Financial Contagion and Contagion Channels in the Forex Market: A New Approach via the Dynamic Mixture Copula-extreme Value Theory

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Abstract

This paper presents the new approaches to the study of financial contagion and contagion channels in the forex market by using a dynamic mixture copula-extreme value theory (DMC-EVT) model. This method allows us to elucidate the complex and dynamic dependence between forex markets. By analysing 39 currencies that are actively traded on the forex market during the period 2005–2009, our empirical study shows that the DMC-EVT model outperforms the alternative copula models. Furthermore, we confirm the existence of financial contagion in the forex market during the 2007–2009 global financial crisis, and find that wealth constraints are the contagion channel during the crisis. Our results provide important insights on portfolio and risk management.

Keywords: Financial Contagion, Foreign Exchange, Forex Market, Dynamic Mixture Copula-extreme Value Theory

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1. Introduction

The past 30 years have been marked by several financial crises in both developing and developed economies; these include the 1994 Mexican peso collapse, the 1997 Asian financial crisis, and the 2007–2009 global financial crisis (GFC). A typical feature of these crises is that they can spread rapidly from one market to another. This financial feature is generally referred to as 'financial contagion', which is recognized as a threat to economic stability. For instance, the GFC originated in the U.S. subprime mortgage market, spread rapidly across global financial markets on an unprecedented scale, caused worldwide financial disasters, and ultimately resulted in financial system

collapse and social unrest (Bekaert et al., 2014). This financial crisis, along with many others, has motivated a large number of financial risk managers, international investors, and scholars to investigate how and why financial contagion occurs, and what actions can be taken to mitigate risk from the crisis source country. Therefore, investigating financial contagion and its mechanism is a core topic in the study of international finance.

Financial contagion appears to prevail in financial markets and a natural stream of research focuses on the contagion mechanism of financial crises. By understanding the contagion mechanism, investors and risk managers can make appropriate decisions to hedge against market downturns and mitigate risk from the source country. Contagion channels can be roughly divided into two categories: fundamental-induced channels, such as international trade and foreign direct investment; and investor-induced channels.

Compared with other financial markets, the forex market has several unique and important features that prompt the study of financial contagion in that context. First, unlike other financial markets, the forex market is non-centralized, with no central trading location, and traders can find competing rates from dealers globally. Second, the forex market operates 24 h a day, and trading's occur in a synchronous manner. As a result, the transmission mechanism of financial crises in the forex market may differ from that in other financial markets. Third, the forex market has the largest trading volume and liquidity among all financial markets, so it can directly or indirectly influence other financial markets. Lastly, the forex market connects a country's economy and trade with those of other countries. All in all, the forex market affects the balance of international payments and the development of the domestic real economy, and thus it plays a vital role in national security and social stability.

To our knowledge, the literature on financial contagion in the forex market is relatively scarce. There are different approaches to confirm the existence of financial contagion in the forex market. By developing an econometric methodology, Fundamental-induced contagion in the forex market exists, especially in European countries. The Google search volume index as a proxy for investor attention, and show that investors induced the financial contagion in the forex market. However, the authors did not investigate whether the investor-induced contagion was caused by wealth constraints or portfolio rebalancing behaviour. This paper aims to fill this gap by proposing a new approach using a dynamic mixture copula-extreme value theory (DMC-EVT) model to systematically study financial contagion and its contagion channels in the forex market.

The literature contains various definitions of financial contagion of which is the most popular. By their definition, financial contagion is present if a statistically significant increase is observed in cross-market correlation after the occurrence of extreme shocks. Using this definition, many empirical methods have been employed to identify the existence of financial contagion. However, correlation cannot capture the nonlinear dependence that is usually observed between markets. To overcome this, instead of

correlation, several recent studies have measured financial contagion based on the dependence between financial markets.

2. Financial contagion and contagion channels

A contagion is the spread of an economic crisis from one market or region to another and can occur at both a domestic or international level. Contagion can occur because many of the same goods and services, especially labour and capital goods, can be used across many different markets and because virtually all markets are connected through monetary and financial systems.

The real and nominal interconnections of markets can act as a buffer for the economy against economic shocks, or as a mechanism to propagate and even magnify shocks. The latter case is typically what economists and other commentators refer to as contagion, with a negative connotation likening the effect to the spread of a disease.

Contagions are typically associated with the diffusion of economic crises throughout a market, asset class, or geographic region; a similar effect can occur with the diffusion of economic booms. Contagions occur both globally and domestically, but they have become more prominent phenomena as the global economy has grown, economies within certain geographic regions have become more connected to one another, and economies have become more financialized.

Usually associated with financial crises, contagions can be manifested as negative externalities diffuse from one crashing market to another. In a domestic market, it can occur if one large bank sells most of its assets quickly and confidence in other large banks drops accordingly. In principle, the same process occurs when international markets crash, with cross-border investment and trade contributing to a domino effect of closely correlated regional currencies, as in the 1997 crisis when the Thai baht collapsed.

This watershed moment, the roots of which lay in gross excess of dollar-denominated debt in the region, quickly spread to nearby East Asian countries, resulting in widespread currency and market crises in the region. The fallout from the crisis also struck emerging markets in Latin America and Eastern Europe, which is indicative of the capacity of contagions to spread quickly beyond regional markets.

