CRANFIELD UNIVERSITY

HERU RAHADYAN

INVESTIGATION INTO CURRENCY AND BANKING CRISES: A NOVEL APPROACH TO THE IDENTIFICATION AND PREDICTION OF TWIN CRISES

SCHOOL OF MANAGEMENT
PhD Programme

Doctor of Philosophy
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This thesis is submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy

ABSTRACT

This thesis focuses on providing novel insights into the relationship between currency crises and banking crises and building a tool to identify and predict the crises. Even though currency and banking crises have occurred periodically, the nature of twin crises is still unclear. There are still debates on whether currency crises trigger banking crises. The dates of twin crises are still difficult to identify due to the limitation of the existing technique. In addition, economists have difficulty in examining the risk of the crises as there is no consensus on how to define them.

To address the issue, we examine the twin crises literature using the systematic literature review methodology. We then identify the pressure dynamics of the twin crises in Latin American and East Asian countries during the period 1980-2007. Finally, we examine the crisis risk of the currency and banking crises in 80 countries during 1970-2016.

The literature suggests that banking crises often precede currency crises. However, on the contrary, we show that currency crises often precede banking crises by minimising the bias in the identification techniques. While the literature argues that foreign liabilities are responsible for twin crises, we explain that liquidity shortages and the insolvencies of banks may also trigger twin crises. In addition, we argue that currency crises may also trigger bank crises. Thus, twin crises should be examined as a two-way relationship.

Furthermore, we combine the Exchange Market Pressure Index and the Money Market Pressure Index into a c-index to evaluate the twin crises episodes in the existing literature. We find that the model is able to pinpoint the dates of the twin crises episodes in our sample countries.

Finally, we divide the crises into four levels as there is no consensus on how to define the crises. We demonstrate that the c-index can predict the probability of any given condition to *shift* to the 'next crisis level' in the next two years. The findings also suggest that regulators and investors are risk takers in low-pressure periods and become *risk-averse* when conditions worsen.

Keywords: currency and banking crisis, twin crises, Financial Market Pressure

ACKNOWLEDGEMENTS

To God, *the Gracious and the Merciful*. Thank you for your blessings.

To Sachroni and Rahayu, *my dad and mum*. I present this thesis for you. Thank you for your unconditional love and support.

To Kanti, Azka, and Freya, *my wife, son and daughter.* I could not do it without you. You are the light and the inspiration of my life.

To Bank Indonesia, *my sponsor*. Thank you for trusting me with this education.

To Prof Figueira, Prof Belghitar and Dr Angus, *my supervisor, the chair and member of panel review*. I will always be grateful for your feedbacks and support throughout the programme.

To Giorgio, Alex, Boim, Sezsy and all friends in Cranfield. You made the PhD journey much easier. A true family when we were far away from our home.

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LIST OF ABBREVIATIONS

ABS	Association of Business Schools
C-Index	Index of Financial Market Pressure
EMP	Exchange Market Pressure
EMPI	Exchange Market Pressure Index
FMP	Financial Market Pressure
IFS	International Financial Statistics
IFE	International Fisher Effect
ITF	Inflation Targeting Framework
KR	Kaminsky & Reinhart
LV	Laeven & Valencia
MMP	Money Market Pressure
MMPI	Money Market Pressure Index
OLS	Ordinary Least Square
STV	Sach, Tornel, & Velasco

Chapter 1

THESIS INTRODUCTION

1.1. Research Background

Financial crises – in particular, currency crises and banking crises – have occurred periodically (Bicaba *et al.,* 2014). Along with the growing integration of financial markets, financial institutions such as banks have become increasingly vulnerable to financial turmoil elsewhere (Mendoza & Quadrini, 2010). Moreover, financial turmoil that originates from one type of financial crisis often develops into another type of financial crisis, giving rise to what is known as 'twin crises' (Kaminsky & Reinhart, 1999). The increasing frequency of twin crises since 1980 may be due to financial liberalisation among emerging markets (Glick & Hutchison, 1999).

Despite the abundance of currency and banking crises literature, the nature of crises is still unclear. The causes of crises are still disputed: either they are random (Diamond & Dybvig, 1983; Obstfeld, 1986) or fundamental-based (Jacklin & Bhattacharya, 1988; Krugman, 1979).

In recent decades, interest has grown in the study of the contagion effect on currency and banking crises. One strand of literature focuses on the contagion effect from one banking problem to other banks, known as systemic risk (Rochet & Tirole, 1996). Another strand of literature investigates the contagion effect from a banking crisis to a currency crisis, known as twin crises (Kaminsky & Reinhart, 1999).

While the theory of twin crises is considered the third generation of currency crisis model, it is not discussed in the study of banking crises. The twin crises literature views banking crises as the source of currency crises (see Burnside *et al.*, 2001; Chang & Velasco, 2000; Corsetti e*t al.,* 2004; McKinnon & Pill, 1996) due to over-borrowing to finance a bank's lending in the presence of government

guarantees. Furthermore, these government guarantees also encourage banks to extend loans in foreign currency; thus making currency and banks vulnerable simultaneously.

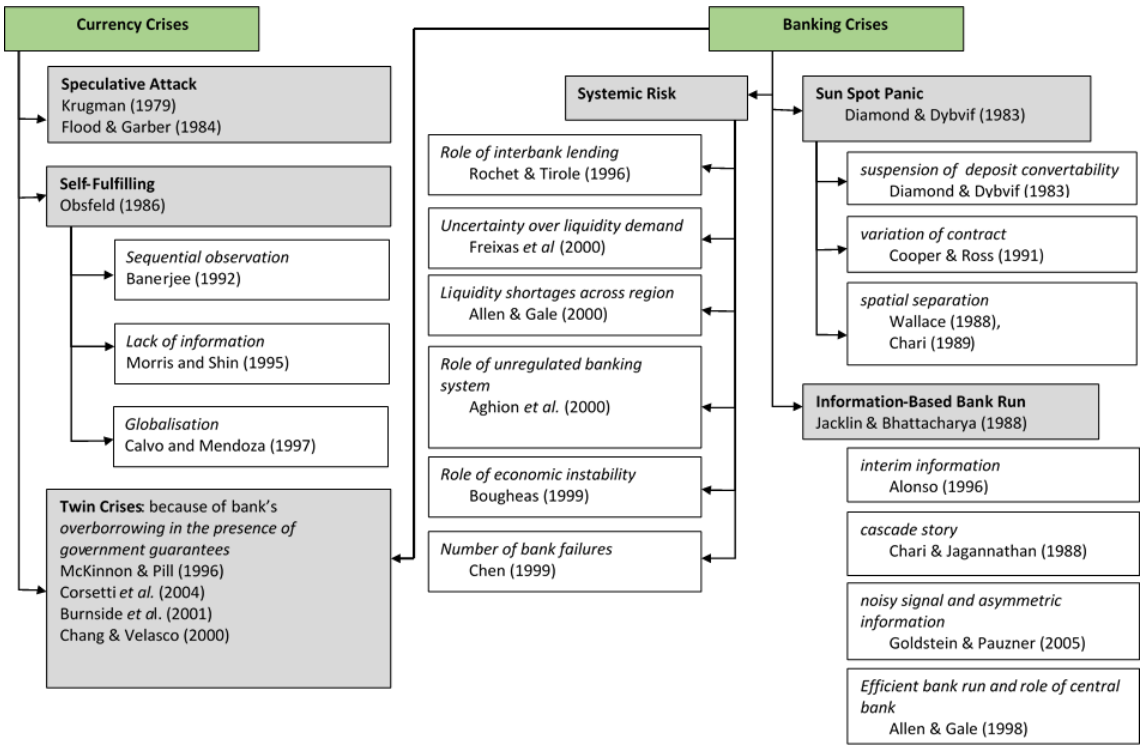
However, there is evidence that twin crises could also occur even though banks are not exposed to foreign liabilities (Bleaney *et al.,* 2008; Flood & Marion, 2004). In addition, literature also suggests that there is a vicious cycle between currency and banking crises. They are often driven by similar factors (Glick & Hutchison, 1999; Schnabel, 2004). Unfortunately, these phenomena are not investigated further in this strand of literature.

1.2. Initial Review of the Literature

To provide a foundation for the work on twin currency and banking crises in this thesis, we provide an initial review of the literature on currency crises and banking crises. This scoping study aims "to assess the relevance and size of the literature and to delimit the subject area or topic" (Tranfield *et al.,* 2003, p.214). On the basis of an initial assessment of the literature, the following scoping study question is defined: *what are the main causes of currency and banking crises?*

In line with the focus study and the limitations of the scoping study, this paper provides an overview of the literature based on two major themes. First, we explore the extant studies on currency crises to identify the generations of theories and drivers behind the volatility of exchange rates. Second, we review some studies on banking crises that provide insights into the causes and models of banking crises. The theory of currency and banking crises is shown in Figure 1.1.

Figure 1.1: Theory of Currency and Banking Crises



Source: Compiled by Author

1.2.1. Theory of Currency Crises

A currency crisis is a situation when depreciation of currency (Frankel & Rose, 1996) or the Exchange Market Pressure Index (Eichengreen *et al.,* 1995) exceeds a particular threshold. Even though there is no clear single threshold to determine a currency crisis, it is clear that currency crises have a significant impact on the economy by reducing the output for a few years (Hutchison & Noy, 2005).

Theories of currency crises have developed over three generations. This section provides an overview of these three generations of currency crises models as shown in Figure 1.1.

1.2.1.1. Speculative Attack

The early model of currency crises is developed by Krugman (1979), who builds on Salant & Henderson's (1978) work regarding the speculative attack on the gold market. Krugman (1979) - developed further by Flood & Garber (1984) – argue that investors undertake a speculative attack if they doubt the government's capacity to keep the exchange rate fixed. Specifically, this condition occurs when the continuation of the current account deficit leads to a decline in foreign exchange reserves. As a result, the speculative attack causes the remaining reserves to move to investors; thus negatively affecting the currency.

Following Flood & Marion (1999), the first-generation model can be explained as follows. Let us recall the domestic money market equilibrium:

$$m - p = -\alpha(i),\ \alpha > 0 \qquad (1.1)$$

where, m is the "the change of domestic high-powered money supply", p is the "the change of domestic price level", and i is the "domestic currency interest rate" in *levels*.

The "domestic money supply" is calculated based on "domestic credit" (d) and "foreign reserves" (r), therefore:

$$m = d + r \qquad (1.2)$$

Assuming purchasing power parity holds, we can restate "domestic price level" (p) as a fraction of "foreign price level" (p^*) and "exchange rate" (s), as follows:

$$p = p^* + s \qquad (1.3)$$

Imposing uncovered interest rate parity, we can substitute "domestic currency interest rate" (i) with "foreign currency interest rate" (i^*) and "change in exchange rate" (Δs), as follows:

$$i = i^* + \Delta s \qquad (1.4)$$

In a fixed exchange rate regime, where s is equal to "future exchange rate" (s^e), it implies that $\Delta s = 0$ and $i = i^*$. By substituting Equations (1.2) – (1.4) into Equation (1.1) with $\Delta s = 0$, it follows that:

$$r + d - p^* - s^e = -\alpha(i^*) \qquad (1.5)$$

Therefore, in a fixed exchange rate regime (assuming "foreign currency interest rate" and "foreign price level" are fixed), "domestic credit" grows at the same rate of the fall of "foreign reserve" ($\Delta d = -\Delta r$). Ultimately, the foreign reserve will run out and force central banks to break the fixed exchange rate regime. Thus, the change in exchange rate policy will lead to speculative attack, which in turn leads to a crisis.

The main contribution of the model by Krugman (1979) is the idea that the speculative attack on the currency stems from a rational act rather than from investor panic. This model succeeded in explaining the currency crisis in Latin America just a few years after it was developed; prompting researchers to examine currency crises as rational events.

1.2.1.2. Self-Fulfilling Prophecy

The second-generation model of currency crises originated during the mid-1980s when Obstfeld (1986) used the term self-fulfilling prophecy in the formation of currency crises. The second-generation model stresses "market expectations, multiple equilibria and herding behaviour of investors" (Skamnelos, 2003, p.43) arising from nonlinearities in government behaviour "so that speculative attacks can occur because of self-fulfilling expectations" (Burnside *et al.*, 2007, p. 4).

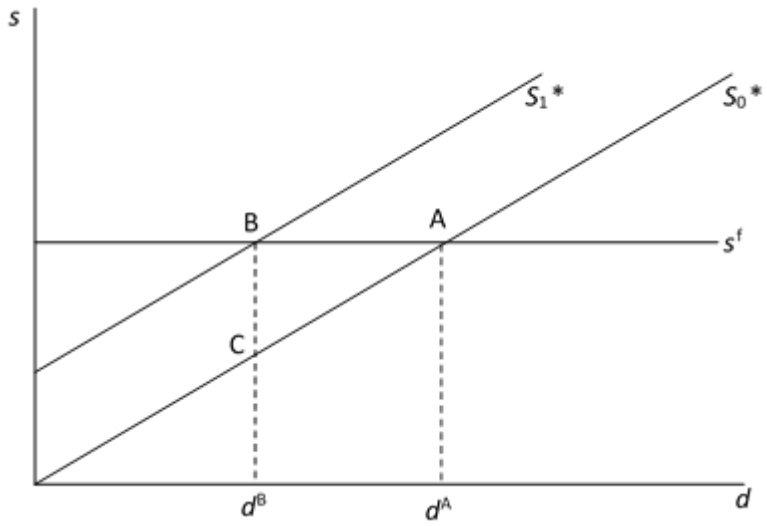
However, this second-generation model had just come under scrutiny after the de facto breakdown of the European Monetary System in 1992-1993 (Claessens & Kose, 2013). The first-generation model had failed to explain the above phenomena because there was no evidence of expansionary macroeconomic policies as suggested by the first-generation model.

Flood & Marion (1999) provide examples to explain the second-generation model. Flood & Marion impose a conditional shift in domestic credit growth into the first-generation model. In this model, the government tries to accelerate credit growth (g) to boost the economy, which leads to a currency attack. Let's denote

g_0 as credit growth in the time of no attack, and g_1 as the accelerated credit growth that leads to a currency attack.

Figure 1.2 simulates the attack on conditional policy shift. s_0* and s_1* represent "shadow exchange rate lines" correlating to the rate of credit growth at g_0 and g_1 respectively. s^f is fixed exchange rate, which intersects with shadow exchange rate line s_0* at point A and shadow exchange rate line s_1* at point B.

Figure 1.2: Attack times with attack-conditional policy shift



Source: Modified from Flood & Marion (1999)

Assuming "domestic credit" (d) is at the left side of point d^B ($d \leq d^B$), "the shadow rate" is at point C if there is no attack and jumps to point B if there is an attack. In this simulation, the "shadow rates" (s*) are always below (or maximum at) the fixed exchange rate ($s^* \leq s^f$); thus giving no incentive to speculators to attack the fixed exchange rate.

The multiple equilibria can occur when "domestic credit" is in the range between d^A and d^B. The fixed exchange rate could be maintained if investors believe that the government can defend the currency in the time of attack (there

is no immediate benefit). On the contrary, the "exchange rate" could shift to the upper "shadow rate line" (s_1*) if investors believe there will be an attack on the currency that leads to the breakdown of the fixed exchange rate. Consequently, all investors will sell domestic currency, leading to the collapse of the fixed exchange rate. However, there are multiple equilibria in this condition as the attack can only succeed if there is a large investor or coordinated action of small investors to launch an attack of sufficient size.

Another example of the second-generation model is provided by Banerjee (1992). Banerjee argues that investors' actions rely on the sequential observation of other investors' actions. If an investor observes that many other investors are selling currency, the investor will join the herd, despite his own information. Thus, the equilibrium will move from no-attack to attack equilibrium.

Furthermore, Morris & Shin (1995) show that a lack of information between investors can lead to an attack and breakdown of the fixed exchange rate even though there is no coordinated action between investors. In this example, investors always observe the state of the economy and consider other investors' beliefs on the sustainability of a fixed exchange rate. Assuming other investors believe that the fixed exchange rate is unsustainable, investors will launch an attack if the price of attack is not too costly. Thus, the only equilibrium at multiple equilibria condition (at range d^A and d^B) is the attack equilibrium.

Another example of the second-generation model is provided by Calvo & Mendoza (1997). They argue that globalisation creates many investors who make identical decisions in selecting their portfolios. Driven by relative performance to other investors' performances, investors select the same portfolio with other investors to match their performances and create herding behaviour, which leads to attack equilibrium.

The drawback of the self-fulfilling model is the fact that the model implies the difficulty of predicting currency crises. It implies limited roles for the policymaker in managing the exchange rate. However, Morris & Shin (1998) demonstrate that the attack can only succeed within a specific range of

fundamentals. Therefore, the policymaker can manage currency crises by managing the fundamentals (Jeanne, 1999).

1.2.1.3. Twin Crisis

Recent literature shows an interest in the interaction between banking crises and currency crises. Even though some economists (Chang and Velasco, 2000; Krugman, 1999) call this strand of study the third-generation model of currency crises, the term "third generation" is not widely accepted. Jeanne (1999) argues that currency crises themselves are a consequence of government policies when considering the appropriate level of the exchange rate, which can influence speculators' decisions. Under this view, this third-generation model can be considered as a sub-model of older models.

Some scholars (see Corsetti *et al.,* 2004; McKinnon & Pill, 1996) argue that one of the causes of twin crises lies in over-borrowing to finance a bank's lending in the presence of government guarantees. Furthermore, these government guarantees also encourage banks to extend loans in foreign currency; therefore making the currency and banks vulnerable simultaneously (Burnside *et al.,* 2001). The contribution of foreign currency-denominated loans to the occurrence of twin crises is also in line with Chang & Velasco (2000).

McKinnon & Pill (1996) use the model of open international capital flows to explain the impact on the banking system of a currency crisis. Assuming that there is no moral hazard, they argue that "a strong regulatory system prevents banks from discounting bad macroeconomic outcomes" (McKinnon & Pill, 1996, p.192). The expected rise in income in the future allows for higher loans, which encourage people to increase today's consumption. Savings will decline, and the current account will be a deficit. If there is a moral hazard, banks are encouraged to lend over-aggressively and boost consumption. The increase in consumption can lead to the wrong signal of an over-optimistic economy and invites capital flows to finance the consumption. However, the consumption also increases the current account deficit. Savings will decline further. This condition will create a

bubble and cannot be sustained. Soon, firms and households will have difficulty paying the loan. Current account deficits and high non-performing loans will lead to banking crises and massive capital outflow. As a result, the currency will crash.

1.2.2. Theory of Banking Crises

Hutchinson & Noy (2005) show that the cost of banking crises is higher than other types of financial crises. Therefore, it is crucial to mitigate banking crises or to reduce the impact of banking crises on the economy (Jing *et al.*, 2015).

The theories of banking crises can be divided into three groups. This section provides an overview of these three groups of banking crises models as shown in Figure 1.1.

1.2.2.1. Sunspot Panic

The theory of random withdrawal – also known as sunspot panic - is heavily influenced by Diamond & Dybvig (1983). In the Diamond and Dybvig model, agents use the bank as an insurer against the risk to cover the uncertainty of consumption needs. To achieve this, banks provide liquidity and guarantee when agents liquidate their investments before maturity. In doing so, banks can increase welfare but are exposed to risk. Thus, they create the possibility of a self-fulfilling bank run.

Following Diamond & Dybvig (1983), the model has three periods (T = 0, 1, 2) where agents have one short-term investment from T=0 to T=1 and one long-term investment from T=0 to T=2. All agents are identical at T=0 and learn their type at T=1: being type 1 agents or being type 2 agents who care only about consumption in T=1 or T=2 respectively. The salvage value of the long-term investment is equal to initial investment if it is interrupted at T=1. Banks provide an optimal insurance contract “by providing liquidity; banks guarantee a reasonable return when the investor cashes in before maturity, as is required for optimal risk-sharing” (p. 408). There are two important assumptions in the

Diamond & Dybvig model that can lead to bank panic: agents cannot claim physical assets in exchange for their deposits, and deposit withdrawals follow the first-come-first-served rule. Based on these assumptions, there will be two equilibriums: good equilibrium occurs when type 1 agents withdraw their deposits at T=1 and type 2 agents withdraw at T=2, and bad equilibrium occurs when there is panic. If a bank run is anticipated, agents will try to cash their assets as "the face value of deposits is larger than the liquidation value of the bank's assets" (Diamond & Dybvig, 1983, p.409).

The model suggests that banks' long-term assets are costly to liquidate. As banks invest heavily in long-term-assets, thus, banks will have difficulty to provide liquidity if there is a bank run. Due to the fear of banks' bankruptcy, agents will try to withdraw their funds if agents believe that banks are at risk. Furthermore, the fear of bankruptcy will encourage agents to race to withdraw their money as banks apply the first-come-first-served rule. Thus, bankruptcy is self-fulfilling. Mervyn King, former Governor of the Bank of England, once said "it may not be rational to start a bank run, but it is rational to participate in one" (Munchau, 2012).

There are many arguments concerning the source of panics. Diamond & Dybvig (1983, p. 410) suggest that panic could occur because of "a random earnings report, a commonly observed run at some other bank, a negative government forecast, or even sunspots" due to the lack of information held by the depositor. However, Cone (1983) argues that panic could be avoided if banks do not follow the first-come-first-served rule. The other obstacle in the Diamond-Dybvig model is the difficulty in observing beliefs (Gorton, 1988). However, Cooper & Ross (1991) find that panic will lead to expensive liquidation cost, and therefore can only occur when agents are risk-averse. Consequently, understanding the source of panic is essential (Smith, 1991).

Furthermore, Wallace (1988) introduces spatial separation of agents in the Diamond-Dybvig model and argues that panic could occur because the institutional structure fails to provide liquidity. In this model, Wallace argues that separated local banks will prevent agents from conducting coordinated withdrawals. Problems in separated local banks should be addressed by a local

reserve bank. Therefore, panic is related to an institutional structure in the banking system when liquidity fails to be provided. However, panic could be avoided if banks can perform an interbank loan market. Furthermore, to prevent panic, Chari (1989) suggests that policymakers should force separated local banks to hold adequate reserves.

As the first-come-first-served rule is an essential ingredient for a bank run, eliminating this rule will also eliminate the possibility of a bank run. As an alternative to this rule, Diamond & Dybvig (1983) propose the suspension of deposit convertibility in the event of a bank run, while Cooper & Ross (1991) suggest a variation of the contract to accommodate the possibility of a bank run (an allow-bank run contract and a run-proof contract).

1.2.2.2. Information-Based Bank Run

One of the weaknesses of Diamond & Dybvig (1983) is the unclear trigger of the bank run. Furthermore, Postlewaite & Vives (1987) show that the source bank runs are not necessarily an exogenous event such as random events, as specified in the earlier model. In addition, Cooper & Ross (1991) show that the liquidation cost of long-term investments is more significant than what is assumed in Diamond & Dybvig's model. These conditions encourage the emergence of information-based models where the bank run is a logical consequence of a rational change of risk in bank portfolios (Jacklin & Bhattacharya, 1988).

In Jacklin & Bhattacharya's (1988) model, there are three periods (T = 0, 1, 2) where agents have one short-term investment from T=0 to T=1 and one long-term investment from T=0 to T=2. All agents are identical at T=0. Differing to Diamond & Dybvig (1983), Jacklin & Bhattacharya impose three assumptions: first, agents will adjust their preferences based on information on T=1. Second, the returns on long-term investments are random. Third, long-term investment yields a zero payoff if liquidated at T=1. As there is no information about the returns on long-term investments, agents always observe their investments based on the newly available information. If agents believe that the bank portfolio

is at risk based on the latest available information, agents will withdraw their deposits. Consequently, Jacklin & Bhattacharya argue that bank runs are information-based.

Information-based models view banks as providers of a valuable service (by creating non-marketable bank loans) rather than providers of liquidity insurance as mentioned by the sunspot model. However, non-marketable loans in the bank portfolio are challenging to monitor; thus creating asymmetric information between banks and agents.

A critical extension of Jacklin & Bhattacharya (1988) is provided by Alonso (1996). Alonso uses Jacklin & Bhattacharya (1988, p.75) to abstract the panic aspects by imposing the assumption that agents "are unable to observe each other's withdrawals at the time when the interim information is revealed". Furthermore, Alonso also assumes that banks are aware that some agents receive interim information and understand the implications of different types of contracts. Thus, a little change in the contract will discourage agents to conduct a bank run. However, different types of contracts will have different utility, and banks, would purposefully, on occasion, choose a contract which allows a bank run.

The role of interim information is also studied by Chari & Jagannathan (1988). They argue that agents with no interim information cannot observe the real value of a bank. Thus, they learn about a bank's condition by observing other depositors. However, agents cannot distinguish between whether the source of withdrawal is for consumption needs or a run by informed depositors. Therefore, risk-averse agents could assume the worst-case scenario, which leads to panic.

In addition, Goldstein & Pauzner (2005) show that a noisy signal and asymmetric information between agents could lead to a bank run, even when the fundamentals are sufficient. Furthermore, Allen & Gale (1998) argue that a bank run could be efficient as there is risk sharing between agents. However, the liquidation cost would make a bank run inefficient, so central banks should intervene to control the liquidation cost.

1.2.2.3. Systemic Risk

Another model of banking crises focuses on the systemic risk in the banking industry. Rochet & Tirole (1996, p.733) define systemic risk as "propagation of an agent's economic distress to other agents linked to that agent through financial transactions". Based on this model, interbank lending can overcome the moral hazard problem between the bank owner and depositors due to the supervision of peer banks. However, interbank lending also increases the risk of contagion for banks (Rochet & Tirole, 1996).

One strand of the study of systemic risk focuses on uncertainty over liquidity demand. As agents are uncertain about where they want to consume, banks face the risk of withdrawal and the transference of agents' deposits to other areas. To address this problem, banks create an interbank money market. Thus, there is no need to liquidate their long-term investments to meet the agents' cash demands. However, an interbank money market could create contagious bank failures when there is a gridlock in the payment system. Therefore, agents could panic when they fear there is insufficient reserve among banks (Freixas *et al.*, 2000). Furthermore, Allen & Gale (2000) show that the interbank money market grows because of different liquidity shortages across regions. In this sense, the spread of contagion is influenced by the types of claims in the interbank money market.

Another view of systemic risk is provided by Aghion *et al.* (2000) who study the role of the unregulated banking system on the systemic risk. They focus their research on claims that bank failures are influenced by safety-net regulations. Thus, minimal regulatory intervention is required to regain financial stability. Furthermore, financial market arrangement by a private institution (e.g. clearing house) is more efficient in preventing systemic shocks. Aghion *et al.* (2000, p.718) argue that "the more efficient such a system is at reducing the potential insolvency of individual banks, the more it exposes itself to contagious runs should there be a global liquidity shortage". Therefore, an unregulated banking system is not immune to systemic risk. They argue that an interbank money

market has a central role in developing systemic risk. If an interbank money market cannot support one illiquid bank, a systemic bank run may occur as agents may assume that there is not enough liquidity in the banking system.

