.0328	-0.3888	0.1894	-2.05	0.040
DomCredBSGDP	0.0007	0.0104	0.0043	2.42	0.015
CapFlowBon	0.1050	0.8784	0.3882	2.26	0.024
ExVar_log	0.0412	0.5216	0.1338	3.90	0.000
Post-crisis period (Y=2)					
Constant		-3.6086	0.8648	-4.17	0.000
IntResGrowth	-0.1178	-0.9542	0.3942	-2.42	0.016
RGDPGrowth	-0.0130	-0.1122	0.0322	-3.48	0.000
DomCredBSGDP	0.0018	0.0159	0.0038	4.20	0.000
BCrisisFC	-0.1048	-0.9144	0.3260	-2.81	0.005
ExVar_log	0.0417	0.4000	0.1172	3.41	0.001
InfCrisis	0.0935	0.8036	0.3453	2.33	0.020
TEDGDP_log	0.1352	1.1287	0.2702	4.18	0.000
Pseudo R-squared	0.1759				

Sovereign debt crises

In the final multinomial logit estimation for sovereign debt crises only ten variables are retained. Interestingly, the dummy variable capital flow bonanza also increases the probability of entry into sovereign debt crises. This result is consistent with Reinhart and Reinhart (2008) illustrated in figure 6. A decline in the trade to GDP ratio raises the probability of entry into crisis and at the same time seems to reduce the probability of being in a crisis, although the latter is inconsistent with descriptive statistics. Trade might be a more important indicator for debt crises compared to banking crises, since export and import growth on average is lower during the pre-crisis period than in the tranquil phase for debt crises (table 13). The opposite pattern is true for banking crises (table 12).

Current account balance relative to short-term debt has a positive marginal effect of entry into crisis, but is insignificant for the probability of being in crisis. Total external debt relative to GDP is the only variable measuring solvency and has a positive marginal effect on the probability of entry into crisis. While total external debt (relative to GDP) was significant and positive only for being in a banking crisis, it is significant and positive for both entry into and being in a sovereign debt crisis. This result supports the possible temporal pattern from banking to debt crises reported by Reinhart and Rogoff (2010). Unexpectedly, export variability as a proxy for perceived difficulties of debt service by investors is not found to be significant for entry into debt crisis.

A few variables are only significant for the probability of being in a crisis. Inflation variability increases the probability of being in a crisis which is consistent with the empirical finding by Reinhart and Rogoff (2009) illustrated in figure 7. Moreover, a fall in export variability or M2 relative to reserves only increases the probability of being in a crisis. Finally, measures of liquidity such as debt service on total external debt (relative to export) and short-term debt (relative to international reserves) only have significant positive marginal effects for being in a post-crisis period.

Table 5. Final multinomial logit estimation for sovereign defaults

Variable – Debt crisis	Marginal Effect	Coefficient	Standard Error	Z-statistics	P-value
Pre-crisis period (Y=1)					
Constant		0.9132	1.8216	0.50	0.616
CapFlowBon	0.1149	1.7447	0.5512	3.17	0.002
BCrisisFC	-0.1113	-1.1203	0.5098	-2.20	0.028
TradeGDP	-0.0026	-0.0265	0.0128	-2.07	0.039
CABSTD	0.0475	0.7797	0.2832	2.75	0.006
TEDGDP_log	0.0226	1.4817	0.6048	2.45	0.014
Post-crisis period (Y=2)					
Constant		2.0049	1.2414	1.62	0.106
ExVar_log	-0.1156	-0.5042	0.1398	-3.61	0.000
CapFlowBon	0.1952	1.2071	0.5060	2.39	0.017
BCrisisFC	0.2183	0.7773	0.3476	2.24	0.025
InfVar_log	0.2535	1.0886	0.1536	7.09	0.000
DSerTEDEx	0.3455	1.6281	0.7756	2.10	0.036
TradeGDP	0.0048	0.0164	0.0064	2.58	0.010
M2ResMoney_log	-0.2111	-0.8756	0.3126	-2.80	0.005
TEDGDP_log	0.6159	2.7941	0.4519	6.18	0.000
STEDIntRes_log	0.0905	0.4540	0.1952	2.33	0.020
Pseudo R-squared	0.4234				

Twin Crises

Only seven significant variables are retained in the final MNL model for twin crises. Somewhat unexpectedly, a capital flow bonanza is significant in neither determining entry into nor being in a twin crisis, in contrast to pure banking or sovereign debt crises. Furthermore, trade balance (relative to GDP) and inflation variability have a negative marginal effect on entry into crisis consistent with descriptive statistics.

The only vulnerability indicator with positive marginal effects on being in a pre-crisis period is M2 to Reserve Money. According to Bauer et al. (2007), an increase in the ratio of M2 to reserves signals excess liquidity in the financial system, impeding the monetary authority to effectively defend the currency from speculative attacks. Thus an increase in M2 to reserves raises the likelihood of a currency crisis and most certainly the probability of a twin banking and debt crisis. This might be explained by the fact that a majority of twin banking and debt crises coincide with currency crises (compare table 1 & 11 in appendix 1). Furthermore, Bauer et al. (2007) find the ratio of M2 to gross international reserves to have a significant and positive effect on twin currency and sovereign debt crises.

None of the vulnerability indicators that were found significant in determining entry into crisis are significant for the probability of being in crisis. Export variability indicates a negative marginal effect on being in crisis, while debt service on private non-guaranteed debt (relative to GDP) and real exchange rate variability signal an increased probability the economy experiences a post-crisis period[25]. A positive marginal effect of the real exchange rate in the post-crisis period, indicates a depreciation or devaluation of the currency and might be explained by the relatively high frequency of triple crises (table 11).

Table 6. Final multinomial logit estimation for twin crises

Variable – Twin crisis	Marginal Effect	Coefficient	Standard Error	Z-statistics	P-value
Pre-crisis period (Y=1)					
Constant		-12.0923	6.5697	-1.84	0.066
TradeGDP	0.0000	-0.1015	0.0348	-2.92	0.004
TradeBalGDP	-0.0029	-6.9370	2.7732	-2.50	0.012
InfVar_log	-0.0004	-0.9214	0.4337	-2.12	0.034
M2ResMoney_log	0.0017	3.9876	1.4605	2.73	0.006
Post-crisis period (Y=2)					
Constant		2.0618	1.1002	1.87	0.061
ExVar_log	-0.0548	-0.5215	0.1319	-3.95	0.000
DSerPNGEDGDP	5.0234	47.8491	11.5835	4.13	0.000
RER_log	0.0145	0.1383	0.0469	2.95	0.003
Pseudo R-squared	0.2084				

[25] The coefficient of debt service on PNG external debt (relative to GDP) should be interpreted with care due to very high standard errors.

Predictive Ability

The final step of building an early warning system is evaluation of its suitability as a policy tool for pre-emptive measures by the decision maker. To test the predictive ability, a binomial logit model is estimated with variables that were found to be significant only in the pre-crisis period. This implies that all observations for the post-crisis period (Y=2) are dropped and a particular threshold must be determined.

Since no precise rule of identifying an optimal threshold exists, a tradeoff between too many false alarms (type I error) and the risk of not being able to detect the onset of a crisis (type II error) must be established. The decision-maker's loss function facilitates the task of determining a suitable threshold level. Welfare costs associated with pre-emptive policy measures after a false alarm are typically less severe than the failure of a policymaker to notice and fend off an eminent crisis. Additionally, policy action in response to a false alarm does not necessarily have to be a mistake, since there might be increased vulnerability in the economy mitigated by appropriate measures (Fuertes and Kalotychou, 2007).

To compare the predictive ability, a goodness-of-fit measure called the '*percent correctly predicted*' is applied to each type of crisis (see appendix 5). If one of the outcomes is infrequent, which is the case for pre-crisis observations of banking, debt and twin crises used in this thesis, a relatively low critical value is appropriate. For example the number of pre-crisis observations for twin crises is only about 5 percent of the total number of observations in the sample. If the estimated probability of a pre-crisis observation is, for example, never above a 0.5 threshold, it could be the case that when $y_j = 1$ none of the twin crisis observations are correctly predicted. One solution to this problem applied in this thesis, is to choose a critical value based on the in-sample frequency of pre-crisis observations[26].

The number of correctly predicted pre-crisis observations will be much higher compared to a threshold of 0.5, but so will the number of false alarms. Two different threshold values clearly illustrate the trade-off between correctly predicted pre-crisis episodes and the number of false alarms. Importantly, the threshold chosen is mostly consistent with the optimal critical value according to Candelon et al. (2010) shown in appendix 6. The in-sample predictive ability of significant variables from the final estimation for each type of crisis is tested for the period 1980-2000. However, the out-of-sample predictive ability must be examined to verify the vulnerability indicators suitability for forecasting of crisis. Hence, another binomial logit is estimated with macroeconomic data from 1980 to 1996 for predicting crises from 1997 to 2000.

In-sample performance

The summary of in-sample predictive performance in table 7 suggests that the model for twin crises is superior to that for debt crises followed by banking crises. The number of total observations correctly called is high for twin crises, somewhat lower for debt crisis and considerably worse for banking crises. The ability to predict pre-crisis observations is quite good for all three models although somewhat better for debt and twin crises. Finally, concerning the ability to issue as few false alarms as possible the model for twin crises clearly

[26] A cutoff-value for each crisis is estimated by dividing the in-sample frequency (1980-2000) of pre-crisis observations with the total number of observations. The higher cutoff-value corresponds to the in-sample frequency without post-crisis periods while the lower value includes these observations.

outperforms the others. Furthermore, the number of false alarms seems to be significantly lower for debt crises in comparison to banking crises.

The tradeoff between successfully signaling a crisis ahead of time and issuing too many false alarms becomes apparent when comparing cutoff-values for banking and debt crises. However, for twin crises the relation disappears due to relatively few pre-crisis observations. The higher cutoff-value for each type of crisis seems to correspond well to the probability cutoff of the intersection between the sensitivity curve and the specificity curve in appendix 6. In addition, a ROC curve analysis (see appendix 7) illustrates that the area under the ROC curve of twin crises is the largest (0.8722), followed by debt crises (0.8191) and finally banking crises (0.7224). The ROC curve analysis supports the finding that twin crises have superior predictive ability compared to pure debt or banking crises. This result is consistent with the finding of Kaminsky and Reinhart (1999), that an early warning system for twin banking and currency crises has superior predictive ability compared to single banking or currency crises. Bauer et al. (2007) also show that when treated as a specific type of crisis, a majority of twin currency and sovereign debt crises can be predicted at a very low cost in terms of false alarms.