2.1 Financial Contagion Fundamentals

The term was first coined during the 1997 Asian financial markets crisis, but the phenomenon had been functionally evident much earlier. The global Great Depression, triggered by the 1929 U.S. stock market crash, remains an especially striking example of the effects of contagion in a heavily indebted, economically integrated global economy.

Financial contagion refers to "the spread of market disturbances – mostly on the downside – from one country to the other, a process observed through co-movements in exchange rates, stock prices, sovereign spreads, and capital flows".[1] Financial

contagion can be a potential risk for countries who are trying to integrate their financial system with international financial markets and institutions. It helps explain an economic crisis extending across neighbouring countries, or even regions.

Financial contagion happens at both the international level and the domestic level. At the domestic level, usually the failure of a domestic bank or financial intermediary triggers transmission when it defaults on interbank liabilities and sells assets in a fire sale, thereby undermining confidence in similar banks. An example of this phenomenon is the subsequent turmoil in the United States financial markets.[2] International financial contagion, which happens in both advanced economies and developing economies, is the transmission of financial crisis across financial markets for direct or indirect economies. However, under today's financial system, with the large volume of cash flow, such as hedge fund and cross-regional operation of large banks, financial contagion usually happens simultaneously both among domestic institutions and across countries. The cause of financial contagion usually is beyond the explanation of real economy, such as the bilateral trade volume.[3]

The term financial contagion has created controversy throughout the past years. Some argue that strong linkages between countries are not necessarily financial contagion, and that financial contagion should be defined as an increase in cross-market linkages after a shock to one country, which is very hard to figure out by both theoretical model and empirical work. Also, some scholars argue that there is actually no contagion at all, just a high level of market co-movement in all periods, which is market "interdependence".[4]

More generally, there is controversy surrounding the usefulness of "contagion" as a metaphor to describe the "catchiness" of social phenomena, as well as debate about the application of context-specific models and concepts from biomedicine and epidemiology to explain the diffusion of perturbations within financial systems, see Figure 1.[5]
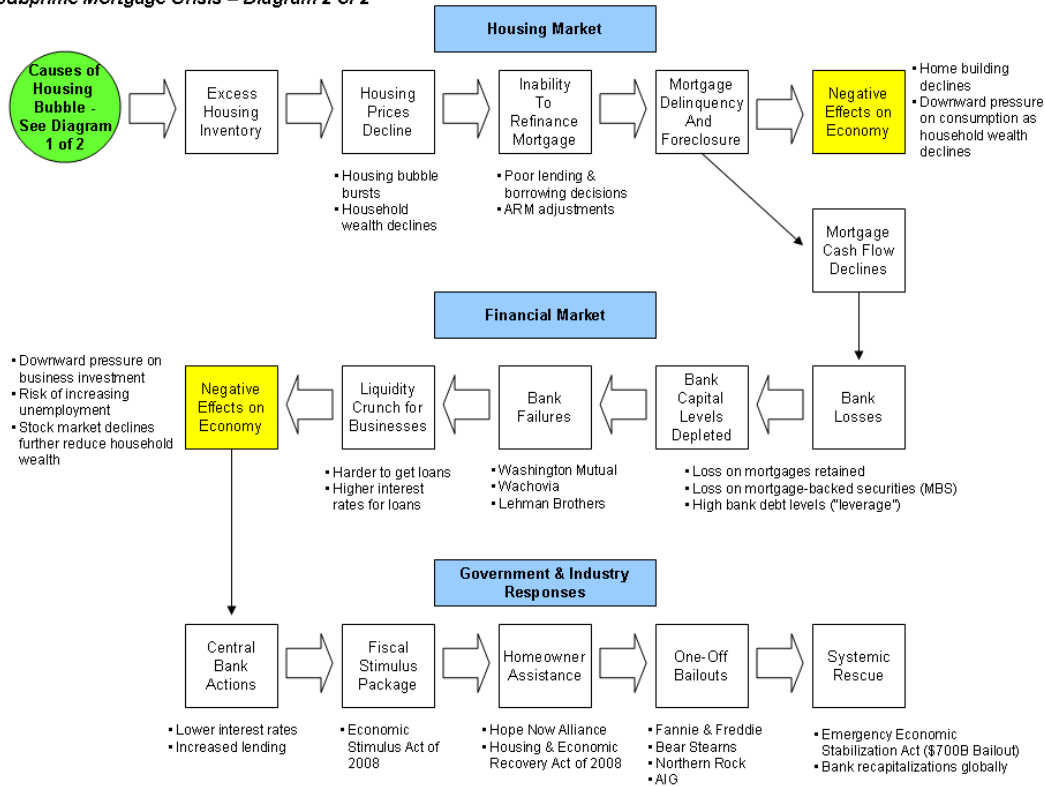
Figure 1 Financial Contagion Fundamentals Crisis Diagram

After the Asian financial crisis, scholars started to investigate how previous financial crises spread across national borders, and they concluded that the "nineteenth-century had periodic international financial crises in virtually every decade since 1825."

In that year, a banking crisis that originated in London spread to the rest of Europe and eventually Latin America. In a pattern that has been repeated ever since, the roots of the crisis were in the expansion of debt through the global financial system.

After much of Latin America had been liberated from Spain in the early part of the 19th century, speculators in Europe poured credit into the continent. Investment in Latin America became a speculative bubble and, in 1825, the Bank of England (BoE), fearing massive gold outflows, raised its discount rate, which in turn sparked a stock market crash. The ensuing panic spread to continental Europe.

