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Financial Interdependence or Contagion? Evidence from a Meta-analysis

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During the last two decades, the phenomenon of financial contagion has been investigated in numerous pieces of research. In spite of its severe implications for the stability of domestic financial systems as well as potential diversification benefits of international portfolio investment, there has yet to be universally agreed conclusion on the relevance of financial contagion. Thus, our current study has been designed to apply the meta-analysis approach to investigate the statistical significance of financial contagion based on past empirical contagion studies. Our meta-analysis concludes that financial contagion is a significant phenomenon. As implications, policy makers should establish contingent credit lines to ensure the liquidity of financial market during the turbulence time, and portfolio investors should diversify away from the potentially contagious markets. It is suggested that future contagion-based meta-analysis may include contagion studies with different methodologies, as well as meta-regression analysis to provide more insights on the sources of variability in the contagion studies.

1. Introduction

Since the 1990s, financial liberalization and globalization have become significant phenomena across both developed and developing economies. It is believed that the enthusiastic liberalization efforts of the domestic policy makers, as well as the subsequent hike in cross-country capital

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flows and financial transactions, have intensified such phenomena (Ceballos et al., 2012). Despite the traditionally perceived benefits brought about by financial integration, namely economic growth and enhanced risk-adjusted returns (Arteta et al., 2001; Kose et al., 2009), integrated financial markets will also increase the vulnerability of domestic markets to adverse external shocks (Caramazza et al., 2004). In other words, the integrated financial markets tend to co-move more closely with their global counterparts in the wake of economic turmoil.

Traditionally, the adverse shocks are transmitted through fundamental economic linkages between countries, particularly through international trade and financial networks. Such phenomenon has been commonly referred to as the market interdependence (Forbes and Rigobon, 2002). Since 1990s a series of financial crises have revealed a unique mechanism on the cross-market spread of the adverse financial shocks. In contrast with the traditional transmission mechanism of cross-market fundamental economic linkages, the market turmoil has been spread rapidly from the crisis-originated market to other markets that share little economic linkages or with different markets structures (Billio and Caporin, 2010). These crises include the 1994 Mexico Peso crisis, the 1997 Asian financial crisis, the 1999 Russian Ruble crisis, and even the recent 2008 US Subprime crisis. For example, when Hong Kong was severely hit by the 1997 Asian financial crisis, its stock market declined dramatically in October 1997. Being countries with different market sizes and structures, the stock markets of Brazil and South Africa have co-moved closely with the sharp falls of the Hong Kong stock market (Forbes and Rigobon, 2002).

Since adverse shocks can be transmitted to countries with little economic linkages, shared economic fundamentals are insufficient to explain the increased cross-market co-movements of asset market returns (Billio and Caporin, 2010). In the scenario that the excess cross-market co-movements are beyond the explanatory power of the economic fundamentals, the shift of the transmission mechanism rather than the shared economic fundamentals is believed to be the primary cause for the intensified co-movements during economic turmoil. More specifically, such phenomenon has been commonly perceived as the contagion effects of the financial turbulence (Bekaert et al., 2005).

The differentiation between financial interdependence and contagion is an important topic in the field of international finance, the importance of which can be understood from its two-dimensional implications: the stability of the domestic financial system, and the potential diversification benefits for international portfolio investors. As for the domestic policy makers, it is of foremost important for them to understand the mechanisms through which an external shock could be transmitted to the domestic economy. With an adequate knowledge on the transmission mechanism of shocks, they can structure appropriate preventive policies to safeguard the domestic economy against the adverse effects of the external shocks. If a crisis is spread through the fundamental economic linkages between countries, the policies should emphasize on the improvement of macroeconomic fundamentals (Moser, 2003).

As for international portfolio investors, their primary concern is to optimize the potential diversification benefits of their portfolio investments. Finance theory suggests that the potential benefits of portfolio diversification can be maximized when the basket of investments are diversified into weakly correlated markets (Masih and Masih, 2001). Since financial contagion effect will significantly increase the cross-market co-movements in wake of the adverse financial shocks, the potential diversification benefits of the portfolio investments will be severely undermined, when it is needed the most (Pericoli and Sbracia, 2003). Thus, it is crucial for the international portfolio investors to take into account the financial contagion risk in structuring their optimal portfolio investments.