Table 7. In-sample prediction of banking, debt and twin crises

In-sample prediction	Banking Crisis		Debt Crisis		Twin Crisis	
Cutoff-value	0.12	0.15	0.13	0.19	0.04	0.05
Number of total observations correctly called	59%	64%	66%	74%	77%	81%
Number of pre-crisis observations correctly called	78%	67%	84%	73%	79%	79%
Number of false alarms	45%	36%	38%	26%	23%	19%

Out-of-sample performance

Prediction out-of-sample is clearly worse than in-sample for debt and twin crises, as both models issue a higher number of false alarms while the number of correctly called pre-crisis observations is roughly the same or lower. The considerable swing in the number of pre-crisis observations correctly called for twin crises is because of relatively few out-of-sample observations (figure 13 in appendix 6). However, predictive ability for banking crisis out-of-sample seems to outperform in-sample performance with a higher number of correctly called crises and fewer false signals. Importantly, the probability cutoff for debt crises in the sensitivity/specificity report (figure 12 in appendix 6), indicate that a higher cutoff value than 0.19 is appropriate. A ROC-curve evaluation (appendix 7) shows that the area under the ROC curve is still highest for twin crises (0.7404), followed by debt crises (0.7385) and finally banking crises (0.7288). The area under the ROC curve out-of-sample (0.7288) is somewhat higher than in-sample (0.7224) for banking crises and this is consistent with the previous finding.

Table 8. Out-of-sample prediction of banking, debt and twin crises

Out-of-sample prediction	Banking Crisis		Debt Crisis		Twin Crisis	
Cutoff-value	0.12	0.15	0.13	0.19	0.04	0.05
Number of total observations correctly called	60%	69%	60%	68%	67%	69%
Number of pre-crisis observations correctly called	89%	78%	85%	77%	60%	40%
Number of false alarms	44%	32%	45%	34%	33%	30%

Robustness Analysis

There are several tests that are commonly applied in a general to specific approach with multinomial logit models (MNLM). It is important to test for multicollinearity in all MNLM estimations when more than one variable is included in the regression. Multicollinearity has been controlled for by computing the Variance Inflation Factor (VIF) for all groupwise and general MNL estimations (appendix 3) as well as the final estimations (table 4, 5 and 6). The Variance Inflation Factor shows how an estimator's variance is inflated by multicollinearity and if VIF exceeds 10 then a variable is considered to be highly collinear (Gujarati, 2004). Moreover, a general rule of thumb is that further investigation is necessary if VIF > 4 and since all variables in the groupwise, general and final MNL estimations have a VIF < 2 multicollinearity should not be a concern.

To test whether all coefficients associated with an independent variable equals zero, Likelihood-ratio tests are conducted for all final models and the results show that all independent variables have a significant effect. Moreover, a Wald test is applied to all final models to test if all coefficients associated with a pair of outcomes are zero. Since the zero hypotheses are rejected for all final models, categories of the dependent variables should not be collapsed. In addition, robust regressions of all final models are conducted to check whether the MNL estimations are misspecified[27]. All variables from the final estimations of banking and twin crises are also significant in the robust estimations (table 25 & 27 in appendix 8). However, for sovereign defaults short-term external debt (to international reserves) is significant in both the pre- and post-crisis period while service on total external debt (to exports) no longer is significant in the post-crisis phase (table 4 & 26).

Davis et al. (2010) show that leading indicators of financial crises might vary across regions due to different financial and economic structures. A robustness check is conducted by comparing the global sample with a regional sample including only Latin American countries (table 28 & 29 in appendix 8). Interestingly, domestic credit provided by the banking sector (to GDP) and capital flow bonanzas are also significant in the regional sample and increase the probability of entering a banking crisis (table 25 & 28). However, in contrast to the global sample real GDP growth is found to be significant and has a negative marginal effect on the probability of being in a pre-crisis period. Furthermore, international reserves (to short-term external debt) and export variability were not found to be significant in the pre-crisis period in the regional sample. In the post-crisis period only real GDP growth and the inflation crisis dummy are significant and have somewhat stronger marginal effects compared to the global sample.

Determinants of sovereign debt crises differ considerably between the global and regional sample (table 26 & 29). It is only current account balance (to short-term debt) that is significant in the pre-crisis period in both samples. Interestingly, service on total external debt (to export) is found to be positive and significant in both the pre- and post-crisis period for the regional sample, which might indicate that a deterioration of liquidity ratios could be more problematic in Latin American countries. However, all variables in the post-crisis period for the regional sample are significant and have the same sign as in the global sample except for service on total external debt (to exports).

[27] Multinomial logit regressions with robust variance estimates (Huber White and sandwich estimator).

A very important question is if estimations are robust to other definitions of banking and sovereign debt crises. The number of banking and debt crises is somewhat lower in the supplementary dataset compared to the original dataset but the number of twin crises is higher (table 30 in appendix 9). A different definition of banking and debt crises does not alter the relatively high frequency of banking, debt and twin crises in the country sample.

Robust re-estimations of the final multinomial logit models for banking, debt and twin crises are found in appendix 9 (table 31, 32 and 33). The definition of banking crises according to Laeven and Valencia (2010) shows that domestic credit provided by the banking sector (to GDP) no longer is significant during the pre-crisis period for banking crises (table 31). However, real GDP growth is found to be significant and indicate that a drop in the growth rate increase the probability of entering a banking crisis which is consistent with the regional sample (table 28 & 31). Interestingly, international reserves (to short-term external debt), capital flow bonanzas and export variability are significant and have the same sign in both the original and supplementary global dataset. In addition, all variables in the post-crisis period except the growth rate of international reserves are significant and have the same sign as in the original sample.

The definition of sovereign debt crises according to Manasse and Roubini (2009), shows that an increase in export variability or M2 (to reserve money) raises the probability of entering a sovereign default in contrast to the original dataset (table 26 & 32). However, short-term external debt (to international reserves) is no longer significant in the pre-crisis period yet still in the post-crisis phase. Moreover, although capital flow bonanzas, trade (to GDP) and M2 (to reserve money) are significant in the pre-crisis period they are not during the post-crisis phase in contrast to the original dataset. Finally, trade balance (to GDP) is the only indicator that is significant during the pre-crisis period for twin crises in both the original and supplementary global dataset (table 27 & 33). A worsening of the trade balance (to GDP) seems to raise the probability of entering a twin crisis irrespective of definition applied. Export variability is found to have a significant and positive marginal effect on entering all three types of crisis in the supplementary dataset.

In summary, all final MNL estimations show that capital flow bonanzas are found to have a significant and positive probability of entering a banking crisis (table 4, 25, 28 & 31). Capital flow bonanzas are also found to be significant with a positive marginal effect on being in a pre-crisis period for all sovereign debt crises except for the regional dataset (table 5, 26 & 32). Moreover, an increase in domestic credit provided by the banking sector (to GDP) raises the probability of entering a banking crisis in the global and regional estimations but not in the supplementary dataset. In addition, a drop in the growth rate of real GDP raises the probability of being in a pre-crisis period for banking crisis in both the regional and supplementary dataset. This result is consistent with Davis et al. (2010) that real GDP growth is a very important indicator for banking crisis. Another interesting finding is that high inflation seems to coincide with being in all types of crisis. A surge in inflation measured by the inflation crisis dummy or higher inflation variability is found to be significant in all post-crisis periods for all datasets, except the original global dataset for twin crises. This is consistent with a high simultaneous occurrence of sovereign defaults and inflation crises (figure 7). Finally, a higher ratio of total external debt (to GDP) increases the probability of being in a post-crisis period for banking crises and the pre-crisis phase for sovereign defaults (table 4, 5, 25, 26, 31 & 32). This result indicates the possibility of a temporal pattern from banking to sovereign debt crises consistent with the sequencing of crisis (figure 10) according to Reinhart and Rogoff (2009).

Concluding Remarks and Implications for Policy

"The global economy is in a dangerous new phase. Global activity has weakened and become more uneven, confidence has fallen sharply recently, and downside risks are growing (IMF, p. xv, 2011b)".

As the world is entering a danger zone, the need to identify potential vulnerabilities in emerging and developed countries, has never been as important as today. The most important finding in this thesis, is the relatively high frequency of banking and sovereign debt crises in emerging countries and that different kinds of financial crises "tend to go hand in hand" as Carmen Reinhart says[28].

This thesis is probably the first to investigate common determinants of twin banking and sovereign debt crises, where such a combination is treated as a specific kind of crisis. The superior predictive ability of twin crises over pure banking and debt crises is not entirely unexpected, since twin crises are generally more severe and costly in terms of lost output. This is consistent with results for twin currency and banking crises by Kaminsky and Reinhart (1999) and for twin currency and debt crises by Bauer et al. (2007). Empirical evidence in this thesis suggests that twin banking and debt crises should be treated as a specific kind of crisis.

Moreover, determinants of banking, debt and twin crises have been identified and related to theory. The most striking finding was that a surge in capital inflows is significant during the run-up of both banking and debt crises for emerging countries. Recent research by De Grauwe (2011) and Mensori (2011), show that capital flow bonanzas also seem to be the main cause of the Eurozone debt crisis. Ratios of solvency and liquidity seem to be important indicators prior to sovereign defaults but not for banking crises. On the other hand do some variables, such as domestic credit provided by the banking sector (relative to GDP) and international reserves (relative to short-term external debt) be particularly important on the eve of banking crises. Interestingly, a deterioration of the trade balance (relative to GDP) has been found to be significant only prior to twin crises but not for pure banking or debt crises in the final model.

Further research needs to include additional variables that might be important, for example housing prices, credit ratings and income inequality. Contagion from other countries in the same region, and state dependence of banking and debt crises, should also be accounted for when investigating financial crises. In addition, systemic risks to the global financial system should somehow be incorporated in models that address vulnerabilities in developed countries.

I strongly disagree with the belief that the exact timing of crisis emphasized by Besley and Hennessy (2009) is so important, because the trigger (in this case the failure of Lehman) of a crisis is intrinsically unpredictable. The belief that it is important to be able to predict the timing of crisis is misleading. Predicting the timing of crisis is also a precarious task, since if economic variables have a poor track record of predictive ability this might induce us to falsely believe that financial crises are random events.

Kindleberger was right[29]. Triggers are particular; underlying vulnerabilities are general. If financial crises can be described as "a specific trigger superimposed on an underlying

[28] E-mail correspondence with Carmen M. Reinhart (2011-09-12).

[29] "For historians each event is unique. Economics, however, maintains that forces in society and nature behave in repetitive ways. History is particular; economics is general (Kindleberger, p. 14, 1978)"

vulnerability (Ghosh et al., 2009)", then this implies that financial crises consist of both a historic (particular) part and an economic (general) part. It is crucial to disentangle the underlying vulnerability from the trigger when investigating financial crises. The difficulty of predicting the timing of financial crises can be described as follows:

"You can see that an economy is vulnerable, and maybe even fairly reliably you say you'll have a crisis in five to ten years, but until it's upon you it's hard to narrow the window down with any precision. […] The analogy is someone who's vulnerable to a heart attack. You can go to the doctor and they can see your cholesterol is high and you have risk factors, but you might go on for 20 years without anything happening. Or it might be 20 hours (Klein, 2010)."

The question is now whether looking at underlying vulnerabilities for previous financial crises can help to predict crises today; in particular the Second Great Contraction. One of the leading experts on financial crises, Kenneth Rogoff provides the following answer in an interview in the Washington Post:

"As Carmen Reinhart and I have emphasized, it really boils down to arrogance and ignorance. Across the huge range of crises we look at, the similarities are remarkable. Countries have different policy responses, central bank systems, political institutions and financial systems, but they share the quantitative markers that precede these crises: Run-ups in housing prices and huge leverage are major indicators. So the people who think this was all about Lehman haven't read our book [This Time Is Different]. This wasn't about some mistakes made over one weekend the way many books portray it. Housing prices had doubled, debt had exploded, we were set to lose trillions of dollars in the value of our capital stock [underlying vulnerabilities]. Lehman was the spark [trigger], but the idea that it could've been largely avoided is very naive. If people think that the only real problem was letting Lehman fail, then that bodes badly for the steps we'll take to prevent future crises (Klein, 2010)."