2.2 Makes Economies More Susceptible to Contagion

When markets are robust and flexible, the effects of a negative economic shock to one market can be spread out across many related markets in a way that reduces the impact of participants in any one market. Imagine dropping a steel ball bearing onto a trampoline. The impact gets spread out by the interwoven threads of the trampoline and

dampened by the springs to which it is attached, without causing damage to the material.

On the other hand, when markets are fragile or rigid, a strong enough negative shock in one market can not only cause that market to fail, but spread serious damage to other markets, and perhaps the entire economy. In this case, imagine dropping the same steel ball bearing onto a large pane of window glass, see Figure 2. It can not only break the glass at the point of impact but spread cracks or even shatter the entire window. This is what happens in an economic contagion, where a large shock to one market spreads cracks or shatters an entire economy.
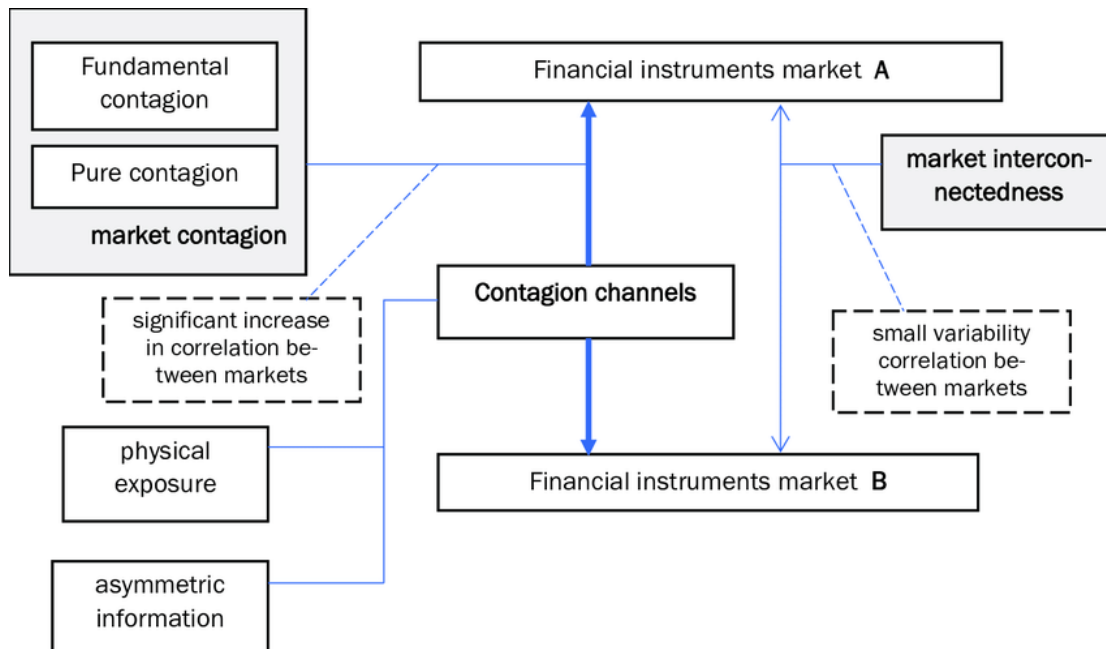

Figure 2 Contagion in The Financial Instruments Market

This means that the major factor driving economic contagion between markets is the robustness (or fragility) and flexibility of those markets. Markets that are heavily dependent on debt; where participants are dependent on some specific commodity or other input; or where conditions prevent the smooth adjustment of prices and quantities, entry and exit of participants, and adjustments to business models or operations will be more fragile and less flexible.

The more fragile and inflexible any given market is, the more it will suffer from a negative shock. Moreover, the more fragile and inflexible markets are in general, the more likely that a negative shock in one market will develop into a contagion between markets.

Beyond the robustness (or fragility) of the individual markets themselves, the scale and intensity of connections between different markets also matters. Markets that are

not, or are only weakly, interconnected to one another will not transmit shocks among one another as effectively, see Figure 3.
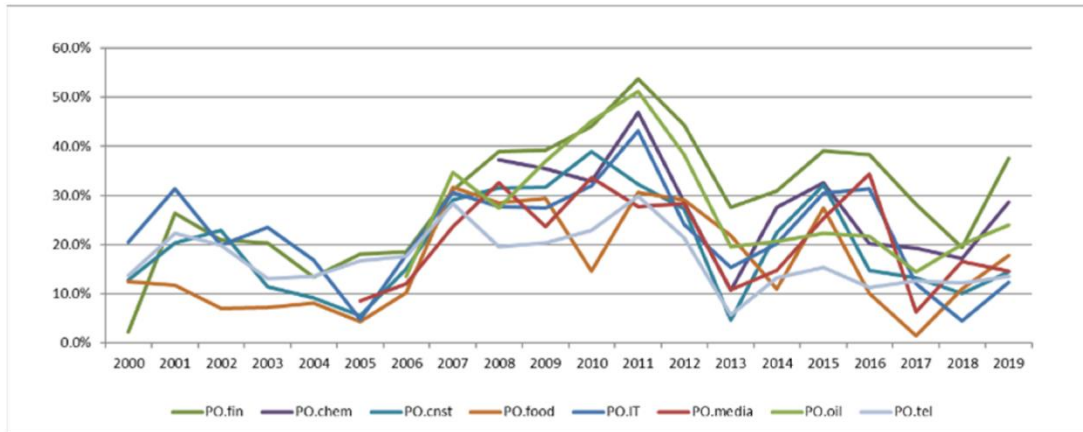

Figure 3 Financial Contagion Patterns in Individual Economic Sectors

Using the analogy from above, imagine dropping a steel ball bearing onto a dozen eggs. It will completely shatter one or two eggs, but leave the rest completely unscathed. This is a double-edged sword, however; avoiding interconnection among markets also means reducing the size and scope of the division of labour across an economy and the resulting gains from trade.