Furthermore, Bougheas (1999) shows that a problem in one bank is not sufficient to create panic. It can only be systemic when the problem occurs at a time of economic instability. In addition, Chen (1999) argues that agents of one specific bank can have interim information; however, they do not have access to the interim information of other banks. Therefore, they will observe the number of bank failures as a proxy for interim information regarding macroeconomic conditions and the performance of other banks. In this sense, agents may conduct a bank run if they observe there are some bank failures.

1.3. Emerging Issues in the Literature

The initial review shows that, despite the abundant amount of currency and banking crises literature, the nature of the crises is still unclear. The causes of the crises are still disputed: whether they are random (Obstfeld, 1986; Diamond & Dybvig, 1983) or fundamental-based (Krugman, 1979; Jacklin & Bhattacharya, 1988). These are discussed in the first and second-generation of currency and banking crises models.

The third-generation of currency and banking crises models discuss the spill-over effect of the crises. The banking crises literature focuses on the impact of a problem in one bank on the other banks, known as the systemic risk (Rochet & Tirole, 1996). On the other hand, the currency crises literature examines the banking crises as the source of currency crises, known as the twin crises (Kaminsky & Reinhart, 1999). While the twin crises' studies are rather popular in the currency crises literature, this field is relatively ignored in the banking crises literature. Thus, the study on the two-way relationship between the currency and banking crises is still underdeveloped.

Furthermore, the twin crises are examined by comparing the starting date of the banking and currency crises. Kaminsky & Reinhart (1999) define twin crises as a condition when banking crises are followed by currency crises in a four-year window period. However, this method could not provide clear dates of twin crises, which is an essential ingredient in the empirical study. This might be the reason why most twin crises literature is theoretical or conceptual.

In addition, the absence of a consensus on how to define the crises may complicate the crises investigation. While some economists may focus on very severe crises only, other economists may investigate the weaker forms of the crises. A crisis episode in one particular literature may not be a crisis episode in the other literature. Thus, empirical investigations on the crises are difficult to interpret as the studies may adopt various crises databases.

As every financial crisis has unique features, the failure to recognise these may lead to empirical bias (Bauer *et al.,* 2007). Hence, it is essential to understand the nature of the twin crises, mainly as they appear to have a far more profound impact than that resulting from isolated shocks, as claimed by Hutchinson & Noy (2005).

1.4. Research Aims and Objectives

Given the above initial review, this thesis attempts to narrow the gap in the literature by providing novel insights into the relationship between currency and banking crises, as well as tools to identify and predict the twin crises.

The overarching research question that is addressed in this work refers to the extent to which a currency crisis relates to a banking crisis. In a more formal term, the overarching research question that informs this study can be stated as follows:

How can we determine and predict the dynamics of the twin currency and banking crises?

To be able to reach the objective, this overarching question is divided into three sub-questions: (1) *what can the relationship between the exchange market and the money market tell us about the dynamics of the twin currency and banking crises?* (2) *how do we determine the 'pressure' dynamics associated with the twin currency and banking crises?* and (3) *how can the dynamics of the twin currency and banking crises be predicted?*

1.5. Thesis Structure

This thesis consists of three papers on different issues to answer each of the sub-questions that have been previously defined.

In the next chapter, the first paper, we review the extant literature on the twin crises using the Systematic Literature Review procedure. Firstly, we re-examine the starting dates of the currency and banking crises by minimising the bias in the identification techniques. The relationship between banking and currency crises is determined by the starting dates of the two crises. However, we argue that there is a potential bias in the literature as the choice of crises database might influence our perspective on the currency and banking crises relationship. Second, we extend the twin crises literature into a currency and banking (in)stability framework to explain the reason why there is a vicious cycle between currency and banking crises (Schnabel, 2004). The twin crises literature shows that the banking crises trigger the currency crises due to the foreign liabilities in the banking system. We argue that the liquidity shortages and insolvencies may also be responsible for the occurrence of the twin crises. In addition, we show that currency crises may also lead to banking crises. Thus, the extended framework views the twin crises as a two-way relationship between currency and banking crises.

In the second paper, we combine the Exchange Market Pressure Index and the Money Market Pressure Index into the c-index to identify the twin crises. We argue that the existing approaches in the twin crises literature could not provide clear dates of the twin crises. This might be the reason for the limited number of empirical studies in the twin crises. To address the issue, we transform the currency and banking (in)stability framework into a practical model to identify the dynamics of the twin crises. In doing so, we employ a mathematical model of Exchange Market Pressure (Girton & Roper, 1977) as a foundation of our model. We then extend the above model into a mathematical model of Financial Market Pressure (FMP). The FMP is then transformed into an index of financial market pressure, which we refer as the c-index to determine the dynamics of the twin currency and banking crises.

In the last paper, we employ the c-index to predict twin currency and banking crises. The absence of a consensus on how to define the crises makes it difficult to interpret the empirical findings. A crisis episode in one crises database may be considered as a normal time in the other crises database, or vice versa. To address the issue, we divide the crises into four levels, crisis level 1 to crisis level 4. While crisis level 1 represents the lowest pressure in the financial market (normal period), crisis level 4 represents the highest pressure in the financial market (severe crisis period). We then demonstrate that the c-index can measure the current pressure in the financial market, as well as the probability of the current situation to *shift* to the 'next crisis levels' in the next two years.

Finally, we conclude the findings and contributions to knowledge in Chapter 5. In addition, we also highlight the implications, research impacts and dissemination, limitations and suggestions for future research in this chapter.

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Chapter 2 – Paper 1

CURRENCY AND BANKING (IN)STABILITY FRAMEWORK

Abstract

This article examines the literature on the twin currency and banking crises using the systematic literature review methodology. The twin crises literature suggests that banking crises often precede currency crises, not vice versa. However, on the contrary, we show that currency crises often precede the banking crises by minimising the bias in the identification techniques. While the literature argues that the foreign liabilities are responsible for the twin crises, we explain that the liquidity shortages and the insolvencies on the banks may also trigger the twin crises. In doing so, we extend the twin crises literature into a currency and banking (in)stability framework which views the twin crises as a two-way relationship between the currency and banking crises.

Keywords:

currency crisis, banking crisis, twin crises, systematic literature review

JEL Classification: G10, G15, G17

2.1. Introduction

Currency and banking crises have occurred periodically (Bicaba *et al.*, 2014). The collapse of the Medici Bank in the 15th century (Livingstone, 2008) is an example of banking failure in the early days of banking development. The stories of bank failure have continued for centuries. The latest series of financial crises was started by the subprime mortgage crisis in the US in 2007-2008 (Ambrose & Diop, 2014), which was then followed by the banking crisis in the UK in 2008-2009 (Hall, 2009) and the recent Spanish banking crisis (Sagarra *et al.*, 2015).

Along with the growing integration of the financial markets, financial turmoil in one country may lead to financial crises in another country (Mendoza & Quadrini, 2010). This condition has also influenced the increasing number of twin crises since 1980 (Glick & Hutchison, 1999). Thus, financial crises that originate from banking crises often develop into currency crises (Kaminsky & Reinhart, 1999).

Despite centuries of history on currency and banking crises, the strand of literature that deals with currency crises (Krugman, 1979; Obstfeld, 1986) and banking crises (Diamond & Dybvig, 1983; Jacklin & Bhattacharya, 1988; Rochet & Tirole, 1996) was developed just four decades ago.

Furthermore, in the early 2000s, the theory of twin “banking and currency” crises has emerged (Burnside *et al.*, 2001; Corsetti *et al.*, 2004; McKinnon & Pill, 1996). However, while currency crisis literature has extensive studies on the twin crises, twin crises are relatively ignored in the banking crises literature. This is arguably due to the idea that twin crises model views banking crises as a trigger to currency crises, not vice versa (Kaminsky & Reinhart, 1999). Thus, the twin crises model is also considered as the third-generation of currency crisis model.

However, there is evidence of a vicious cycle between currency and banking crises (Schnabel, 2004) and they are often driven by similar factors (Glick & Hutchison, 1999). Unfortunately, these phenomena are not investigated further in this strand of literature.

In this paper, we aim to reassess the relationship between currency and banking crises. by demonstrating that, in contrast to the existing twin crisis model, currency crises often precede banking crises, and, in addition to the liquidity mismatch, banks' liquidity shortages and insolvencies are also responsible for the occurrence of twin banking and currency crises.

Our study is motivated by a guiding question: *what can the relationship between the exchange market and the money market tell us about the dynamics of the twin currency and banking crises?* To be able to reach the objective, this overarching question is divided into three sub-questions: (1) *how do we identify the currency and banking crises*? (2) *what methodologies are employed in the currency and banking crises' studies?* (3) *what is the relationship between the currency and banking crises?*

To answer the above questions, systematic literature review methodology has been chosen as it allows us to generate replicable "best" evidence (Tranfield, Denyer, & Smart, 2003) and is considered by some researchers as more robust than a traditional narrative review (Denyer & Neely, 2004).

Furthermore, we re-evaluate the starting date of the currency and banking crises to demonstrate that currency crises often precede banking crises. Existing literature suggests that banking crises often precede currency crises. However, we argue that there is a bias in the banking crisis identification technique.

Studies in the banking crises typically identify banking crises using the event approach, which is regarded as biased by some economists (Goldstein *et al.,* 2000). To address the issue, the Money Market Pressure Index (MMPI), which has a growing interest in the aftermath of the global financial crisis of 2008, is applied to identify banking crises. We then compare the starting dates of currency crises, which is examined by using the Exchange Market Pressure Index (EMPI), with the starting dates of banking crises, which is identified by using the MMPI. By doing so, in contrast to existing literature, we show that currency crises often precede banking crises.

Finally, we re-examine some of the key tenets of the currency and banking studies to explain why twin crises should not be viewed as a one-way relationship from banking crises to currency crises as is suggested by the existing twin crises model. By doing so, we extend the existing twin crises framework into a currency and banking (in)stability framework.

The structure of the paper is as follows. The next section explains the structured search, the third and fourth sections are findings and discussion. The final section concludes.

2.2. Structured Search

The systematic literature review focuses on the twin crises literature. To understand the depth of existing studies in twin crises, we conduct a comprehensive and structured search (Klassen *et al.*, 1998) in a specific twin crises literature.

Our structured search was undertaken in seven steps. First, we designed the inclusion and exclusion criteria regarding the literature to be explored. Along with our research interest to investigate the twin crises, the literature should investigate both currency crises and banking crises literature, while ignoring literature on isolated currency crises or isolated banking crises. In particular, we were only interested in the literature that discussed the causes, predictions and the relationship between currency and banking crises. Therefore, we excluded articles that failed to discuss twin crises or only focussed on the output/impact of twin crises, as we want to focus on the causes/sources of twin crises. However, as we acknowledged the limited amount of this kind of literature, we also considered other types of crises literature as long as it helped to develop our understanding regarding twin crises.

Furthermore, we focused our search on English peer-reviewed academic journals as they produced high impact validated knowledge (Podsakoff *et al.*,

2005) which is in line with the aim of our research. To capture as much relevant available literature as possible, the search was employed in three different popular databases: ABI/Inform ProQuest, EBSCO and Science Direct.

Second, we developed keywords that were in line with the selection criteria. We divided our keywords into two distinct groups. The first group represented keywords of currency crises literature, while the second group was a proxy of banking crises literature. As both groups had the same keyword "crises", for simplification, we then separated these keywords and group them into a third group which represented the keyword "crises". We then combined these three groups with Boolean operator "AND". To produce more relevant articles, we decided to keep the third group as close as possible to the first and second groups. Thus, we changed the operator "AND" with NEAR/1.

Furthermore, we also added keyword "twin crises" in our keywords to capture a specific phrase that was popular in twin crises literature. Taken together, our final keywords could be represented as (("Group Currency" AND "Group Banking") NEAR/1 "Group Crises") OR "Twin Crises". Our complete keywords are shown in Table 2.1.

Table 2.1: List of Keywords

Group 1	Group 2	Group 3	Group 4
(Currenc* OR "balance of payment*" OR "exchange rate*")	(bank* OR financ*)	(cris?s OR crash* OR attack* OR problem* OR instab* OR run* OR panic* OR fail* OR insolvenc* OR bankruptc*)	("twin cris?s")
Complete keywords: ((Group 1 AND Group 2) NEAR/1 Group 3) OR Group 4			

Third, we employed our keywords in selected databases. Our full-text search hit 86,059 articles in EBSCO, 12,855 articles in ABI/Inform and 15,699

articles in Science Direct, with the total number of articles reaching 114,613. To limit the search results to more relevant articles, we then re-ran our search and focused on finding a match in the abstract of the articles. Our second search found 2,652 articles in EBSCO, 1,397 articles in ABI/Inform and 502 articles in Science Direct. We then filtered these 4,551 total articles to remove duplicate articles and obtained 3,296 unique articles from 871 different journals.

Fourth and fifth, based on our inclusion and exclusion criteria, we conducted a relevancy screening analysis for the remaining 3,296 articles to identify whether the articles were relevant. The screening was carried out in two steps: first, we reviewed the title and abstract of the articles to ascertain a short list of potentially relevant articles. Second, we reviewed the full text of the shortlists for further investigation. Based on a full-text review of 270 potentially relevant articles, we concluded that 62 articles from 30 different journals were relevant. Of the articles, 54 articles from 22 different journals were considered as 3 and 4-star journals based on the Association of Business Schools (ABS) journal ranking 2015.

Sixth, acknowledging our keywords limitation, we extended our literature, based on references and other articles we found to be relevant. As a result, we included an additional six articles that were not captured in our keyword search.

Seventh, we conducted a full-text analysis of 68 relevant articles. Our initial design was to limit our full-text analysis to 3 and 4 star or high impact factor journals, which we considered to be of high quality. However, we decided to analyse all relevant articles as we had only a limited number of relevant articles.

Based on the result of a structured keyword search, we evaluated 68 articles to answer our questions. While we can consider that twin crises can be started by banking or currency crises, it is evident that most literature discussing twin crises argues that most twin crises are started by banking crises. This is known as the third-generation of currency crisis model. This is arguably influenced by the work of Kaminsky & Reinhart (1999) who introduce the term “twin crises” and provide a comprehensive work regarding the twin crises. The summary of keyword search results is shown in Figure 2.1.

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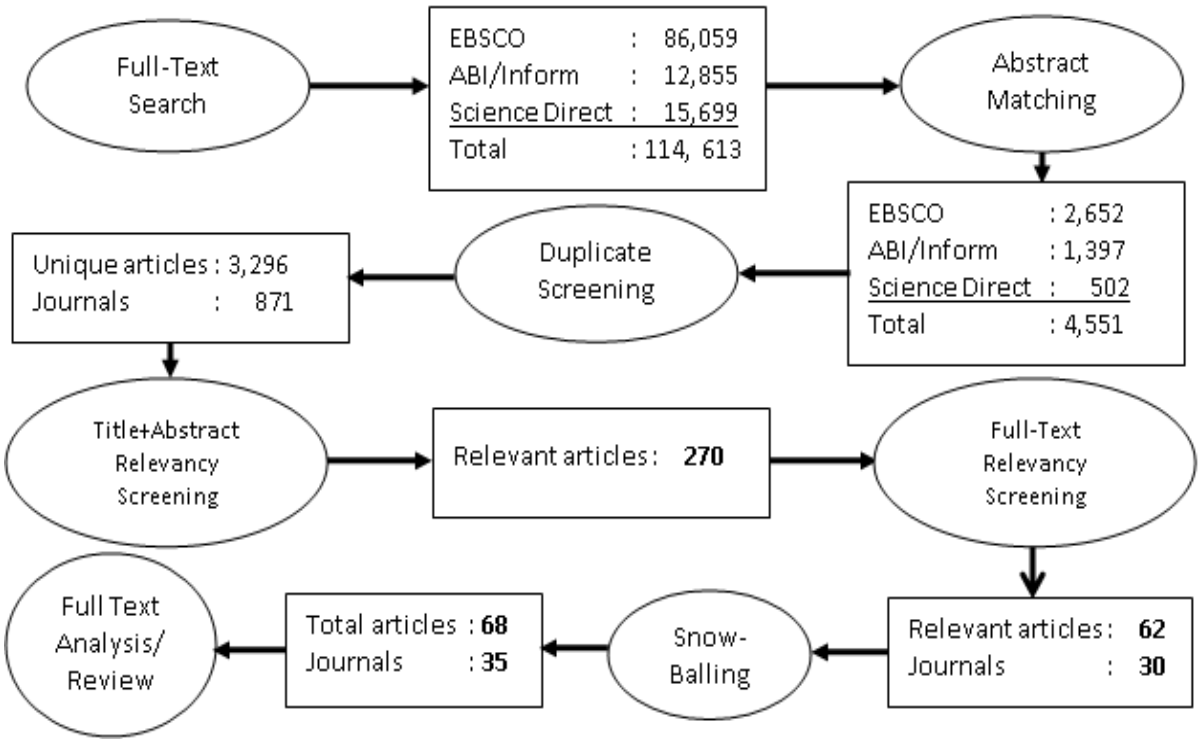
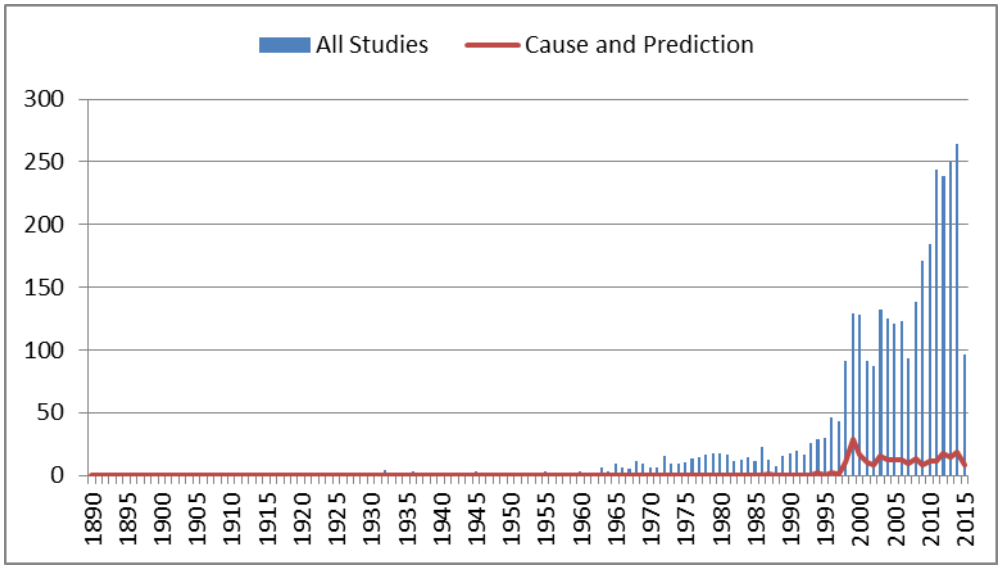
Figure 2.1: Summary of keyword search results



Despite a limited number of articles on twin crises literature, we find that there is a growing interest in the literature. In the aftermath of the Asian crisis at the end of the 1990s, the amount of literature grows significantly. The trend continues in the 2000s and the 2010s. In the first half of the 2010s, the number of articles in the field of banking and currency crisis has exceeded the total studies in the 2000s. Thus, it shows that this area of literature is still growing. The number of studies in twin crises literature is shown in Figure 2.2.

Figure 2.2: Number of Studies in Twin Crises Literature



Source: Compiled by Author from EBSCO, ABI/Inform, and Science Direct

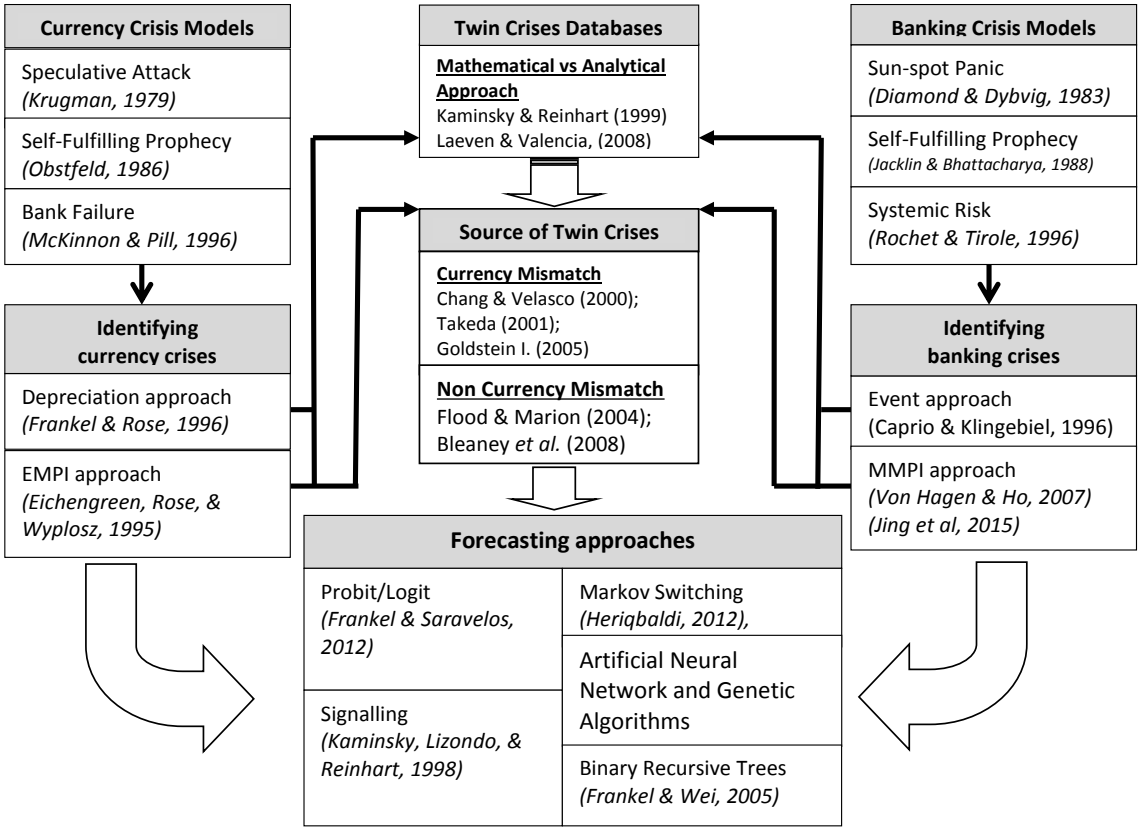
2.3. Findings

In this section, we review 68 relevant articles which are collected using the systematic literature review procedure. To understand whether currency crises precede banking crises, we focus our examination on the various techniques to identify the starting dates of currency and banking crises. Furthermore, to identify additional links between currency and banking crises, we re-assess various literature which discusses the relationship between currency and banking crises. In addition, we also review various methodologies to forecast currency and banking crises.

Our review is explored in three subsections: (1) the identification of currency and banking crises, which discusses the approaches to identify twin

crises, (2) the relationship between the currency and the banking crises, which explains how banking crises create the currency crises, and (3) the methodology, which explores the methodologies to determine the drivers of twin crises. Figure 2.3 shows the summary of currency and banking crises literature. This new figure shows the models of currency and banking crises. In addition, the figure also shows various techniques to develop twin crises databases, the sources of twin crises and forecasting techniques in currency and banking crises literature.

Figure 2.3: The Summary of Currency and Banking Crises Literature



Source: Compiled by Author

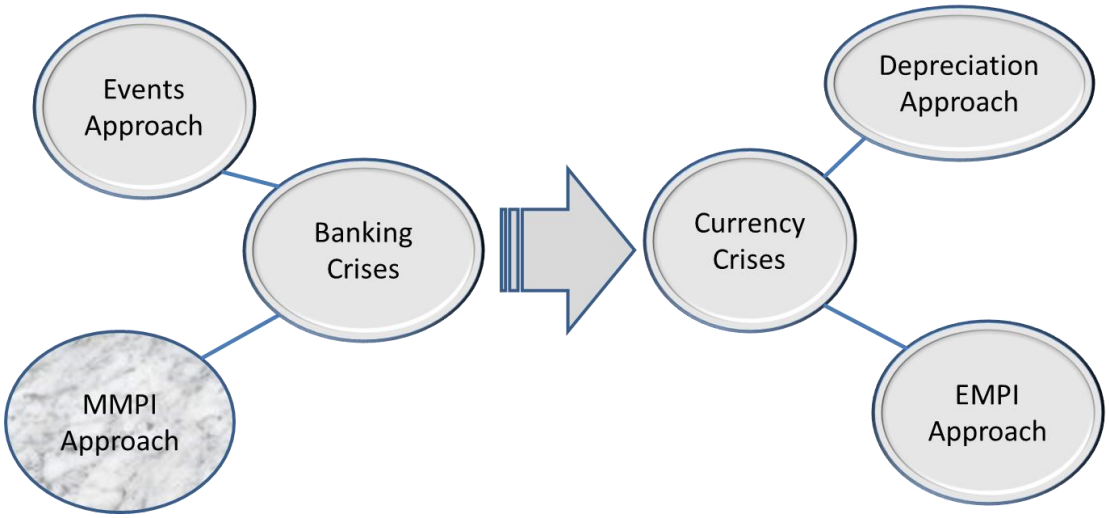
2.3.1. The Identification of Currency and Banking Crises

Despite the growing interest in twin crises literature, the linkages between currency and banking crises are still ambiguous. It is difficult to identify whether

twin crises are triggered by either currency or banking crises for two reasons: first, “the run on the currency and the deposit withdrawals reinforce each other in a vicious circle” (Schnabel, 2004, p.822); second, banking and currency crises are sometimes driven by common factors (Glick & Hutchison, 1999). Ultimately, it is difficult to identify which crisis causes the other. Therefore, it is essential to identify the start date of crises to determine the trigger of the twin crises.

Twin crises are a condition where banking crises are followed by currency crises (Kaminsky and Reinhart, 1999). By this definition, the existing twin crises are examined by comparing the start and end dates of banking and currency crises. Thus, the twin crises literature relies heavily on the accuracy of currency and banking crises database. The way to identify twin crises is generally conducted in three steps: to identify currency crises episodes, to identify banking crises episodes, and to compare the dates of both crises, as shown in Figure 2.4. The following subsections describe each step.

Figure 2.4: Methodologies to identify currency and banking crises



2.3.1.1. Identifying Currency Crises

In general, there are two methods to determine the date of currency crises. Many studies of currency crises identify the currency crises by calculating exchange rate depreciation. There is no consensus about the threshold of currency depreciation to identify currency crises. For example, Frankel & Rose (1996, p.352) define a 'currency crash' as "a nominal depreciation of the currency of at least 25% that is also at least a 10% increase in the rate of depreciation".

However, using exchange rate depreciation to identify the date of currency crises may be biased when the central bank intervenes in order that the exchange rate does not depreciate despite considerable pressure on the currency. Even though central banks announce that they are employing an inflation targeting framework or a free float exchange rate regime, it is commonly acknowledged that central banks do intervene in the foreign exchange market to smooth exchange rate volatility or to maintain the exchange rate in a specific band due to the "fear of floating" (Calvo & Reinhart, 2000).