Interestingly, the results in this thesis are consistent with the quantitative markers emphasized by Kenneth Rogoff. Capital flow bonanzas, that are mainly debt-creating flows, were found to be a significant vulnerability indicator of both banking and debt crises irrespective of dataset applied. Furthermore, total external debt (as a percentage of GDP) was significant in predicting sovereign debt crises. In addition, an increase in domestic credit provided by the banking sector (as a percentage of GDP), that to some degree is correlated with higher housing prices, is a significant vulnerability indicator for banking crises in both the global and regional sample.

From the finding by Reinhart and Rogoff (2009) that key underlying vulnerabilities are remarkably similar between countries (which is consistent with thesis) there emerges a tremendously positive implication for policy. Investigating underlying vulnerabilities in the economy enables us to see when there is an increased probability of a financial crisis. If we know when the economy is more vulnerable to some unexpected trigger, we can make our societies more robust by taking pre-emptive action and thereby mitigating the economic, social and political consequences.

However, information on underlying vulnerabilities to the economy is not enough. People who try to warn us about mounting vulnerabilities in the economy are ignored, ridiculed or put under enormous pressure to keep quiet[30]. Morris Goldstein a former Deputy Director of the Research Department at the IMF says that "Fundamentally, early warning systems come down to being willing to make the call in public, […] It is about balls as much as brains

[30] This happened to Olivier Blanchard when talking in Spain about problems of capital inflows (Krugman, 2011), Nouriel Roubini at the IMF in 2006 when trying to warn on the unsustainable increase in U.S. housing prices (Roubini Global Economics) and Morris Goldstein on problems in the Japanese economy in the 1990s (Beattie, 2009).

(Beattie, 2009)". Unfortunately, policymakers have a tendency not to take action if the timing of a crisis is hard to call. Why should I worry if a financial crisis is not going to happen on my watch? But due to the human costs of financial crises, policymakers must take responsibility for the economy even in the longer term (Klein, 2010).

The failure of the "collective imagination" stressed by Besley and Hennessy (2009) might be due to a combination of the illusion of 'this time is different', and that (global) financial crises are perceived as highly improbable events. It has been shown in this thesis that financial crises in emerging countries are relatively common events. Reinhart and Rogoff (2009) show that financial crises, that are global or multicountry in scope, occur at regular intervals[31].

One solution, to the failure of the "collective imagination" in the face of this kind of global crisis, might be to increase the "collective knowledge" of financial crises in general, and the First and now Second Great Contraction in particular. If more people have a profound understanding of the nature, causes and consequences of financial crises, perhaps the illusion of 'this time is different' can be mitigated. Hopefully, policymakers will no longer be able to easily ignore early warnings of increasing vulnerabilities. People will demand that these vulnerabilities are addressed directly, if possible, or at least that policymakers take pre-emptive policy measures to mitigate the negative economic, social and political impact. Importantly, academic institutions will have to play a key role in providing the public good, "collective knowledge" of financial crises.

Emerging economies are an essential part of the global recovery, particularly at a moment when growth prospects of the developed countries seem to be getting weaker. However, the empirical finding in this thesis and by Reinhart and Reinhart (2008b), that capital flow bonanzas that are followed by a sudden stop (i.e. a sharp decline in capital flows) cause financial crises, indicate a precarious situation in emerging markets at present.

"*While developed countries stumble, the situation for emerging markets may be changing for the worse. Since August [2011], we've seen bond spreads for emerging markets increase, their equity markets have declined like in developed markets, and capital flows have declined sharply (Zoellick, 2011).*"

One aim of this thesis has been to investigate underlying vulnerabilities of financial crises. However, financial crises are in themselves underlying vulnerabilities (or triggers) of political instability[32]. If the current economic situation deteriorates further, there is an increasing risk of retreat to populism, protectionism and beggar-thy-neighbor policies that characterized the First Great Contraction. It is imperative that we maintain political stability, by leadership over brinkmanship and action over reaction, whatever happens to the world economy in the near future. I leave the final word to the President of the World Bank Robert B. Zoellick:

"In 2008, many people said they did not see the turbulence coming. Leaders have no such excuse now. And dangerous times call for courageous people (Zoellick, 2011)"

[31] There are a number of financial crises that are global or multicountry in scope: the crisis of 1825-26 (global), the panic of 1907 (global), First Great Contraction 1929-37 (global), debt crises of the 1980s (multicountry), Asian crisis 1997-98 (multicountry) and today the Second Great Contraction 2008- (global).

[32] The term political instability refers here to for example international conflict, civil war, empowerment of extremist political parties, social unrest and violence toward ethnic minorities etc.

Appendix 1 – Banking, Currency and Sovereign Debt Crises

Table 9.Twin banking and currency crises (1980-2002)

Country	Starting date for currency crises[33] (Laeven &Valencia, 2008)	Number of currency crises	Year of banking crisis (Demirgüc-Kunt)	Twin banking and currency crisis
Argentina	1981; 1987; 2002	3	1980-82; 1989-90; 1995; 2001-…	1980-82; 1987-90; 2001-…
Brazil	1982; 1987; 1992; 1999	4	1990; 1994-1999	1990-1992
Chile	1982	1	1981-87	1981-87
China	-	-	1997-99 (Caprio et al.)	-
Colombia	1985	1	1982-85; 1999-2000	-
Dom. Republic	1985; 1990	2	-	-
Ecuador	1982; 1999	2	1995-…	-
Egypt	1990	1	1980-81 (Caprio et al.)	-
El Salvador	1986	1	1989	-
Hungary	-	-	1991-95 (Caprio et al.)	-
Indonesia	1998	1	1992-1995; 1997-…	1997-…
Korea, Rep. Of	1998	1	1997-2002…	1997-2002
Malaysia	1998	1	1985-88; 1997-2001	1997-2001
Mexico	1982; 1995	2	1982; 1994-97	1982; 1994-97
Morocco	1981	1	1983 (Caprio et al.)	1981-83
Nigeria	1983; 1989; 1997	3	1991-95 (-97)	1989-95
Pakistan	-	-	-	-
Panama	-	-	1988-89	-
Peru	1981; 1988	2	1983-90	1981-90
Philippines	1983; 1998	2	1981-87; 1998-…	1981-87; 1998-…
Poland	-	-	1991-1994**	-
Russia	1998	1	1995; 1998-99 (Caprio et al.)	1998-99
South Africa	1984	1	1985	1984-85
Thailand	1998	1	1983-87; 1997-…	1997-…
Tunisia	-	-	1991-95	-
Turkey	1984; 1991; 1996; 2001	4	1982-85; 1991; 1994; 2000-…	1982-85; 1991; 1994-96; 2000-…
Uruguay	1983; 1990; 2002	3	1981-85; 2002-…	1981-85; 2002-…
Venezuela	1984; 1989; 1994; 2002	4	1993-97	1993-97
Total 28		**42**	**41**	**25**

[33] A currency crisis is defined as "a nominal depreciation of the currency of at least 30 percent that is also at least a 10 percent increase in the rate of depreciation compared to the year before (Laeven & Valencia, p. 6, 2008)".

Table 10.Twin currency and sovereign debt crises (1980-2002)

Country	Starting date for currency crises (Laeven &Valencia, 2008)	Number of currency crises	Year of debt crisis (Ciarlone)	Twin DEBT and currency crisis
Argentina	1981; 1987; 2002	3	1983-95; 2001-…	1981-95; 2001-…
Brazil	1982; 1987; 1992; 1999	4	1983-93; 1998-…	1982-93; 1998-…
Chile	1982	1	1983-90	1982-90
China	-	-	-	-
Colombia	1985	1	1988	-
Dom. Republic	1985; 1990	2	1982-99; 2002-…	-
Ecuador	1982; 1999	2	1983-2000	1982-2000
Egypt	1990	1	1980-91; 1995	-
El Salvador	1986	1	1984; 1989-92	1984-86
Hungary	-	-	-	
Indonesia	1998	1	1997-…	1997-…
Korea, Rep. Of	1998	1	1980-81; 1984; 1997-99	1997-99
Malaysia	1998	1	-	-
Mexico	1982; 1995	2	1982-92; 1995-96	1982-92; 1995-96
Morocco	1981	1	1983-92; 1999	1981-92
Nigeria	1983; 1989; 1997	3	1986-…	-
Pakistan	-	-	1981-82; 1998-2000	-
Panama	-	-	1983-95	-
Peru	1981; 1988	2	1980; 1983-96; 2000	1980-81
Philippines	1983; 1998	2	1984-91; 1994	1983-91
Poland	-	-	1981-93	-
Russia	1998	1	1989-…	-
South Africa	1984	1	1985-89; 1993	1984-89
Thailand	1998	1	1981; 1997-99	1997-99
Tunisia	-	-	1991	-
Turkey	1984; 1991; 1996; 2001	4	1980-82; 2000-…	2000-…
Uruguay	1983; 1990; 2002	3	1983; 1986-88; 2002-…	1983; 2002-…
Venezuela	1984; 1989; 1994; 2002	4	1984-94; 1998	1984-94
Total 28		**42**	**44**	**20**

Table 11.Triple banking, currency and sovereign debt crises (1980-2002)

Country	Starting date for currency crises (Laeven &Valencia, 2008)	Year of debt crisis (Ciarlone)	Year of banking crisis (Demirgüc-Kunt)	Triple crisis[34]
Argentina	1981; 1987; 2002	1983-95; 2001-…	1980-82; 1989-90; 1995; 2001-…	2001-…
Brazil	1982; 1987; 1992; 1999	1983-93; 1998-…	1990; 1994-1999	-
Chile	1982	1983-90	1981-87	1981-90
China	-	-	1997-99 (Caprio et al.)	-
Colombia	1985	1988	1982-85; 1999-2000	-
Dom. Republic	1985; 1990	1982-99; 2002-…	-	-
Ecuador	1982; 1999	1983-2000	1995-…	-
Egypt	1990	1980-91; 1995	1980-81 (Caprio et al.)	-
El Salvador	1986	1984; 1989-92	1989	-
Hungary	-	-	1991-95 (Caprio et al.)	-
Indonesia	1998	1997-…	1992-1995; 1997-…	1997-…
Korea, Rep. Of	1998	1980-81; 1984; 1997-99	1997-2002…	1997-2002…
Malaysia	1998	-	1985-88; 1997-2001	-
Mexico	1982; 1995	1982-92; 1995-96	1982; 1994-97	1982-92
Morocco	1981	1983-92; 1999	1983 (Caprio et al.)	1981-92
Nigeria	1983; 1989; 1997	1986-…	1991-95 (-97)	-
Pakistan	-	1981-82; 1998-2000	-	-
Panama	-	1983-95	1988-89	-
Peru	1981; 1988	1980; 1983-96; 2000	1983-90	1981-96
Philippines	1983; 1998	1984-91; 1994	1981-87; 1998-…	-
Poland	-	1981-93	1991-1994**	-
Russia	1998	1989-…	1995; 1998-99 (Caprio et al.)	-
South Africa	1984	1985-89; 1993	1985	1984-89
Thailand	1998	1981; 1997-99	1983-87; 1997-…	1997-…
Tunisia	-	1991	1991-95	-
Turkey	1984; 1991; 1996; 2001	1980-82; 2000-…	1982-85; 1991; 1994; 2000-…	2000-…
Uruguay	1983; 1990; 2002	1983; 1986-88; 2002-…	1981-85; 2002-…	1981-85; 2002-…
Venezuela	1984; 1989; 1994; 2002	1984-94; 1998	1993-97	-
Total 28	**42**	**44**	**41**	**12**

[34] A triple crisis refers to a banking crisis that is either succeded or preceded by both a currency and sovereign external debt crisis within a two year period.