3. Forex and financial contagion and contagion channels, causes and consequences

Financial contagion can create financial volatility and can seriously damage the economy and financial systems of countries. There are several branches of classifications that explain the mechanism of financial contagion, which are spillover effects and financial crisis that are caused by the influence of the four agents' behavior. The four agents that influence financial globalization are governments, financial institutions, investors, and borrowers.[6]

The first branch, spill-over effects, can be seen as the negative externalities. Spillover effects is also known as fundamental-based contagion.[1] These effects can happen either globally, heavily affecting many countries in the world, or regionally, affecting only neighboring countries. The big players, who are more of the larger countries, usually have a global effect. The smaller countries are the players who usually have a regional effect. "These forms of co-movements would not normally constitute contagion, but if they occur during a period of crisis and their effect is adverse, they may be expressed as contagion."[1]

"Fundamental causes of contagion include macroeconomic shocks that have repercussions on an international scale and local shocks transmitted through trade links,

competitive devaluations, and financial links."[1] It can lead to some co-movements in capital flows and asset prices. Common shocks can be similar to the effects of financial links. "A financial crisis in one country can lead to direct financial effects, including reductions in trade credits, foreign direct investment, and other capital flows abroad."[1] Financial links come from financial globalization since countries try to be more economically integrated with global financial markets. Allen and Gale (2000),[7] and Lagunoff and Schreft (2001) [8] analyse financial contagion as a result of linkages among financial intermediaries. The former provides a general equilibrium model to explain a small liquidity preference shock in one region can spread by contagion throughout the economy and the possibility of contagion depends strongly on the completeness of the structure of interregional claims, as shows in Figure 4. The latter proposed a dynamic stochastic game-theoretic model of financial fragility, through which they explain interrelated portfolios and payment commitments forge financial linkages among agents and thus make two related types of the financial crisis can occur in response.
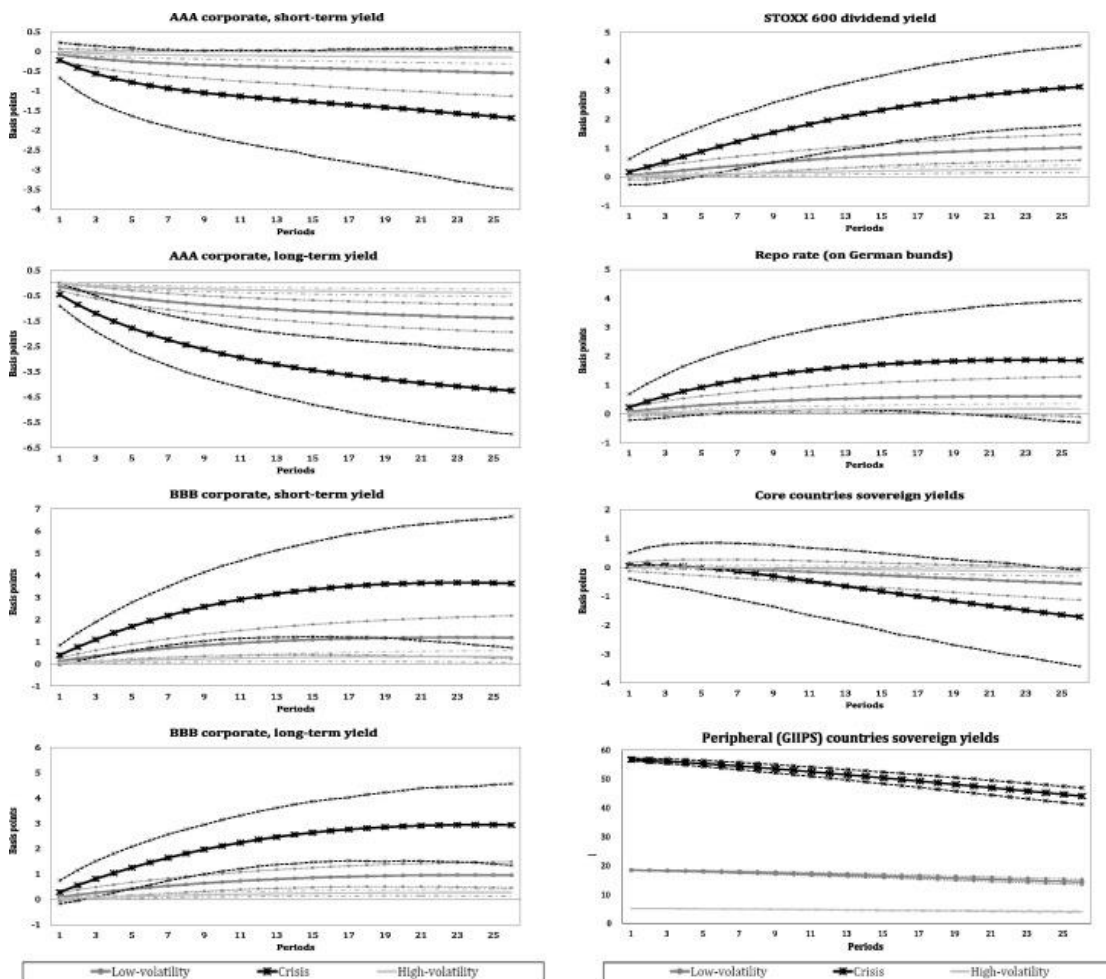
Figure 4 Identifying and measuring the contagion channels at work in financial crises