Motived by the enormous implications of the contagious crises, voluminous researches have been undertaken to investigate the presence of the financial contagion among emerging as well as mature equity markets. Such trend has been dramatically picked-up after the incidence of the 1997 Asian financial crisis (Khalid and Kawai, 2003), and then pushed into new height after the demise of the recent 2008 US Subprime Crisis (Forbes, 2012). However, past researches have revealed mixed evidences on the presence of financial contagion, even if the crisis period and countries under investigation are same. Some believed that the cross-market transmission of crisis is because of the fundamental links between countries, others upheld that it is the contagion effects of the crisis induced those transmissions.

In order to answer whether financial contagion is a relevant phenomenon based on the past contagion researches, a number of qualitative systematic reviews have been undertaken, for instance (Cheung et al., 2009; Dornbusch et al., 2000; Paas and Kuusk , 2012) to name a few. Although these qualitative syntheses have provided comprehensive overview on the findings of the past empirical contagion researches, there has yet to be solid conclusions on whether contagion effects or fundamental economic linkages play the dominant role in the transmissions of financial crises during the last two decades. As an effective remedy, it is proposed that the Meta-analysis, being a quantitative approach of systematic review, could be a better alternative to explore the variability in the past contagion researches (Paas and Kuusk, 2012).

According to our knowledge on financial contagion, there has been no Meta-analysis on the subject except the study of Kuusk (2012). In his study, Kuusk (2012) revealed that on average there has been confirmed evidence on the presence of financial contagion among the past empirical studies, but the effect is only moderate. In addition, the variations of the empirical methodology and the choices of the focused financial crisis have played significant moderating roles in the heterogeneity of the past empirical results. In spite of its fruitful insights, his study has only focused on studies that adopted linear correlation approach to assess financial contagion. To extend the study of Kuusk (2012), our current meta-analysis focuses on contagion studies that applied Copulas model, a non-linear correlation approach, to examine the existence of financial contagion.

The remainder of the paper is organized as follows. In Section 2, we provide a brief theoretical background on financial contagion. In Section 3, we elaborate on the application of Copulas theory on financial contagion. Section 4 thoroughly explains on the methodology of meta-analysis. Detailed results of meta-analysis results are discussed in Section 5. In the end, Section 6 concludes the study.

2. Theory of Financial Contagion

Theories pertaining to the cross-country propagations of shocks can be generalized into two broad categories, namely the Crisis-Contingent and Non-Crisis Contingent theory (Forbes and Rigobon, 2001). In particular, the former assumes that the cross-country transmission mechanisms will

change in the wake of a crisis, whereas the latter upholds that the mechanisms are stable across tranquil and crisis periods. As implications, the Crisis-Contingent Theory explains the increased cross-market co-movements during the crisis period, whereas the Non-Contingent theory enlightens the relative constant cross-market correlations across the two periods. Putting it differently, the Crisis-Contingent Theory provides support for the incidence of contagion, whereas the Non-Crisis-Contingent Theory explains the phenomenon of interdependence (Billio and Pelizzon, 2003).

Crisis-Contingent Theory

According to Forbes and Rigobon (2001), the Crisis-Contingent theory can be divided into dimensions, including jumps between multiple equilibria, endogenous liquidity, and political contagion. Each dimension can be perceived as a transmission mechanism that propagates shocks from one country to another, holding that the mechanism is stable across tranquil and turmoil periods. First, the propagation of shocks can be explained through multiple equilibria. In particular, the theory of multiple equilibria upheld that a crisis in a country may act like sunspots that coordinate the devaluation expectations of investors in another country (Jeanne and Masson, 2000). Such revision of expectations will shift the economic equilibrium of the second country from a good to a bad one, even if the economic fundamentals of the second country remain stable and healthy (Masson, 1999).

The jumps between multiple equilibria can also be explained by investors' self-fulfilling beliefs and the incomplete information in the market (Pericoli and Sbracia, 2003). In addition, they explained that when an adverse shock hits one country and the market is dominated by investors' devaluation belief, investors' herding speculative attacks on the currency will increase the cost of defending the peg. Consequently, it will force the authority of the country to abandon its defense. Thus, the self-fulfilling expectations of the investors may become the primary culprit for the incidence of currency crises.