Appendix 2 – Descriptive statistics

Table 12. Mean of explanatory variables for banking crisis

Banking Crises – Explanatory variables	Sample mean (1980-2000)	Tranquil mean (Y=0)	Pre-crisis mean (Y=1)	Post-crisis mean (Y=2)
Ratio of Current Account Balance to Short Term Debt	-0.3202	-0.3689	-0.3214	-0.1391
Current account balance growth	-0.6350	-0.6144	0.2979	-1.3188
Domestic credit provided by banking sector (% of GDP)	61.6405	58.7628	62.8714	71.7064
Export growth	0.0746	0.0770	0.0980	0.0508
Export variability (logged)	7.1109	6.9050	7.8181	7.4429
FDI (% of GDP)	1.7151	1.7291	1.4656	1.8387
Import growth	0.0780	0.0880	0.1070	0.0220
Inflation rate (logged)	2.5653	2.4778	2.8614	2.7036
Inflation variability (logged)	2.0251	1.8921	2.4528	2.2574
International reserves growth	0.1835	0.2086	0.1905	0.0845
Ratio of debt service on PNG external debt to GDP	0.0110	0.0087	0.0102	0.0204
Ratio of international reserves to imports	0.3043	0.2945	0.3045	0.3416
Ratio of international reserves to short-term external debt	1.2315	1.3740	0.8725	0.9581
Ratio of M2 to reserve money (logged)	1.4809	1.4565	1.5600	1.5206
Ratio of short-term external debt to int. res. (logged)	0.3318	0.2730	0.4355	0.4771
Ratio of total debt service on external debt to exports	0.4274	0.4388	0.4355	0.3802
Ratio of total debt service on external debt to int. res.	1.7020	1.7843	1.6454	1.4351
Ratio of total external debt to GDP (logged)	-0.7737	-0.8231	-0.8503	-0.5344
Real Exchange Rate (logged)	-1.4352	-1.3346	-1.0692	-2.0719
Real GDP growth	3.5924	4.1910	3.6786	1.1833
Real Interest rate	9.0541	8.7501	10.1849	9.4997
Trade (% of GDP)	58.3625	58.3135	53.4364	62.0293
Trade balance (% of GDP)	-0.0198	-0.0219	-0.0550	0.0137
U.S. inflation	4.2345	4.2632	4.9596	3.5993
U.S. treasury bill rate	6.8227	6.8696	7.1038	6.4313

Table 13. Mean of explanatory variables for sovereign debt crisis

Sovereign debt crises – explanatory variables	Sample mean (1980-2000)	Tranquil mean (Y=0)	Pre-crisis mean (Y=1)	Post-crisis mean (Y=2)
Ratio of Current Account Balance to Short Term Debt	-0.3202	-0.4288	-0.3888	-0.1445
Current account balance growth	-0.6350	-0.9171	0.5356	-0.6382
Domestic credit provided by banking sector (% of GDP)	61.6405	68.6019	56.2847	52.6799
Export growth	0.0746	0.0942	0.0406	0.0576
Export variability (logged)	7.1109	7.3537	7.4427	6.6895
FDI (% of GDP)	1.7151	1.9924	1.3657	1.4115
Import growth	0.0780	0.0975	0.0169	0.0698
Inflation rate (logged)	2.5653	2.2172	2.5770	3.0460
Inflation variability (logged)	2.0251	1.4940	1.6715	2.7953
International reserves growth	0.1835	0.1748	0.0373	0.2477
Ratio of debt service on PNG external debt to GDP	0.0110	0.0108	0.0134	0.0105
Ratio of international reserves to imports	0.3043	0.3159	0.3104	0.2846
Ratio of international reserves to short-term external debt	1.2315	1.7208	0.7250	0.7218
Ratio of M2 to reserve money (logged)	1.4809	1.5798	1.4607	1.3351
Ratio of short-term external debt to int. res. (logged)	0.3318	-0.1082	0.7104	0.8191
Ratio of total debt service on external debt to exports	0.4274	0.3488	0.5629	0.4926
Ratio of total debt service on external debt to int. res.	1.7020	1.1896	2.2333	2.2411
Ratio of total external debt to GDP (logged)	-0.7737	-1.0170	-0.7631	-0.4365
Real Exchange Rate (logged)	-1.4352	-1.5180	-1.9047	-1.1241
Real GDP growth	3.5924	4.8234	2.3814	2.1488
Real Interest Rate	9.0541	8.0702	10.6381	10.0857
Trade (% of GDP)	58.3625	62.5286	47.6307	55.8039
Trade balance (% of GDP)	-0.0198	-0.0301	-0.0444	0.0049
U.S. inflation	4.2345	4.2602	5.2421	3.8208
U.S. treasury bill rate	6.8227	6.6382	8.1281	6.6220

Table 14. Mean of explanatory variables for twin crisis

Twin crises – explanatory variables	Sample mean (1980-2000)	Tranquil mean (Y=0)	Pre-crisis mean (Y=1)	Post-crisis mean (Y=2)
Ratio of Current Account Balance to Short Term Debt	-0.3202	-0.2875	-0.6201	-0.3994
Current account balance growth	-0.6350	-0.6360	0.9561	-1.0235
Domestic credit provided by banking sector (% of GDP)	61.6405	60.3096	57.0352	69.4795
Export growth	0.0746	0.0771	0.0620	0.0654
Export variability (logged)	7.1109	7.1183	8.1177	6.8586
FDI (% of GDP)	1.7151	1.8314	1.2723	1.2665
Import growth	0.0780	0.0805	0.0895	0.0630
Inflation rate (logged)	2.5653	2.5130	2.6763	2.8090
Inflation variability (logged)	2.0251	2.0520	1.0793	2.0828
International reserves growth	0.1835	0.1835	0.0622	0.2137
Ratio of debt service on PNG external debt to GDP	0.0110	0.0095	0.0154	0.0175
Ratio of international reserves to imports	0.3043	0.3122	0.2721	0.2734
Ratio of international reserves to short-term external debt	1.2315	1.3427	0.6545	0.8415
Ratio of M2 to reserve money (logged)	1.4809	1.4763	1.6202	1.4630
Ratio of short-term external debt to int. res. (logged)	0.3318	0.2879	0.6011	0.4753
Ratio of total debt service on external debt to exports	0.4274	0.4181	0.5505	0.4430
Ratio of total debt service on external debt to int. res.	1.7020	1.5682	2.1498	2.2398
Ratio of total external debt to GDP (logged)	-0.7737	-0.8016	-0.8178	-0.6251
Real Exchange Rate (logged)	-1.4352	-1.5235	-1.0457	-1.1325
Real GDP growth	3.5924	3.7456	4.1258	2.6689
Real interest rate	9.0541	9.4574	8.2463	7.3935
Trade (% of GDP)	58.3625	60.3859	48.6339	51.0917
Trade balance (% of GDP)	-0.0198	-0.0142	-0.0889	-0.0280
U.S. inflation	4.2345	4.1361	5.8732	4.2757
U.S. treasury bill rate	6.8227	6.6196	8.2263	7.4727

Appendix 3 – Estimation results

Table 15. Single MNL regressions – Banking Crises

Indicator name (independent variables) – Banking crisis step 1	Indicator Code	Sig. R=1	Sig. R=2	Correct sign
Banking crisis in financial center (dummy)	BCrisisFC	-	YES***	-
Ratio of Current Account Balance to Short Term Debt	CABSTD	-	YES**	YES
Capital flow bonanza (dummy)	CapFlowBon	YES***	-	-
Current account balance growth	CABGrowth	-	-	-
Domestic credit provided by banking sector (% of GDP)	DomCredBS.GDP	-	YES***	YES
Export growth	ExGrowth	-	-	-
Export Variability (logged)	ExVar_log	YES***	YES***	YES
FDI (% of GDP)	FDIGDP	-	-	-
Import growth	ImGrowth	-	YES***	YES
Inflation crisis (dummy)	InfCrisis	YES***	YES***	-
Inflation rate (logged)	InfRate_log	YES**	-	YES
Inflation variability (logged)	InfVar_log	YES**	-	YES
International reserves growth	IntResGrowth	-	YES**	YES
Ratio of debt service on PNG external debt to GDP	DSerPNGED.GDP	-	YES***	YES
Ratio of international reserves to imports	IntRes.Im	-	-	-
Ratio of international reserves to short-term external debt	IntResSTED	YES**	YES**	YES
Ratio of M2 to reserve money (logged)	M2ResMoney_log	-	-	-
Ratio of short-term external debt to international reserves (logged)	STEDIntRes_log	-	-	-
Ratio of total debt service on external debt to exports	DSerTED.Ex	-	-	-
Ratio of total debt service on external debt to international reserves	DSerTEDIntRes	-	-	-
Ratio of total external debt to GDP	TEDGDP_log	-	YES***	YES
Real Exchange Rate (logged)	RER_log	-	-	-
Real GDP growth	RGDPGrowth	-	YES***	YES
Real interest rate	RIR	-	-	-
Severe recession (dummy)	SevRec	-	YES***	-
Trade (% of GDP)	TradeGDP	-	-	-
Trade balance (% of GDP)	TradeBalGDP	YES**	YES***	YES
U.S. inflation	USInf	-	YES**	YES
U.S. treasury bill rate	USTBR	-	-	-

Table 16. Groupwise MNL regressions – Banking Crises

Indicator name (independent variables) – Banking crisis step 2	Indicator Code	Sig. R=1	Sig. R=2	Correct sign
International Reserves				
Ratio of international reserves to short-term external debt	IntResSTED	YES**	-	YES
International reserves growth	IntResGrowth	-	YES***	YES
GDP / Credit / Capital inflow				
Real GDP growth	RGDPGrowth	-	YES***	YES
Severe recession (dummy)	SevRec	-	-	-
Domestic credit provided by banking sector (% of GDP)	DomCredBSGDP	-	YES***	YES
Capital flow bonanza (dummy)	CapFlowBon	YES***	-	-
Banking crisis in financial center (dummy)	BCrisisFC	-	YES***	-
Trade / Current Account				
Export Variability (logged)	ExVar_log	YES***	YES**	YES
Import growth	ImGrowth	-	YES***	YES
Trade balance (% of GDP)	TradeBalGDP	-	YES***	YES
Ratio of Current Account Balance to Short Term Debt	CABSTD	-	-	-
Inflation				
Inflation crisis (dummy)	InfCrisis	-	YES***	-
Inflation rate (logged)	InfRate_log	-	-	-
Inflation variability (logged)	InfVar_log	-	-	-
U.S. inflation	USInf	-	YES***	YES
Debt ratios & debt service				
Ratio of total external debt to GDP	TEDGDP_log	-	YES***	YES
Ratio of debt service on PNG external debt to GDP	DSerPNGED.GDP	-	YES***	YES