Trade links is another type of shock that has its similarities to common shocks and financial links. These types of shocks are more focused on its integration causing local impacts. "Any major trading partner of a country in which a financial crisis has induced a sharp current depreciation could experience declining asset prices and large capital outflows or could become the target of a speculative attack as investors anticipate a decline in exports to the crisis country and hence a deterioration in the trade account."[1] Kaminsky and Reinhart (2000)[9] document the evidence that trade links in goods and services and exposure to a common creditor can explain earlier crises clusters, not only the debt crisis of the early 1980s and 1990s, but also the observed historical pattern of contagion.

Competitive devaluation is also associated with financial contagion. Competitive devaluation, which is also known as a currency war, is when multiple countries compete against one another to gain a competitive advantage by having low exchange rates for their currency. "Devaluation in a country hit by a crisis reduces the export competitiveness of the countries with which it competes in third markets, putting pressure on the currencies of other countries; especially when those currencies do not float freely."[1] This action causes countries to act irrationally due to fear and doubt. "If market participants expect that a currency crisis will lead to a game of competitive devaluation, they will naturally sell their holdings of securities of other countries, curtail their lending, or refuse to roll over short-term loans to borrowers in those countries."[1]

Another branch of contagion is a financial crisis, which is also referred to irrational phenomena. A financial crisis as a branch of contagion is formed when "a co-movement occurs, even when there are no global shocks and interdependence and fundamentals are not factors."[1] It is caused by any of the four agents' behaviours who influence financial globalization. Some examples that can cause contagion are increased risk aversion, see Figure 5, lack of confidence, and financial fears. Under the correlated information channel, price changes in one market are perceived as having implications for the values of assets in other markets, causing their prices to change as well (King and Wadhwani (1990)).[10] Also, Calvo (2004) argues for correlated liquidity shock channel meaning that when some market participants need to liquidate and withdraw some of their assets to obtain cash, perhaps after experiencing an unexpected loss in another country and need to restore capital adequacy ratios.[11] This behaviour will effectively transmit the shock.
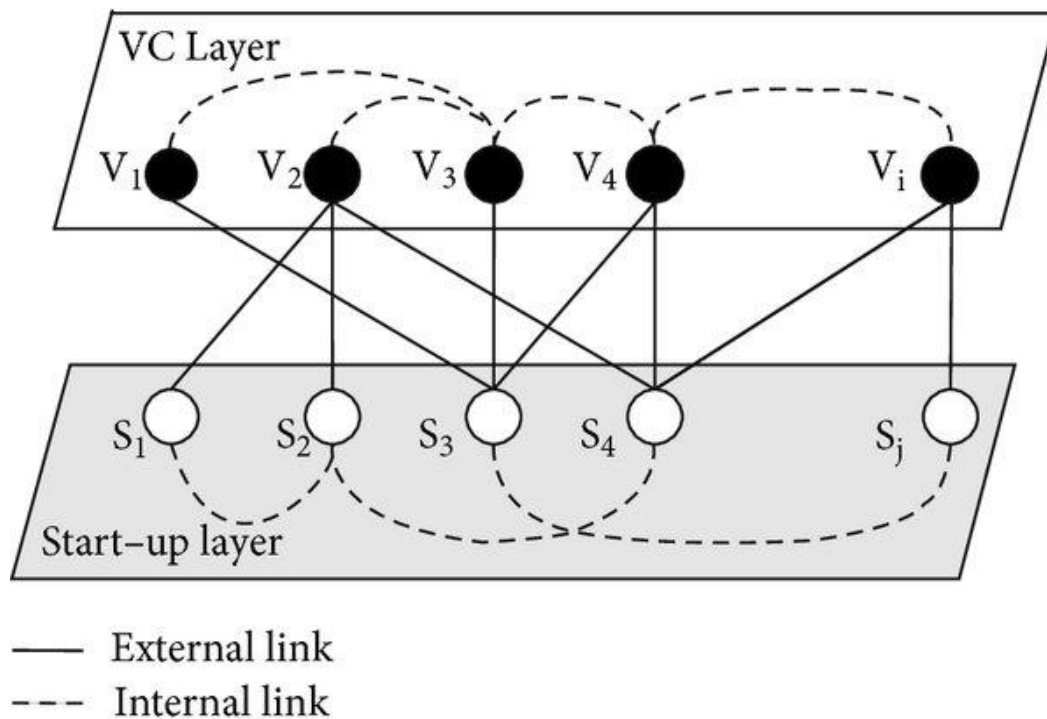
Figure 5 A Multilayer Network to Represent the Risk Contagion Channels

Out of the four agents, an investor's behaviour seems to be one of the biggest one that can impact a country's financial system.[1] There are three different types of investor behaviours, which generally are considered rational or irrational and individually or collectively.