As for the shift of economic equilibria stems from the incomplete market information, Pericoli and Sbracia (2003) stated that when an adverse shock hits a country but yet to affect the economic fundamentals of another country, the news of the crisis in the first country may act as the

sunspot to coordinate market participants' investment actions towards a speculative attack. In other words, when uninformed investors fail to tell whether the devaluation of an asset is because of liquidity or fundamental shocks, the decline of one asset price may serve as the signal for these investors in predicting the devaluations in all assets (Halstead et al., 2004). As the result of such incomplete market information, the coordinated investment actions of the uninformed investors may force the economic fundamentals of the second country to shift from a good to a bad equilibrium.

The endogenous liquidity theory is another Crisis-Contingent approach to explain the cross-market transmission of crises. When a crisis hits one country, the liquidity of its market participants will be negatively affected. Because of the regulatory requirements of the first country, investors' liquidity constrain will pressure them to short some of their portfolio investments in other countries to fulfill these requirements, even if the economic fundamentals of the latter countries have yet to be affected (Valdes, 1997).

Last but not least, the Crisis-Contingent theory can also be elaborated through the aspect of political contagion. The political contagion theory suggests that the transmission of crises can be partially explained by the political-oriented decisions of the policy makers (Drazen, 1999). In a related study, such theory has been named differently as membership contagion (Moser, 2003).

Non-Crisis Contingent Theory

In contrast with the Crisis-Contingent Theory that assumes structure-breaks in the transmission mechanisms of shocks, this category of theories upholds the stable transmission mechanism throughout the tranquil and crisis periods. In other words, the increased cross-country co-movements of asset market returns in wake of economic turbulences are the continuation of linkages existing prior to the crisis. Such linkages have been commonly referred to as the fundamentals-based transmission mechanisms, which comprises of trade spillovers, policy coordination, country re-evaluation, and random aggregate shocks (Forbes and Rigobon, 2001). The explanations on each aspect of the Non-Crisis Contingent theory are elaborated in the following paragraphs.

Trade spillover refers to the scenario when a country is hit by an adverse economic shock, the economic contraction in the country will result in the decline of the domestic demand and then the devaluation of the home currency. Consequentially, the imports volume from its major trading partners to the crisis-hit country will decrease (Moser, 2003). If the contraction of the domestic demand and the devaluation of home currency are severe enough, the exports of its trading partners will decrease dramatically. Eventually, it will result in the devaluation of currency in the major trading partners of the crisis-hit country (Forbes and Rigobon, 2001). And this in turn will bring about the increased probability of currency attacks in these countries, particularly for countries with fixed exchange rate regime (Dornbusch et al., 2000). Similarly, countries tend to link with each other through financial linkages as well. In fact, the integration process of a country into the global economic system can be attributed to both trade and financial links (Dornbusch et al., 2000). In particular, the financial links can be divided into direct and indirect ones. The direct financial links refer to the bilateral cross-market investments, whereas the indirect ones are the common international investors such as banks, mutual funds, and pension funds (Moser, 2003).

In terms of policy coordination, it is believed that when an economic crisis hits one country the policy response of the country induces another country to follow the similar policy adopted in the first country. Consequentially, it will result in the intensified cross-market co-movements (Forbes and Rigobon, 2001). The authors further explained that when a group of countries are bonded by a trade agreement, the expansionary monetary policy in one country may force other member countries to raise trade barriers in order to secure their trade account.

The third category of the non-crisis contingent theory refers to investors' re-evaluation or learning process (Forbes and Rigobon, 2001). This theory assumes that after one country is hit by a crisis, investors tend to apply the lessons learned in this country on other countries with similar macroeconomic structure and policies. In other words, the crisis in the first country acts as the wake-up call for the investors in the second country, which induces these investors to reevaluate the economic fundamentals in their country (Goldstein, 1998). If investors detect some problems or risks that failed to be observed before, it may lead to contagion (Moser, 2003).

Last but not least, the random aggregate shock or global shock is another non-crisis contingent theory that explains the cross-country transmission of crisis. According to Forbes and Rigobon (2001), this theory assumes that a crisis will affect the economic fundamentals of several economies simultaneously. For instance, when there is an increase in the international interest rate, a decrease in the international capital supply, or a contraction in the international demand for commodities, many countries will suffer economic depression simultaneously. As the result of such simultaneous adverse shock, the cross-market co-movements tend to increase significantly. In other studies, such phenomenon of simultaneous shocks have been named differently, including common shocks (Dornbusch et al., 2000), common external shocks (Costinot and Roncalli, 2000), and monsoonal effects (Masson, 1998).