Table 17. General MNL regression – Banking Crises

Indicator name (independent variables) – Banking crisis step 3	Indicator Code	Sig. R=1	Sig. R=2	Correct sign
Ratio of international reserves to short-term external debt	IntResSTED	YES**	-	YES
International reserves growth	IntResGrowth	-	YES**	YES
Real GDP growth	RGDPGrowth	-	YES***	YES
Domestic credit provided by banking sector (% of GDP)	DomCredBSGDP	YES***	YES***	YES
Capital flow bonanza (dummy)	CapFlowBon	YES**	-	-
Banking crisis in financial center (dummy)	BCrisisFC	YES**	-	-
Export Variability (logged)	ExVar_log	YES***	YES**	YES
Import growth	ImGrowth	-	-	-
Trade balance (% of GDP)	TradeBalGDP	-	-	-
Inflation crisis (dummy)	InfCrisis	-	YES**	-
U.S. inflation	USInf	-	-	-
Ratio of total external debt to GDP	TEDGDP_log	-	YES***	YES
Ratio of debt service on PNG external debt to GDP	DSerPNGEDGDP	-	-	-
Ratio of international reserves to imports	IntResIm	-	-	-
Export growth	ExGrowth	-	-	-

Table 18. Single MNL regressions – Debt Crises

Indicator name (independent variables) – Debt Crisis step 1	Indicator Code	Sig. R=1	Sig. R=2	Correct sign
Banking crisis in financial center (dummy)	BCrisisFC	YES**	YES***	-
Ratio of Current Account Balance to Short Term Debt	CABSTD	-	YES***	YES
Capital flow bonanza (dummy)	CapFlowBon	YES***	-	-
Current account balance growth	CABGrowth	-	-	-
Domestic credit provided by banking sector (% of GDP)	DomCredBSGDP	YES**	YES***	YES
Export growth	ExGrowth	YES**	YES**	YES
Export variability	ExVar	-	YES***	YES
FDI (% of GDP)	FDIGDP	YES**	YES***	YES
Import growth	ImGrowth	YES***	-	YES
Inflation crisis (dummy)	InfCrisis	-	YES***	-
Inflation rate (logged)	InfRate_log	-	YES***	YES
Inflation variability (logged)	InfVar_log	-	YES***	YES
International reserves growth	IntResGrowth	YES**	-	YES
Ratio of debt service on PNG external debt to GDP	DSerPNGEDGDP	-	-	-
Ratio of international reserves to imports	IntResIm	-	-	-
Ratio of international reserves to short-term external debt	IntResSTED	YES***	YES***	YES
Ratio of M2 to reserve money (logged)	M2ResMoney_log	-	YES***	YES
Ratio of short-term external debt to international reserves (logged)	STEDIntRes_log	YES***	YES***	YES
Ratio of total debt service on external debt to exports	DSerTED.Ex	YES***	YES***	YES
Ratio of total debt service on external debt to international reserves	DSerTEDIntRes	YES***	YES***	YES
Ratio of total external debt to GDP (logged)	TEDGDP_log	YES***	YES***	YES
Real Exchange Rate (logged)	RER_log	-	-	-
Real GDP growth	RGDPGrowth	YES***	YES***	YES
Real interest rate	RIR	-	-	-
Severe recession (dummy)	SevRec	YES**	YES***	-
Trade (% of GDP)	TradeGDP	YES***	YES**	YES
Trade balance (% of GDP)	TradeBalGDP	-	YES***	YES
U.S. inflation	USInf	YES**	-	YES
U.S. treasury bill rate	USTBR	YES***	-	YES

Table 19. Groupwise MNL regressions – Debt Crises

Indicator name (independent variables) – Debt crisis step 2	Indicator Code	Sig. R=1	Sig. R=2	Correct sign
International Reserves				
Ratio of international reserves to short-term external debt	IntResSTED	YES***	YES***	YES
International reserves growth	IntResGrowth	-	YES**	YES
GDP / Credit / Capital inflow				
Real GDP growth	RGDPGrowth	YES***	YES***	YES
Severe recession (dummy)	SevRec	-	-	-
Domestic credit provided by banking sector (% of GDP)	DomCredBSGDP	-	YES***	YES
Ratio of M2 to reserve money (logged)	M2ResMoney_log	-	-	-
FDI (% of GDP)	FDIGDP	YES**	-	YES
Capital flow bonanza (dummy)	CapFlowBon	YES***	-	-
Banking crisis in financial center (dummy)	BCrisisFC	YES**	YES***	-
Trade / Current Account				
Ratio of Current Account Balance to Short Term Debt	CABSTD	-	YES***	YES
Export growth	ExGrowth	-	YES***	YES
Export Variability (logged)	ExVar_log	-	YES***	YES
Import growth	ImGrowth	-	-	-
Trade (% of GDP)	TradeGDP	YES**	YES***	YES
Trade balance (% of GDP)	TradeBalGDP	-	YES**	YES
Inflation				
Inflation crisis (dummy)	InfCrisis	-	-	-
Inflation rate (logged)	InfRate_log	-	-	-
Inflation variability (logged)	InfVar_log	-	YES***	YES
U.S. inflation	USInf	-	-	-
U.S. treasury bill rate	USTBR	-	YES***	NO
Debt ratios & debt service				
Ratio of total external debt to GDP	TEDGDP_log	-	YES***	YES
Ratio of total debt service on external debt to exports	DSerTEDEx	YES***	YES**	YES
Ratio of total debt service on external debt to international reserves	DSerTEDIntRes	-	-	-
Ratio of short-term external debt to international reserves (logged)	STEDIntRes_log	YES***	YES***	YES

Table 20. General MNL regression –Debt Crises

Indicator name (independent variables) – Debt crisis step 3	Indicator Code	Sig. R=1	Sig. R=2	Correct sign
Ratio of international reserves to short-term external debt	IntresSTED	-	-	-
International reserves growth	IntResGrowth	-	-	-
Export growth	ExGrowth	-	-	-
Export Variability (logged)	ExVar_log	-	YES***	YES
Trade balance (% of GDP)	TradeBalGDP	-	-	-
Real GDP growth	RGDPGrowth	-	-	-
Domestic credit provided by banking sector (% of GDP)	DomCredBSGDP	-	YES**	NO
FDI (% of GDP)	FDIGDP	-	-	-
Capital flow bonanza (dummy)	CapFlowBon	YES***	YES***	-
Banking crisis in financial center (dummy)	BCrisisFC	YES***	-	-
Inflation variability (logged)	InfVar_log	-	YES***	YES
Ratio of total debt service on external debt to exports	DSerTEDEx	YES**	YES***	YES
Ratio of total debt service on external debt to international reserves	DSerTEDIntRes	-	-	-
Trade (% of GDP)	TradeGDP	YES**	-	YES
Ratio of debt service on PNG external debt to GDP	DSerPNGEDGDP	-	-	-
Ratio of M2 to reserve money (logged)	M2ResMoney_log	-	YES***	YES
Ratio of Current Account Balance to Short Term Debt	CABSTD	YES***	YES**	YES
Ratio of total external debt to GDP (logged)	TEDGDP_log	YES**	YES***	YES
Ratio of short-term external debt to international reserves (logged)	STEDIntRes_log	-	YES**	YES

Table 21. Single MNL regressions – Twin Crises

Indicator name (independent variables) – Twin crisis step 1	Indicator Code	Sig. R=1	Sig. R=2	Correct sign
Banking crisis in financial center (dummy)	BCrisisFC	-	YES***	-
Ratio of Current Account Balance to Short Term Debt	CABSTD	-	-	-
Capital flow bonanza (dummy)	CapFlowBon	YES***	YES***	-
Current account balance growth	CABGrowth	-	-	-
Domestic credit provided by banking sector (% of GDP)	DomCredBSGDP	-	YES**	YES
Export growth	ExGrowth	-	-	-
Export variability (logged)	ExVar_log	YES**	-	YES
FDI (% of GDP)	FDIGDP	-	YES**	YES
Import growth	ImGrowth	-	-	-
Inflation crisis (dummy)	InfCrisis	-	-	-
Inflation rate (logged)	InfRate	-	-	-
Inflation variability (logged)	InfVar_log	YES**	-	YES
International reserves growth	IntResGrowth	-	-	-
Ratio of debt service on PNG external debt to GDP	DSerPNGEDGDP	YES**	YES***	YES
Ratio of international reserves to imports	IntResIm	-	-	-
Ratio of international reserves to short-term external debt	IntResSTED	-	YES**	YES
Ratio of M2 to reserve money (logged)	M2ResMoney_log	-	-	-
Ratio of short-term external debt to international reserves (logged)	STEDIntRes_log	-	-	-
Ratio of total debt service on external debt to exports	DSerTEDEx	-	-	-
Ratio of total debt service on external debt to international reserves	DSerTEDIntRes	-	YES***	YES
Ratio of total external debt to GDP (logged)	TEDGDP_log	-	YES**	YES
Real Exchange Rate (logged)	RER_log	-	-	-
Real GDP growth	RGDPGrowth	-	-	-
Real interest rate	RIR	-	-	-
Severe recession (dummy)	SevRec	-	-	-
Trade (% of GDP)	TradeGDP	-	YES**	YES
Trade balance (% of GDP)	TradeBalGDP	YES***	-	YES
U.S. inflation	USInf	YES***	-	YES
U.S. treasury bill rate	USTBR	YES***	YES***	YES

Table 22.Groupwise MNL regressions – Twin Crises

Indicator name (independent variables) – Twin crisis step 2	Indicator Code	Sig. R=1	Sig. R=2	Correct sign
GDP / Credit / Capital inflow				
Domestic credit provided by banking sector (% of GDP)	DomCredBSGDP	-	YES**	YES
FDI (% of GDP)	FDIGDP	-	-	-
Capital flow bonanza (dummy)	CapFlowBon	YES***	YES***	YES
Banking crisis in financial center (dummy)	BCrisisFC	-	YES**	YES
Trade / Current Account				
Export Variability (logged)	ExVar_log	YES**	-	YES
Trade (% of GDP)	TradeGDP	-	YES**	YES
Trade balance (% of GDP)	TradeBalGDP	YES***	YES**	YES
Inflation / Interest rate				
Inflation variability (logged)	InfVar_log	YES**	-	YES
U.S. inflation	USInf	-	-	-
U.S. treasury bill rate	USTBR	-	YES***	YES
Debt ratios / Debt service / International reserves				
Ratio of debt service on PNG external debt to GDP	DSerPNGEDGDP	YES***	YES***	YES
Ratio of total debt service on external debt to international reserves	DSerTEDIntRes	-	-	-
Ratio of total external debt to GDP	TEDGDP_log	-	-	-
Ratio of international reserves to short-term external debt	IntResSTED	-	-	-