For that reason, most recent studies use Exchange Market Pressure (EMP) as the basis to identify currency crises. This model was initially developed by Girton & Roper (1977, p. 537) as a monetary model to "provide a measure of the volume of intervention necessary to achieve any desired exchange rate target". The use of the Exchange Market Pressure Index (EMPI) to identify currency crises was first employed by Eichengreen *et al.* (1995).

The EMPI illustrates that the pressure on the exchange rate is not only reflected in the depreciation but also on the amount of central bank intervention through the spot market (and sometimes through the interest rate). In the event of intervention by central banks to slow the depreciation rate, the EMPI shows higher pressure in the exchange market despite there being only limited depreciation in the exchange rate.

In the spirit of Eichengreen *et al.* (1995), Kaminsky & Reinhart (1999) identify the date of currency crises using the EMPI with the following formula:

$$EMPI = \frac{\Delta e}{e} - \frac{\sigma_e}{\sigma_R}.\frac{\Delta R}{R} \qquad (2.1)$$

where $\frac{\Delta e}{e}$ is the change of the exchange rate, $\frac{\Delta R}{R}$ is the change of foreign reserve, σ_e and σ_R is the standard deviation of the exchange rate depreciation and percentage change in foreign reserve.

Kaminsky & Reinhart (1999) define currency crises as the EMPI exceeding three standard deviations or more above the mean, with some exceptions for some countries with high inflation. While there is no consensus on how to define the crisis threshold, Kaminsky & Reinhart (1999) argue that this definition replicates currency crises that are described in various articles.

2.3.1.2. Identifying Banking Crises

There are two popular methods to date banking crises episodes. The first method is based on events, such as bank performance, government bailout, widespread bank failures, the extent of a bank run, and professional analysis to specify bank crises (Caprio & Klingebiel, 1996; Demirguc-Kunt & Detragiache, 1998).

Kaminsky & Reinhart (1999, p.476) identify the beginning of banking crises based on two events: first, “bank runs that lead to the closure, merging, or take over by the public sector of one or more financial institution”. And second, “if there are no runs, the closure, merging, takeover, or large-scale government assistance of an important financial institution (or group of institutions) that mark the start of a string of similar outcomes for other financial institutions”.

Despite its popularity, it is difficult to identify the start date of banking crises using this event method (Goldstein *et al.,* 2000). For example, a government bailout typically occurs at the peak of crises; While it sometimes involves a political process which delays the bailout, the bailout itself does not necessarily mark the end of the crisis. Thus, identifying the start and the end date of the banking crisis requires judgement of the analyst.

The second method is inspired by the EMPI in the currency crises literature. To address the drawback of the event methods, Von Hagen & Ho (2007) propose

a Money Market Pressure Index (MMPI) to help identify the date of the banking crisis. The MMPI can be reformulated as:

$$MMPI_t = \omega_1 \Delta\gamma_t + \omega_2 \Delta i_t \qquad (2.2)$$

where $\Delta\gamma_t$is changes in reserves to bank deposits ratio, Δi_t is changes in short-term real interest rate, and ω is weight between variables.

Even though this model was introduced prior to the Global Financial Crisis of 2007-08, it gained popularity in its aftermath. The main reason for the acceptance of the MMPI appears to be the reliability of the model, albeit its simplicity. While it is based on only two variables (money growth and interest rate), it fits well with the existing banking crises databases in both developed and emerging markets (Jing *et al.,* 2015). Thus, researchers may avoid the complexity of asset prices, housing prices and other financial indicators as the proxy of the banking crisis. While the study on those financial variables may help in explaining the source of banking crises, the turbulence in those financial indicators is also reflected in the change of interest rates and money supply. Thus, these two money market pressure variables are sufficient for the identification of banking crises. In addition, the MMPI provides a clear indication of the start and the end date of banking crises - a feature that is not available in the 'so-called' event approach.

2.3.1.3. Identifying Twin Crises

Kaminsky & Reinhart (1999, p.47) identify twin crises as "episodes in which the beginning of a banking crisis is followed by a balance-of-payments crisis within 48 months". Investigating 20 countries during the period of 1970-mid 1995, Kaminsky & Reinhart (1999) find 19 episodes of twin crises and conclude that banking crises are often followed by currency crises.

Laeven & Valencia (2013) use currency depreciation to identify the date of currency crises and the combination of financial distress indicators and policy measures to date banking crises episodes. In addition, they define twin crises as the banking crisis in year *t*, combined with a currency crisis during the period (T-

1, T+1). Investigating a systemic banking crises database for the period of 1970-2011, they conclude that "banking crises frequently occur together with currency or sovereign debt crises" (Laeven & Valencia, 2013, p. 250).

Despite its simple twin crises definition, in practice, the precise dates of twin crises are difficult to obtain. As the dates of the banking crises and the currency crises are often in different years, economists have difficulty in identifying the start and the end date of twin crises. This might be the reason why most studies on twin crises are theoretical or conceptual.

2.3.2. The Methodology

Following the models to identify currency and banking crises that have been described in the previous section, many empirical studies have been made to forecast the twin crises.

There are two popular methodologies to investigate banking and currency crises. First, the multivariate probit/logit model is arguably the most popular methodology to analyse currency and banking crises (Frankel & Saravelos, 2012). This model uses the event of a crisis as a dummy dependent variable, with a value of one if there is a crisis and a value of zero if there is no crisis. As independent variables, a set of macroeconomic indicators is used. These binary models are occasionally also combined with the panel method when investigating a large sample of countries (Demirguc-Kunt & Detragiache, 1998). Despite its popularity, binary models fail to provide useful forecasts (Berg & Pattilo, 1999).

The second strand of literature uses a non-parametric approach to developing an early warning system. One commonly used non-parametric methodology to examine currency crises is the signalling method, which was first employed by Kaminsky et al. (1998). In their model, first, Kaminsky et al. define the events of crises using the market pressure-based approach. Figure 2.5. shows some of the main methodologies to forecast currency and banking crises.

Furthermore, to develop the early warning system, Kaminsky *et al.* (1998) first identify the crises periods using the market pressure-based approach.

Variables are then investigated to determine the signal threshold of each variable. The thresholds are calculated based on a specific percentile (e.g. 5 per cent). After the thresholds are identified, signals are calculated when a variable "departs from its mean beyond a given threshold level" (Kaminsky *et al.*, 1998, p. 17). The signals are then categorised into correct signals, missing signals, wrong signals, or, correctly does not produce a signal, by comparing them to crises periods within the following two-year window after the signal was produced. The classification of the signal is shown in Figure 2.6.

Figure 2.5: Main methodologies to forecast currency and banking crises

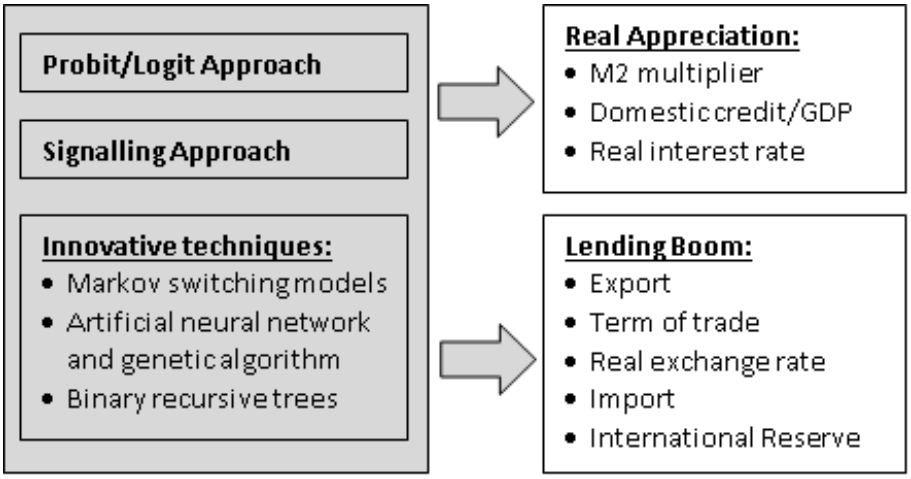


Figure 2.6: Signal classification

	Crisis	No Crisis
Signal was issued	Correct Signal (A)	False Signal (B)
No Signal was issued	Missing Signal (C)	Correctly no signal (D)

Source: Modified from Kaminsky *et al.* (1998)

Once the signals are identified, Noise-to-Signal Ratio is then calculated to determine the forecasting power of each variable to predict the crises. The Noise-to-signal ratio can be formulated as follows:

$$Noise - to - Signal\ Ratio = \frac{\frac{B}{(B+D)}}{\frac{A}{(A+C)}} \qquad (2.3)$$

The signalling method is considered the most successful method to forecast financial crises (Berg & Pattilo, 1999). However, the signalling method has one main drawback. It evaluates the variables individually. Thus, we need to create a composite index to measure the result. However, a composite index "is highly variable, and it is hard to interpret the probabilities" (Edison, 2003).

Moreover, the most recent study employs innovative techniques such as Markov switching models (Heriqbaldi, 2012), artificial neural network and genetic algorithms (Apoteker & Barthelemy, 2000), and binary recursive trees (Frankel and Wei, 2005). While these new techniques are more complicated, there is relatively no new finding in the literature. Thus, the use of these techniques is still limited.

In general, the above methodologies find that twin crises are typically preceded by similar factors, such as a real appreciation and a lending boom (Sachs *et al.*, 1996; Tornell & Westermann, 2002). Those two variables are signs of a boom period in the business cycle.

An expected rise in income in the future allows people to have higher loans, which encourage people to increase today's consumption. Savings will decline, and the current account will be in deficit. If there is a moral hazard, banks are encouraged to lend over-aggressively and boost consumption. The increase in consumption can lead to the wrong signal of an over-optimistic economy and invites capital flows to finance the consumption. However, the consumption also

increases the current account deficit. Savings will decline further. This condition will create a bubble and cannot be sustained.

In an empirical study, the lending boom is often represented as financial sector indicators (e.g. M2 multiplier, domestic credit/GDP, real interest rate), and real appreciation is often represented as external sector indicators (e.g. export, the term of trade, real exchange rate, import, international reserve).

As banking and currency crises are often triggered by similar factors, in the event of a twin crisis, it is difficult to determine a particular crisis as the trigger to the other crisis.

2.3.3. The Relationship between Currency and Banking Crises

The work of Kaminsky & Reinhart (1999) is arguably the most influential study in the twin crises literature. Following this study, there is a growing interest in the study to explain the link between banking and currency crises. However, most twin crises researches consider the twin crises as being started by banking crises, in line with the findings of Kaminsky & Reinhart (1999).

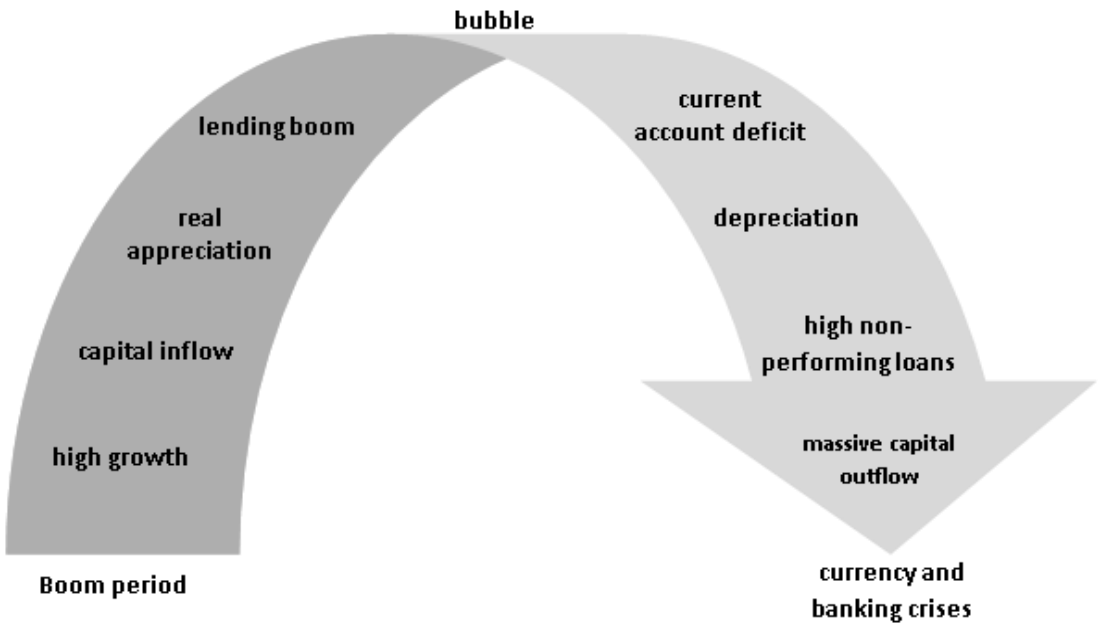
In general, Burnside *et al.* (2001, p.1151) argue that the link between banking and currency crises shares three elements. Firstly, “banks have a currency mismatch between their assets and liabilities”; second, “banks do not completely hedge the associated exchange rate risk”; and third, “there are implicit government guarantees to banks and their foreign creditors”. However, “the first two features arise from government guarantees”.

The above findings are quite similar to the work of other scholars (Corsetti *et al.*, 2004; McKinnon & Pill, 1996) who argue that one of the causes of twin crises lies in over-borrowing to finance a bank’s lending in the presence of government guarantees. According to this model, the government guarantees may stimulate banks to over-borrow in foreign currency. Thus, banks and currency are exposed to high risk simultaneously (Burnside *et al.*, 2001; Chang & Velasco, 2000). The impact of a bank’s vulnerability to currency crises is also investigated by McKinnon & Pill (1996, p.192) who show that -if there is no moral

hazard- “a strong regulatory system prevents banks from discounting adverse macroeconomic outcomes”.

In this subsection, we employ the theory of business cycle to understand the relationship between currency and banking crises. In a boom period, the economy typically enjoys high growth, high export and massive capital inflows. High capital flows are usually dominated by hot money, which is invested in portfolio instruments such as stocks and bonds. Thus, stock and bond prices start to increase (Aliber, 2005). On the other hand, these also lead to a real appreciation of currency (Velasco, 1987; Weller, 2001). The relationship between banking and currency crises is shown in Figure 2.7.

Figure 2.7: Banking and Currency Crises Relationship



Source: Compiled by Author

If real appreciation continues, exporters start to lose competitiveness, which leads to decreasing exports, increasing imports and current account deficits.

Alternatively, an overvalued currency also provides an incentive for investors to attack the currency. Thus, the economy fundamentally becomes fragile.

Funded by capital flows, banks start pushing their lending, leading to a significant increase in speculative financing (Weller, 2001). On the other hand, to avoid the adverse effect of real appreciation, the central bank starts to intervene by buying foreign currency and selling domestic currency. Both foreign reserve (Aizenman & Hutchison, 2012) and the domestic money supply increase. Abundant liquidity encourages banks to push their lending and creates a lending boom. The bank's liquidity ratio starts to decrease, and the banking system becomes weaker.

Current account deficit pressures currency to depreciate. If foreign investors start pulling out their money, currency depreciates faster, along with the fall in asset prices (Singh, 2009). Furthermore, liquidity becomes tight, and interest rates increase.

Soon, firms and households have difficulty paying the loan. Current account deficit and high non-performing loans will lead to banking crises and massive capital outflow. As a result, the currency will crash.

As fast currency depreciation is devastating, the central bank tries to intervene to smooth the volatility (in free float rate regime) or to defend the currency (in fixed-rate regime). The success of the central bank's intervention depends on two things: the amount of foreign reserve and the amount of domestic liquidity. Even though the central bank collects sufficient foreign reserve during a boom period, the intervention may fail if there is not sufficient domestic currency in the market to be bought.

Therefore, it is essential for the central bank to manage two things in a boom period: first, to manage real appreciation. By doing so, the central bank maintains the competitiveness of export and builds a foreign reserve to defend the currency against large and sudden capital reversal. Second, managing the lending boom. By doing so, the central bank ensures that banks have sufficient liquidity at the time of the attack. It is essential to bear in mind that at the time of the attack, the

need for liquidity is doubled due to the decreasing value of the domestic currency and liquid assets held by banks.

The above relationship also shows that there is a link between the banking crisis and the currency crisis as there is a discussed by the twin crises model, which argues that banking crises trigger currency crises due to exposure on foreign currency liabilities in the banking system.

However, our literature review suggests that a currency attack may also trigger banking crises. The attack on the currency encourages investors to withdraw their money to fund the attack. Thus, the bank run is inevitable. However, in the event of a bank run, many investors reinvest their fresh cash speculatively in foreign currency. Thus, twin banking and currency crises should be extended as a two-way relationship between currency and banking crises as is suggested by Schnabel (2004).

Furthermore, the bank run in the first round of crises suggests that liquidity shortages have an important role in the occurrence of twin crises. In addition, currency depreciation may cause higher non-performing loans that lead to failures in the banking system. These two variables are also underdeveloped in the twin crises model.

2.4. Discussion

While there is an abundance of literature relating to currency and banking crises, most studies isolated currency or banking crises and systemic banking crises. Consequently, the study on the twin crises is still limited. Regarding twin crises literature, the twin crises literature suggests that banking crises may lead to currency crises, not vice versa. This is arguably influenced by the empirical findings that show banking crises often precede currency crises (Kaminsky & Reinhart, 1999). A bank's foreign liability is considered as the source of twin crises (Corsetti *et al.,* 2004; McKinnon & Pill, 1996).

Despite its simple twin crises definition, in practice, it is difficult to pinpoint the exact date of twin crises. Most literature identifies twin crises using the mathematical approach of the Exchange Market Pressure Index (EMPI) to identify currency crises and the analytical model of the event approach to identify banking crises. Different approaches to identify the date of currency and banking crises may lead to identification bias.

On the one hand, a more mathematical approach to date currency crises episodes (such as the EMPI) could lead to more volatile (and more frequent) crises. Most of the EMPI study follows the work of Eichengreen *et al.,* (1995), Kaminsky *et al.,* (1998), and Sachs *et al.,* (1996) who calculate a change in one observation period of spot rate and foreign reserve as the EMPI.

Unfortunately, this interpretation could lead to a short-term extreme pressure index. For example, if a currency suffers high depreciation in one day ($high\ \Delta e_t$), the EMPI reflects this condition with a high pressure index in that particular day. However, if the currency remains at the new level the following day ($\Delta e_t = 0$), EMPI shows a low pressure index despite there still being a huge pressure in the exchange market, thus, the currency crisis is identified for only one day.

On the other hand, an analytical model (such as the event approach) to date banking crises episodes could result in an inconsistent starting point of the crises (and less frequent crises). For example, banking crises are often examined by the extent of bailouts in the banking system. However, the bailouts are often delayed due to the political process. In addition, the bailouts do not necessarily end the crises. Thus, economists have difficulty to identify the start and end dates of banking crises.

As the number of currency crises is much larger than the number of banking crises, it is easier to presume that some currency crises were translated into banking crises than vice versa. For example, Kaminsky & Reinhart (1999) find that there were 26 currency crises with only three banking crises in the 1970s. In this case, it is easier to assume that the probability of 3 of 26 currency crises trigger three banking crises is higher than vice versa.

The reason why some currency crises are considered earlier than banking crises also relates to the nature of the currency and banking system. Currency crises are highly correlated with the foreign exchange market, as they are measured by the pressure in the exchange market (Eichengreen, *et al.,* 1995). Thus, following the efficient market hypothesis, one could argue that the most recent information is almost instantaneously reflected in the exchange rate. On the other hand, banks are highly regulated institutions and manage some market risk mitigations to absorb the impact of negative news in the market. It implies that the impact of currency attack on exchange market pressure is earlier than the impact of a bank run on the health of the banking system. Therefore, logically, currency crises are more likely to occur earlier than banking crises. However, the literature suggests contrary evidence (Kaminsky & Reinhart, 1999).

One possible reason for this discrepancy is the possible bias in identifying banking crises, as the banking crises may be identified too early, due to the limitation of the event approach (Goldstein *et al.,* 2000).

As there is no consensus on how to identify a crisis (Goodhart, 2004; Sedghi-Khorasgani, 2010), economists may set their own crisis definitions. Crisis time in one database may be considered as a normal time on other databases, or vice versa. Thus, various crises databases may lead to different currency and banking crises relationships.

To understand the presence of methodological bias, we re-examine the start dates of the currency and banking crises by minimising the bias in the identification techniques. In doing so, we examine the dates of currency crises, which are identified by using the Exchange Market Pressure Index, and compare them to the dates of banking crises, which are identified by busing the Money Market Pressure Index. We then compare the findings to the twin crises database, which was produced by Kaminsky & Reinhart (1999), to check the consistency of the findings.

2.4.1. The Bias on Currency and Banking Crises Database

Due to the absence of consensus on how to define currency and banking crises, there are various currency and banking crises databases available, which have different dates of crises. However, by comparing the start dates of currency and banking crises, literature typically finds that banking crises start earlier than currency crises.

One source of the variety of crises databases is the differences in how to examine the crises. On the one hand, currency crises are typically identified by the Exchange Market Pressure Index (EMPI). This is a mathematical model, which has a strict rule on how to define a crisis. To identify currency crises, economists set pre-determined threshold and define a currency crisis as a condition where the EMPI exceeds the threshold.

On the other hand, banking crises have typically been determined by an analytical technique, which is known as the event approach. This technique has no strict rule and needs a sophisticated analysis as well as judgement (Claessens & Kose, 2013). Thus, the starting dates of banking crises are often identified too early without a clear indication of the end date of the crises episodes (Goldstein *et al.,* 2000).

As the comparison between a mathematical model of the Exchange Market Pressure Index (EMPI) and the analytical model of the event approach is considered as being unreliable, the development of the Money Market Pressure Index (MMPI) (Von Hagen & Ho, 2007) to determine banking crises may resolve the issue. Unfortunately, to the best of our knowledge, the EMPI and the MMPI have never been employed in the twin crises literature. In this subsection, we compare two mathematical-based crises databases to evaluate their impact on twin crises databases.

Our identification is based on existing studies and can be divided into four steps. First, we decide to employ the EMPI to determine the dates of currency crises and the MMPI to date banking crises' episodes. MMPI is inspired by EMPI,

and both of them use the mathematical approach to identify the crises. Thus, they are comparable.

Second, we carefully select a similar weighting method for both the EMPI and MMPI. It is essential to compare the EMPI and MMPI with a similar weighting method as a different weighting procedure in market pressure-based approaches will lead to various crises'databases (Pontines & Siregar, 2008).

Applying the above restrictions, we employ the MMPI's banking crises database which is developed by Jing *et al*. (2015) and EMPI's currency crises database, which is developed by Pontines & Siregar (2008). The two databases are chosen as they adopt similar weighting methods. The weighting method is first introduced by Sachs *et al.* (1996). As both databases are based on market pressure-based approach and have similar weighting methods, thus, the database bias is minimised. For comparison purposes, we exclude countries that are not available in both articles.

Third, following Kaminsky & Reinhart (1999), we define twin crises as a type of crisis followed by another type of crisis, 48 months after the beginning of the first crisis.

Fourth, we make two assumptions. As Jing *et al.* (2015) do not provide the month for the beginning of banking crises, therefore, we apply the following assumptions in the case of the starting year of the banking crisis being the same with a currency crisis.

If a banking and currency crisis start and end in the same year, we reach an undecided conclusion. However, if the two crises start in the same year but end in different years, we define the earlier crisis as the one that ends earlier. This assumption based on the idea that the earlier crises trigger bigger later crises like a snowball. Thus, the later crises should have a more profound effect and last longer.

Comparing the currency crises database in Pontines & Siregar (2008) and the banking crises database in Jing *et al*. (2015), we find that banking crises are often preceded by currency crises. Our findings suggest that currency crises are

earlier than banking crises in 10 of 14 twin crises in the database, with only one banking crisis is earlier than currency crisis. The other three twin crises episodes are undecided as they occur in the same year. This finding is contrary to the existing literature (Kaminsky & Reinhart, 1999) which argues that banking crises often precede currency crises. Table 2.2 shows a list of currency and banking crises that occurred in East Asian and Latin America.

Table 2.2: Currency and Banking Crises in East Asian and Latin America

Country	Currency Crises*	Banking Crises**	Preceded by
Argentina	Apr/Dec 1989	1989-1990	currency crisis
Brazil	May 1994	1994–1998	currency crisis
Chile	Jan 2003	2004	currency crisis
Indonesia	Aug 1997, May 1998	1997–1998	currency crisis
Korea, Republic of	Jul 1986	1984	banking crisis
	Jan 1988	1989–1992	currency crisis
	Dec 1997	1997	Undecided
Malaysia	May/Dec 1997	1997–1998	currency crisis
Mexico	Apr/Dec 1994, Nov 1995	1994–1995	currency crisis
	Sep 1998	1998–1999	currency crisis
Philippines	Feb/Dec 1986, Aug 1990	1989–1990	currency crisis
	Nov 2000	2001	currency crisis
Thailand	Dec 1985	1985	Undecided
	Jul 1997	1997	Undecided

* currency crises based on EMPI using STV weighting system (Pontines & Siregar, 2008)

** banking crises based on MMPI using STV alike weighting system (Jing *et al*. , 2015)

Source: Pontines & Siregar (2008), Jing *et al*. (2015)

While many popular financial crises databases identify East Asian crises as being started by banking crises, we find that they are started by currency crises. Since our finding implies that twin crises could be started by currency or banking crises depending on the methodologies that were chosen, we need to revisit conceptual frameworks of the currency and banking crises relationship, which are based on an empirical study that finds that twin crises are often preceded by banking crises.

Our finding has an important implication for the future of the currency crises literature. Economists now have an alternative view on how to explain twin crises, where currency crises as the source of twin crises. This view may lead to future study to find new drivers of twin crises and different policy mitigations. Furthermore, the view that currency crises may trigger banking crises may also encourage economists to develop a new model of banking crises which can be regarded as the fourth generation model of banking crises.

Recently, the currency crises literature has become less popular compared to the banking crises literature. This is reflected by the development of the theory of the currency crises.

The first generation of currency crisis model suggests that a currency crisis stems from the problem in the current account and the fixed exchange rate regime. As most countries adopt the free float exchange rate regime, the first-generation model has lost its significance. Furthermore, the second-generation of the currency crises model suggests that the crises are triggered by something random. The randomness cause of the crisis, to some extent, discourages the study of the crisis, as it suggests the limited roles of the regulators.

The third-generation of the currency crises model argues that a currency crisis is triggered by the banking crisis. As the first-generation model of currency crises has lost its significance due to the adoption of free-float exchange rate regime and the second-generation model discourages the study of currency crises due to its randomness, the third-generation model of currency crises gains more attention in recent years. However, as the third-generation model argues that the banking problem as the source of currency crises, many economists re-

focus their investigation to banking crises as a mean to avoid currency crises. Thus, the study of banking crises becomes more popular than the study of currency crises. However, our research shows that the role of currency crises has been underestimated in the twin crises literature.

2.4.2. Currency and Banking (In)Stability Framework

Most literature identifies twin crises as a banking crisis which is followed by a currency crisis in a specific window period. However, it is hard to judge whether the second crisis is influenced by the first crisis, as they are often driven by similar factors (Glick & Hutchison, 1999), and they reinforce each other in a vicious cycle (Schnabel, 2004).