3. Financial Contagion and Copulas Theory

Copulas are functions that model joint multivariate distributions with univariate marginal functions (Nelsen, 2006). Introduced by Seklar (1959), Copulas capture information about non-linear dependence of a vector of random variables (Rodriguez, 2007). Since Copulas enable researchers to model multivariate distributions with varying patterns of tail behavior as well as different kinds of asymmetry, it is believed to be an effective alternative to the linear correlation approach in modeling the financial risks (Rodriguez, 2007).

It is believed that the cornerstone of the Copula theory is derived from the Sklar theorem (Horta et al., 2010). According to Sklar's theorem, let a *n*-dimensional joint distribution function *D* with a vector of univariate marginal distribution functions $F_1, \dots, F_n$. Then there exists a *n*-dimensional Copula *C*: $[0,1]^d \rightarrow [0,1]$ such that:

$$D(x_1, \dots, x_n) = C\big(F_1(x_1), \dots, F_n(x_n)\big) \qquad (1)$$

The copula *C* capture all the information pertaining to the dependence between univariate marginal distribution function F_n (Bergmann et al., 2015). An important advantage of the Sklar's theorem is that it enables flexible modeling of the multivariate joint distribution (Aloui et al., 2013). Horta et al. (2010) explained that when both the marginal distribution function and copula function are known, the joint distribution will be derived directly through the Sklar's theorem, represented by function (1)

above. Thus, the copulas function alone can construct the dependence, through the probability distribution of the random variables for the given marginal distributions (Bergmann et al., 2015).

The variety of Copulas model can be classified into three major families, namely elliptical, Archimedean, and extreme value (Aloui et al., 2013). The elliptical family consists of both Gaussian Copula and the *t*-student Copula, which are commonly applied to examine the symmetric dependence structure (Horta et al., 2010). In terms of the Archimedean family it includes Gumbel, Clayton, and Frank Copula, which are appropriate for measuring the right tail dependence, left tail dependence, and symmetric with tail dependence, respectively (Horta et al., 2010). As for the extreme value copula, it usually uses the mixed versions of Copulas to examine the extreme dependence between random variables (Aloui et al., 2013). For instance, the Gumbel-Clayton Copula model is adequate for modeling dependence when random variables assemble symmetry relationship. Such hybrid model is also appropriate to model variables with different forms of asymmetry and even independence (Horta et al., 2010).

In order to quantitatively measure the dependence between variables in the copula model, rank correlation coefficients such as the Kendall's τ and Spearman's ρ have been commonly used (Schmidt, 2006). In reference to Nelsen (2006), both τ and ρ can be derived directly from the bivariate Copulas functions such that:

$$\tau_{kendall}(X_1, X_2) = 12 \int_0^1 \int_0^1 (C(u_1, u_2) - u_1 u_2) du_1 du_2 \qquad (2)$$

$$\rho_{spearman}(X_1, X_2) = 1 - 4 \int_0^1 \int_o^1 \frac{\partial C(u_1, u_2)}{\partial u_1} \frac{\partial C(u_1, u_2)}{\partial u_2} du_1 du_2 \qquad (3)$$

Since the specification of copulas function could be different for different random variables, the dependence parameters of the copulas function are not comparable. In contrast, as the value of the rank correlations ranges between -1 and 1, Kendall's τ and Spearman's ρ enables comparative analyses of dependence structure.

In addition, dependence between variables in the Copulas functions can also be examined through the dependence in the tails of the distribution. In particular, upper (λ_U) and lower tail asymptotic coefficient (λ_L) associated with the Copulas can be used to measure the tendency for markets to boom and crash together, respectively (Aloui et al., 2013; Horta et al., 2010). In reference to Aloui et al. (2013), the λ_U and λ_L are defined as:

$$\lambda_U = \lim_{t \to 1} P(Y > G^{-1}(t) | X > F^{-1}(t)) \tag{4}$$

$$\lambda_L = \lim_{t \to 0} P(Y \leq G^{-1}(t) | X \leq F^{-1}(t)) \tag{5}$$

where *X* and *Y* are the random variables with marginal distribution functions of *F* and *G*.