Table 23. General MNL regression – Twin Crises

Indicator name (independent variables) – Twin crisis step 3	Indicator Code	Sig. R=1	Sig. R=2	Correct sign
Ratio of international reserves to short-term external debt	IntResSTED	-	-	-
Export growth	ExGrowth	-	-	-
Export Variability (logged)	ExVar_log	-	YES***	YES
Trade balance (% of GDP)	TradeBalGDP	YES**	-	YES
Domestic credit provided by banking sector (% of GDP)	DomCredBSGDP	-	YES***	YES
Capital flow bonanza (dummy)	CapFlowBon	-	-	-
Banking crisis in financial center (dummy)	BCrisisFC	-	-	-
Inflation variability (logged)	InfVar_log	YES**	-	YES
Real Exchange Rate	RER_log	-	YES***	YES
U.S. inflation	USInf	-	-	-
Trade (% of GDP)	TradeGDP	YES**	-	YES
Ratio of debt service on PNG external debt to GDP	DSerPNGEDGDP	-	YES***	YES
Ratio of M2 to reserve money (logged)	M2ResMoney_log	YES***	-	YES
U.S. treasury bill rate	USTBR	-	-	-
Ratio of total external debt to GDP (logged)	TEDGDP_log	-	-	-

Appendix 4 – Econometric model

The general formula for the probability of a country being in one of the three regimes, where the variable X_t denotes the set of explanatory variables for observation t and $\theta^k \equiv \beta^k - \beta^0$ for k = 1, …, K, is as follows:

$$\Pr(Y_t = j) = \frac{\exp\,(\beta^j X_t)}{\sum_{k=0}^{K} \exp\,(\beta^k X_t)}, \quad k = 0,1, \dots, K$$

Dividing the numerator and the denominator by exp $(\beta^0 X_t)$, we get the following expression:

$$\Pr(Y_t = j) = \frac{\exp\,(\theta^j X_t)}{1 + \sum_{k=1}^{K} \exp\,(\theta^k X_t)}, k = 0,1, \dots, K$$

It is possible to express all probabilities in terms of θ^k, where k = 1, …, K; independently of β^0. If we impose the restriction that$\beta^0 = 0$, we can identify the parameters β^k where k = 1, …, K.

The probability of being in one of the three regimes can be expressed as follows:

$$\Pr(Y_t = 0) = \frac{1}{1 + \exp(\beta^1 X_t) + \exp\,(\beta^2 X_t)}, k = 0, 1, \dots, K$$

$$\Pr(Y_t = 1) = \frac{\exp(\beta^1 X_t)}{1 + \exp(\beta^1 X_t) + \exp\,(\beta^2 X_t)}, k = 0, 1, \dots, K$$

$$\Pr(Y_t = 2) = \frac{\exp(\beta^2 X_t)}{1 + \exp(\beta^1 X_t) + \exp\,(\beta^2 X_t)}, k = 0, 1, \dots, K$$

The vectors β^1 and β^2 measure the marginal effect of a change in the explanatory variables, on the probability of being in the pre-crisis or post-crisis regime relative to the tranquil regime.

$$\exp(\beta^1 X_t) = \frac{\Pr(Y_t = 1)}{\Pr(Y_t = 0)}$$

$$\exp(\beta^2 X_t) = \frac{\Pr(Y_t = 2)}{\Pr(Y_t = 0)}$$

Appendix 5 – Goodness-of-fit measure

The theoretical approach to estimate the 'percent correctly predicted' presented below has been adopted from Wooldridge (2006). Assume a binary response model with the following response probability:

$$\Pr(y = 1|\boldsymbol{x}) = \Pr(y = 1|x_1, x_2, \dots, x_k) = G(\beta_0 + \beta_1 x_1 + \dots + \beta_k x_k) = G(\beta_0 + \boldsymbol{x\beta})$$

The set of explanatory variables is denoted with **x.** In the case of a logit model, G(z) is a logistic function with values strictly between 0 and 1, $0 < G(z) < 1$, for all real numbers z.

$$G(z) = \frac{\exp(z)}{1 + \exp(z)}$$

Maximum likelihood estimation (MLE) is an applicable method for estimating non linear binary response models and since MLE is based on the distribution of x given y, it automatically accounts for the heteroskedasticity in Var(y|x). Given a sample of size *n*, the maximum likelihood estimator conditional on the explanatory variables, can be computed with information on the density of y_j given x_j.

$$f(y|\boldsymbol{x_j}; \boldsymbol{\beta}) = [G(\boldsymbol{x_j\beta})]^{y}[1 - G(\boldsymbol{x_j\beta})]^{1-y}, \; y = 0,1$$

Taking the log of this equation produces the log-likelihood function for observation *j* as a function of the data and parameters.

$$l_j(\boldsymbol{\beta}) = y_j log[G(\boldsymbol{x_j\beta})] + (1 - y_j)\log\,[1 - G[\boldsymbol{x_j\beta}]$$

Summing across all observations the log-likelihood can be obtained for a sample of size *m.*

$$\mathcal{L}(\boldsymbol{\beta}) = \sum_{j=1}^{m} l_j(\boldsymbol{\beta})$$

The maximum likelihood estimation of β (denoted $\hat{\beta}$) maximizes this log-likelihood and since G(z) is a logit cumulative distribution function, $\hat{\beta}$ is the logit estimator. To estimate the *percent correctly predicted*, a binary predictor of y_j is defined to be one, if the predicted probability is at least the chosen critical value and zero otherwise.

$$\tilde{y}_j = 1 \text{ if } G(\hat{\beta}_0 + \boldsymbol{x_j\beta}) \geq critical\ value$$
$$\tilde{y}_j = 0 \text{ if } G(\hat{\beta}_0 + \boldsymbol{x_j\beta}) < critical\ value$$

Conditional on $\{\tilde{y}_j : j = 1, 2, \dots, m\}$, it is possible to estimate how accurately $\tilde{y}_j$ predicts y_j for all observations in the sample. There are four possible combinations of $(\tilde{y}_j, y_j)$ and a correct prediction is only when both are zero or one. The percentage of times when the estimated model signals $\tilde{y}_j = 1$ and the real observation is $y_j = 1$ is the number of pre-crisis observations correctly called. However, if the model signals $\tilde{y}_j = 1$ but the real observation is $y_j = 0$, this is denoted as the number of false alarms. The number of total observations correctly called is the percentage of times that $\tilde{y}_j = y_j$.

Appendix 6 – Sensitivity/specificity-reports

Candelon et al. (2010) propose a statistical framework that can be applied to evaluate Early Warning Systems. To identify the optimal cut-off level for EWS models the authors suggest using sensitivity-specificity plots. The optimal cut-off level C* is computed as follows:

$$C^* = Arg_{\{C\}}[Sensitivity(C) = Specificity(C)], where\ C \in [0,1]$$

The sensitivity/specificity-reports show that the optimal cut-off value according to Candelon et al. (2010) is the intersection between the sensitivity curve and the specificity curve. The graphs illustrate that the optimal cut-off value differs between different types of crises and years.

Table 24. Identification of sensitivity and specificity in test results

		Test Result (T)	
		Positive (+)	Negative (-)
True status of nature (N)	Crisis (+)	A	B
	No Crisis (-)	C	D

Table 24 illustrate how sensitivity and specificity are identified when applying the goodness-of-it measure called 'percent correctly predicted'. Sensitivity is the probability that the test says there is a crisis when the true status of nature is a crisis i.e. $prob(T^+|N^+) = \frac{a}{a+b}$. This is a measure of how good the model is of identifying a crisis when there is a crisis. Specificity on the other hand, measures the probability of a non-crisis episode when there is no crisis i.e. $prob(T^-|N^-) = \frac{d}{c+d}$. The number of false alarms is computed by estimating 1-specificity. An ideal model should have both high sensitivity (high number of correctly predicted crises) and high specificity (low number of false alarms).

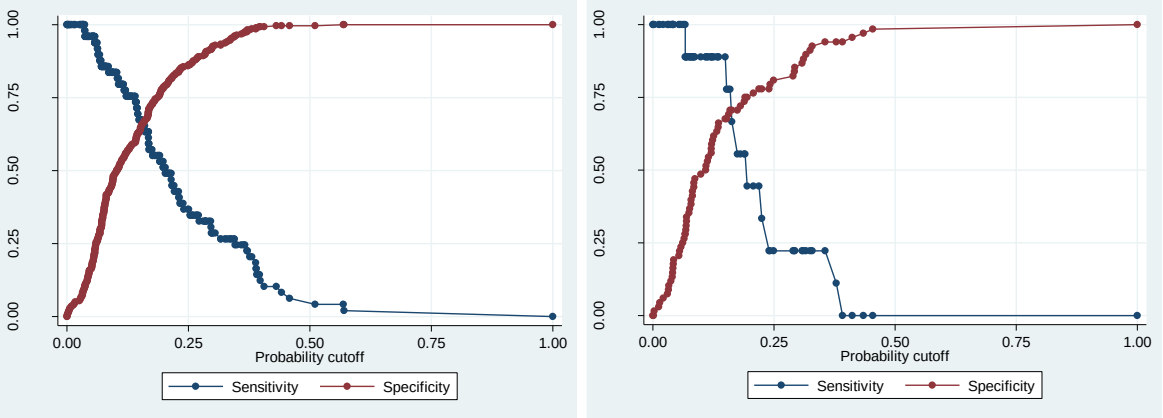

Figure 11. In-sample (left) and out-of-sample (right) specificitity/sensitivity-reports for banking crisis

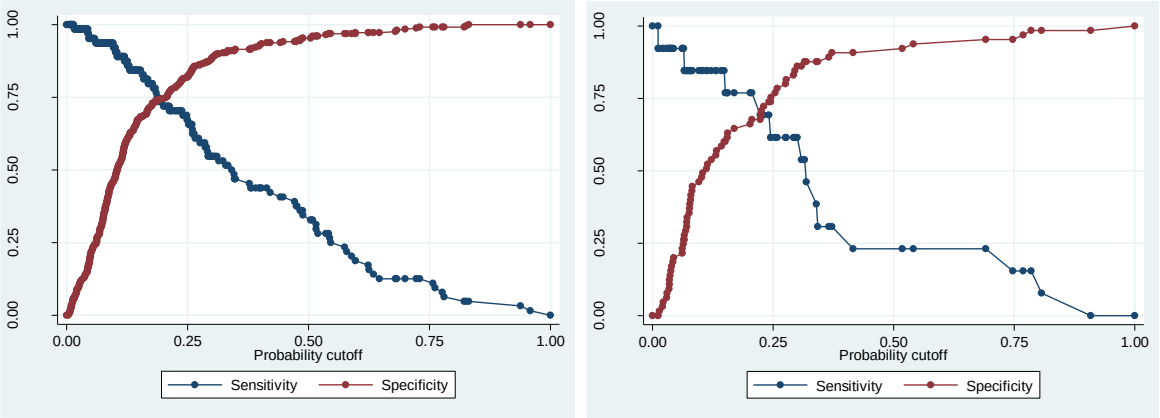

Figure 12. In-sample (left) and out-of-sample (right) specificitity/sensitivity-reports for debt crisis