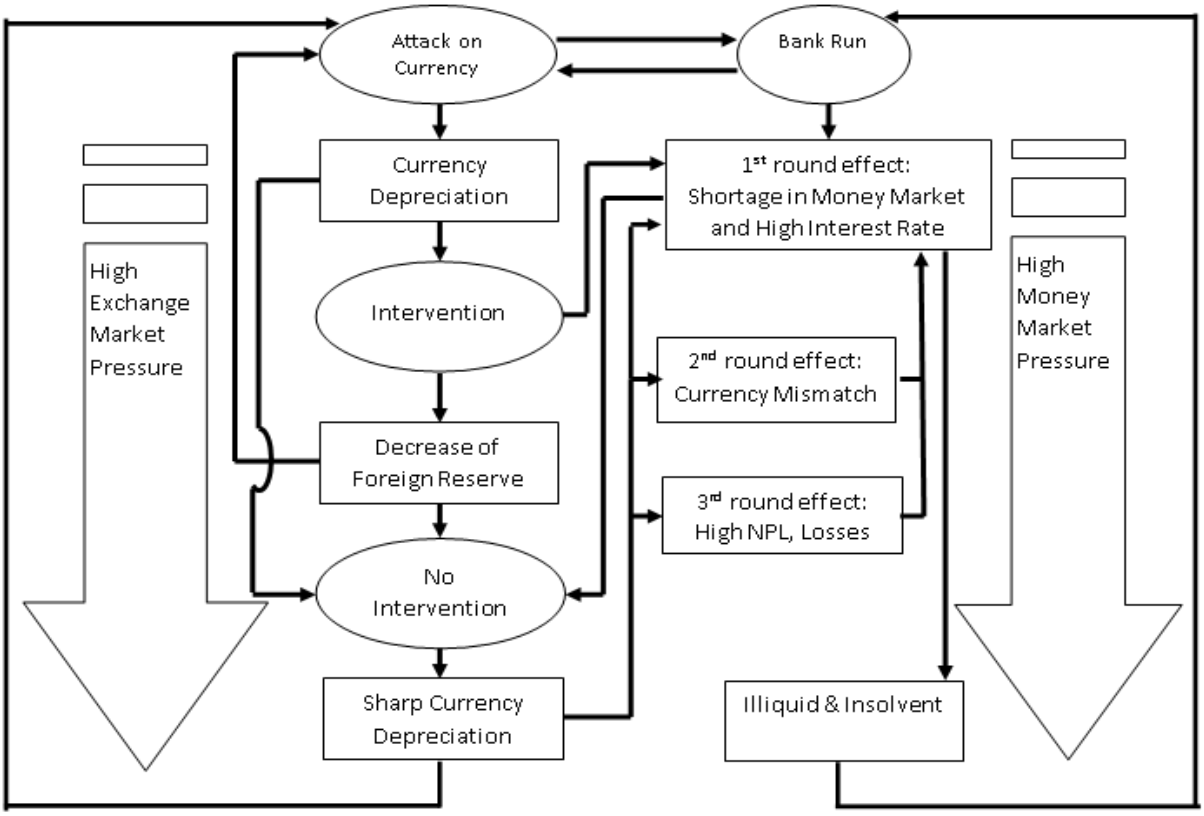
Furthermore, we find that twin crises could be started either by currency crises or banking crises, depending on the methodologies being used to examine the twin crises. Therefore, different approaches to identify twin crises could lead to different twin crises databases. Since it is difficult to justify whether the banking crisis triggers the currency crisis, there is a need to view the current twin crises literature from another perspective to understand the currency and banking crises relationship.

To explain the relationship between currency and banking crises, we extend the existing twin crisis framework by bringing some of the key tenets of the currency and banking literature, such as twin crises exposure on banks with no foreign liabilities (Bleaney *et al.*, 2008), herd behaviour in financial crisis (Calvo & Mendoza, 1997), similar drivers of currency and banking crises (Glick & Hutchison, 1999), bank's resilience to currency mismatch and bank's exposure on economic downturn (Sahminan, 2007), and a vicious cycle between currency and banking crises (Schnabel, 2004), into the currency and banking (in)stability framework as being shown in Figure 2.8.

Extending the existing twin crises model which shows one-way relationship from banking crises to currency crises through the liquidity mismatch, Figure 2.8

shows a two-way relationship between currency and banking crises through liquidity shortages and insolvencies, as well as liquidity mismatch.

Figure 2.8: Currency and Banking (In)Stability Framework



Source: Compiled by Author

On the one hand, investors start to attack the currency, either because of economic fundamentals (Krugman, 1979) or panic (Obstfeld, 1986). Currency starts to depreciate and the pressure in the exchange market increases. A high expected return in currency speculation or the fear of a currency crash may lead to a currency attack. To fund the attack, investors remove their money in banks, create pressure in the exchange market and destabilise the banking system.

On the other hand, when investors see an increased risk in the banking system, or there is a spread of negative news, information-based (Jacklin &

Bhattacharya, 1988) and sun-spot panic (Diamond & Dybvig, 1983) theory suggest a bank run, which then provides liquidity to attack the currency.

The above illustration shows that twin currency and banking crises can be triggered by either crisis, which reinforces each other in a vicious cycle (Schnabel, 2004). This may be the reason why currency and banking crises are often driven by similar factors (Glick & Hutchison, 1999).

A prospective currency crisis will lead to the decline of asset prices and attacks in the currency. As banks are highly exposed to asset prices, the drop in the asset prices could trigger a banking problem (Singh, 2009). Furthermore, as international portfolio investors are driven by the relative performance to other investors, they match their portfolio with other investors and create herding behaviour, which leads to attack equilibrium (Calvo & Mendoza, 1997). Therefore, countries with high international portfolio investors have a higher possibility to suffer from twin crises.

To avoid sharp depreciation of the currency, the central bank starts intervening by selling foreign reserve and buying domestic currency. The money supply is contracted, and pressure in the money market becomes higher. Banks start to have liquidity problems (Stoker, 1994).

Investors will observe the central bank's capability to intervene and decide whether to continue the attack. Investors will attack the currency if the central bank indicates its defence of the currency in limited foreign reserve (Krugman, 1979). However, if the central bank decides to allow the currency to depreciate, negative news and fear of depreciation may create panic and a self-fulfilling prophecy (Obstfeld, 1986).

The central bank's intervention ceases when there is an insufficient foreign reserve to sell, or there is a lack of domestic currency to be bought, which then leads to a sharp depreciation of the currency. Indeed, the central bank could sterilise the intervention by purchasing domestic bonds. However, in many cases, the amount of available liquid and high-quality bonds are relatively limited compared to the value of intervention.

Due to the low value of the domestic currency (and the fall of financial asset prices), demand for domestic currency to buy foreign currency is doubled. There is a liquidity shortage in the money market, which leads to a high-interest rate. Some banks may have liquidity problems and become failed banks.

Furthermore, the second-round effect of currency depreciation starts affecting banks that are exposed to foreign liabilities (Mishkin, 1996). Some banks have currency mismatch. High depreciation of currency will put pressure on the bank's balance sheets. As banks are exposed to foreign currency liabilities such as foreign currency borrowings or deposits, the currency depreciation could lead to currency mismatch because the bank's assets are in domestic currency (Chang & Velasco, 2000; Goldstein, 2005; Takeda, 2001).

However, Sahminan (2007) demonstrates that many banks are relatively resilient to currency mismatch. This may be because banks are highly regulated and have prepared market risk mitigations to absorb the effect of currency depreciation.

While the liquidity mismatch has a profound effect, the twin crises also occur even though banks are not exposed to foreign liabilities (Bleaney *et al.*, 2008; Flood & Marion, 2004). Sahminan (2007) shows that the third-round effect of the crises is devastating. While banks are not exposed to the foreign currency, the currency depreciation decreases debtors' financial performance which leads to an increase in domestic and foreign currency non-performance loans (NPLs). Therefore, both banks with and without foreign liabilities, suffer from losses and have liquidity and insolvency problems.

The framework shows that the exchange market pressure (Krugman, 1979; Eichengreen *et al.*, 1995; Kaminsky *et al.*, 1998; Sachs *et al.*, 1996) and money market pressure index (Von Hagen & Ho, 2007; Jing *et al*., 2015) has an essential role in the twin crisis. In line with the model, we define twin crises as a condition where significant pressure in the exchange market creates significant pressure in the money market or vice versa. It implies that the twin crises may be identified by measuring both the exchange market and money market pressures.

As is suggested by Schnabel (2004), there is a link between currency and banking crises in the financial market. On the one hand, when investors conduct a bank run, they may re-invest the fund to foreign currencies. On the other hand, when investors attack a currency, they need to withdraw their money from banks to fund the attack. Thus, raise the pressures in the money market and the exchange market simultaneously. These pressures are reflected by the change in the money market pressure index (Jing *et al.,* 2015) and the exchange market pressure index (Eichengreen *et al.,* 1995).

The framework also indicates that neither fixed nor a free float exchange rate regime is crises proof. Thus, policymakers should not focus only on the regime, since successful intervention by the central bank may still lead to a banking crisis through liquidity shortage channel. In addition, the model shows that banks, with and without foreign exchange exposure, are vulnerable to twin crises since a successful attack on currency could lead to a banking crisis in three channels: First, the attack on the currency may encourage investors to withdraw their money from the banking system to fund the attack. Second, sharp currency depreciation directly creates currency mismatch for banks with foreign liquidity exposure. Finally, sharp currency depreciation affects the economy and decreases debtors' financial performance, which leads to increasing NPL, both for domestic and foreign currency loans.

2.5. Conclusions

Despite the devastating impact of the twin currency and banking crises, the study on twin crises is still limited. To provide a holistic view of the twin crises literature, we use the systematic literature review methodology to evaluate the banking and currency crises literature.

We find that there are two popular methodologies to investigate banking and currency crises. First, the multivariate probit/logit model is arguably the most popular methodology to analyse currency and banking crises (Frankel &

Saravelos, 2012). The second strand of literature uses the signalling method for developing an early warning system. Both employ binary crisis or no-crisis as the dependent variable.

Furthermore, we show that currency and banking crises often develop in a similar cycle. In general, the twin crises are typically preceded by similar factors, such as a real appreciation and a lending boom (Tornell & Westermann, 2002; Sachs *et al.*, 1996). Those two variables are signs of a boom period in the business cycle.

While there is evidence that currency and banking crises often share similar drivers (Glick & Hutchison, 1999) and develop in a vicious cycle (Schnabel, 2004), empirical studies show that currency crises are often preceded by banking crises (Kaminsky & Reinhart, 1999). Thus, twin crises literature views banking crises as the source of the currency crises, not vice versa.

We argue that there is a potential bias on the twin crises study, as there is no consensus on how to define the crises (Goodhart, 2004; Sedghi-Khorasgani, 2010). As there are various currency and banking crises databases, the choice of crises database may affect the result of the investigation.

To test this idea, we re-examine the start dates of currency and banking crises by minimising the bias in the identification techniques and compare them to Kaminsky & Reinhart (1999) to check whether the finding is consistent. By choosing market pressure-based currency and banking crises databases with similar weighting method, we find that currency crises often precede twin crises. This is in contrast to existing literature.

Finally, to explain how banking and currency crises interact, we extend the twin crises literature by bringing some of the key tenets of currency and banking literature, such as twin crises exposure on banks with no foreign liabilities (Bleaney *et al.*, 2008), herd behaviour in financial crisis (Calvo & Mendoza, 1997), similar drivers of currency and banking crises (Glick & Hutchison, 1999), bank's resilience to currency mismatch and bank's exposure on economic downturn

(Sahminan, 2007), and a vicious cycle between currency and banking crises (Schnabel, 2004), into a currency and banking (in)stability framework.

The currency and banking (in)stability framework shows that there is a link between currency and banking crises in the financial market. The model also shows that the exchange rate regime and the foreign exchange intervention are not sufficient to avoid the twin crises. The framework shows that both banks with or without foreign exchange exposures are vulnerable to twin crises. As the framework shows that the crises are reflected in the pressure on both the exchange market and the money market, we define twin crises as a condition where significant pressure in the exchange market create significant pressure in the money market or vice versa. Thus, the twin crises may be determined by measuring both the exchange market and money market pressures.

The currency and banking (in)stability framework also addresses some critical debates in the literature, such as the role of exchange rate regime, foreign exchange intervention, the impact of the crisis on the bank with no exposure to the foreign currency and the third-round effect of the financial crisis. Thus, it is interesting to reinvestigate the currency and banking crisis with this new perspective. We leave this idea for future research.

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Chapter 3 – Paper 2

MEASURING THE DYNAMICS OF TWIN CURRENCY AND BANKING CRISES IN EAST ASIA AND LATIN AMERICA USING THE C-INDEX

Abstract

This article focuses on the development of a method to identify the pressure dynamics of the twin currency and banking crises. The twin crises are identified by comparing the dates of banking and currency crises. However, this technique cannot pin-point the exact dates of the twin crises. To address the issue, we combine the Exchange Market Pressure and the Money Market Pressure into an index of Financial Market Pressure, which we refer as the c-index, to measure the dynamics associated with twin crises. We find that the c-index identifies twin crises episodes in Latin American and East Asian countries during the period 1980-2007. In addition, this model enables the identification of different stages of pressure in twin crises. This provides an essential contribution to the existing literature, which has so far mainly focused on binary outputs, i.e.'crisis' and 'no crisis' periods when examining financial market pressures.

***JEL* Code:** C10; C51; G10; G15; G17

Keywords: financial crisis; financial market pressure

3.1. Introduction

Financial crises have occurred regularly over time (Bicaba *et al.,* 2014), yet researchers still face essential challenges when investigating them. There is a significant amount of literature on financial crises, and new approaches to their investigation have recently emerged **(**Joy *et al.*, 2017; Karimi & Voia, 2015; Patnaik *et al.*, 2017). Previous studies have tended to mainly focus on individual financial crises (e.g. currency crises or banking crises).

Kaminsky & Reinhart (1999) is the first study that has successfully highlighted the distinction between twin crises and isolated currency or banking crises. They define twin crises as "episodes in which the beginning of a banking crisis is followed by a balance-of-payments crisis within 48 months" (Kaminsky & Reinhart, 1999, p.47). Since then, and despite a growing interest in the twin crises literature, most published studies remain primarily theoretical or conceptual in their approach. Empirical research on twin crises is still sparse.

As every financial crisis has unique features, failure to recognise these may lead to empirical bias (Bauer *et al.,* 2007). Hence, it is essential to understand the nature and drivers of twin crises, mainly as they appear to have a far more profound impact than that resulting from isolated shocks, as claimed by Hutchinson & Noy (2005).

It may be argued that a reason for the existence of limited empirical research on twin crises is the lack of a clear method to identify such crises. Currently, twin crises are identified by comparing the start date of banking with currency crises. According to Kaminsky & Reinhart (1999), if a banking crisis is followed by a currency crisis within a four-year period, we can conclude that there has been a twin crisis. However, this method does not enable us to pinpoint the exact dates of a twin crisis, as a banking crisis episode often starts at a different period to a currency crisis episode.

In addition, the comparing approach is limited in that it only produces a binary output, i.e. 'crisis' or 'no crisis', whenever a currency crisis follows (or not)

a banking crisis. Policymakers often require information on the build-up towards crises in order to employ appropriate responses (Farelius, 2013). In fact, the categorisation associated with the dynamics of the pressure facing financial markets - normal, low, high or critical pressure -, is of much use to policymakers in that different policy responses are required in different circumstances. It is therefore essential to be able to identify and characterise the state of financial markets; particularly if this is achieved before they reach the so-called 'critical pressure' stage. However, the empirical identification of the stages of a twin crisis requires a careful choice of a technique, which ensures a robust investigation of such crises.

Previously, to investigate the drivers of financial crises, most empirical studies have identified financial states as 'crisis' or 'no crisis', by employing probit/logit models (e.g. Ari & Cergibozan, 2016) or the signalling method (e.g. Megersa & Cassimon, 2015). Unfortunately, despite their popularity, probit/logit models have limited prediction power in these circumstances (Berg & Pattilo, 1999). On the other hand, it is often quite hard to interpret the results of the signalling method (Edison, 2003).

Summarily, the existing literature is unable to provide a clear indication of the start date and the various stages associated with twin crises. In addition, the literature also fails to examine the dynamics of twin crises, as twin crises are only examined as a crisis or no crisis condition. The pressures in twin crises are developed gradually in multiple stages of crises. Different stages of crises should have different policy responses. Thus, the inability to identify the pressure dynamics of twin crises may lead to ineffective mitigation policies.

As the investigation of financial crises depends on the accuracy with which crises are determined, the identification of a twin crisis is critical for future research in this area. Therefore, the overarching question that underpins this research is as follows: *how do we determine the 'pressure' dynamics associated with the twin currency and banking crises?* This study aims to contribute to the development of a method that can pinpoint the exact dates of twin crises and

measure the dynamics associated with them, particularly with respect to financial market pressure.

The rest of the paper is organised as follows: in the next section, we will provide a theoretical background that serves as the platform for the development of the Financial Market Pressure model presented in section 3.2. Section 3.3 explains the model development. Sections 3.4 and 3.5 discuss the methodology and data, while Sections 3.6 and 3.7 discuss the main findings and the robustness test. The concluding remarks are presented in the final section of the paper.

3.2. Theoretical Background

While there is much evidence that financial crises occur periodically (Bicaba *et al.,* 2014), theories underpinning the analysis of financial crises only started emerging in the late 1970s, and they have tended to focus on isolated currency and banking crises.

One strand of the literature on the currency and banking crises argues that these are triggered by random events. Diamond & Dybvig (1983) developed what is nowadays regarded as the first theory on banking crises – the sunspot panic theory -, which advocates that a bank run can occur due to random events such as sunspots. As banks primarily invest in long-term illiquid assets, a massive bank run tends to lead to liquidity problems.

Following the European currency crises of 1992-93, a new model emerged to explain the currency crises. The self-fulfilling model developed by Obstfeld (1986) focuses on herd behaviour by investors, resulting from panic. According to this type of model, the source of herd behaviour, such as sequential observation (Banerjee, 1992), information cascade (Morris & Shin, 1995), globalisation (Calvo & Mendoza, 2000) and coordinated action (Flood & Marion, 1999) can be precursors for currency attacks, even if economic fundamentals are

performing well. While the self-fulfilling prophecy theory has been developed within the context of the currency crisis literature, recent studies suggest that it can also explain some of the banking crises (Adler & Lizarazo, 2015).

There is, however, another strand of the currency and banking crisis literature that argues that the crises stem from fundamental problems. Krugman (1979) argues that the fixed exchange rate regime is vulnerable to currency attack when the country suffers from current account deficits. In this model, the government dries up the international reserve in order to maintain the fixed exchange rate. Due to limited foreign reserve, speculators may successfully attack the currency (Gumus, 2016).

In the study of banking crises, the fundamental problem as the source of banking crises is also discussed by Jacklin & Bhattacharya (1988), who shows that the change of bank's risk profile may encourage investors to conduct a bank run.

The last strand of currency and banking crises literature focuses primarily on the spill-over effect of the crises. On the one hand, the banking crises literature focus on the spill-over from a problem in one bank to the entire banking system, known as systemic risk (Rochet & Tirole, 1996). On the other hand, currency crises literature investigates the spill-over effect from banking crises to currency crises (Corsetti *et al.,* 2004).

However, while the methods to identify individual currency and banking crises are well established, there is still no robust technique to identify twin crises. To identify twin currency and banking crises, some economists examine the start date of both crises. If a banking crisis is followed by a currency crisis in a certain period, it is considered as a twin crisis. However, this method could not provide an exact date of twin crises, which is an essential ingredient for empirical study.

Furthermore, as currency and banking crises are identified via different approaches, there is a potential bias if we try to use these to identify twin crises (Bauer *et al.,* 2007). In fact, different weighting approaches (Pontines & Siregar, 2008), or a variation of the thresholds considered (Nasir *et al.*, 2015) may lead

to, for example, a different start date of a crisis episode (Claessens & Kose, 2013; Goldstein *et al.,* 2000). Thus, there is a need to develop a new framework to identify and examine twin currency and banking crises.

To overcome the bias discussed above, in this study, we combine the Exchange Market Pressure (EMP) and the Money Market Pressure model into a Financial Market Pressure (FMP) model. We then test the ability of the Financial Market Pressure to correctly identify twin crises to ensure that this model meets its purpose.

To understand the Financial Market Pressure, first, we need to examine the relationship between the exchange market and economic activity. The relationship between the exchange market and economic activity was first investigated by Girton & Roper (1977) in the Exchange Market Pressure model. Following the model, the monetary equilibrium is achieved when money supply is equal to the demand for money. While the money supply is measured as money that is created by the central bank, the demand for money is calculated as a function of price, output and interest rate. These all variables are then measured in first derivative forms.

. As the exchange rate of a country is influenced by the balance of payment between two countries, Girton & Roper (1977) show that policymakers may calculate the foreign reserve required to achieve a particular exchange rate target by examining the *inflation and output growth differential* between two countries, the *domestic money growth* and the *change in interest rate*, and the *money growth* in a counterpart country.

As most central banks adopted a fixed exchange rate regime, the EMP has gained its popularity in the 1980s due to its ability to help central banks defend the fixed exchange rate regime. Eichengreen *et al.* (1995) extend the model into an EMP Index (EMPI) to identify currency crises. Prior to the EMPI, currency crises were identified by a sharp depreciation of the exchange rate. However, Eichengreen *et al.* (1995) argue that central banks may intervene in the exchange market to reduce the depreciation. Thus, the currency may appear stable amid high tension in the exchange market. By employing the Index of Exchange Market

Pressure, Eichengreen *et al.* (1995) show various 'new' currency crises episodes, which were not identified beforehand. While the EMPI is still the most popular method to identify currency crises, the Exchange Market Pressure model has become less popular in recent decades due to a shift in central bank policy framework to inflation targeting.

The relationship between the interest rate and liquidity is partly demonstrated by the Money Market Pressure Index (Von Hagen & Ho, 2007). Inspired by the EMPI, the research by Von Hagen & Ho (2007) shows that banking crises can be identified using the Money Market Pressure Index (MMPI). Examining sets of variables, Von Hagen & Ho (2007) find that index of the *reserves to bank deposit ratio* and the *interest rate* may be used to identify the banking crises. Following the idea, Von Hagen & Ho (2007, p.1039) argue that "a banking crisis is characterised by a sharp increase in the banking sector's aggregate demand for central bank reserves". To address the crisis, the central banks may try to keep the total supply of bank reserves by raising the interest rate or inject the reserve through market operation or discount window lending. Thus, an increase in the interest rate or/and in the volume of central bank reserves indicates the pressure in the money market.

Although the MMPI was introduced prior to the Global Financial Crisis of 2007-08, it gained popularity in its aftermath due to its reliability and simplicity. Jing *et al.* (2015) demonstrate that while it is based on only two variables, the MMPI can identify banking crises in both developed and emerging markets. In addition, the MMPI provides a clear indication of the start and end dates of banking crises - a feature which is not available in the 'so-called' event approach (Goldstein *et al.,* 2000).

However, it is also important to stress that despite its popularity, the Money Market Pressure Index is based purely on empirical work and lacks a mathematical model, which can demonstrate why money growth and interest rate should be sufficient variables to act as vehicles for the identification of banking crises.

As the twin crises are defined as a condition where banking crises are followed by currency crises (or vice versa), thus, the theory suggests that the currency and banking crises are connected. As currency crises can be identified using the exchange market pressure index and banking crises can be determined using the money market pressure index, one may argue that the twin crises can be identified by combining the exchange market and money market pressure into a financial market pressure.

To identify twin crises episodes, the next section extends a mathematical model of Exchange Market Pressure into a mathematical model of the Money Market Pressure model. Furthermore, we combine both models into a mathematical model of Financial Market Pressure to explain why we can view twin crises as a disturbance in both exchange and money markets.

3.3. The Model

To understand the Financial Market Pressure, we extend a mathematical model of the Exchange Market Pressure (Girton & Ropper, 1977) to relate the exchange market and money market to economic activities. The model developed here is a monetary model, derived from money demand and money supply equilibrium to explain the relationship between the financial market and the real market. Following Girton & Ropper (1977), the monetary equilibrium equation can be presented as follows:

$$M^s = M^d \tag{3.1}$$

where:

M^s= total money supply issued by the Central Bank

M^d= total demand for money

On the one hand, money is supplied by the central bank, which creates money by buying foreign reserves (F_t) and domestic assets (D_t). On the other hand, the

demand for money can be represented as a function of price (P_t), income (Y_t) and interest rate (R_t). Thus, equation (3.1) can be rewritten as:

$$F_t + D_t = P_t Y_t^{\beta_t} \exp(-\alpha_t R_t) \quad (3.2)$$

where:

F_t= money supply from buying foreign reserves at time *t*

D_t= money supply from domestic credit expansion at time *t*

P_t= the price level at time *t*

Y_t= real income at time *t*

R_t= index of the interest rate at time *t*

β_t= income elasticity > 0 at time *t*

α_t= interest rate coefficient > 0 at time *t*

As the money created by buying foreign reserves can be measured by multiplying foreign reserves by the exchange rate, equation (3.2) can be represented as follows:

$$(FR_t . ER_t) + D_t = P_t Y_t^{\beta_t} \exp(-\alpha_t R_t) \quad (3.3)$$

where:

FR_i= foreign reserves bought by the central bank at time *t*

ER_i= the exchange rate at the time of purchase (at time *t)*

The real measure of monetary equilibrium can be obtained by deflating the changes in the money supply by total money supply created by the Central Bank.

$$f_t + d_t = \pi_t + \beta_t y_t - \alpha_t r_t \quad (3.4)$$

where:

$f_t = \Delta(FR_t . ER_t)/M_t$

$d_t = \Delta D_t / M_t$

$\pi_t = \Delta P_t / P_t$

$$y_t = \Delta Y_t / Y_t$$

$$r_i(t) = \Delta R_t / dt$$

In an open economy, the monetary equilibrium is affected by other countries. Thus, the interaction between country *a* and country *b* can be determined by employing the International Fisher Effect to the monetary equilibrium:

$$f_a - f_b + d_a - d_b = \beta_a y_a - \beta_b y_b + \pi_a - \pi_b - \alpha(r_a - r_b) \quad (3.5)$$

By adjusting the change of foreign reserves and the change of price by the rate of appreciation of currency *a* in terms of currency *b* (e_{ab}), equation (3.5) can be rewritten as:

$$f_a - f_b + e_{ab} + d_a - d_b = \beta_a y_a - \beta_b y_b + \pi_a - \pi_b + e_{ab} - \alpha(r_a - r_b) \quad (3.6)$$

Equation (4.6) can be rewritten as follows:

$$f_a + e_{ab} = -d_a + f_b + d_b + \beta_a y_a - \beta_b y_b + \pi_a - \pi_b + e_{ab} - \alpha(r_a - r_b) \quad (3.7)$$

Girton & Roper (1977) refer to $(f_a + e_{ab})$ as a measure of the exchange market pressure. Using the above model, Girton & Roper (1977) demonstrate that the policymaker can calculate the foreign reserve required to achieve a particular exchange rate target. Following the model development, the Exchange Market Pressure has been empirically tested in various countries (Erler *et al.,* 2015; Fiador & Biekpe, 2015; Kim, 1985). The ability to calculate the right amount of foreign reserve was an important feature in the 1970s, as most countries adopted a fixed exchange rate regime.