If financial contagion is defined in accordance with Forbes and Rigobon (2002) as the increased cross-market linkages during the crisis period, the existence of the phenomena can be assessed by investigating whether dependence between variables has increased significantly (Horta et al., 2010). If financial contagion does exist, the null hypothesis as follows deems to be rejected:

$$\begin{cases} H_0 : \Delta\tau(i) = \tau_{crisis}(i) - \tau_{tranquil}(i) \leq 0 \\ H_1 : \Delta\tau(i) = \tau_{crisis}(i) - \tau_{tranquil}(i) > 0 \end{cases} \tag{6}$$

where $\tau_{crisis}(i)$ and $\tau_{tranquil}(i)$ refers to the dependence between the crisis-hit and potential-affected market *i* during the crisis and tranquil period, respectively, and $\Delta\tau(i)$ represents the increases in the cross-market dependence from the tranquil to crisis period.

In addition, financial contagion can also be assessed by assessing the changes in the lower tail dependence during the crisis period (Bergmann et al., 2015). In particular, if financial contagion does exist, the null hypothesis as follows will be rejected:

$$\begin{cases} H_0: \Delta\lambda_L(i) = \lambda_{L_{crisis}}(i) - \lambda_{L_{tranquil}}(i) \leq 0 \\ H_1: \Delta\lambda_L(i) = \lambda_{L_{crisis}}(i) - \lambda_{L_{tranquil}}(i) > 0 \end{cases} \quad (7)$$

where $\lambda_{L_{crisis}}(i)$ and $\lambda_{L_{tranquil}}(i)$ refers to the lower tail dependence between the crisis-hit and potential-affected market *i* during the crisis and tranquil period, respectively, and $\Delta\lambda_L(i)$ represents the increases in the cross-market lower tail dependence from the tranquil to crisis period.

4. Methodology of Meta-analysis

Meta-analysis can be simply defined as "the analysis of analyses". The application of such statistical technique can be traced back to its origin in 1976 by Gene Glass. In particular, Glass defined it as the "statistical analysis of a large collection of results from individual studies for the purpose of integration the finding" (Glass, 1976). More recently, it has been referred to as the statistical approach to synthesize the empirical evidences on a particular research subject (Kuusk and Paas, 2010), with the considerations of the heterogeneous characteristics among the studies (de Dominicis et al., 2008). In short, it is a quantitative approach to summarize the empirical findings through a series of statistical analyses.

In reference to the meta-analysis research guidelines of Glass et al., (1981) and Hunter et al., (1982), our current meta-analysis is conducted in accordance with the following procedures:

1. Define the research subject, or the dependent variable.
2. Construct the sample article database which includes all the relevant studies.
3. Calculate the effect size for each primary estimates.
4. Compute the meta-effect size with weights assigned to the effect size of each independent estimate.

The detailed explanations for each of the preceding steps are discussed in the following paragraphs.

Define the Dependent Variable

In our current meta-analysis, financial contagion has been defined in accordance with Forbes and Rigobon (2002) as the phenomena that cross-market linkages have intensified significantly in wake of adverse external shocks. The chosen definition is preferred because of the following two advantages. First, it enables to test for the presence of financial contagion effect through a straightforward approach. Second, it avoids the complex measurement of the turbulence transmission mechanism (Horta et al., 2010). Since our current meta-analysis focuses on the Copula-based contagion studies only, the presence of financial contagion can be assessed either through the changes of cross-market dependence from the tranquil to crisis period, or by the increase in the cross-market lower tail dependence during the crisis period.

Construct the Sample Article Database

The second step in our meta-analysis is to collect all the available studies pertaining to the research subject. In particular, we have relied on the Scopus database to look for the relevant articles. Having said that the primary objective of this study is to investigate the relevance of financial contagion. The following searching and screening criteria are used to select the relevant articles for our analysis:

1) The keyword "financial contagion" will be used to perform the initial search from the Scopus database.

2) The theoretical and qualitative oriented research papers are excluded from the analysis, and only empirical studies are retained.

3) Among the empirical studies, we only select the researches that define financial contagion according to Forbes and Rigobon (2002). Thus the sampled studies are further narrowed down to those that examine the changes in cross-market dependence and lower tail dependence.

The Effect Size

After the filtering process on the sampled studies, the next step in the meta-analysis is to select a singular statistic measure that is applicable for

all the sampled studies. Such measure has commonly known as the "effect size". According to Lipsey and Wilson (2001), it is the statistics that standardizes a collection of empirical findings, and consequentially it ensures the comparability of the findings across different studies. In theory, so far as a measure takes into account the direction and strength of a relationship, able to be expressed as a point estimate with confidence interval, and enables the comparisons across studies, it can be used as an effect size (Littell et al., 2008).