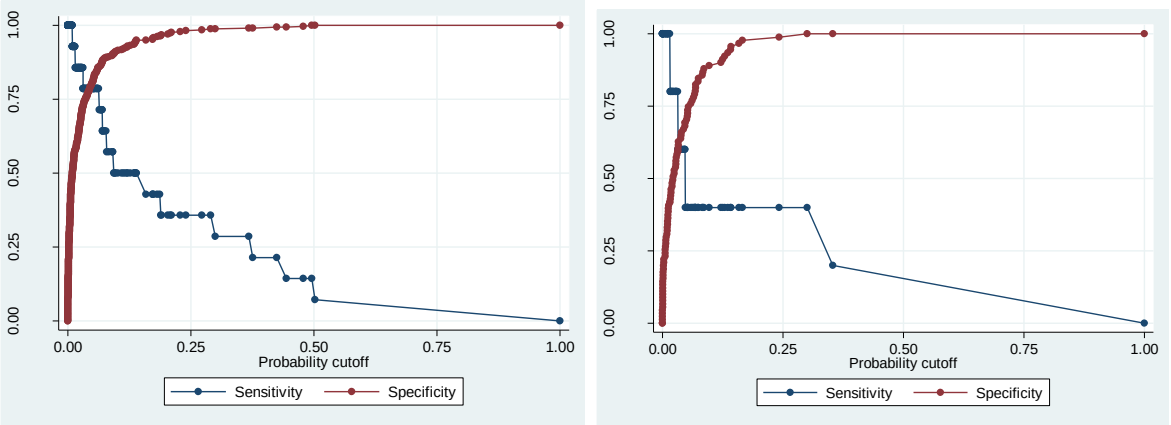

Figure 13. In-sample (left) and out-of-sample (right) specificitity/sensitivity-reports for twin crisis

Appendix 7 – ROC curves

A "Receiver operating Characteristics" (ROC) curve plots the number of correctly predicted crisis episodes (sensitivity) against the number of false alarms (1-specificity). Each point on the ROC curve corresponds to a sensitivity/specificity pair for a particular cutoff value. If we have a test with perfect discrimination (i.e. perfect predictive ability) then the ROC curve passes through the upper left corner. In the upper left corner, the number of correctly predicted pre-crisis observations is 100 percent and the number of false alarms is 0 percent. Accordingly, the closer the ROC curve is to the upper left corner the more accurate is the test, and the area under the ROC curve is a measure of predictive ability. The tangent line at each cutoff point on the ROC curve, gives the likelihood ratio (LR) for that particular probability value of the test. If the ROC curve equals the 45 degree line the test is completely random. Finally, the ROC curve clearly illustrates the trade-off between the number of correctly predicted pre-crisis observations and the number of false alarms for different cutoff values (Zweig and Campbell, 1993).

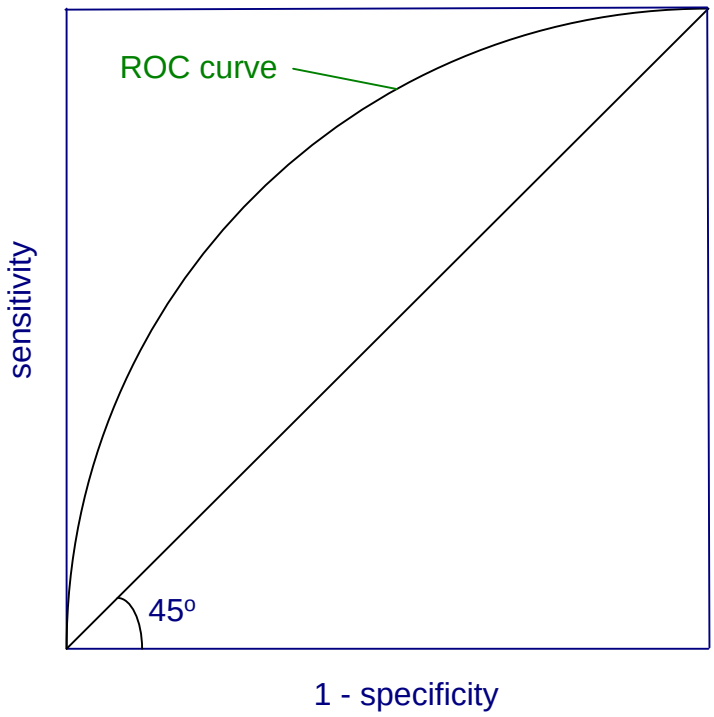

Figure 14. Receiver Operating Characteristics (ROC) curve

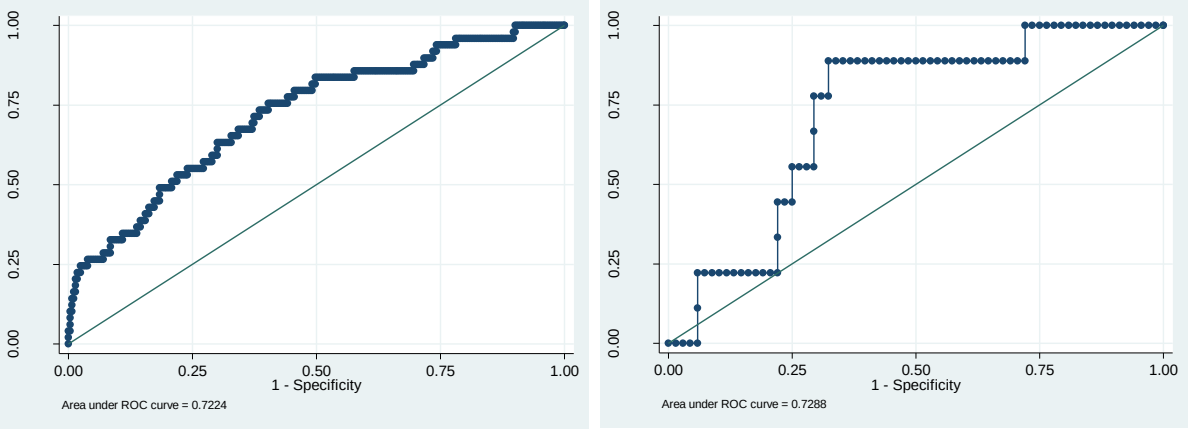

Figure 15. In-sample (left) and out-of-sample (right) ROC curves for banking crisis

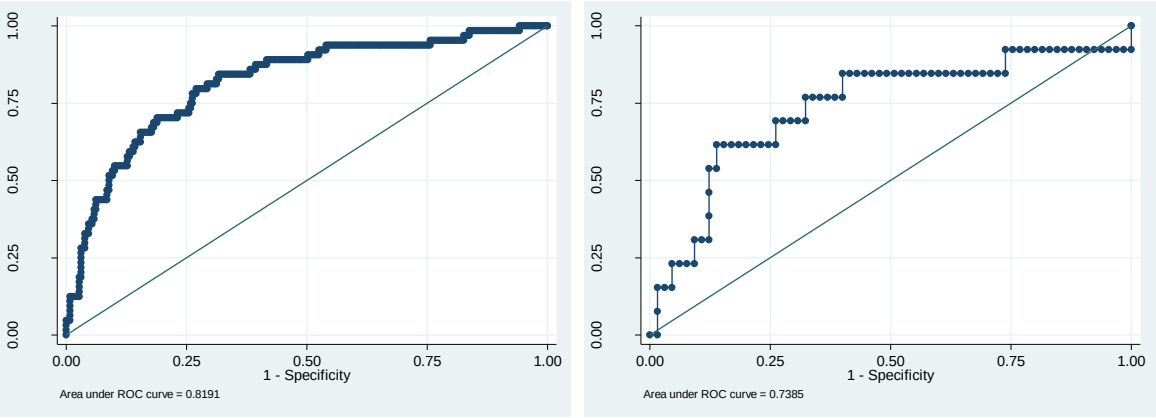

Figure 16. In-sample (left) and out-of-sample (right) ROC curves for debt crisis

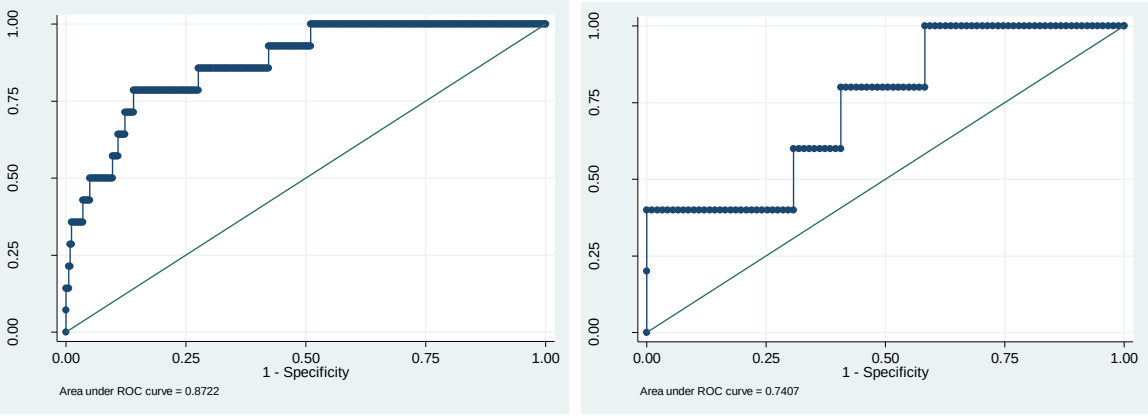

Figure 17. In-sample (left) and out-of-sample (right) ROC curves for twin crisis

Appendix 8 – Robustness Analysis

Global sample – robust estimations

Table 25. Robust MNL estimation of global dataset for banking crises

Variable – banking crisis	Marginal Effect	Coefficient	Robust S. E.	Z-statistics	P-value
Pre-crisis period (Y=1)					
Constant		-5.5786	1.1266	-4.95	0.000
IntResSTED	-0.0328	-0.3888	0.1643	-2.37	0.018
DomCredBSGDP	0.0007	0.0104	0.0044	2.35	0.019
CapFlowBon	0.1050	0.8784	0.3816	2.30	0.021
ExVar (log)	0.0412	0.5216	0.1298	4.02	0.000
Post-crisis period (Y=2)					
Constant		-3.6086	0.7773	-4.64	0.000
IntResGrowth	-0.1178	-0.9542	0.4077	-2.34	0.019
RGDPGrowth	-0.0130	-0.1122	0.0339	-3.32	0.001
DomCredBSGDP	0.0018	0.0159	0.0032	4.90	0.000
BCrisisFC	-0.1048	-0.9144	0.3213	-2.85	0.004
ExVar (log)	0.0417	0.4000	0.1121	3.57	0.000
InfCrisis	0.0935	0.8036	0.3583	2.24	0.025
TEDGDP (log)	0.1352	1.1287	0.2761	4.09	0.000
Pseudo R-squared	0.1759				