However, in recent decades, most central banks have shifted their policy to achieve their targets by managing interest rates. Thus, the Exchange Market Pressure model has lost its popularity in central bank study. While the central bank mainly manages the interest rate by managing public expectation using a policy rate, it is still important to manage a right amount of liquidity to manage the interest rate. To measure the liquidity required to manage the interest rate, we extend the Exchange Market Pressure into a Money Market Pressure model.

Let us recall equation (3.7):

$$f_a + e_{ab} = -d_a + f_b + d_b + \pi_a - \pi_b + e_{ab} + \beta_a y_a - \beta_b y_b - \alpha(r_a - r_b)$$

While the Exchange Market Pressure shows the relationship between the exchange market and the macroeconomy, the impact of the domestic money market on the macroeconomy can be shown by placing the exchange market variables ($f_a + e_{ab}$) to the right-hand side and the money market variables ($-d_a - \alpha r_a$) to the left-hand side. Thus, equation (3.7) can be represented as follows:

$$d_a + \alpha r_a = -f_a - e_{ab} + f_b + d_b + \pi_a - \pi_b + e_{ab} + \beta_a y_a - \beta_b y_b + \alpha r_b \qquad (3.8)$$

We refer to $d_a + \alpha r_a$ as Money Market Pressure (MMP), which shows domestic liquidity required to manage the interest rate.

The MMP may provide support to the MMP Index (Von Hagen & Ho, 2007) which argues that the demand for central bank's reserves and the rise of the interest rates are sufficient to identify the banking crises. While Jing *et al.,* (2015) demonstrate that the MMP Index can identify the banking crises in developed and emerging markets, it is based merely on the empirical evidence and lack of theoretical support. Thus, equation (3.8) may provide the theoretical explanation for why the MMP is sufficient to determine banking crises.

Furthermore, the above model shows that the Exchange Market Pressure and the Money Market Pressure can only partially explain the dynamics of the macroeconomy, as well as a partial monetary policy objective.

While the Exchange Market or the Money Market Pressure model can only show a small portion of the financial market, the combination of both models may provide a complete perspective on the state of the economy. Thus, by returning the Exchange Market Pressure variables to the left-hand side, equation (3.8) can be reformulated as:

$$f_a + e_{ab} + d_a + \alpha r_a = (\pi_a - \pi_b + e_{ab}) + (\beta_a y_a - \beta_b y_b) + (f_b + d_b) + \alpha r_b \qquad (3.9)$$

We refer to ($f_a + e_{ab} + d_a + \alpha r_a$) as the Financial Market Pressure. The model indicates the foreign reserve and domestic liquidity required to manage the exchange rate and interest rate.

In a final form, equation (3.9) can be represented as:

$$f_a + e_{ab} + d_a + \alpha r_a = \bar{\pi}_{ab} + \bar{y}_{ab} + \mathrm{m}_b + r_b \qquad (3.10)$$

where:

$\bar{\pi}_{ab}$= Inflation differential between two countries in term of currency b $(\pi_a - \pi_b + e_{ab})$

$\bar{y}_{ab}$ = output growth differential between two countries $(\beta_a y_a - \beta_b y_b)$

m_b = total money creation in a foreign country $(f_b + d_b)$

Furthermore, currency crisis literature (Eichengreen *et al.,* 1995) and banking crisis literature (Von Hagen & Ho, 2007) argue that currency crises and banking crises can be identified by measuring the pressure on exchange market and money market, respectively. As the twin crises model argues that the two crises are highly connected, thus, the FMP should indicate the presence of twin currency and banking crises. This may be the reason why the currency and banking crisis often share similar drivers (Glick & Hutchison, 1999) and develop in a vicious cycle (Schnabel, 2004).

The Financial Market Pressure also shows a strong relationship between the financial market and the macroeconomic. This is in line with Borio (2011) who argues that financial stability and the economic stability are "two sides of the same coin".

While this paper focuses on the identification of 'existing' twin currency and banking crises, the FMP could also be potentially employed to examine 'hidden' currency and banking crises. The 'hidden crisis' is a condition when the disturbance in an exchange market or a money market is relatively low amid high tension in exchange and money markets. This can occur as the central bank may intervene in the money market to ease the pressure in exchange market or vice versa. Thus, 'hidden crises' could not be captured by traditional isolated currency or banking crises databases. This can be achieved by adjusting the optimum crisis threshold, which is the crisis threshold that produces the lowest loss of crises, as explained in Section 3.4.2. However, this path will not be pursued in this paper as this would also shift the focus of the investigation.

3.4. Methodology

Literature suggests that currency crisis is characterised by a sharp depreciation of the exchange rate. To address the issue, central banks may sell their foreign reserve to stabilise the exchange rate. Thus, currency may seem stable amid high pressure in the exchange market (Eichengreen *et al.,* 1995).

Furthermore, the banking crisis is identified by a sharp increase in the banking sector's aggregate demand for central bank reserves. To address this issue, central banks may try to keep the total demand on bank reserves by raising the interest rate. Thus, the total demand on bank reserves may seem stable amid high pressure in the money market (Von Hagen & Ho, 2007).

Extending the existing literature, the Financial Market Pressure model shows that central banks may also intervene in the exchange market to reduce pressure in the money market, or vice versa. As a result, the exchange market or the money market may seem stable amid high pressure in the exchange and money market. Thus, the FMP is a crucial tool to examine the overall pressure in the exchange and money market.

To test the ability of financial market pressure to identify twin currency and banking crises, we transform the FMP into an index of FMP, which we refer as the c-index. The C-Index is obtained by standardising each variable in the FMP into four levels of crises, level 1 to level 4. We then compare the Index with an Optimum Crisis Threshold to determine the twin crises. The threshold is examined by conducting simulations using the optimum crisis function (Jing *et al.,* 2015). The following subsections explain in detail the various steps taken.

3.4.1. C-Index

Let us represent equation (3.10) as the Financial Market Pressure:

$$FMP_t = f_t + e_t + d_t + r_t \tag{3.11}$$

For practical purposes, following the standard in Market Pressure-based model (Eichengreen *et al.,* 1995; Jing *et al.*, 2015), we transform Financial Market Pressure into an index of financial market pressure, which we refer as the c-index:

$$C - Index_t = \omega_1 f_t + \omega_2 e_t + \omega_3 d_t + \omega_4 r_t \quad (3.12)$$

Where f_t is the percentage change in foreign reserve at time *t*, e_t is the percentage change in the nominal exchange rate at time *t*, d_t is the percentage change in the monetary-base-to-broad-money ratio at time *t*, r_t is the percentage change in interest rate at time *t*, and ω is a weight assigned to each variable.

As the variables included in the c-index have different volatility, careful consideration of the weight associated with each variable is therefore required, so that no particular variable can distort the c-index. To address the issue, we transform each variable into a standardised index number using the standard min-max normalisation method:

$$SV_{i,t} = \frac{Var_{i,t} - Min(Var_i)}{Max(Var_i) - Min(Var_i)} \quad (3.13)$$

where $SV_{i,t}$ is the standardised value of the variable *i* in time *t*; $Var_{i,t}$ denote the value of the variable *i* in time *t* and $Min(Var_i)$ and $Max(Var_i)$ represent the minimum and maximum value of the variable in data series *i,* respectively.

While the academic literature typically presents market pressure indexes as unstandardised index numbers (e.g. from infinity negative to a positive number), organisations such as central banks tend to present pressures using a heatmap. A crisis heatmap is a representation of the state of pressures in the form maps or diagrams. Typically, a crisis heatmap represents crises in four crisis levels, level 1 to level 4. For practical purpose, each level is often represented by a particular colour, where crisis level 1 is presented as green, level 2 is presented as yellow, level 3 is presented as orange, and level 4 is presented as red. By doing so, index numbers can sometimes be easier to interpret. For example, as crisis level 3 is a condition where the index between 2.0 and 2.9, thus, economists will understand that the economy is in crisis level 3 when they find that the index is 2.6.

For example, Riksbank (Farelius, 2013) demonstrates the pressure in the financial market through a heatmap, using four categories: (1) Level 1 - normal condition; (2) Level 2 - pressure with limited impact; (3) Level 3 - pressure with severe impact; and (4) Level 4 - pressure with very severe impact. The standardised heatmaps of crisis level 1 to level 4 also help analysts understand the development of pressures throughout time. Without a standardised heatmap, economists need to translate the index to a correct crisis level as a similar change in the variables may lead to a different level of crises in different time periods or different countries.

To create a heatmap, we standardise the variables using equation (3.13). However, as the heatmap consists of four levels, thus, we need to modify the equation (3.13).

Firstly, we divide each variable into four levels. In doing so, we define a threshold for each level. In this paper, for simplification, we employ a similar threshold across our sample countries. We define the crisis level 1 threshold as 5%, the crisis level 2 threshold as 10%, and the crisis level 3 threshold as 15%. For example, if the change in the exchange rate in 1995 is 3%, then the exchange rate falls into the crisis level 1 category in 1995, while if the change in interest rate in 1997 is 7%, the interest rate falls in the crisis level 2 category.

This method may address the problem with outlier data, as all outliers will be transformed into an index between 3 and 4. The threshold of each category can be refined according to the individual country specification. However, as the crisis threshold which is employed in this paper would be simulated using an optimum crisis threshold function (Jing *et al.,* 2015), adjusting the threshold may not significantly change the crises database.

Second, we define the heatmap categories. We specify that index of 0.0 – 1.0 reflects a normal condition (crisis level 1), index of 1.1 – 2.0 reflect pressure with limited impact (crisis level 2), index of 2.1 – 3.0 indicate pressure with severe impact (crisis level 3), and index of 3.1 – 4.0 reflect pressure with very severe impact (crisis level 4) for each variable. The summary of the data transformation is shown in Table 3.1.

By applying the above rules, equation (3.13) can be rewritten as:

$$SVI_{var} = \begin{cases} \text{IF } Level\ 1 \text{ THEN } \frac{Var - Min}{Level\ 0\ \ Threshold - Min} + 0 \\ \text{IF } Level\ 2 \text{ THEN } \frac{Var - Level\ 0\ Threshold}{Level\ 1\ \ Threshold - Level\ 0\ Threshold} + 1 \\ \text{IF } Level\ 3 \text{ THEN } \frac{Var - Level\ 1\ Threshold}{Level\ 2\ \ Threshold - Level\ 1\ Threshold} + 2 \\ \text{IF } Level\ 4 \text{ THEN } \frac{Var - Level\ 2\ Threshold}{Max - Level\ 2\ Threshold} + 3 \end{cases} \quad (3.14)$$

where SVI_{var} is the Standardised Variable Index for each variable, *Min* is the minimum number in the data series of each variable, *Max* is the maximum number in the data series of each variable.

Table 3.1: Summary of Data Transformations

Heatmap	Value of Variable		Index Transformation	
	Min	Max	Min	Max
Level 1	Min	5%	0.0	1.0
Level 2	>5%	10%	1.1	2.0
Level 3	>10%	15%	2.1	3.0
Level 4	15%	Max	3.1	4.0

As all the variables are transformed into a Standardised Variable Index with equal weights, we can represent equation (3.14) as:

$$c - index_t = SVI(f_t) + SVI(e_t) + SVI(d_t) + SVI(r_t) \quad (3.15)$$

As each variable in equation (3.15) consists of a number between 0 and 4, the sum of all variables (the c-index) is between 0 and 16. To make it consistent with the four-category heatmap, we need to divide the c-index by 4. Thus, the final form of c-index can be reformulated as follows:

$$c - index_t = \frac{SVI(f_t) + SVI(e_t) + SVI(d_t) + SVI(r_t)}{4} \quad (3.16)$$

One crucial feature of the heatmap model is its ability to reduce the impact of extreme outliers. The popular standard deviation-based weighting methods might miss some financial crises if there were extreme outliers in the data series, such as severe financial crises. For example, if a country suffered 1000% currency depreciation per annum (p.a.) in the data series, 20% depreciation p.a. (which is typically categorised as crises episode) might be viewed as normal. Therefore, some financial crises may be unidentified, despite their significant impact on the financial market. While other techniques, such as winsorisation, can deal with this kind of outliers, this heatmap model is more straight forward and simple as we do not need to specify the threshold of outliers in each variable. Thus, all extreme situations are automatically identified as crisis level 4.

3.4.2. Optimum Crisis Threshold

For investigation of twin crises using Ordinary Least Square (OLS), economists may employ the c-index as a dependent variable. Thus, there is no need to specify the time of crises. However, many policymakers do need the exact time of crises to justify their policy responses, since some governments or central banks may use different powers in different circumstances. For example, while a government may not have the authority to 'freeze' the banking system or to bail-out particular banks in non-crisis times, a government may have to use 'additional' powers in crisis times.

Other econometric approaches, such as logistic regressions or signalling method analysis, also require a specific crisis time in their variables to identify 'crisis or no crisis' periods. The specific time of crisis is identified by comparing the value of c-index with the crisis threshold. The crisis threshold is a predetermined index number, whereby any value above the threshold is determined as a crisis period. There is no consensus on how to determine the threshold. While Kaminsky & Reinhart (1999) specify the threshold based on standard deviation, Frankel & Rose (1996) define the threshold based on the percentage change of the variables. Higher crises thresholds (e.g. an index value of 3) will produce fewer 'false crises' (but higher 'missing crises'), while lower

crises thresholds (e.g. an index value of 1) will lead to higher 'false crises' (but fewer 'missing crises').

Furthermore, policymakers are assumed to respond to crisis signals. A signal is flared when the c-index exceeds the crises threshold. There are three types of crises signals. The correct crises signal is a condition when the signal correctly predict future crises, the false crises signal is a condition when there is no crisis in the aftermath of the signal, and the missing crises signal is a condition when a crisis occurs without any signals.

If a signal is flared, either correct or false signal, the government will launch a mitigation policy to avoid the crises. This will trigger a mitigation cost. If there is a missing signal, the crises occur without any mitigation policy, this will generate a cost of crises.

As a lower crises threshold may lead to higher 'false crises' signals and higher 'mitigation cost', and a higher crises threshold may lead to higher 'missing crises' signals and higher 'cost of crises', it is crucial to determine the optimum crisis threshold, which produces the lowest loss of crises.

To gain the optimum crisis threshold, we adopt the loss function (Jing *et al.,* 2015). The simple loss function for c-index can be presented as follows:

$$L(H) = \rho(H)c_1 + e(H)c_2 \tag{3.17}$$

where *H* is the crisis threshold, $L(H)$ is the 'crises losses' if the crisis threshold is set on *H,* $\rho(H)$ is the probability that the c-index will indicate 'crisis episodes' at threshold *H*, $e(H)$ is the probability that the c-index will produce 'missing crisis episodes', c_1 is the 'mitigation cost' of the crises when the c-index indicates 'crises episodes' and c_2 is the 'cost of crises' if the government fails to prevent the crises because of 'missing crisis episodes'.

Following equation (3.17), the c-index identifies a crisis when the index exceeds the threshold *H.* If the c-index indicated a crisis, the government might launch mitigation policies to prevent the crisis. These policies create a mitigation cost (c_1). On the other hand, if the c-index failed to identify a crisis, the government might fail to prevent the crises. As the crisis occurs, the government

suffers from the cost of the crisis (c_2). The crises losses are the total of mitigation cost and cost of the crisis. Since we expect the mitigation cost of crises to be smaller than the cost of crises, it is assumed that c_1 is smaller than c_2.

As the government might launch the mitigation policies because of both correct crisis and false crisis, we can rewrite the probability of crisis ($\rho(H)$) as the notion of type I and type II error. Type I error is a condition when the c-index fails to identify crises in the benchmark database (missing crisis), and type II error is a condition when the c-index defines crises that are not identified in the benchmark database (false crisis).

Furthermore, let $a(H)$ be the probability of 'missing crisis episodes', let $b(H)$ be the probability of 'false crises episodes' and let ρ_0 represent the probability of a crisis. Thus, the correct and false crises can be represented as $\big(1 - a(H)\big)\rho_0$ + $b(H)(1 - \rho_0)$. Taken together, equation (3.17) can be reformulated as follows:

$$\begin{aligned} L(H) &= c_1\big[\big(1 - a(H)\big)\rho_0 + b(H)(1 - \rho_0)\big] + c_2 a(H)\rho_0 \\ &= \rho_0 c_1 \left[1 + \left(\tfrac{c_2 - c_1}{c_1}\right) a(H) + \left(\tfrac{1-\rho_0}{\rho_0}\right) b(H)\right] \end{aligned} \quad (3.18)$$

Following equation (3.18), policymakers set the crises threshold at *H*. When the threshold is set too high, some crises are not identified (missing crises). This will lead to a higher 'cost of crises' and higher 'loss of crises'. In order to reduce the number of unidentified crises, policymakers may set a lower crisis threshold. However, a lower crisis threshold will lead to misidentification, where a normal condition is identified as a crisis (false crises). This will increase the 'mitigation cost' and 'loss of crises'. Equation (3.18) suggests that the larger the 'cost of crises' (c_2) relative to the 'mitigation cost' (c_1), the higher the cost of 'missing crises' signals relative to 'false crises' signals (and *vice versa*).

3.5. Data

We focus our investigation on the application of the c-index on Latin America and East Asia region. As these regions are regarded as relatively vulnerable to changes in political or economic conditions, they have often suffered from recurring financial crises over the last four decades (see, among others, Devlin & Ffrench-Davis, 1995; Mishkin, 1999; Radelet & Sachs, 1998; Kaminsky & Reinhart, 1999; Laeven & Valencia, 2008).

There is an abundant amount of currency and banking crises literature. In particular, the East Asia financial crisis of 1997 attracted particular attention for its unique nature, as it cannot be explained by the first and the second-generation models of currency crises. In the East Asia financial crisis of 1997, some economists (Kaminsky & Reinhart, 1999) identify an interaction between banking and currency crises, which leads to the development of the twin crises model. In line with Radelet & Sach (1998), most literature on the East Asia financial crisis of 1997 focuses on Indonesia, Malaysia, Philippines, Thailand, and South Korea, which suffered most from the East Asia financial crisis of 1997.

Furthermore, the financial crisis in Latin America in the 1980s, which sometimes is known as the lost decade when Latin America countries suffered from recession and high inflation, also attracted various researchers to investigate. Most literature on Latin America focuses on Argentina, Brazil, Chile and Mexico as the biggest economy in Latin America (see, among others, Pontines & Siregar, 2008; Hegerty, 2015).

In addition, we also examine Venezuela as it has attracted more attention in recent studies. Saraiva & Jamrisko (2017) argue that Venezuela is the most miserable country in the world due to the economic and political problems in the last few years. Taken together, in line with the above researchers, we focus our study on Indonesia, Malaysia, Philippines, Thailand, South Korea, Argentina, Brazil, Chile, Mexico and Venezuela.

We observe annual data from 1970 to 2007 for these countries (although the data period for each country varies depending on data availability, as shown in Table 3.2). Our data were obtained from the International Financial Statistics (IFS). We use Exchange Rate (refer to line *...DE.* on IFS), International Reserve (refer to line*.1DA* on IFS), Interest Rate (refer to line *60B..* or *60L..* on IFS), and Ratio of Monetary Base to Broad Money (refer to line *39ABIR* on IFS).

Table 3.2: List of Countries

No.	Country Name	Data Period
1	Argentina	1985-2007
2	Brazil	1991-2007
3	Chile	1978-2007
4	Indonesia	1981-2007
5	Malaysia	1972–2007
6	Mexico	1983-2007
7	South Korea	1978-2007
8	Philippines	1980-2007
9	Thailand	1978-2007
10	Venezuela	1984-2007

As a benchmark, we use Laeven & Valencia (LV) (2008, 2012) and Kaminsky & Reinhart (KR) (1999) crises databases. For comparison purposes, we evaluate the crisis episodes, which were stated in LV and KR. However, there are differences between the LV and KR crises databases, due to different identification methods. To address this issue, we group consecutive years of crises as one crisis episode. We then combine the years of similar crises from both databases. For example, if banking crises according to LV are in 1996-97 and KR are in 1997-98, we consider the banking crisis episode as spanning the period 1996-98. LV and KR crises databases are summarised in Table 3.3.

Table 3.3: LV and KR Financial Crises Databases

Country	LV (2008, 2012)		KR (1999)		Twin Crisis
	Banking	Currency	Banking	Currency	
Argentina	1989-91, 1995, 2001-03	1987, 2002	1985-89, 1994-95	1986, 1989, 1990	1985-91 2001-03
Brazil	1990-98	1999	1994-96	1991	1990-99
Chile	1981-85	1982	1981-83	1982, 1984	1981-85
Indonesia	1997-01	1998	1992	1983, 1986 1997	1997-01
Malaysia	1997-99	1998	1985-86	1997	1997-99
Mexico	1981-85, 1994-96	1982, 1995	1982-84, 1992-96	1982, 1994	1981-85 1992-96
South Korea	1997-98	1998	n/a	n/a	1997-98
Philippines	1983-86, 1997-01	1983, 1998	1981-85	1983-84 1997	1981-86 1997-01
Thailand	1983, 1997-00	1998	1983-85	1981, 1984 1997	1983-85 1997-00
Venezuela	1994-98	1984, 1989 1994 2002	1993-94	1994	1994-98

Source: Adapted from Laeven and Valencia (LV) (2008, 2012) and Kaminsky and Reinhart (KR) (1999)

Following LV criteria, we identify twin crises as a situation in which the starting year of the second crisis is within the first crisis period or in the following year. The first crisis is the initial crisis that spread into the other crisis (the second crisis). Thus, we calculate the start and the end date of twin crises episodes by

counting the consecutive years between the earliest and the latest of both types of crises episodes.

For example, if a banking crisis period spans across 1996 and 1998 and a currency crisis between 1998 and 1999, then the twin crises period is assumed to be 1996-99.

Table 3.3 shows that there were 15 banking crisis episodes and 16 currency crisis episodes according to the LV database, and there were 11 banking crisis episodes and 18 currency crisis episodes according to KR database. Taken together, we identify 14 twin crisis episodes during the 1980-2007 period.

As the existing literature identifies twin crises by comparing the starting dates of currency and banking crises, this paper aims to provide a mathematical model to identify the dates of twin crises by employing the c-index. The findings are then compared with the existing twin crises databases (Table 3.3) to test its robustness.

3.6. Findings

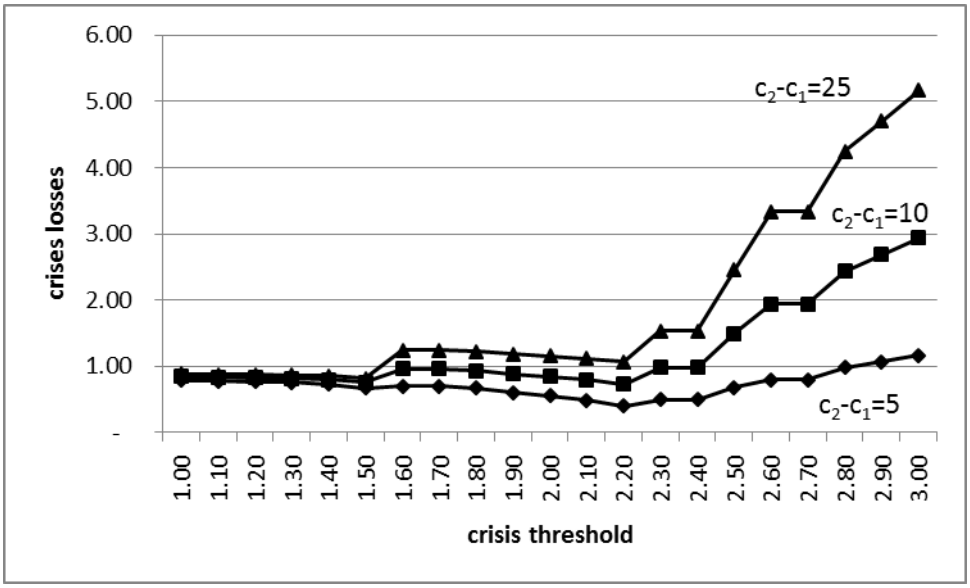
Using the c-index, we use in-sample frequencies to estimate the optimum 'crises threshold'. We calculate ρ_0 as the total number of 'crisis years' according to LV and KR divided by the total number of years in our data series. We calculate the 'probability of missing crises episodes' ($a(H)$) as the frequency of 'missing crises episodes' divided by the total number of 'crisis episodes' at crisis threshold H. Similarly, the 'probability of false crises episodes' ($b(H)$) is calculated as the frequency of 'false crises episodes' divided by the sum of 'correct crisis episodes' and 'false crises episodes' at crisis threshold H. For example, $a(1)$ is the probability of 'missing crises episodes' when the crisis threshold is set equal to 1.

To examine the best performance of crises thresholds, we conduct simulations for different values of H. As the heatmap model data set only consists

of values from 0 to 4, we set the value of H to vary between 1.0 and 3.0 (with steps of 0.1).

Furthermore, following Jing *et al.* (2015), we set c1 equal to 1 and let (c2 - c1) equal to 5, 10 or 15. The optimal crisis threshold is the lowest 'crises losses' in each (c2 - c1) condition. Figure 3.1 shows the overall values of the loss function for c-index for various values of (c2 - c1).

Figure 3.1: 'Crises losses' with various thresholds



As the 'cost of crisis' is higher than 'mitigation cost', one may assume that the greater the difference between 'mitigation cost' and 'cost of crises' (c2 – c1), the greater the 'crises losses'. Therefore, policymakers may set a lower threshold if they believe that the 'cost of crises' is substantially larger than the 'mitigation cost'. However, our findings suggest that the optimum crises threshold is not the lowest threshold. Thus, economists should define the threshold carefully.

Figure 3.1 shows that the minimum loss of crises is reached when the threshold is at 2.2. Prior to the optimum crisis threshold, the lower threshold leads to higher 'loss of crises'. However, after exceeding the optimum crisis threshold,

the 'loss of crises' becomes higher, along with an increasing threshold. For example, assuming that (c2 – c1) equal to 5, the loss of crises is 0.67 when the threshold is set on 1.5, the loss of crises is 0.40 when the loss of crises is set on 2.2, and the loss of crises is 0.68 when the loss of crises is set on 2.5.

Furthermore, while one may argue that heterogeneity across countries may lead to a different optimum crisis threshold, our simulation suggests that the optimum crisis threshold on a country level is consistent at 2.2. This implies that the impact of changes in exchange rate, foreign reserve, interest rate and money growth is relatively consistent across countries. However, the 'crises losses' differs across countries. The 'crises losses' of each country on the optimum threshold is shown in Table 3.4.