Three categories of effect size have been commonly used in the past researches, including mean-based, coefficient or odds ratio-based, and correlation-based measures (Borenstein et al., 2009). They further explained that the choice of a proper effect size measure depends on the type of data used in the primary studies. In particular, the means-based measure is adequate for the means and standard deviations of the sample groups, the odds ratio-based measure is suitable for binary outcomes, and the correlation-based measure is appropriate for the correlation coefficient between random variables. Since our study primarily concerns about the changes in the cross-country dependence of financial market, none of the three types of effect size measures can be directly used as the effect size in the meta-analysis. Instead, the effect size can be measured through the difference in the cross-market dependence, namely the changes in Kendall's τ coefficient ($\Delta\tau(i)$) and lower tail asymptotic coefficient ($\Delta\lambda_L(i)$) between variables.

Thus, the effect sizes for each independent estimate can be computed through

$$ES_{ij} = \tau_{crisis}(ij) - \tau_{tranquil}(ij), \quad (8)$$

Or

$$ES_{ij} = \lambda_{L_{crisis}}(ij) - \lambda_{L_{tranquil}}(ij) \quad (9)$$

where ES_{ij} denotes the effect size for the *i*th independent estimate in the *j*th study.

As the weight assigned to the effect size is inversely associated with the variance of the estimate (i.e. $1/V_{ij}$), the use of the simply correlation coefficient approach to measure the effect size will provide biased results

in the meta-analysis. This is because an estimate that has larger correlation tends have lower standard error (or variance), consequentially more weights are assigned to these estimates. To address such biasness, the correlation coefficients of the sampled studies need to undergo the Fisher's Z value transformation to improve the accuracy of the meta-analysis results (Borenstein et al., 2009). Statistically, the individual effect size based on the transformed changes of correlations between two sub-periods ($\Delta\tau(ij)$ or $\Delta\lambda_L(ij)$) can be computed as

$$ES_{Z_{ij}} = 0.5\, ln(\frac{1+\Delta\tau(ij)}{1-\Delta\tau(ij)}), \tag{10}$$

Or

$$ES_{Z_{ij}} = 0.5\, ln(\frac{1+\ \Delta\lambda_L(ij)}{1-\ \Delta\lambda_L(ij)}) \tag{11}$$

This transformed effect size will be used latter to calculate the pooled effect size of the sampled studies.

Meta-effect Size

Once the measure of the common statistics is established, the next step is to assign weights to each individual estimates. According to the inverse variance method of Hedges and Olkin (1985), such weight can be computed through:

$$w_{Z_{ij}} = \frac{1}{V_{Z_{ij}}} = \frac{1}{\frac{1}{n_{ij}-3}} = n_{ij} - 3, \tag{12}$$

where $V_{Z_{ij}}$denotes the variance of the effect size for the *i*th independent estimate in the *j*th study, and n_{ij} refers to the sample size of the corresponding estimate.

Consequentially, the pooled effect size or meta-effect size is computed through the weighted average of all the individual effect sizes. In particular, such meta-effect size can be computed through fixed effects or random effects estimators.

The fixed effects estimator assumes the homogeneity among the empirical findings, and the variability among the findings is solely due to the

sampling error (Borenstein et al., 2009). In other words, there is only one true effect that underlies all the primary estimates. The equation below formally depicts the fixed effects model:

$$TES_{FE} = \hat{\theta} = \frac{\sum_{i=1}^{k} w_{Z_{ij}} ES_{Z_{ij}}}{\sum_{i=1}^{k} w_{Z_{ij}}}, \quad (13)$$

where $w_{Z_{ij}}$ denotes the weight assigned to the ith independent estimate in jth study, k indicates the total number of the independent estimates, and $ES_{Z_{ij}}$ is the effect size for the corresponding primary estimate. Putting it differently, the total effect size is the sum of the products of $w_{Z_{ij}} ES_{Z_i}$ (individual effect size multiply by its assigned weight) divided by the sum of the weights.

On the other hand, the random effect estimator assumes the heterogeneous effect size in the sampled studies (Borenstein et al., 2009). And the pooled effect size is believed to be comprised of two normally distributed components, namely the random variations of the primary estimate effect size ($\mu_{Z_{ij}}$) and the sampling error ($\varepsilon_{Z_{ij}}$) (de Dominicis et al., 2008). The formal representation of the random effect model can be depicted as:

$$TES_{RE} = \frac{\sum_{i=1}^{k} w^*_{Z_{ij}} ES_{Z_{ij}}}{\sum_{i=1}^{k} w^*_{Z_{ij}}}. \quad (14)$$

where "*" denotes random effect approach.