The first type of behaviour is when "investors take action that is ex-ante individually rational but lead to excessive co-movements – excessive in the sense that they cannot be explained by real fundamentals."[1] It breaks down into two sub-categories, liquidity and incentive problems and information asymmetries and coordination problems. The first sub-category is liquidity and incentive problems. A reduction of equity prices can result in a loss of money for investors. "These losses may induce investors to sell off securities in other markets to raise cash in anticipation of a higher frequency of redemptions."[1] These liquidity problems are also challenges for banks, specifically commercial banks. Incentive problems can also have the same effects as liquidity problems.

For instance, the first signs of a crisis may cause investors to sell their holdings in some countries, resulting in equity and different asset markets in economies to decline in value. This causes the value of currencies in these economies to also decrease. The second sub-category is information asymmetries and coordination problems. This type of investor behaviour can either be considered rational or irrational. This sub-category is when one group, or country, has more or significantly better information compared to another group or country. This can cause a market failure problem, which could potentially cause a financial crisis.

The second type of investor behaviour concentrates on multiple equilibriums. It focuses on the investor's behavioural changes when the financial market can have multiple equilibrium changes. Thus, "contagion occurs when a crisis in one financial market causes another financial market to move or jump to a bad equilibrium, characterized by a devaluation, a drop in asset prices, capital outflows, or debt default."[1] The third type of behaviour is when there is a change in the international financial system, or in the rules of the game. It can make investors adjust their behaviours after a financial transaction occurs internationally or an initial crisis occurs. These behaviours can lead to spill over effect, causing contagion.

In addition, there are some less-developed explanations for financial contagion. Some explanations for financial contagion, especially after the Russian default in 1998, are based on changes in investor "psychology", "attitude", and "behaviour". This stream of research date back to early studies of crowd psychology of Mackay (1841) [12] and classical early models of disease diffusion were applied to financial markets by Shiller (1984).[13] Also, Kirman (1993) analyses a simple model of influence that is motivated by the foraging behaviour of ants, but applicable, he argues, to the behaviour of stock market investors.[14] Faced with a choice between two identical piles of food, ants switch periodically from one pile to the other. Kirman supposes that there are N ants and that each switch randomly between piles with probability ε (this prevents the system getting stuck with all at one pile or the other), and imitates a randomly chosen other ant with probability δ, see Figure 6. [15] Eichengreen, Hale and Mody (2001) focus on the transmission of recent crises through the market for developing country debt.[16] They find the impact of changes in market sentiment tends to be limited to the original region. They also find market sentiments can more influence prices but less on quantities in Latin America, compared with Asian countries.
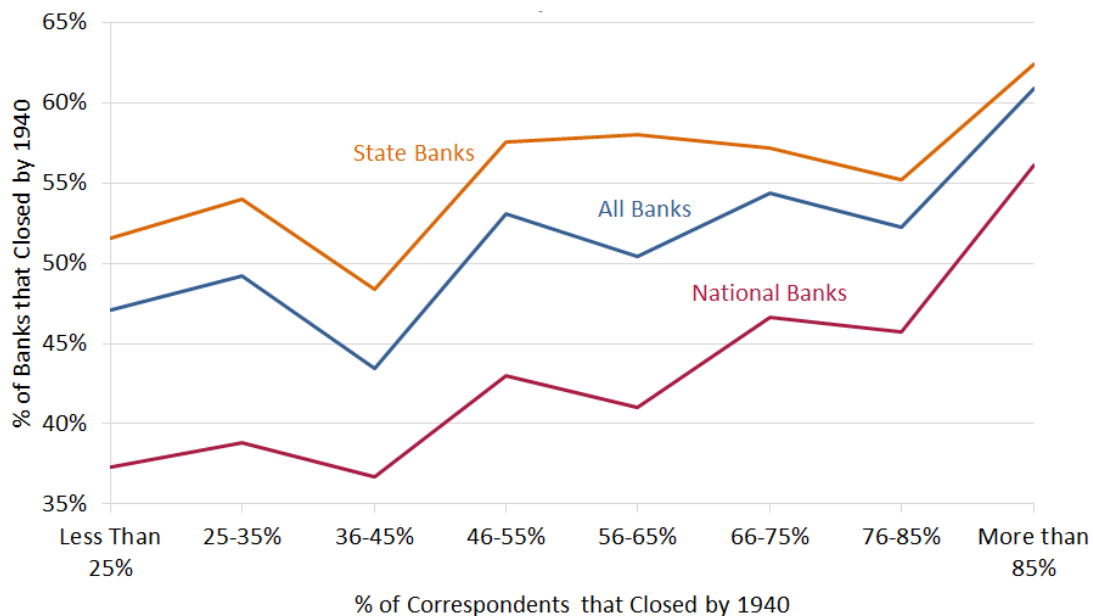
Figure 6 Financial Contagion: From the Great Depression

Besides, there are some researches on geographic factors driving the contagion. De Gregorio and Valdes (2001) examine how the 1982 debt crisis, the 1994 Mexican crisis, and the 1997 Asian crisis spread to a sample of twenty other countries.[17] They find that a neighbourhood effect is the strongest determinant of which countries suffer from contagion. Trade links and pre-crisis growth similarities are also important, although to a lesser extent than the neighbourhood effect.