Table 3.4: Summary of the 'Crises Losses'

	Optimum Threshold	Crises Losses		
		c2-c1=5	c2-c1=10	c2-c1=25
Argentina	2.2	0.43	0.68	0.82
Brazil	2.2	0.59	0.83	0.93
Chile	2.2	0.17	0.31	0.42
Indonesia	2.2	0.59	0.67	0.73
Malaysia	2.2	0.08	0.16	0.23
Mexico	2.2	0.40	0.64	0.78
South Korea	2.2	0.07	0.13	0.19
Philippine	2.2	0.37	0.60	0.75
Thailand	2.2	0.82	2.03	3.54
Venezuela	2.2	0.61	0.69	0.76
Overall	2.2	0.44	0.76	1.09

Based on the simulations using the optimum crisis threshold, we define a crisis as a situation in which the index exceeds 2.2. This is relatively in line with

the assumption that the index of 2.2 represents a pressure with severe impact (crisis level 3).

There were seven twin crises episodes during the period 1980-2007 in Latin America. In the early 1980s, the crises hit the Mexican and Chilean economies profoundly, followed by turmoil in the Argentinean economy. Following the lost decade of Latin America in the 1980s (Devlin & Ffrench-Davis, 1995), the Tequila crisis hit Mexico (Mishkin, 1999) and generated financial crises in Brazil and Venezuela throughout the 1990s. In the early 2000s, the Argentinean economy collapsed, despite a series of attempts to stabilise its currency in the late 1990s.

Aligned with thee combined LV-KR databases, the c-index correctly indicates twin crises in Chile (1982), Mexico (1985, 1994), Argentina (1987, 1989, 2001-02), Brazil (1994, 1998) and Venezuela (1994-98).

Furthermore, we also calculate the c-index for five countries in East Asia. In East Asia, there were seven twin crises during 1980-2007. In the 1980s, the Philippines and Thailand suffered from profound crises. In the 1990s, Indonesia, Malaysia, South Korea, Philippines and Thailand's economies were severely hit by the East Asian financial crisis of 1997.

In line with the LV-KR database, the c-index correctly indicates twin crises in 1983-84 (Philippines) and 1986 (Indonesia). Furthermore, our calculation suggests that all sample countries suffered from twin crises of 1997. In total, the c-index model identifies seven twin crises episodes in Latin America and seven twin crises episodes in East Asia.

The ability of the c-index to identify twin crises has simplified the identification process of twin crises. Previously, economists have to identify dates of currency and banking crises independently and then compare the dates of the crises to examine the presence of twin crises. The c-index employs a single mathematical equation that can pinpoint the dates of twin crises without the necessity to identify individual currency or banking crises. In addition, this method also addresses the limitation of existing literature, which cannot pinpoint the dates of twin crises.

Table 3.5: Summary of twin crises in East Asia and Latin America

Country	The C-Index	LV-KR
Argentina	1987, 1989,	1985-91
	2001-2002	2001-03
Brazil	1994, 1998	1990-99
Chile	1982	1981-85
Indonesia	1986,	
	1997,	1997-01
Malaysia		
	1997	1997-99
Mexico	1985,	1981-85
	1994	1992-96
South Korea		
	1997	1997-98
Philippines	1983-1984,	1981-86
	1997	1997-01
Thailand		1983-85
	1997	1997-00
Venezuela	1989	
	1998	1994-98

The findings suggest that the c-index can determine the dates of twin crises. For example, the LV-KR database shows that there are twin crises in the period of 1985-1991 in Argentina. However, our model indicates that the twin crises episodes are only in 1987 and 1989. Thus, the remaining years can be considered as isolated crisis periods. This is an essential feature of this model,

as the inability to examine the dates of twin crises has refrained economists to investigate the twin crises.

Despite its ability to explain the twin crises in the LV and KR crises databases, the model fails to identify Thailand's twin crises of the early 1980s that is listed in Table 3.3. The summary of twin crises is shown in Table 3.5.

On the one hand, in Thailand, Laeven & Valencia (2008, 2012) argue that there was banking crisis in 1983, without any indications of currency crisis. However, Kaminsky & Reinhart (1999) suggest that there were banking crises in 1983-1985 and currency crises in 1981 and 1984, thus, there were twin crises in the 1980s. Re-examining the data, we find that,, during 1983-1985, while Thailand's currency depreciated from THB 23/USD to THB 26.65/USD, its foreign reserve increased from USD 1,633.58 million to USD 2,285.69 million. These imply a low-moderate pressure in the exchange market, which is in line with Laeven & Valencia (2008, 2012) who argue that there was no currency crisis in that period.

Furthermore, we find that, while the liquidity ratio (M_0/M_2) decreased from 15.83% to 12.02%, the interest rate also decreased from 14.95% to 13.48%. This implies a moderate-high pressure in the money market, which is in line with both Laeven & Valencia (2008, 2012) and Kaminsky & Reinhart (1999). Taken together, the c-index indicates moderate pressure during this period.

One possible reason for this anomaly is the misidentification of currency crises. According to the exchange market pressure index, the currency depreciation has to be set-off by the rise of international reserves, thus, the model suggests a no crisis condition. However, the rise of international reserve did not come from the buying of foreign currency, but from the international support to Thailand's government. This support also increased investors' confidence in money markets and led to a decrease in the interest rate amid the liquidity shortage. Thus, we need may re-consider this condition as a crisis, as is suggested by Kaminsky & Reinhart (1999).

On the other hand, the c-index also indicates a 'false crisis episode' in Indonesia in the mid-1980s. The fall in oil prices forced the Indonesian Rupiah to depreciate in 1986. This devaluation had destabilising effects, which led to a rise in interest rates and a decrease in foreign reserve. Indeed, Kaminsky & Reinhart (1999) identify 1986 as a currency crisis episode, but they do not mention any banking crisis around this year. However, Von Hogen & Ho (2007) show that there was a banking crisis in Indonesia in 1985. This is in line with Hartono & Ehrmann (2001), who acknowledge this episode as one of the most profound economic crisis episodes in Indonesia.

A similar condition occurred for Venezuela. Our model suggests that there is a twin crises episode at the end of the 1980s. While Laeven & Valencia (2008) identify currency crises in 1984 and 1989, they are unable to determine a banking crisis in that period. However, Reinhart & Rogoff (2010) argue that there were not only twin crises in the 1980s but also inflation crisis, stock market crash and the debt crisis in Venezuela.

One possible reason for this discrepancy is that the LV-KR may not have identified all financial crises (Jing *et al.,* 2015), as some data are not consistently available across the data series. Thus, by considering Von Hagen & Ho (2007) and Reinhart & Rogoff (2010) who suggest that there were twin crises in Indonesia and Venezuela in the above periods, we argue that the 'false crises episodes' are actually 'correct crises episodes' (hence, 'refined' column in Table 3.8). This is an important feature of the model, as other approaches typically produce 'false crises signals'. The 'false crises signals' may stimulate the policymakers to respond and - in turn – 'suffer' the impact of 'mitigation costs'.

Furthermore, our investigation shows that the country's responses to the twin crises vary. For example, during the twin crises of 1987, Argentina massively intervened in the exchange market to stabilise the exchange rate, which led to liquidity shortages and high interest rate. However, to address another twin crises in 2001, Argentina also intervened in the exchange market. However, as the pressure continued, Argentina let the exchange rate to depreciate in the following year.

Furthermore, Indonesia's responses to the twin crises of 1997 were quite limited due to limited international reserve and high-quality domestic currency bonds, which led to high depreciation and high interest rates The components of pressure in Latin America and East Asia are shown in Figure 3.2 to Figure 3.11.

Figure 3.2: C-Index in Argentina

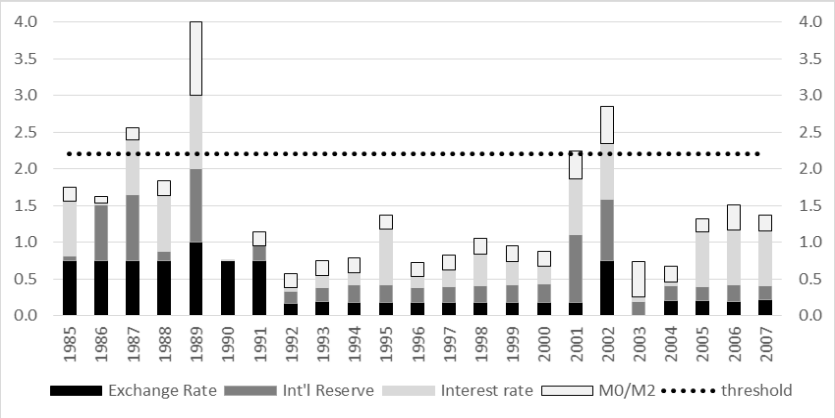


Figure 3.3: C-Index in Brazil

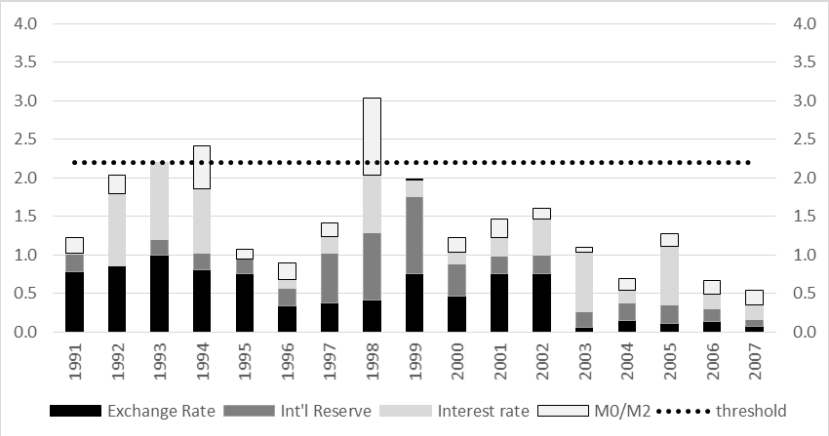


Figure 3.4: C-Index in Chile

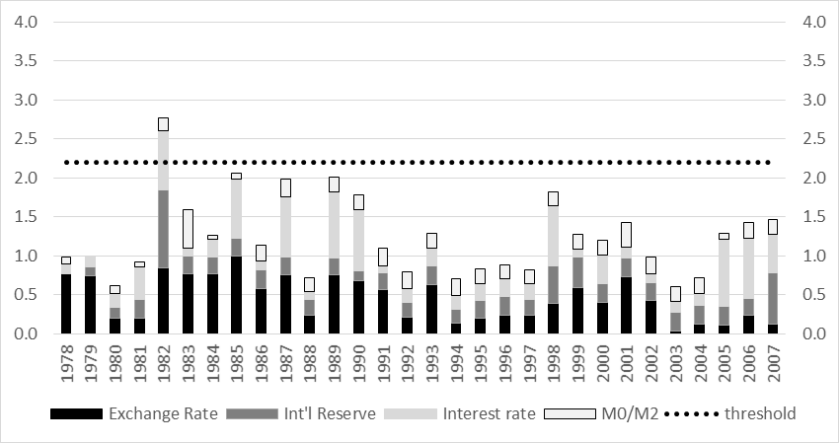


Figure 3.5: C-Index in Mexico

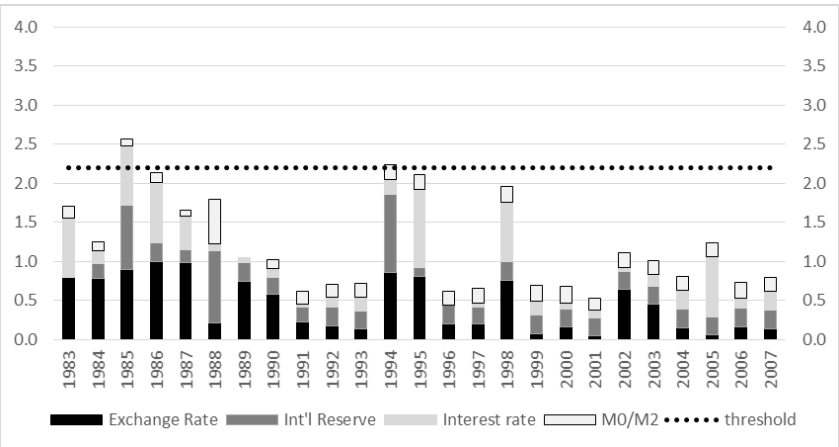


Figure 3.6: C-Index in Venezuela

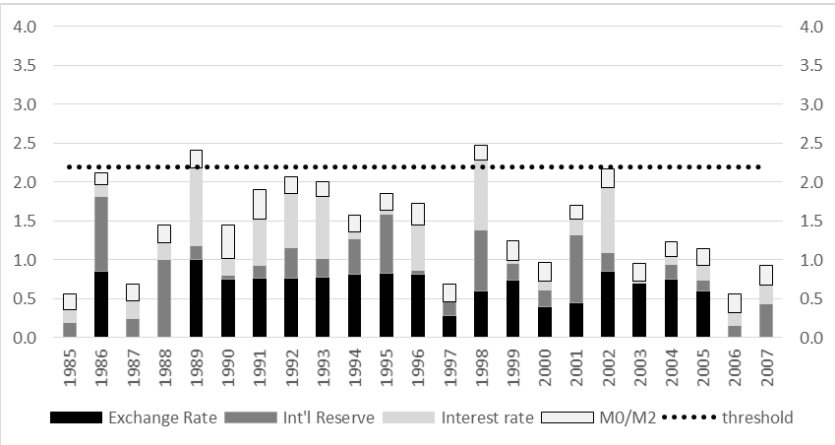


Figure 3.7: C-Index in Indonesia

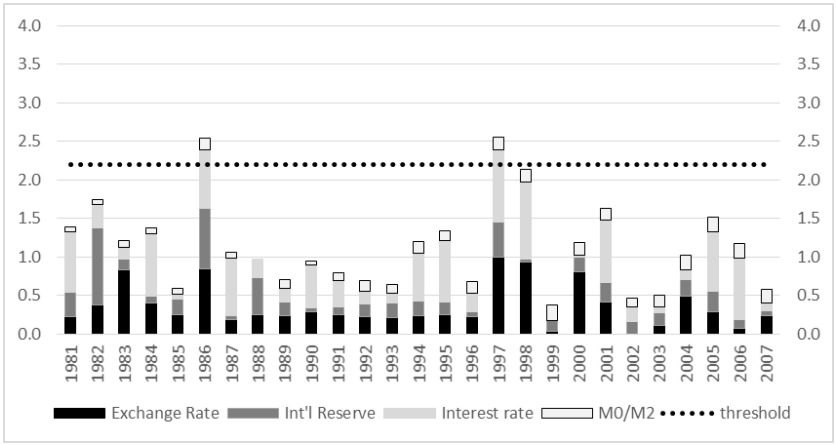


Figure 3.8: C-Index in Malaysia

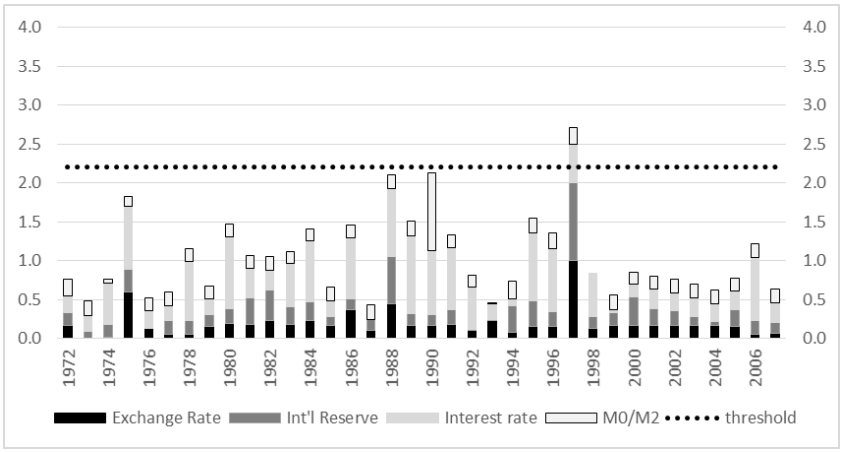


Figure 3.9: C-Index in South Korea

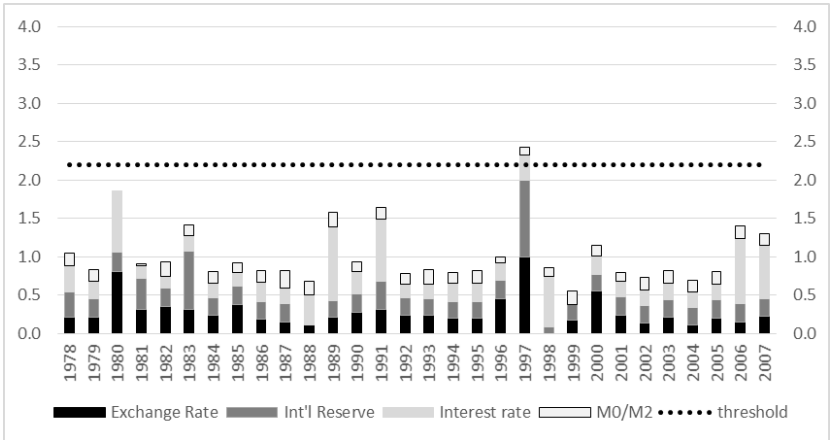


Figure 3.10: C-Index in the Philippines

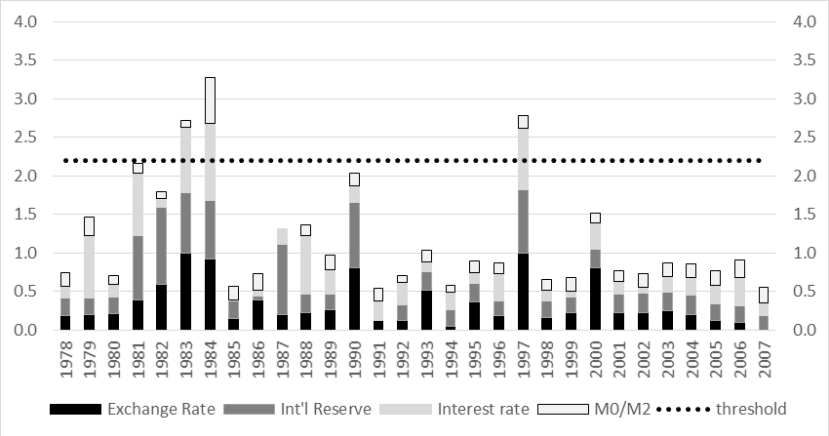
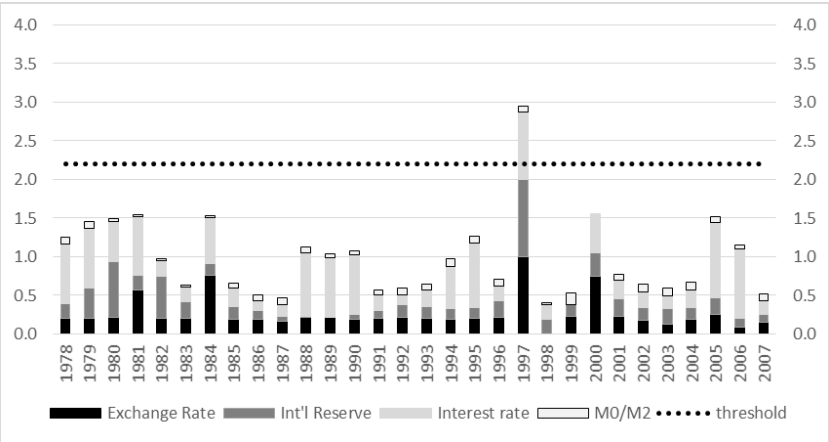


Figure 3.11: C-Index in Thailand



3.7. Robustness Test

In this paper, we aim to develop a mathematical method to identify twin crises. To examine the robustness of the c-index, in line with Jing *et al.* (2015), we calculate the prediction error of the c-index. Firstly, we examine type I error by calculating the missing crises ratio, which constitutes the inability of the c-index

to indicate a crisis condition. A missing crisis is defined as a condition when the c-index suggests a no crisis condition when it is a crisis.

Second, we examine type II error by calculating the false crises ratio, which constitutes the inability of the c-index to indicate a no crisis condition. A false crisis is defined as a condition when the c-index indicates a crisis condition when there is no crisis. For both ratios, a lower ratio means a more robust model.

To calculate the above ratios, we set out to check whether the c-index is consistent with the databases prepared by Laeven & Valencia (LV) (2008; 2012) and Kaminsky & Reinhart (KR) (1999). If part of the c-index crisis episode is within the LV-KR crisis episode, it is then considered as a 'correct crisis episode'. If the c-index crisis episode is not available in the LV-KR crises database, it is considered as a 'false crisis episode'. If the LV-KR crisis episode is not available in the c-index, it is considered as a 'missing crisis episode'.

For example, if the c-index crisis episode is 1993-94 and the closest LV-KR crisis episode is 1993-95, then we conclude that the c-index's 1993-94 crisis episode is a 'correct crisis episode'. If there is no crisis episode in LV-KR around 1993-94, then we conclude that the c-index's 1993-94 crisis episode is a 'false crisis episode'. However, if the c-index did not indicate the LV-KR crisis episode of 1993-94, then we conclude that there is a 'missing crisis episode'. The signal categories and an example of the application of signal categories are shown in Table 3.6 and Table 3.7.

Table 3.6: Signal Categories

Crises	Identified in LV-KR	Not identified in LV-KR
Identified in the c-index	Correct crisis	False crisis
Not identified in the c-index	Missing crisis	

Source: adapted from Jing *et al.* (2015)

Table 3.7: An Application of the Signal Category Approach

C-Index	LV-KR	Category
	1989-90	Missing crisis episode
1993-94	1993-95	Correct crisis episode
2002-03		False crisis episode

Based on the specific signal categories, we are then able to calculate the 'ratio of missing crises episodes', which is defined as the total 'missing crises episodes' divided by the total 'crises episodes' of LV-KR. Similarly, this approach also enables us to calculate the 'ratio of false crises episodes', which is defined as the total 'false crises episodes' divided by the total 'episodes' ('correct crises episodes' + 'false crises episodes'). The robustness of different models considered is shown in Table 3.8.

Table 3.8: Robustness of the C-Index

C-Index	LV-KR	Refined
Episodes of crises in LV-KR	14	14
Episodes of missing crises	1	1
Episodes of false crises	2	0
Ratio of missing crises episodes	7%	7%
Ratio of false crises episodes	14%	0%
Accuracy to identify crises episodes	93%	93%
Accuracy to identify no crises episodes	86%	100%

On the one hand, we find that the model is sufficiently accurate to identify 93% of total twin crises (one missing crisis). As discussed previously, our dataset

may fail to capture the existence of international support of Thailand's government at the time, which increased the foreign reserve amid currency depreciation. This support also increased investors' confidence in money markets and led to a decrease in the interest rate amid the liquidity shortage. Thus, for future research, one should carefully assess the impact of international support on the financial market pressures. In doing so, one should exclude the amount of international supports from the international reserves owned by a country. Thus, the rise of international reserves (because of international supports) does not significantly reduce the pressure in the exchange market.

On the other hand, the model correctly determines 86% of 'no crises' episodes as the c-index wrongly identifies two crisis episodes (two false crises) which are not listed in Table 3.3. However, as discussed previously, we argue that these were actually 'correct crises episodes'. This is in line with other studies (Von Hagen & Ho, 2007; Reinhart & Rogoff, 2010), which suggest that there were banking and currency crises during those periods (hence, 'refined' column in Table 3.8). Thus, we claim that the c-index model correctly identifies 100% of 'no crises' episodes (no false crises).

3.8. Conclusions

Although there is a growing interest in the identification of the drivers of twin currency and banking crises, this area remains relatively unstudied. One reason behind the limited number of empirical studies on the twin crises is the lack of methods to pinpoint the dates of the crises. Currently, twin crises are identified by comparing the dates of currency and banking crises. While this method is complicated as it requires the identification of individual currency and banking crises, it fails to pinpoint the dates of twin crises.. As financial crises investigations depend on the accuracy of crisis determination, the ability to identify the dates of twin crises is critical for future research in this area. As different dates of crises may lead to different drivers of crises and different mitigation policies, to address

this issue, we aim to develop a mathematical method to identify twin crises, which can pinpoint the dates of twin crises.

To contribute to the development of a method to measure the dynamics of twin crises, first, we extend a mathematical model of Exchange Market Pressure into a mathematical model of Financial Market Pressure to explain the relationship between exchange market and money market and the economic activity. For practical purposes, we transform the FMP into a c-index to identify twin currency and banking.

Following the above technique, a crisis threshold is determined, by employing the loss function as per Jing *et al.* (2015). In addition, we conduct a robustness test (Jing *et al.,* 2015) to evaluate the reliability of our model.

We establish that the optimum crisis threshold is an index of 2.2. In addition, the simulations produced suggest that a lower threshold produces higher 'false crises' and lower 'missing crises'. However, a lower threshold may not always correspond with lower 'crises losses'. Prior to the optimum crisis threshold, a lower threshold may lead to higher 'crises losses'. However, after exceeding the optimum crisis threshold, the 'crises losses' go higher along with the increasing threshold. Thus, policymakers should carefully set the threshold on the optimum crisis threshold.

We find that the c-index can clearly identify twin crises in Latin American and East Asian countries, which are listed in Laeven & Valencia (2008, 2012) and Kaminsky & Reinhart (1999) financial crises databases. The findings imply that economists can now distinguish between the isolated currency or banking crises episodes and the twin crises episodes. For example, while existing twin crises databases argue that Argentina's twin crises span from 1985-1991, our model suggests that the twin crises were only in 1987 and 1989. Thus, the remaining years can be considered as isolated crises episodes. This is an essential feature of this model, as the inability to examine specific dates of twin crises has discouraged economists investigating the twin crises. Different dates of crises may lead to a different set of drivers and policy responses. Thus, twin crises are often examined as currency crises with banking crises as one of the drivers.

However, as is discussed in the previous chapter, in line with Kaminsky & Reinhart (1999), twin crises should be regarded as a unique type of crises, which are driven by a unique set of drivers and need to be addressed by different policy responses.

Furthermore, we have conducted a test to confirm that our results are robust. The model correctly determines 100% of the 'no crises' episodes (no false crisis). Thus, every crisis identified by the c-index is related to a crisis in the twin crises databases. This is an important feature of the model, as other approaches typically produce high 'false crises signals', which may lead policymakers to act unnecessarily and be affected by the consequences of 'mitigation costs'.

However, the model identifies 93% of total twin crises (one missing crisis), as it fails to identify Thailand's twin crises of the 1980s. One possible reason for this anomaly is the existence of international support of Thailand's government at the time, which increased the foreign reserve amid currency depreciation. While it is not captured in our dataset, this support also increased investors' confidence in money markets and led to a decrease in the interest rate amid the liquidity shortage. Therefore, for future research, one should carefully assess the impact of international support on the financial market pressures.

The findings also show that twin crises are dynamic, with pressure in financial markets moving from an index value of 0 to index value of 4 over time. Consequently, omitting these dynamics by using only a binary variable denoting 'crisis' or 'no crisis' may lead to an incomplete perspective on crises. This is, in fact, the main reason as to why binary models fail to deliver useful estimates (Berg & Pattilo, 1999).