Table 26. Robust MNL estimation of global dataset for sovereign debt crises

Variable – Debt crisis	Marginal Effect	Coefficient	Robust S. E.	Z-statistics	P-value
Pre-crisis period (Y=1)					
Constant		0.9132	1.8197	0.50	0.616
CapFlowBon	0.1149	1.7447	0.5349	3.26	0.001
BCrisisFC	-0.1113	-1.1203	0.4709	-2.38	0.017
TradeGDP	-0.0026	-0.0265	0.0135	-1.96	0.049
CABSTD	0.0475	0.7797	0.2348	3.32	0.001
TEDGDP (logged)	0.0226	1.4817	0.6115	2.42	0.015
STEDIntRes (logged)		0.5364	0.2237	2.40	0.016
Post-crisis period (Y=2)					
Constant		2.0049	1.2234	1.64	0.101
ExVar (log)	-0.1156	-0.5042	0.1562	-3.23	0.001
CapFlowBon	0.1952	1.2071	0.4940	2.44	0.015
BCrisisFC	0.2183	0.7773	0.3664	2.12	0.034
InfVar (log)	0.2535	1.0886	0.1578	6.90	0.000
TradeGDP	0.0048	0.0164	0.0055	2.98	0.003
M2ResMoney (log)	-0.2111	-0.8756	0.2815	-3.11	0.002
TEDGDP (log)	0.6159	2.7941	0.5338	5.23	0.000
STEDIntRes (log)	0.0905	0.4540	0.1955	2.32	0.020
Pseudo R-squared	0.4234				

Table 27. Robust MNL estimation of global dataset for twin crises

Variable – Twin crisis	Marginal Effect	Coefficient	Robust S. E.	Z-statistics	P-value
Pre-crisis period (Y=1)					
Constant		-12.0923	6.6421	-1.82	0.069
TradeGDP	0.0000	-0.1015	0.0294	-3.45	0.001
TradeBalGDP	-0.0029	-6.9370	3.3501	-2.07	0.038
InfVar (logged)	-0.0004	-0.9214	0.3265	-2.82	0.005
M2ResMoney (logged)	0.0017	3.9876	0.9481	4.21	0.000
Post-crisis period (Y=2)					
Constant		2.0618	0.9862	2.09	0.037
ExVar (logged)	-0.0548	-0.5215	0.1048	-4.98	0.000
DSerPNGEDGDP	5.0234	47.8491	11.3241	4.23	0.000
RER (logged)	0.0145	0.1383	0.0500	2.77	0.006
Pseudo R-squared					

Regional sample (Latin America) – robust estimations

Table 28. Banking crises robust estimation (Latin America)

Variable – banking crisis	Marginal Effect	Coefficient	Robust S. E.	Z-statistics	P-value
Pre-crisis period (Y=1)					
Constant		-3.6584	1.3971	-2.62	0.009
RGDPGrowth	-0.0074	-0.1265	0.0582	-2.17	0.030
DomCredBSGDP	0.0018	0.0285	0.0079	3.59	0.000
CapFlowBon	0.1802	1.6613	0.6038	2.75	0.006
Post-crisis period (Y=2)					
Constant		-3.4532	1.0047	-3.44	0.001
RGDPGrowth	-0.0160	-0.1586	0.0579	-2.74	0.006
InfCrisis	0.1308	1.2416	0.5142	2.41	0.016

Table 29. Sovereign Debt crises robust estimation (Latin America)

Variable – Debt crisis	Marginal Effect	Coefficient	Robust S. E.	Z-statistics	P-value
Pre-crisis period (Y=1)					
Constant		0.8645	2.7454	0.31	0.753
DSerTEDEx	0.0224	2.4929	1.2266	2.03	0.042
CABSTD	0.0693	0.7496	0.3452	2.17	0.030
Post-crisis period (Y=2)					
Constant		-2.3137	1.9135	-1.21	0.227
BCrisisFC	0.3797	1.8338	0.6255	2.93	0.003
InfVar_log	0.1854	1.0481	0.2446	4.29	0.000
DSerTEDEx	0.3883	2.6441	1.2197	2.17	0.030
TradeGDP	0.0111	0.0552	0.0134	4.12	0.000
M2resMoney_log	-0.4949	-2.8747	0.5856	-4.91	0.000
TEDGDP_log	0.5648	3.2005	1.0447	3.06	0.002
STEDIntRes~g	0.2537	1.5615	0.4236	3.69	0.000

Appendix 9 - Supplementary dataset

Table 30. Supplementary dataset of banking crises (Laeven & Valencia, 2010) and sovereign debt crises (Manasse & Roubini, 2009).

Country	Year of banking crisis[35] (Laeven& Valencia)	No. of banking crises	Year of debt crisis[36] (Manasse&Roubini)	No. of debt crises	Year of twin crisis	No. of twin crises
Argentina	1980-82; 1989-91; 1995; 2001-…	4	1982-94; 1995*; 1996; 2001; 2002	3	1980-94; 2001-…	2
Brazil	1990-94; 1994-98	2	1983-95; 1998*; 1999*; 2000; 2001*; 2002*	3	-	0
Chile	1981-85	1	1983-91	1	1981-91	1
China	1998	1	-	0	-	0
Colombia	1982; 1998-2000	2	-	0	-	0
Dom. Republic	-	0	1981-	1	-	0
Ecuador	1982-86; 1998-2002	2	1982-96; 1999-2001	2	1982-96; 1998-2002	2
Egypt	1980	1	1984-85	1	-	0
El Salvador	1989-90	1	1981-97	1	-	0
Hungary	1991-95	1	-	0	-	0
Indonesia	1997-2001	1	1997*-2001; 2002	2	1997-2001	1
Korea, Rep. Of	1997-98	1	1980*; 1981*; 1982; 1997*; 1998*; 1999	2	1997-99	1
Malaysia	1997-99	1	-	0	-	0
Mexico	1981-85; 1994-96	2	1982-91; 1995*; 1996	2	1981-91; 1994-96	2
Morocco	1980-84	1	1983-84; 1986-91	2	-	0
Nigeria	1991-95	1	-	0	-	0
Pakistan	-	0	1998-2000	1	-	0
Panama	1988-89	1	1983-97	1	-	0
Peru	1983	1	1983-98	1	1983-98	1
Philippines	1983-86; 1997-2001	2	1983-93	1	1983-93	1
Poland	1992-94	1	-	0	-	0
Russia	1998	1	1998-2001	1	1998-2001	1
South Africa	-	0	1985-88; 1989-90; 1993-94	3	-	0
Thailand	1983; 1997-2000	2	1981*; 1982; 1997*; 1998	2	1981-83; 1997-2000	2
Tunisia	1991	1	1991*; 1992	1	1991-92	1
Turkey	1982-84; 2000-2001	2	1980*; 1981*; 1982; 1983; 2000*; 2001*; 2002	2	1980-84; 2000-2002	2
Uruguay	1981-85; 2002…	2	1983-86; 1987-88; 1990-92	3	1981-86	1
Venezuela	1994-98	1	1983-89; 1990-91; 1995-98	3	1994-98	1
Total 28		**36**		**39**		**19**

*Starred years are added by IMF loans.

[35]In a systemic banking crisis "a country's corporate and financial sectors experience a large number of defaults and financial institutions and corporations face great difficulties repaying contracts on time. As a result, non-performing loans increase sharply and all or most of the aggregate banking system capital is exhausted. This situation may be accompanied by depressed asset prices (such as equity and real estate prices) on the heels of run-ups before the crisis, sharp increases in real interest rates, and a slowdown or reversal in capital flows (Laeven & Valencia, p. 5, 2010)".

[36]Manasse and Roubini classify a country experiencing a sovereign debt crisis when either it is identified by Standard &Poors to experience a default or if IMF provide a non-concessional loan in excess of 100 percent of its IMF quota. According to the definition used by Standard & Poor's, a country is in default when the government is unable to pay the principal or interest on its external obligations in time (Manasse and Roubini, p. , 2009).

Table 31. Supplementary dataset - Robust MNL regression for banking crises

Variable – banking crisis	Marginal Effect	Coefficient	Robust S. E.	Z-statistics	P-value
Pre-crisis period (Y=1)					
Constant		-5.1638	1.2725	-4.06	0.000
IntResSTED	-0.0231	-0.3499	0.1669	-2.10	0.036
RGDPGrowth	-0.0059	-0.0954	0.0426	-2.24	0.025
CapFlowBon	0.0991	1.0731	0.4097	2.62	0.009
ExVar_log	0.0310	0.4782	0.1485	3.22	0.001
Post-crisis period (Y=2)					
Constant		-5.0943	1.0634	-4.79	0.000
RGDPGrowth	-0.0092	-0.1662	0.0423	-3.93	0.000
DomCredBSGDP	0.0009	0.0151	0.0037	4.14	0.000
BCrisisFC	-0.0909	-1.5323	0.4228	-3.62	0.000
ExVar_log	0.0267	0.4962	0.1511	3.29	0.001
InfCrisis	0.0991	1.4298	0.4386	3.26	0.001
TEDGDP_log	0.0592	1.0445	0.3560	2.93	0.003
Pseudo R-squared	0.2100				

Table 32. Supplementary dataset - Robust MNL regression for sovereign debt crises

Variable – Debt crisis	Marginal Effect	Coefficient	Robust S. E.	Z-statistics	P-value
Pre-crisis period (Y=1)					
Constant		-5.3812	2.8454	-1.89	0.059
ExVar_log	0.0069	0.4755	0.2148	2.21	0.027
CapFlowBon	0.0430	2.0339	0.7604	2.67	0.007
BCrisisFC	-0.0309	-2.4355	0.8849	-2.75	0.006
TradeGDP	-0.0005	-0.0510	0.0191	-2.68	0.007
M2ResMoney~g	0.0167	1.6598	0.5579	2.98	0.003
TEDGDP_log	0.0186	2.2833	0.7019	3.25	0.001
Post-crisis period (Y=2)					
Constant		1.5875	1.4082	1.13	0.260
ExVar_log	-0.1583	-0.7001	0.1528	-4.58	0.000
BCrisisFC	0.1693	0.7185	0.3287	2.19	0.029
InfVar_log	0.1982	0.8887	0.1407	6.31	0.000
TEDGDP_log	0.2189	1.0111	0.3246	3.12	0.002
STEDIntRes~g	0.0801	0.3677	0.1666	2.21	0.027
Pseudo R-squared	0.4118				

Table 33. Supplementary dataset - Robust MNL regression for twin crises

Variable – Twin crisis	Marginal Effect	Coefficient	Robust S. E.	Z-statistics	P-value
Pre-crisis period (Y=1)					
Constant		-6.7815	2.1995	-3.08	0.002
ExVar_log	0.0032	0.5192	0.2241	2.32	0.021
TradeBalGDP	-0.0301	-5.0875	2.0488	-2.48	0.013
DSerPNGEDGDP	0.2647	55.9451	18.4254	3.04	0.002
Post-crisis period (Y=2)					
Constant		1.6982	0.9861	1.72	0.085
ExVar_log	-0.0507	-0.4527	0.1104	-4.10	0.000
InfVar_log	0.1982	0.5458	0.1279	4.27	0.000
DSerPNGEDGDP	0.5343	67.9752	16.8040	4.05	0.000
M2ResMoney~g	-0.0575	-1.1644	0.4035	-2.89	0.004
Pseudo R-squared	0.2703				

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