4. Dynamic mixture copula-evt model

The copula is a function that contains all the information about the dependence between random variables. It allows one to describe any multivariate distribution with its marginal distributions and a copula that describes the dependence structure between the random variables. It is a flexible and effective tool to describe various patterns of dependence structures and has been widely used to measure financial contagion (e.g., Jayech, 2016; Cubillos-Rocha et al., 2019; Fenech and Vosgha, 2019). According to Sklar's (1959) theorem, let Z1 and Z2 denote two random variables with bivariate joint distribution function and two continuous marginal distribution functions F1 and F2, then there is a unique copula C: $[0, 1]2 \rightarrow [0, 1]$ such that [18]:

$$F_{Z_1,Z_2}(z_1, z_2) = C\left(F_1(z_1), F_2(z_2)\right).$$

One advantage of the copula models is that they can describe the tail dependence, which measures the probability that two variables exhibit extremely small values or extremely large values together. The lower tail dependence coefficient (λL) and upper tail dependence coefficient (λU) are correspondingly defined as [19]:

$$\lambda^L = \lim_{\varepsilon \to 0} P\left[Z_1 < F_1^{-1}(\varepsilon) \,|\, Z_2 < F_2^{-1}(\varepsilon)\right] = \lim_{\varepsilon \to 0} \frac{C(\varepsilon,\varepsilon)}{\varepsilon},$$

$$\lambda^U = \lim_{\varepsilon \to 1} P\left[Z_1 \geq F_1^{-1}(\varepsilon) \,|\, Z_2 \geq F_2^{-1}(\varepsilon)\right] = \lim_{\varepsilon \to 1} \frac{1 - 2\varepsilon + C(\varepsilon,\varepsilon)}{1 - \varepsilon},$$

where and are two marginal quantile functions and λL, λU $\in [0, 1]$. λL being 0 and positive implies independence and dependence of Z1 and Z2 in the lower tail, respectively. Larger λL suggests stronger dependence. A similar statement holds for the dependence in the upper tail based on the value of λU..

5. Foreign exchange using dynamic mixture copula-extreme value approach

The lower tail dependence and upper tail dependence are the main measurements of financial contagion and contagion channels. Therefore, the copula functions that describe both the upper- and lower-tail dependence are preferred. The Gaussian,

Student-t, Clayton, and Gumbel are the commonly used single copulas, and they can capture the overall dependence, symmetrical tail dependence, lower tail dependence, and upper tail dependence, respectively. However, the lower and upper tail dependence often coexist between two financial markets, and asymmetrical behavior is usually observed. To accommodate this, four static mixture copulas, Clayton–Gumbel (CG), Clayton–survival Clayton (CSC), Gumbel–survival Gumbel (GSG), and Symmetric–Joe Clayton (SJC), have been constructed to measure tail dependence (e.g., Jayech, 2016; Wang et al., 2018; Cubillos-Rocha et al., 2019). They can capture both the upper- and lower-tail dependence and allow them to be asymmetric. Liu et al. (2017) and Christensen et al. (2019) show that, compared to single copulas, mixture copulas are more flexible and performed better. However, it is worthwhile to note that the dependence measured by these mixture copulas is assumed to be static, while the real dependence between two financial markets is dynamic and varies with the external market environment, see Figure 7 [20].
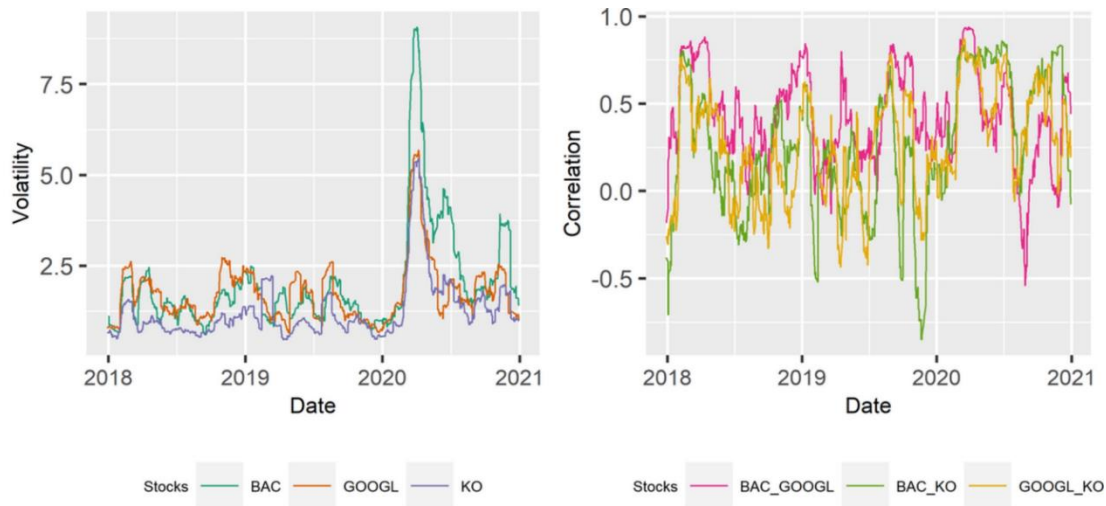

Figure 7 Volatility and dynamic dependence modelling: Review, Applications, And Financial Risk Management

Dynamic copula models with different time-varying structures have been developed to describe the dynamic dependence between financial markets (see Manner and Reznikova, 2012 for details). As summarized in Manner and Reznikova (2012) [21], the choice of copulas with different time-varying modeling is a matter of taste and computational capability of the software. As a compromise of estimation precision and computation cost, we use Patton's model (Patton, 2006) as the time-varying modeling for the following reasons [22], [23]:

(1)   It has been widely used to describe the dynamic dependence in financial markets (e.g., Dias and Embrechts, 2012; Hoesli and Reka, 2015; Luo et al., 2015; Fenech and Vosgha, 2019; Ji et al., 2019; Supper et al., 2020).