As the c-index allows policymakers to capture the dates and the dynamics of twin crises, such an index should be investigated and developed further. However, due to the limitation of the PhD study, this thesis only aims to provide a tool to identify and predict currency and banking crises. By doing so, this thesis provides a foundation for more practical researches. Future research may include an in-depth study of the drivers of twin crises and the development of an early warning system of twin crises in an individual country, as each country has unique

characteristics. Furthermore, the ability to differentiate the various stages of twin crises may allow governments to become more efficient and effective in their policies to address particular financial market conditions.

In addition, the financial market pressure model suggests that there are significant benefits in considering a combined examination of currency and banking crises, rather than independently. As policymakers intervene in the other market, the exchange market or the money market seem stable amid high tension in the overall exchange and money market. Understanding these 'hidden crises' will be the key to future mitigation policy.

Finally, the Financial Market Pressure model indicates that central banks may calculate the foreign reserve and the liquidity required to achieve both the exchange rate and interest target simultaneously. This is an interesting feature of the model, which is worth investigating further. We leave these ideas for future research.

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Chapter 4 – Paper 3

PREDICTING CURRENCY AND BANKING CRISES USING THE C-INDEX

Abstract

This article focuses on the development of an early warning system to predict currency and banking crises. The absence of a consensus on how to define the crises may complicate the crises investigation. A crisis episode in one piece of literature may not be considered as a crisis episode in other literature. To address the issue, we divide the crises into four levels. We then measure the pressures in the exchange and money markets using the c-index. We demonstrate that the c-index may predict the probabilities of any given conditions to shift to a 'next crisis level' in the next two years. Using this approach, we can eliminate a need to specify a particular crisis threshold. The findings also suggest that regulators and investors are risk takers in the low-pressure periods and become *risk-averse* when the condition gets worse.

***JEL* Code:** C10; C51; G10; G15; G17

Keywords: early warning system, banking and currency crises, c-index

4.1 Introduction

Financial crises have been common phenomena for decades. In the last four decades, there were –at least- 147 widespread banking problems and 218 currency crises (Laeven & Valencia, 2012). While currency and banking crises were typically considered as isolated crises, the Asian financial crisis in the late 1990s sparked an interest in twin currency and banking crises (Kaminsky & Reinhart, The twin crises: the causes of banking and balance of payments problems, 1999).

Due to its periodic occurrence (Bicaba *et al.*, 2014) and its profound effect (Hutchinson & Noy, 2005), the study of financial crises has been a popular subject in the central bank study. Initially, economic literature studied financial and economic stabilities as two separate subjects. However, the global financial crisis of 2007-08 has shifted the perception of the relationship between financial and economic stabilities (Nasir *et al.,* 2015). Thus, there is a growing interest to understand the events as "two sides of the same coin" (Borio, 2011).

A particular focus of currency and banking crises literature is the prediction of the crises. Although it has been investigated for decades, there is still a high number of new studies concerning an early warning system for crises. This implies that the existing early warning system has poor forecasting power or is difficult to interpret (Berg & Pattillo, 1999; Edison, 2003; Peltonen, 2006).

One crucial issue in predicting currency and banking crises is the absence of a consensus on how to determine the crises (Goodhart, 2004; Sedghi-Khorasgani, 2010). As crises have various definitions and can be identified by different approaches, thus, there are various currency and banking crises databases. While many papers claim that they examined the same currency and banking crises, they may have investigated different dates regarding the crises. The literature suggests that different crises databases may significantly affect the

forecasting power of an early warning system (Comelli, 2016; Emin & Aytac, 2016).

The multiple crises databases also lead to another issue. Even though empirical investigation may provide significant forecasting ability, it is still difficult to interpret. The date of a crisis in a database may be considered as a normal time in another database or vice versa. Alternatively, a policymaker may aim to predict a lower crisis stage, while others may focus on the higher stage of the crisis.

To address the above issue, this article is driven by an overarching research question: *how can the dynamics of the twin currency and banking crises be predicted?*

To answer the above question, firstly, we divide the crises into four categories, crisis level 1 to level 4. This is an extension to a traditional crisis category, which typically divides the financial distress into two categories, crisis or no crisis. By dividing the crisis condition into four levels, to some extent, we address the absence of consensus on how to define a crisis. In doing so, we accommodate a different type of economists who prefer to have low crises threshold or higher crises threshold.

Second, we define a crisis prediction as an ability to calculate the probability of any given conditions to shift to a higher crisis level. This is different from the traditional approach which predicts the likelihood of a single level of crisis. As the traditional approach only satisfy a particular crises definition (e.g. crisis with a low threshold), our approach predicts the crises possibilities in any crisis levels.

The structure of the paper is as follows. The next section discusses the literature review. The third section describes the methodology and data. The fourth section covers findings and discussions. The fifth section concludes.

4.2 Literature Review

Despite the abundance of literature on currency and banking crises, there is still no consensus on how to determine currency and banking crises (Goodhart, 2004; Sedghi-Khorasgani, 2010). Currency and banking crises have various definitions and can be identified by different approaches. Thus, there are various currency and banking crises databases. As predicting currency and banking crises relies on the ability to specify the time of the crises, the different crises databases may significantly affect the forecasting power of the early warning system (Comelli, 2016; Emin & Aytac, 2016).

Currently, there are various methods to measure currency and banking crises. On the one hand, currency crises studies typically consider a mathematic approach to identify the crises. Initially, economists argue that high exchange rate depreciation is a sign of a currency crisis (Laeven & Valencia, 2012). However, central bank intervention may stabilise the currency amid high pressure in the exchange market. The intervention dries up the foreign reserve. When investors foresee that the central bank cannot sustain the intervention, they speculatively attack the currency. This is partly explained by the first-generation of currency crises model (Krugman, 1979).

As the foreign exchange interventions by central banks influence the exchange rate, thus, the exchange rate does not reflect the pressure in an exchange market. To address this issue, Girton & Roper (1977), extended further by Eichengreen *et al.* (1995), develop a mathematical model of the Exchange Market Pressure (EMP). According to the EMP framework, a currency crisis is reflected by currency depreciation and the extent of the central bank's intervention. Currently, the EMP has become the most popular method to identify currency crises.

On the other hand, there are also two popular methods to define banking crises. Traditionally, banking crises are identified by using an event approach.

Some economists argue that a banking crisis occurs when the banking system shows significant signs of financial distress (such as losses in the banking system, bank runs, bank liquidation) and the regulator significantly intervenes in the banking system in response to significant losses (Demirguc-Kunt & Detragiache, 1998; Laeven & Valencia, 2012).

As the event approach requires intensive qualitative judgement, thus, some economists argue that the method has a kind of methodological bias. Some economists (Goldstein *et al.,* 2000) argue that the event approach may identify the crises too early or too late. To address the issue, Von Hagen & Ho (2007) transform the ratio of central bank reserves to total bank deposits and short-term interest rate into a Money Market Pressure Index (MMPI). According to the MMPI, pressure on the money market should be reflected in the price of money, which is the interest rate. However, the central bank may conduct an expansionary policy to ease pressure on the money market. Thus, the interest rate may be stable amid high pressure on the money market. The MMPI has gained popularity in the aftermath of global financial crises as it can identity banking crises in both developed and emerging countries (Jing *et al.,* 2015). The MMPI also simplifies the procedure to examine the crisis, as it consists of only two variables. Nevertheless, the model can pinpoint the date of a banking crisis, a feature that cannot be provided by the event approach.

Despite the popularity of market pressure-based approaches (such as EMP or MMP), economists fail to agree on how to transform the Market Pressure Index into a crises database (Goodhart, 2004; Sedghi-Khorasgani, 2010). Some researchers employ various standard deviations as a crisis threshold, while others use various percentile points as the threshold. Furthermore, there is also disagreement on how to weight the variables. Due to this phenomenon, most currency and banking crises studies determine their own crises databases with different years of crises.

. The studies show that crisis definitions and threshold choices significantly affect the forecasting power of the *early warning system* models (Comelli, 2016; Emin & Aytac, 2016). In addition, Pontines & Siregar (2008) show that various

weighting methods in the market pressure-based models also lead to various crises databases. Nasir *et al.* (2015) suggest that many early warning studies focus on specifying the 'best' crisis threshold. Thus, there is an empirical bias, as economists may choose the threshold that produces the highest predictive power. While empirical studies claim that they investigate the similar financial crises, they might investigate different crises dates, which are driven by different variables.

For example, two economists have different dates of a crisis. One economist argues that the crisis was started in 1997, while the other suggests that the crisis was begun in 1999. The first economist examined the macroeconomics two years prior to 1997 to understand the drivers of crises of 1997. However, the other economist evaluated the macroeconomics two years prior to 1999, these would be the year of 1997 and 1998. Thus, both economists might conclude different drivers for the same crisis.

Currently, there are two popular approaches to investigate the drivers of currency and banking crises. The first one is a parametric approach, called the probit/logit regression (Frankel & Saravelos, 2012). The second one is a non-parametric approach, called the signalling approach (Kaminsky *et al.*, 1998). Both approaches are a binary model with dummy crisis or no crisis as the dependent variable and macroeconomic indicators as independent variables. Even though the above models are the most popular techniques to investigate currency and banking crises, the probit/logit model fails to provide a useful prediction (Berg & Pattilo, 1999) and the signalling approach is difficult to interpret (Edison, 2003).

The approaches to investigate the drivers of currency and banking crises typically assume that macroeconomic indicators are responsible for the occurrence of the crises. This is in line with the speculative currency attack model (Krugman, 1979) and the information-based bank run model (Jacklin & Bhattacharya, 1988).

However, that is not always the case. Some currency and banking crises occur in good economic conditions. Obstfeld (1986) and Diamond & Dybvig (1983) show that crises can be triggered by something random. When investors believe that there will be a crisis, they will be panic and start withdrawing their

fund from banks or buying foreign currency to protect themselves. Thus, the crisis is self-fulfilling.

The spill-over effect from other problem may also create currency and banking crises. On the one hand, when a bank has a liquidity problem, due to high interaction in the money market, the overall banking system may be crash (Rochet & Tirole, 1996). On the other hand, a banking crisis may also trigger a currency crisis and create twin crises (Kaminsky & Reinhart, 1999).

The randomness of the triggers of currency and banking crises may also be responsible for the weak prediction power of the probit/logit regression or the signalling approach.

Another issue on currency and banking crises is their relationship to economic crises. Some economists (Borio, 2011) argue that the financial crisis and economic crisis should be viewed as "two sides of the same coin". However, currency crises or banking crises often do not reflect the economic crises periods. The two crises are typically identified independently to each other, or to economic conditions.

Following the above literature review, thus, there is a need to enhance the approach to identify currency and banking crises that can reflect the economic condition, as well as an enhanced model to forecast currency and banking crises.

4.3 Methodology and Data

One possible explanation why currency and banking crises often do not reflect economic crises lies in how currency and banking crises are identified. While the economic crises should be reflected in the overall financial market, currency and banking crises are identified independently. Thus, each crisis only reflects a part of the financial market, either the exchange market (Eichengreen *et al.*, 1995) or the money market (Von Hagen & Ho, 2007). To address this issue, currency and banking crises should be investigated as twin currency and banking crises.

Investigating currency and banking crises as twin crises may also lead to the identification of 'hidden twin currency and banking crises'. The 'hidden' currency crises may not be reflected by the exchange rate depreciation as the central bank may intervene to stabilise the pressure in the exchange market. On the other hand, a 'hidden' banking crisis may not only be reflected by the demand of the central bank's reserve as the central bank may intervene to stabilise the pressure in the money market.

Furthermore, the twin crises model (Kaminsky & Reinhart, 1999) suggests that the exchange market and the money market have a strong relationship. Pressure on the money market may be eased by intervention on the exchange market or vice versa. Thus, economists may fail to identify 'hidden' disturbance in the financial market if they only measure one particular market. This might be the reason why the isolated currency or banking crises databases fail to mirror the business cycle.

One possible solution for this issue is to investigate the currency and banking crises as a twin crisis. This can be done by combining the exchange market pressure (EMP) and the money market pressure (MMP) model into the Financial Market Pressure (FMP). As the EMP can be measured by calculating the change in the exchange rate and the change in foreign reserve and the MMP is determined by calculating the change in interest rates and the change in money growth, thus, the FMP can be adopted by examining the above four variables.

To understand how the two models can be combined into a single model, let us recall the Exchange Market Pressure equation (Girton & Roper, 1977):

$$f_a + e_{ab} = -d_a - r_a + \Delta y_{a,b} + \Delta \pi_{a,b} + m_b + r_b \qquad (4.1)$$

where f_a is the change in foreign reserve in the domestic country, e_{ab} is the currency appreciation, d_a is money creation by domestic credit expansion in the domestic country, r_a is the change in interest rate in the domestic country , $\Delta y_{a,b}$ is real output growth differential between the domestic and a foreign countries, $\Delta \pi_{a,b}$ is inflation rate differential between the domestic and a foreign countries,

m_b is money growth in a foreign country, and r_b is the change in interest rate in a foreign country.

Girton & Roper (1977) argue that the above exchange market pressure equation is derived from monetary equilibrium, where the money supply is equal to the money demand. In addition, they add the interaction between two countries into the equation.

While the exchange market pressure model provides new insight into the relationship between the exchange market and other financial and macroeconomic variables, the model can be extended further. On the right-hand side of equation (4.1), we find domestic money market variables which are identified in the money market pressure (Von Hagen & Ho, 2007).

Extending the EMP model, we put money market variables ($d_a \text{and } r_a$) on the left-hand side. Thus, equation (4.1) can be represented as:

$$f_a + e_{ab} + d_a + r_a = \Delta y_{a,b} + \Delta \pi_{a,b} + m_b + r_b \quad (4.2)$$

We refer to $f_a + e_{ab} + d_a + r_a$ as Financial Market Pressure (FMP).

Even though the exchange market pressure and the money market pressure models were developed separately, we show that they can be combined into a financial market pressure model. In addition, the right-hand side of the FMP equation suggests that the pressure in the financial market should be reflected in macroeconomic condition. This is in line with Borio (2011), who views financial stability and economic stability as "two sides of the same coin".

While the FMP addresses a part of identification issues, there is still no consensus on how to identify a crisis using the FMP. The problem in a traditional binary 'crisis or no-crisis' approach is its failure to accommodate various 'crisis appetites' of policymakers. While some policymakers are risk-averse and require a lower crisis threshold, others are risk-takers and require a higher crisis threshold. For example, while some economists argue that we should examine the 'high crisis level', others prefer to evaluate a 'low crisis level'. As there are various crises databases in the literature, choosing a single threshold as the crises threshold may lead to empirical bias.

To address the 'crisis appetite' issue, we divide crises into four levels, crisis level 1 to crisis level 4. Each crisis level is then divided into 10 sub-level. In doing so, the data series is transformed into a standardised index from 0 to 4. The crisis *Level 1* condition is represented by the index values from 0.0 to 0.9, the crisis *Level 2* condition is shown by the index values from 1.0 to 1.9, the crisis *Level 3* condition is measured by the index values from 2.0 to 2.9, and the crisis *Level 4* condition is reflected by the index value from 3.0 to 4.0. The summary of the data transformation is shown in Table 4.1.

Table 4.1: Summary of Data Transformations

Heatmap	Value of Variable		Index Transformation	
	Min	**Max**	**Min**	**Max**
Level 1	Min	3%	0.0	0.9
Level 2	>3%	5%	1.0	1.9
Level 3	>5%	6%	2.0	2.9
Level 4	>6%	Max	3.0	4.0

To create the heatmap, thresholds of each category are defined. Based on the thresholds, each value in the data series is then grouped into four classes of the heatmap.

There is no consensus on how to define crises thresholds. Based on simulations, some economists may adjust the threshold to suit their preferences. Some economists may have a similar percentage range in each level, while other economists may argue that a higher crisis level should have a smaller percentage range. Some economists may also conduct simulations to find a preferable threshold. For example, an economist sets crisis level 2 threshold at 5% and then compares the results with the existing crisis databases. When he finds that the optimum crisis threshold is at index of 2.2, he may lower the threshold to 3% so the optimum crisis threshold is at index of 2.0 as he defines index of 2.0 as the threshold of crisis level 2.

In this paper, after some simulations, we define crisis level 1 as a condition when the percentage change of each variable is less than 3%. Furthermore, crisis level 2 is defined when the percentage change of each variable is between 3% and 5%. In addition, crisis level 3 is identified when the percentage change of each variable is between 5% and 6%. All percentage changes above 6% for each variable are defined as crisis level 4. This approach may solve the outlier issue, as all outliers will be transformed into indexes between 3 and 4.

For practical purposes, inspired by the Exchange Market Pressure Index (Eichengreen *et al.*, 1995) and the Money Market Pressure Index (Von Hagen & Ho, 2007), we transform the FMP into a c-index as follows:

$$c - index_t = \omega_1 f_t + \omega_2 e_t + +\omega_3 d_t + \omega_4 r_t \tag{4.3}$$

where f_t is the amount of intervention measured by the percentage change in foreign reserve, e_t is the currency depreciation, d_t is the percentage change in monetary-base-to-broad-money ratio, r_t is the rise in the interest rate, and ω is the weight of each variable so that no variable can significantly influence the c-index.

To transform the values in the data series into a standardised index from 0 to 4, the equation (4.3) is modified using the following formula:

$$\begin{aligned}
SVI = \ & \text{IF } value \leq 3\% && \text{THEN } \frac{Value - Min}{3\% - Min} + 0 \\
& \text{IF } 3\% < value \leq 5\% && \text{THEN } \frac{Value - 3\%}{5\% - 3\%} + 1 \\
& \text{IF } 5\% < value \leq 6\% && \text{THEN } \frac{Value - 5\%}{6\% - 5\%} + 2 \\
& \text{IF } value > 6\% && \text{THEN } \frac{Value - 6\%}{Max - 6\%} + 3
\end{aligned} \tag{4.4}$$

where *SVI* is the standardised variable index from 0 to 4 for each variable at time *t*, *Min* is the minimum value in the data series for each variable, and *Max* is the minimum value in the data series for each variable.

As all four variables are transformed into a standardised index, the c-index is then calculated using the following formula:

$$C\text{-}Index = (SVI_f + SVI_e + SVI_d + SVI_r) / 4 \quad (4.5)$$

where *f*, *e, d, r* represent the foreign reserve, exchange rate, money ratio, and interest rate, respectively.

Even though the four-category c-index heatmap approach may arguably provide more information than the two-category binary approach, focusing the investigation on a specific crisis level may still suffer from the database bias. Therefore, predicting a particular crisis level may not suit the various 'crises appetites' of policymakers.

For example, a policymaker may prefer to evaluate the probability of the occurrence of a crisis *Level 2*, while others may focus on examining the potential of a crisis *Level 3*. To address the issue, the early warning system should propose a method to provide a probability of 'any given conditions' to *shift* to a 'next crisis level' in a particular window period. As this approach examines any given conditions, it may accommodate various 'crises appetites' of the economists.

One possible approach to examine financial crises is to understand the cycles of the crises. In the aftermath of the financial crisis of 2008, there was a growing interest in the study of the financial cycle as the source of economic crisis (Ma & Zhang, 2016). In the financial cycle theory, a bust period is typically preceded by a boom period. As there is a pattern in the financial crisis cycle, thus, we argue that the current condition may have information on the likelihood of the future condition.

One way to predict the currency and banking crises is to develop a scoring system, such as the z-score (Altman, 1968). By calculating five variables into a z-score, Altman (1968) measures the probabilities that a firm will go into bankruptcy within two years. The prediction is determined by comparing the z-score with the real bankruptcy data.

Inspired by the z-score, we use the c-index to predict the probability of a crisis within two years. However, there should be some modification in the prediction technique, as the crisis is determined by the index itself. In doing so, we assume the c-index shows the presence of the financial cycle. We argue that

'any given index' in each crisis level should provide information on the *shifting probability* to the 'next crisis level' within two years. Using this approach, we can eliminate the need to specify a single crisis threshold. Thus, this technique may satisfy various crisis appetites of economists.

For analysis, we modify the signalling approach (Kaminsky *et al.,*1998) to test the prediction power of the c-index. We employ the c-index as a predictor of the *shift* to the 'next crisis level' within two years. In doing so, we define a *warning* as a condition when the c-index exceeds a threshold index. We also define a *shift* as a condition when the current crisis level *shifts* to the 'next crisis level' within two years after the *warnings*.

If a *warning* is followed by a *shift* within two years, we calculate a *correct shift*. However, if there is no *shift* in the window period following a *warning*, we identify a *false warning*. Furthermore, we measure a *missing shift* when a *shift* occurs without *warning* in the previous window period. The *warning* and *shift* classification is shown in Table 4.2.

Table 4.2: Warning and Shift Classifications

	There is a shift	**There is no shift**
There is a warning	Correct Shift (A)	False Warning (B)
There is no warning	Missing Shift (C)	Correctly no Warning (D)

For example, we examine the probability of a c-index of 0.5 (crisis *Level 1*) to shift to the crisis *Level 2* or above in the next two years. Firstly, we count a *warning* every time the c-index is equal or greater than 0.5. We then identify a *shift* as a condition when the crisis *Level 1* shifts to crisis *Level 2* or above within two years after the *warnings*. Furthermore, we calculate the total *shifts*, total *warnings*, *false warnings*, and *missing shifts*.

Based on the *warning* and *shift* classification, we calculate the probability of *missing shifts* (type I error) and the probability of *false warnings* (type II error) using the following formula:

$$PMS = \frac{number\ of\ missing\ shifts}{number\ of\ shifts} \quad (4.6)$$

$$PFW = \frac{number\ of\ false\ warnings}{number\ of\ warnings} \quad (4.7)$$

$$TE = \frac{PMS+PFW}{2} \quad (4.8)$$

$$SP = 100\% - TE \quad (4.9)$$

where *PMS* is the probability of *missing shifts*, *PFW* is the probability of *false warnings*, *TE* is the *total error*, and *SP* is the *shifting probability.*

For our investigation, we examine the yearly data from 80 countries from 1970 – 2016. However, due to data limitation, each country has a different time series. In addition, due to the model limitation, for Eurozone countries, we only examine the data prior to the Euro adoption.

4.4 Findings and Discussion

We calculate c-indexes from 80 countries spanning 1970-2016. The pressures in the exchange and money market are divided into four crises levels, which are level 1 to level 4. We then count the number of countries for each crisis level. Each crisis level is presented by ten c-indexes. For example, while the *Level 1* of crisis is reflected by c-index of 0.0 to 0.9, the *Level 2* of crisis is presented by c-index of 1.0 to 1.9.

Our calculation shows that there are 1089 crises *Level 2*, 391 crises *Level 3* and 42 crises *Level 4* during 1970 – 2016. Thus, depending on the 'crises appetite', economists may investigate a wide range of crises. While some economists may choose to investigate crises level 1, other economists may examine crises level 2 or level 3.

Furthermore, the findings suggest a much higher number of crises than existing databases. For example, IMF reported there were 158 currency crises and only 54 banking crises during 1980-1995 (Kaufman, 2000). As the c-index is a combination of currency and banking crises, one may assume that the number of crises should equal to the existing currency and banking crises. One possible reason for this discrepancy is differences in crises definitions, as various crises databases have different number of crises. Another explanation for the above variation is the presence of 'hidden currency and banking crises', which are not identified by isolated currency or banking crises approaches. One possible explanation of these 'hidden crises' is the presence of cross-market interventions by the central banks. When the central banks intervene in the exchange market and money market simultaneously, the pressure in a particular market is transferred to the other market. Thus, individually, each market may seem to have moderate pressure. However, in the overall exchange and money market, the pressure is high.

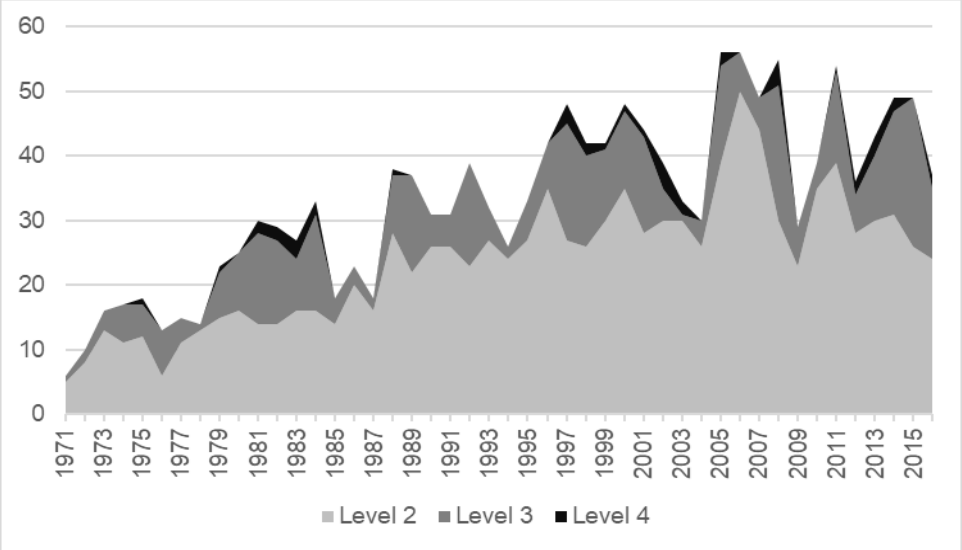
Our findings suggest that while the average number of crises Level 3 and crises Level 4 are relatively stable over the year, the average number of crises Level 2 in the last two decades is higher than in the 1980s, as shown in Table 4.3. This might be due to globalisation and a more integrated financial market (Mendoza & Quadrini, 2010). The failure to examine these 'hidden crises' and the globalisation effect might be the reason for recurring crises.

Table 4.3: Average Number of Twin Currency and Banking Crises per Year

	1980s	1990s	2000s	2010s
Level 2	18	27	34	30
Level 3	9	9	9	12
Level 4	1	1	1	1

The crisis *Level 2* (index of 1.0 - 1.9) dominates the world throughout these years. The findings show that the pressures in each country are very dynamic. As pressures typically spread simultaneously in several countries, the findings also imply a high correlation between economies as suggested by the financial market pressure model. The number of countries for each stage of pressure is shown in Figure 4.1.

Figure 4.1: Number of Countries for Each Stage of Pressure



We then examine the likelihood of 'any given conditions' to *shift* to the 'next crisis level' in the next two year using equation (4.6) to (4.9). In line with our hypothesis; the findings show that the *shifting probabilities* of 'any given conditions' become higher, along with the increasing c-index in each crisis level. The *shifting probabilities* of 'any given conditions' to the 'next crisis level' in the next two years is shown in Table 4.4.

We find that the predictive power of the c-index is exceptionally high. The model consistently predicts all future *shifts* to the 'next crisis level', with no single *missing shifts*. The high number of *correct shifts* indicates the presence of the financial cycle.

Furthermore, our findings show that *false warnings* in the crisis *Level 1* are very low, which suggests that the mitigation policy is less effective in this period. However, the number of *false warnings* heightens when the condition worsens (crisis *Level 2* and crisis *Level 3*), which implies that the mitigation policy is more effective in the higher-pressure periods.