Homogeneity Test

Since the assumptions underlying the fixed and random effects estimators are mutually exclusive, it is necessary for a meta-analysis to determine which estimator is more appropriate for the sampled studies (Feld and Heckemeyer, 2011). In order to choose an adequate meta-analysis estimator, past researches have commonly applied *Q*-test to examine the homogeneity of findings between studies. In particular, this test investigates whether the between-study variance, $\sigma^2_{\mu_{Z_j}}$, is zero. Such *Q*-test will be performed based on the χ^2 distributed *Q*-statistics through

$$= \sum_{i=1}^{k} w_{ij} ES_{Z_{ij}}^2 - \frac{\left(\sum_{i=1}^{k} W_{ij} ES_{Z_{ij}}\right)^2}{\sum_{i=1}^{k} W_{ij}} \quad (15)$$

So far as the *Q*-test rejects the null hypothesis of zero between-study variance, it is safe to conclude that the random-effect estimator is a more appropriate approach to conduct the Meta-analysis. On the other hand, if the null hypothesis is failed to be rejected, it indicates that the fixed-effect estimator is a better choice.

5. Results and Discussion

Given that the objective of this study is to assess the relevance of financial contagion effect based on the past Copula-based contagion studies, a thorough investigation of research papers dealing with our research subject was performed by querying the Scopus database. First, a query was performed in the database using the keyword "financial contagion" for research topic. In addition, the search was confined among English literature, published between 1990 and 2016, and in the area of business economics. The search was performed on 29 January, 2016, and the total number of relevant articles obtained was 908.

Then we screened the title and abstract of the obtained studies to filter out theoretical/qualitative researches and studies that do not test the statistical significance of financial contagion effect. At the end of this filtering process we were left with 61 research papers on our topic of interest. In the final round of literature screening, we finalized the sampled articles to be used in our meta-analysis. In particular, we only retain contagion studies that apply Copulas model to assess the existence of contagion. Furthermore, the included studies must have reported the measure of precision for the test of financial contagion (i.e. standard error, t-statistics, or p-values), which is required data for meta-analysis. Finally, the dependent variables have to be either Kendall's τ coefficient ($\Delta\tau(i)$) and lower tail asymptotic coefficient ($\Delta\lambda_L(i)$) between variables to ensure the comparability of the estimated effect. Subsequently, only 6 studies passed all three rounds of the literature screening process. The descriptive statistics on the selected studies is presented in Table 1.

Table 1: Descriptive Statistics on the Studies Included in the Meta-analysis

Study	Year	Country	Estimate	Crisis	Market	Contagion
Chen, Wei, Lang, et al. (2014)	2014	China	2	SC	SM	Y
Durante & Jaworski (2010)	2010	Austria	9	NA	SM	Y
Hoesli & Reka (2013)	2013	UK	1	SC	RE, SM	Y
Horta, Lagoa, & Martins (2014)	2014	Portugal	14	SC, EDC	SM	Y
Rodriguez (2007)	2007	Netherland	7	AFC, MC	SM	Y
Wen, Wei, & Huang (2012)	2012	China	3	SC	EM, SM	Y

Note: "SC", "NA", "EDC", "AFC", "MC" denotes "Subprime Crisis", "Not Available", "European Debt Crisis", "Asian Financial Crisis", and "Mexican Crisis", respectively; "SM", "RE", EM" reprents "Stock Market", "Real Estate Market", and "Engegy Market, respectively; "Y" indicates the financial contagion effect is statistical significant.

As we can observe from Table 1, the Copula-based contagion is a new research trend that has become increasingly popular after 2007. In addition, most of these studies were conducted in developed countries, on the contagion effect of the 2008 US Subprime crisis. Only 23.3% (or 2 studies) were initiated in the developing country, and 17% (or 1 study) focus on the contagion effect of 1994 Mexican crisis and 1997 Asian financial crisis. Interestingly, all of the studies have examined the stock markets contagion, and concluded the presence of statistical significant financial contagion.