(2) It is more flexible to fit data compared to dynamic copulas that have some restrictions in the dependence structure. For instance, semiparametric dynamic copula is more suitable for smoothly changing processes (Manner and Reznikova, 2012).

(3) It is easy to implement and does not require heavy computation. Then, the Patton's model is added to the previously mentioned four static mixture copulas to construct four dynamic mixture copulas (DMCs), which are dynamic Clayton–Gumbel (DCG), dynamic Clayton–survival Clayton (DCSC), dynamic Gumbel–survival Gumbel (DGSG), and dynamic Symmetric–Joe Clayton (DSJC).

the daily closing prices of bank index, securities index, fund index and insurance index are selected as sample data, and the data comes from Wind database. The sample period is from January 10, 2007 to August 24, 2020, with a total of 3301 selected samples. The sample interval covers the financial crisis in 2008, the European debt crisis in 2011 [24], the stock market crash in China in 2015, the debt disaster in China in 2016 and the outbreak of COVID-19 in China in 2020. Let pit be the daily closing price of index i, and define the daily logarithmic rate of return as rit ¼ lnpit-lnpi, t1: The program in this article is implemented by EViews10, see Figure 8 [25]-[38].
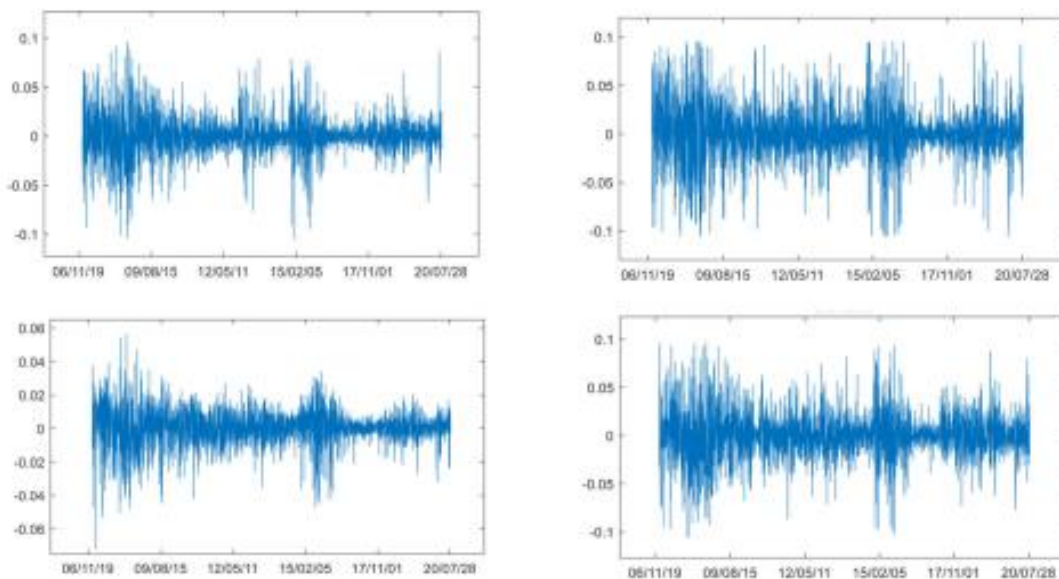

Figure 8 systemic risk contagion of Chinese financial institutions based on GARCH-VMD-Copula-CoVaR model

6. Conclusion

The financial contagion phenomenon recorded in the forex market exhibits serious threats to economic stability. Therefore, investigating financial contagion and its mechanism in the forex market is crucial for policy-makers, financial regulators, and

international investors to develop policies and to design strategies accordingly. We propose a novel three-step approach with a DMC-EVT model to detect the existence of financial contagion and to further study the financial contagion channels in the forex market. The constructed DMC-EVT model takes into account the complex dynamics between forex markets such as nonlinearity, asymmetry, time-varying patterns, and tail dependence.

The empirical study shows that the constructed DMC-EVT model outperforms the alternative copula models. That is, the constructed DMC-EVT model measures the financial contagion between forex markets in a more precise way and the proposed approach would lead to a more reliable analysis of financial contagion in the forex market. The analysis results confirm the existence of the financial contagion in the forex market from the U.S. to a handful of countries. This finding provides essential insights for investors to design risk hedging strategies in the forex market. To reduce the risk of financial losses, investors should decrease the percentages of the assets related to the USD and these contagious forex markets, and increase that of the assets in other forex markets which are not affected during the financial crises.

Furthermore, the contagion channels in the forex market are identified. It is found that the financial contagion was caused by wealth constraints during the GFC. To limit the contagion associated with wealth constraints, the international financial risk managers could provide timely support to the struggling financial institutions so as to reduce investors' perceived risk. Also, policy-makers and experts may re-evaluate the global financial system regulation and take appropriate reactions to limit the recession. Our findings shed light on the transmission mechanism of the financial crisis in the forex market.

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