The model shows that the probabilities of a *shift* from crisis *Level 1* to the next crisis level within two years are close to 100%. It implies that the crisis *Level 1* is very unstable and highly likely to shift to the next crisis level in the next two years. Despite lower *shifting probabilities* in the crisis *Level 2* and crisis *Level 3,* the findings suggest that the *shifting probabilities* in 'any given conditions' are still relatively high.

One possible explanation for this phenomenon is the *irrational exuberance* (Shiller, 2005) in the *lower pressure* period. The term "Irrational exuberance" is popularised by the then-Federal Reserve Board chairman, Alan Greenspan. The phrase is often interpreted as a warning about the over-heating economy that may lead to a crisis. This is triggered by over-optimistic that is not supported by fundamental.

While the economy is in a good state, both regulators and investors are encouraged to adopt an expansionary strategy and become risk-takers. In this period, the seeds of a boom period are planted. The condition may stimulate a higher pressure in the future. This is why the crisis *Level 1* is very likely to *shift* to a higher pressure within two years. Thus, the *irrational exuberance* is partly responsible for the low number of *false warning*s in the crisis *Level 1*. This situation is partly discussed in the Austrian business cycle theory (Macovei, 2015), the debt deflation theory (Shiller, 2013), and the financial instability hypothesis (Minsky, 1992).

Our simulations suggest that the crisis level 1 probability to shift the crisis level 2 or beyond is almost 100% when the index is less than 0.7, however, the probability becomes 100% when the index reaches 0.7.

Table 4.4: Shifting Probabilities in the Next Two Years

	C-Index	Probability of Missing Shifts	Probability of False Warnings	Shifting Probability to the Next Crisis Levels
Crisis Level 1	0.1	0.0%	0.6%	99.7%
	0.2	0.0%	0.6%	99.7%
	0.3	0.0%	0.6%	99.7%
	0.4	0.0%	0.6%	99.7%
	0.5	0.0%	0.6%	99.7%
	0.6	0.0%	0.4%	99.8%
	0.7	0.0%	0.1%	100.0%
	0.8	0.0%	0.1%	100.0%
	0.9	0.0%	0.1%	100.0%
Crisis Level 2	1.0	0.0%	32.3%	83.9%
	1.1	0.0%	30.9%	84.6%
	1.2	0.0%	27.8%	86.1%
	1.3	0.0%	23.3%	88.3%
	1.4	0.0%	20.8%	89.6%
	1.5	0.0%	19.3%	90.4%
	1.6	0.0%	17.4%	91.3%
	1.7	0.0%	16.1%	91.9%
	1.8	0.0%	14.8%	92.6%
	1.9	0.0%	10.3%	94.9%
Crisis Level 3	2.0	0%	81%	59.7%
	2.1	0.0%	76.9%	61.6%
	2.2	0.0%	76.3%	61.8%
	2.3	0.0%	74.5%	62.7%
	2.4	0.0%	72.1%	64.0%
	2.5	0.0%	69.2%	65.4%
	2.6	0.0%	65.7%	67.2%
	2.7	0.0%	58.4%	70.8%
	2.8	0.0%	42.0%	79.0%
	2.9	0.0%	22.2%	88.9%

Once the economy is under higher pressure, both regulators and investors become risk-averse. The result is a more effective policy to avoid a worse state

of the economy. This is why the number of *false warnings* is higher in the crisis *Level 2* and the crisis *Level 3*, as a sign of a more effective mitigation policy.

Our tests find that, when the index is less than 1.5, the shifting probability from crisis level 2 to crisis level 3 is around 80%. However, the shifting probability raises to more than 90% when the index reaches 1.5. Furthermore, the probability of crisis level 3 to shift to crisis level 4 is less than 70% when the index less than 2.7.

Despite a more effective policy under higher pressure conditions, the number of *false warnings* is still relatively low. It suggests that the financial crisis cycle is somehow difficult to avoid. This is partly due to the influence of external pressure in the open economy, as suggested by the financial market pressure model. Thus, it is essential to prepare a buffer for a potential crisis.

In addition, it is crucial for a policymaker to respond to the crisis as early as possible. The findings suggest that the success rate of a mitigation policy is higher at an early stage of pressure. At the crisis *Level 1*, when the index is 1.0, the policy effectiveness may reach 32.3%. However, it reduces to 10.3% when the index is 1.9. A similar condition also applies to the crisis *Level 2*. When the index is 2.0, the policy effectiveness is up to 80.5% and reduces to 22.2% when the index reaches 2.9.

4.5 Conclusions

For decades, banking and currency crises have haunted regulators and investors around the world. However, despite a high number of studies on predicting a financial crisis, the predictive power of an existing early warning system is quite weak (Berg & Pattillo, 1999). In addition, even though some early warning systems can provide higher predictive power, it is still hard to interpret (Edison, 2003; Peltonen, 2006).

There are, at least, two important issues in the study on currency and banking crises. On the one hand, there is no consensus on how to identify them. Thus, there are various banking and currency crises databases available. A crisis in one database may be acknowledged as a normal time in the other database. Crisis appetites of policymakers may also contribute to the variation of crises databases. Some policymakers may aim to predict a lower crisis stage, while others may focus on the higher stage of the crisis. The variation of crises databases may also lead to a bias, as economists may choose a database that produces the highest predictive power (Nasir *et al.,* 2015).

On the other hand, currency and banking crises often do not reflect the business cycles. While some economists (Borio, 2011) argue that financial crises and economic crises are two sides of the same coin, the financial crises and economic crises often occur in different time periods. As there is no consensus on how to define a crisis, predict a single crisis threshold may not satisfy some economists.

To address the above issues, we combine the exchange market pressure (EMP) model, which is typically employed to examine currency crises (Eichengreen *et al*., 1995), and the money market pressure (MMP) model, which is typically adopted to identify banking crises (Von Hagen & Ho, 2007), into a financial market pressure (FMP) model, which represents an overall pressure in the financial market. The FMP equation suggests that the pressure in the financial market reflects the pressure in the macroeconomic condition. This implies that the financial crises and the economic crises are indeed two sides of the same coin.

The FMP also allows us to identify ‘hidden crises’, which is a crisis that is failed to be identified by examining a single market. As the exchange market and the money market is highly correlated, policymakers may ease the pressure in the exchange market by conducting an intervention in money market, or vice versa. Thus, this will reduce the pressure in the exchange and increase the pressure in the money market. If we examine either the exchange or money market individually, we may find that the pressures in each market are only

moderate, thus, we conclude that there is no crisis. However, if we examine overall pressure in the financial market, we may find that there is high pressure in the market, thus, we conclude there is a crisis.

Furthermore, in line with previous market pressure-based studies, for practical purpose, we transform the FMP into a c-index. As a single crisis threshold may not satisfy various types of economists, we divide the crisis into four crisis categories, crisis level 1 to crisis level 4. Each crisis category is then divided into 10 sub-level of crises.

Focusing the investigation only on a particular level of crisis may compromise the ability of policymakers to respond to the crises. Thus, it is essential to examine all levels of the crises. Thus, differs from the typical crisis prediction approach, which only forecasts a single crisis level, we aim to calculate the probability of each crisis level.

In doing so, we assume that there is a financial crisis cycle in our c-index. Thus, any given c-index should provide information about the likelihood of future c-index within two years. In other words, we calculate the probability of 'any given conditions' to shift to a 'next crisis level' within two years in 80 countries. This is calculated by modifying the signalling approach (Kaminsky *et al.,* 1998),

We find the current c-index predicts all future shifts to the next crisis level within two years. This 100% accuracy suggests that the model has high predictive power.

However, we also find some false warnings at different crisis levels. These false warnings indicate an effective crisis mitigation policy. The findings suggest that a mitigation policy is less effective in lower crisis levels. However, when the crises become worse, the mitigation policy becomes more effective.

Furthermore, despite more effective mitigation policies in higher crisis levels, the findings suggest that the *shifting probabilities* in 'any given conditions' are still relatively high. This suggests that the financial crisis cycle is difficult to avoid.

One possible explanation for this phenomenon is a behaviour shift of regulators and investors on different conditions. In the crisis *Level 1*, the *irrational exuberance* may encourage the policymakers and investors to take a greater risk, which stimulates an economic boom. This may compromise the effectiveness of the policy and lead to higher market pressure in the future, thus, mitigation policies become less effective. However, when the state of the economy becomes worse, the regulators and investors may become risk-averse. This condition may lead to a more effective policy and reduce the pressure in the financial market.

As the mitigation policy is more effective in higher pressure conditions, the most severe crisis is the most difficult one to predict due to more effective mitigation policies. In addition, it is necessary for a policymaker to respond as early as possible. The findings suggest that the success rate of a mitigation policy is higher at an early stage of the crisis level.

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Chapter 5

THESIS CONCLUSIONS

5.1 Summary of Research Findings

Due to the periodical occurrence of financial crises, the relevant literature is very popular among economists. Despite an abundant size of literature on the currency and banking crisis, our understanding of twin crises is still limited. There are ongoing debates on whether banking crises precede currency crises. The twin crises model is considered the third generation of the currency crisis model as it views banking crises as the source for currency crises. While the literature suggests that banking crises often precede currency crises, there is evidence that currency crises may lead to banking crises. This is not clearly explained in the literature.

Furthermore, the dates of the twin crises are still difficult to identify due to the limitation of the existing technique. Currently, twin crises are identified by comparing the start dates of banking and currency crises. If banking crises are followed by currency crises in a particular window period, twin crises are identified. However, this method does not allow for the identification of the dates regarding twin crises, which is an essential ingredient in an empirical study of this nature. This might be the reason why most twin crises studies tend to theoretical or conceptual.

In addition, economists have difficulty in examining the risk of the crises as there is no consensus on how to define the crises. While some economists may focus their attention on very severe crises, other economists chose to investigate weaker forms of the crises. Thus, a crisis episode in one particular study may not be considered as a crisis episode in another one. As any given conditions can be considered as a crisis period, the prediction of the crises is difficult to interpret.

This thesis addresses the above issues in three papers. In the first paper, we examine twin currency and banking crises using the systematic literature review methodology. We find that banking and currency crises often share similar drivers, such as a lending boom and a real depreciation, and reinforce each other to create a spiral effect. However, empirical studies show that banking crises often precede currency crises (Kaminsky & Reinhart, 1999).

We find a potential bias on the above empirical studies, as there is no consensus on how to define the crises. The currency crises are typically identified using a mathematical based approach, such as the Exchange Market Pressure Based Index. On the other hand, banking crises are typically examined using an analytical based approach, such as the event method. As different approaches may lead to different dates of crises, thus, the choice of databases may affect the result of the investigation.

We re-examine the banking and currency crises databases using similar mathematical based approaches to minimise the bias. We then compare them to Kaminsky & Reinhart (1999) to check whether the findings are consistent. For the investigation, we employ the Exchange Market Pressure Index to determine the currency crises and the Money Market Pressure Index to identify the banking crises. In addition, we adopt a similar weighting method in both approaches to minimise the bias. In contrast to the existing literature, we find that currency crises often precede twin crises.

Furthermore, the twin crises model suggests that banking crises may trigger currency crises due to the bank's exposure on foreign liabilities. Extending this theory, we show that liquidity shortages and insolvencies in the banking system may also be responsible for the occurrence of twin crises. In addition, we argue that currency crises may lead to banking crises. Thus, twin crises should be examined as a two-way relationship. This extension is explained in the currency and banking (in)stability framework.

The framework implies that the exchange rate regime and foreign exchange intervention are not sufficient to avoid twin crises. The framework also shows that both banks, with or without foreign exchange exposure, are vulnerable

to twin crises. As the framework shows that crises are reflected by pressure on both exchange markets and money markets, we define twin crises as a condition in which significant pressures in the exchange markets create significant pressures in the money markets or vice versa.

In the second paper, we aim to contribute to the development of a method to identify the pressure dynamics of twin crises. Currently, twin crises are determined by comparing the start dates of banking and currency crises. If banking crises are followed by currency crises in a particular window period, twin crises are identified. However, this method could not pinpoint the dates of twin crises. As crises investigations depend on the accuracy of the crises determination, the ability to identify the date of twin crises is critical for future research in this area.

To address this issue, we combine the Exchange Market Pressure and the Money Market Pressure into the Financial Market Pressure model. In doing so, we extend the mathematical model of the Exchange Market Pressure (EMP) model into a Financial Market Pressure (FMP) model. For practical purposes, we transform the FMP into a four-category c-index to identify twin currency and banking crises. Following the above technique, a crisis threshold is determined, by employing the loss function as per Jing *et al.* (2015). In addition, we conduct a robustness test (Jing *et al.,* 2015) to evaluate the reliability of our model.

We find that the c-index can successfully identify twin crises in Latin American and East Asian countries, which are listed in Laeven & Valencia (2008, 2012) and Kaminsky & Reinhart (1999) financial crises databases. For example, based on the start date of the banking crises and the end date of the currency crises, existing twin crises databases indicate that Argentina's twin crises span from 1985-1991, our model suggests that the twin crises occurred only in 1987 and 1989. Thus, the remaining years can be considered as isolated banking or currency crises. This is an essential feature of this model, as the inability to examine the dates of the twin crises has made economists reluctant to investigate the twin crises.

Furthermore, we have conducted a test to confirm that our results are robust. The model correctly determines 100% of the 'no crisis' episodes (no false crisis). Thus, every crisis identified by the heatmap model is related to a crisis in the financial crises databases. This is an important feature of the model, as other approaches typically produce high 'false crises signals', which may cause policymakers to act unnecessarily and face the consequence of 'mitigation costs'.

The findings also show that twin crises are dynamics, with pressures in financial markets moving from an index value of 0 to index value of 4 over time. Thus, omitting these dynamics by using only a binary variable, denoting 'crisis' or 'no crisis', may lead to an incomplete perspective on crises. This is, in fact, the main reason why binary models fail to deliver useful estimates (Berg & Pattilo, 1999). Thus, the four-category c-index heatmap provides a critical extension to the literature, as it accommodates various crises appetites of policymakers to be examined.

Finally, in the third paper, we focus on the development of an early warning system to predict currency and banking crises. The absence of a consensus on how to define crises may complicate the crises investigation. While some economists argue that we should examine a 'high crisis level', others prefer to evaluate a 'low crisis level'. Thus, a crisis episode in one particular literature may not be considered as a crisis episode in the other literature. As there are various crises databases in the literature, choosing a particular threshold as the crises threshold may lead to empirical bias.

To address the issue, we divide the crises into four levels. We then predict the probability of 'any given conditions' to *shift* to the 'next crisis level' within two years. Using this approach, we can eliminate a need to specify a particular crisis threshold. Thus, this technique may satisfy various crises appetites of the economists.

We employ the c-index to predict currency and banking crises in 80 countries. According to the c-index specification, investigating isolated currency or banking crises may only partially explain the financial crises. Thus, it is essential to examine the crises as disturbances in both exchange and money

markets. By doing so, we may mirror the economic cycle with the financial crises. As the c-index shows the presence of the financial cycle, the c-index should reflect the current crisis level and the probability of future crises.

Employing the above technique, we find that pressures typically spread simultaneously in several countries, which suggest a high correlation between economies, as suggested by the financial market pressure model.

Our calculation shows a much higher number of crises than existing crises databases. This is partly due to the presence of 'hidden crises' in the literature. In addition, the investigation shows that there is a trending number of crises over time. This might be due to globalisation and a more integrated financial market (Mendoza & Quadrini, 2010). The failure to examine these 'hidden crises' and the globalisation effect might be the reason for recurring crises.

Furthermore, the findings suggest that there is a wide range of crises, depending on the 'crises appetites'. Thus, focusing the investigation only on a particular level of crises may compromise the ability of policymakers to respond to the crises. Thus, it is essential to examine all levels of crises.

Examining the probability of 'any given conditions' to *shift* to the 'next crisis level', we find that the predictive power of c-index is exceptionally high. The c-index consistently predicts all future *shifts* to the 'next crisis level', with no *missing shifts*. These findings imply the presence of the financial cycle.

The findings also suggest that the higher the pressures, the higher the number of *false warnings*. Thus, the findings indicate that higher crisis levels may lead to more effective mitigation policies. Despite the increasing number of *false warnings* in the higher crisis level, the overall number of *false warnings* is still relatively low.

The low number of *missing shifts* and *false warnings* indicate the presence of financial cycles and ineffective mitigation policies. The model shows that the probability of a *shift* from crisis *Level 1* to the next crisis level within two years is close to 100%. Despite lower *shifting probabilities* in the crisis *Level 2* and crisis

Level 3, the findings suggest that the *shifting probabilities* in 'any given conditions' are still relatively high.

One possible explanation for this phenomenon is a behaviour shift of regulators and investors on different conditions. In the low-pressure period, the irrational exuberance may encourage the policymakers and investors to take a higher risk, which stimulates an economic boom. This may compromise the effectiveness of policy and lead to higher market pressure in the future, thus triggering lower false warnings. However, when the state of the economy worsens, regulators and investors may become risk-averse. This condition may lead to a more effective policy and reduce the pressure in the financial market, thus creating higher false warnings.

As the mitigation policy is more effective in higher pressure conditions, thus, the most severe crisis is the most difficult one to predict due to higher false warnings (in other words, a successful mitigation policy). In addition, it is necessary for a policymaker to respond as early as possible. The findings suggest that the success rate of a mitigation policy is higher at an early stage of pressure.

5.2 Contribution to Knowledge

This thesis contributes to existing knowledge in several ways. First, it suggests that currency crises often precede banking crises. This is an important development to the existing literature.

One of the most crucial elements in the twin currency and banking crises studies is to identify the initial crisis that triggers the second crisis, as the model is heavily developed on this very assumption. Being influenced by the work of Kaminsky & Reinhart (1999) who find that banking crises often precede currency crises, twin crises literature typically views banking crises as the initial crises in the twin crises. Thus, twin crises are often regarded as currency crises which are

triggered by banking crises. This is known as the third generation of currency crises model.

On the one hand, the existing literature typically identifies currency crises using a mathematical method, known as the exchange market pressure index (EMPI). On the other hand, banking crises are typically determined by an analytical approach, known as the event approach. The analytical nature of the event approach often produces inconsistent dates of banking crises. Thus, there is a growing interest to identify banking crises using a mathematical method, known as money market pressure index (MMPI).

By employing the newest technique in the banking crises literature to minimise the bias, we show that currency crises often precede banking crises. This is an essential finding in the literature as it may shift our view of how the crises are developed and how they can be mitigated. By understanding an alternative view that currency crises may trigger banking crises, economists may find a new set of drivers of twin currency and banking crises, as well as new policies to mitigate the crises.

Second, based on the previous finding, we extend the literature into the currency and banking in(stability) framework. The framework suggests that currency and banking crises have a two-way relationship and the bank's liquidity shortages, liquidity mismatch and insolvencies are responsible for the occurrence of twin crises. Currently, the twin crises model suggests a one-way relationship from banking crises to currency crises due to a liquidity mismatch in the banking system.

In addition, the currency and banking (in)stability framework also addresses some of the key tenets of currency and banking literature, such as twin crises exposure on banks with no foreign liabilities (Bleaney et al., 2008), similar drivers and a vicious circle between currency and banking crises (Glick & Hutchison, 1999; Schnabel, 2004), bank's resilience to currency mismatch and bank's exposure on economic downturn (Sahminan, 2007), which are not explicitly addressed in the third generation of currency crises model.

Third, this thesis demonstrates that the dates of twin crises can be pinpointed by identifying twin crises using a mathematical model. This could be done by combining the exchange market pressure index and the money market pressure index into a c-index. Currently, the literature does not appear to provide a mechanism that enables the clear identification of twin crises, which constrains this field of enquiry.

The twin crises are determined by comparing the dates of currency and banking crises. However, this approach cannot pinpoint the actual dates of twin crises. Thus, even though some economists argue that twin crises are different from the isolated currency or banking crises (Kaminsky & Reinhart, 1999), due to this limitation, twin crises are often investigated as currency crises, with banking crises as one of the determinants.

Fourth, this thesis shows that all currency and banking crises should be examined as twin crises to obtain a comprehensive view of the pressure of the financial market. Failure to do so may lead to an inability to examine the 'hidden crises' and their contribution to the crises cycle. Furthermore, we suggest an alternative approach to examine the risk of crises by dividing the crises into four levels and examining the probability of any given condition to shift to the next level of crisis within two years.

Currently, the predictions of currency and banking crises are difficult to interpret, as there is no consensus on how to define them. A crisis according to one economist may be considered as no crisis by other economists. Thus, the main advantages of our approach are its ability to satisfy the various crises appetites of the economists, and its ease of interpretation.

5.3 Implications

In addition to the contribution to knowledge, this investigation also has some implications for practitioners, policymakers and academics.

First, the evidence that currency crises often precede banking crises may encourage economists to re-examine the previous twin crises episodes. For example, some literature argues that banking crises preceded the Asian crises of 1997 (Kaminsky & Reinhart, 1999); however, we show that currency crises are in fact the source of the twin crises. This new evidence may inspire economists to reconstruct what happened in the Asian crises of 1997 and may lead to new policy recommendations on how to mitigate future currency and banking crises.

Furthermore, the currency and banking (in)stability framework, which suggests a two-way relationship between currency and banking crises, may have several implications. It may encourage the development of the fourth generation of the banking crises model, which views currency crises as the source of banking crises. On the other hand, if we consider twin crises as a distinct type (Kaminsky & Reinhart, 1999), we would expect a growing interest in their study due to the new ability to clearly identify the dates of those crises amid their growing number in recent years.

Alternatively, economists may be tempted to recognise all currency and banking crises as twin crises, due to their close relationship, as suggested by the financial market pressure model. This idea may change our understanding of the financial crises. Not only will it lead to the development of a new field of study, but may also lead to the identification of 'hidden crises', which are largely ignored in the literature. In addition, it may also change central banks' policy formulations on how to mitigate currency and banking crises, which are often formulated in two separate departments.

Our approach to examine the risk of crises may also reduce the risk appetites bias. As there is no consensus on how to define the crises, a crisis prediction is difficult to interpret. A crisis period by an economist may be considered as a normal time by others. Thus, our technique, which divides the crises into four levels and examines the probability of any given condition to shift to the next crisis level within two years, may satisfy various crises appetites. In addition, the c-index is easy to interpret as each index has a standard conversion

probability table. Thus, economists may easily understand the probability of shifting by reading the current index.

Finally, the c-index also allows investors and policymakers to examine different stages of pressure in the financial market. In addition, the ability of the c-index to predict the likelihood of a condition to shift to the next crisis level is essential for investors and policymakers to be able to evaluate their risk profile. Thus, the investors may employ a better investment strategy, and the policymakers may set a better policy for each particular crisis level.

5.4 Dissemination

To ensure the study reaches fellow researchers, practitioners and policymakers alike, the papers in this thesis have been presented on various occasions. Each one has been presented in three Doctoral Colloquia at Cranfield School of Management. These events were attended by academics and PhD students from various departments in the Cranfield School of Management. Thus, this thesis has benefitted from feedback in various fields of literature.

The position study, which is presented in the thesis introduction chapter, was presented at the International Academic Conference on Social Science in Barcelona, Spain. The discussions from this conference have shaped the development of the currency and banking (in)stability framework in Paper 1.

Paper 1 was presented at the Annual Global Finance Conference in New York, USA. While the discussions in the conference have contributed greatly to this paper, the conference has also motivated the writing of Paper 3. The development of the c-index has been inspired by the z-score of Prof Altman who was the keynote speaker at the conference. While the z-score is employed to predict the bankruptcy of enterprises by comparing the z-score and the bankruptcy data, we cannot do that in the crises study as the crises is determined by the score/index itself. That is why we divide the crises into four levels and compare the c-index with the next level of crisis.

Paper 2 was presented at the European Economics and Finance Society Annual Conference in Ljubljana, Slovenia. At this conference, we were invited to submit the paper using a fast track system in the Scottish Journal of Political Economy. After a refereeing process, one referee has accepted the paper, the other referee has requested a 'revise and resubmit'.

5.5 Limitations

Despite enriching knowledge regarding the twin crises, this investigation is subject to some limitations. As Paper 2 is based only on a sample of East Asian and Latin American countries, caution should be exercised when generalising the findings and conclusions of the study. Thus, it would be interesting to widen the scope of the investigation to discover if the findings are consistent in other countries.

Furthermore, the Financial Market Pressure model may be difficult to employ in single monetary union countries, such as the Eurozone, as it is challenging to examine individual countries' exchange rates and interest rates. Thus, some adjustments should be applied to these particular countries.

This thesis focuses on the development of techniques to identify and predict twin currency and banking crises; however, it does not investigate the drivers of those crises. Thus, further research should be conducted based on these techniques.

Finally, while this thesis offers a new paradigm on the currency and banking crises relationship, by showing that currency crises may trigger banking crises, it does not offer explanations for what happened to the specific twin crises (i.e. the Asian crises of 1997). Thus, economists may use this thesis as a foundation for future research.

5.6 Avenues for Future Research

A first research avenue would be to complement the findings of this study by investigating the drivers of twin currency and banking crises. Using the c-index to create a new crises database, which can show 'hidden crises' and clear dates of crises, economists may investigate potential new drivers to understand how those drivers are translated into crises. This study should aim to advance our understanding of the nature of financial crises and how to manage them.

The second line of enquiry that arises initially out of this work is to investigate the Financial Market Pressure in the monetary study. This thesis shows that the relationship between exchange rates and interest rates and inflation is not as simple as suggested by the International Fisher Effect or the Covered Interest Rate Parity. Therefore, central banks may have a clearer view on how to formulate their policies, by understanding how external factors, such as inflation rate, output gap, interest rate and money supply from other countries, affect domestic output and the inflation rate. By doing so, central banks may have a clearer view on deciding when to raise interest rates to address currency depreciation. By doing so, this research may provide insight into the debate between the supporters of Inflation Targeting Framework (ITF), who argue that central banks should focus on the interest rate as their main operational target, and supporters of Flexible ITF, who advocate central banks to target the interest rate and exchange rate.

The third extension of this thesis is in the financial market study, especially to solve the forward bias puzzle (Müller, 2011; Sinha *et al.,* 2017). The covered interest parity theory suggests that the forward rate should be equal to the interest rate differential between two currencies. In addition, the efficient market hypothesis argues that the forward rate should be equal to the future spot rate. However, the study suggests that the deviation between the forward rate and the actual 'future' spot rate, hence, the forward bias puzzle. The FMP shows that, while the interest rate differential has an essential role in defining the forward rate,

the future spot rate is also influenced by central bank intervention and the change in external factors differential between two countries. This insight may be useful to solve the puzzle.

5.7 Other Works

During the PhD programme, I have published some articles which are not related to the thesis to help me develop my critical thinking, writing skills, and wider exposure to financial matters.

In 2017, I had a a book chapter “Public-Private Partnership in Indonesia published: The Regulatory Environment, Progress to Date and Lessons Learned. This publication is co-authored by Prof Figueira of Cranfield University and Dr Caselli of University of Cambridge.

In 2018, I had an article “Monetary integration in the ASEAN Economic Community challenge published: the role of the exchange rate on inflation in Indonesia” in the International Journal of Services Technology and Management 24(5/6). This article is co-authored by Mr Lubis of Bank Indonesia.

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