Table 2: Results of Meta-analysis

Model	No. Studies	Point Estimate	Std Error	Variance	Lower limit	Upper limit	Z-value	P-value (2-tails)
Fixed-Effect	6	0.047	0.008	0.000	0.031	0.062	5.942	0***
Random-Effect	6	0.044	0.011	0.000	0.023	0.023	4.085	0***

Noted: *** denotes financial contagion is significant at 1% significance level.

The results of the meta-analysis are given in Table 2. Since all the studies contains more than one estimates and most of them are not independent from one another, the sample data used in our meta-analysis are the mean estimates extracted from the 6 studies covered. In addition, we have run both fixed-effect and random-effect models to assess the statistical significance of financial contagion. Looking at the detailed results, Table 2 documents that the meta-effect size of financial contagion is indeed statistically significant ($P < 0.001$) for both fixed-effect and random-effect models, regardless of the level of significance applied. In addition, we found that the meta-effect size of fixed-effect model (0.047) is very close to the one obtained from the random-effect model (0.044).

Table 3: Results of Homogeneity Test

Q-value	df (Q)	P-value	I-squared
8.077	5	0.152	38.093

In the end, a homogeneity test was performed to examine the homogeneity of the population effect size (de Dominicis et al., 2008). If the null-hypotheses of homogeneity is rejected, it indicates the differences between the sample effect size and the population mean cannot be explained by the sampling error alone (Paas and Kuusk, 2012). In other words, Paas and Kuusk（2012） added that, in such case the variability of the effect sizes may be associated with different study characteristics. In addition, the homogeneity test will also provide information on whether fixed-effect meta-analysis model is suitable. Specifically, if the null hypothesis of between-study homogeneity is rejected, it indicates that the fixed-effect meta-analysis is not adequate (Feld and Heckemeyer, 2011).

In our case, the *Q*-statistic is equal to 8.077, which fails to reject the null hypothesis of homogeneity, with a *p*-value > 0.10. In other words, the individual effect size from the sample is not significantly different from the population mean effect size. Hence, the fixed-effect model is suitable to be applied in our meta-analysis.

6. Conclusion

Due to its severe adverse effects on the vulnerability of a financial system as well as the potential diversification benefits of international portfolio investments, financial contagion has become an important theme in the field of international finance. Despites the increased researches on the notion during the last three decades, researchers have yet to reach universally agreed conclusion on the existence of statistically significant financial contagion. The variations of the research findings can be caused by a number of factors. Recently, contagion studies have revealed that one of the major culprits for such variability is the research model applied.

In order to provide more adequate picture on the relevance of financial contagion, this study has applied a meta-analysis approach to assess the statistical significance of the phenomenon based on the past empirical contagion studies. Having defined financial contagion as the significantly intensified cross-market dependence during the crisis period, our meta-

analysis has focused on non-linear Copulas-based contagion studies. It is believed that our chosen definition enables us to examine financial contagion through a straight-forward approach, which only needs to compare the cross-market dependence coefficients between crisis and tranquil period. In addition, our emphasized copulas model enables us to examine financial contagion from a non-linear approach, with varying patterns of tail behavior as well as different kinds of asymmetry.

After a series of screening process, only 6 researches are selected in our meta-analysis. And the meta-analysis results reveal that, financial contagion is statistically significant for both fixed-effect and random effect models, regardless of the level of significance used. In addition, the homogeneity test shows that the individual effect size from our sampled studies are not significantly different from that of the population mean. Hence, the fixed-effect model is an adequate choice for our meta-analysis.

Since financial contagion is found to be a statistically significant phenomenon, adverse financial shocks can be rapidly transmitted from one market to another, even if these markets share little economic linkages or of different markets structures and sizes. As implications, policy makers should be cautious about the vulnerability of the domestic market to the potential contagion effect in structuring the monetary and financial policies. It is recommended that country should establish contingent credit lines from private financial institutions to ensure the availability of financial resources during a crisis (Claessens and Forbes, 2004). By doing so, it would restore the investors' positions closer into line with economic fundamentals (Moser, 2003). As for the portfolio investors, since some markets would plague together with contagion in wake of financial turmoil, they should avoid diversifying investment portfolio from those potentially contagious markets (Phylaktis and Xia, 2009).

One of the most limitations of our study is that our meta-analysis is confined to empirical studies that apply Copula-based studies. It is suggested that future researches could include different methodologies, both linear and non-linear ones, into the contagion meta-analysis. In addition, meta-regression analysis is also advised to be applied in the future researches to quantitatively examine the sources of heterogeneous findings in the past contagion studies.

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