Analysis of Crisis Contagion in the European Sovereign Debt Crisis Based on MATLAB: Will Macau be the Next Greece?

Tsz Wing Chan[1], Kuok Wai U[2], Dong Li*, Xin Yue Zhang[3]
[1]kitjckatie@gmail.com, [2]thomasu050827@gmail.com
*Corresponding author: dli@imail.puiching.edu.mo, [3]zhangxinyue0415@gmail.com

Pui Ching Middle School Macau, PCMSM, Macau, China
*Pui Ching Middle School Macau, Academic Affairs Office, PCMSM, Macau, China,

Abstract—The European Debt crisis originated in Greece in 2009 and consequently spread across national borders, resulting in a global recession. Eurozone countries failed to finance their budget deficits as confidence in global financial markets weakened. This paper tested for the contagion effects in the Eurozone, Asia, and the United States stock markets during the European Sovereign Debt Crisis. By employing the Pearson correlation coefficient, Spearman correlation and Kendall coefficient, we measured the correlation between Greece and regions including Germany, the United Kingdom, the United States and Hong Kong. Following that, four copula functions are applied to evaluate the tail dependence: Gaussian copula, Student's T copula, Clayton copula and Gumbel copula. Semi-parameter Conditional Maximum Likelihood Estimation and the built-in Matlab program are used for estimation. Then, we proposed a transmission model based on the liquidity theory, which explains the correlation and elucidates the mechanisms of contagion, underlying comparisons between Macau and Greece. The empirical results indicate that contagion is evident between the stock market of Greece and those of Hong Kong and Germany, albeit for different reasons. Finally, suggestions are given to the Macau government to avoid following Greece's tragic path.

Keywords-Crisis Contagion Model; European Debt Crisis; Correlation Analysis; Copula Function; Liquidity Theory; Transmission Model

1 INTRODUCTION

1.1 Background

Since 2009, the Eurozone has been experiencing a severe sovereign debt crisis, presently referred to as the European sovereign debt crisis. The crisis originated in Greece and consequently spread across national boundaries, resulting in a global recession. Rising government deficits and debt levels prompted rating agencies to downgrade the likelihood of debt repayment in several European countries, thereby eroding the confidence in global financial markets.

The debt crisis was precipitated by a variety of events and circumstances, including the unified currency, the Euro, and excessive national debt. All Eurozone members used the same currency and adhered to the same monetary policy. However, each country independently controlled its fiscal policies, which decide government spending and borrowing. This led to low costs of borrowing, encouraging countries like Greece and Portugal to borrow and spend beyond their budgets. Also, currency value has significant effects on exchange rates and exports. During financial crises, governments frequently devalue their currencies in order to stimulate exports. Nevertheless, devaluing a currency also increases the dollar value of existing sovereign debt acquired from other countries, as was the case for European countries like Greece. It precluded Europe from devaluing the Euro and increasing exports, therefore aggravating the European sovereign debt crisis. The sovereign debt crisis resulted in economic contractions, job losses, and social turmoil. Therefore, the aftermath of the crisis featured high unemployment rates, greater income inequality, and more people at risk of poverty.

1.2 Motivation

This paper aims at investigating whether contagion effects exist during the European Debt Crisis by comparing stock indexes in the Eurozone, Asia, and the United States using a variety of correlation coefficients and copula functions. After discovering the reasons for contagion and establishing the transmission of the European Sovereign Debt Crisis, we propose structural economic suggestions to Macau, a city with a social welfare system comparable to Greece, in order to avert a repeat of the crisis.

2 LITERATURE REVIEW

2.1 European sovereign debt crisis

There is rich literature concerning the origins of the European sovereign debt crisis. Philip R. Lane (2012) found that the defects in the euro's original structure are the basis of the European sovereign debt crisis [1]. People do not completely appreciate the fragility of currency unions under crisis conditions, especially when banking unions and other European-level buffer measures are absent. Even though the underlying financial and macroeconomic imbalances were more significant, Greece's decision-makers were to fault for fiscal irresponsibility.

According to Georgios P. Kouretas (2010), the adoption of the euro has provided several benefits to all its members, especially those with historically high inflation rates and lack of credibility in economic policy, such as Greece [2]. Thus, the introduction of the euro has led to a decrease in inflation. Private investment increased as a result of the low inflation environment and corresponding fall in nominal interest rates. Greece has experienced rapid growth after joining the eurozone, with real growth rates of 3.9% per year between 2001 and 2008.

Unfortunately, the Greek government failed to capitalize on the low-inflation environment from 2001 to 2009. Greece's fiscal accounts show a significantly larger deficit averaged 6% of GDP, as well as an increase in the amount of government spending in the economy. These figures

shocked the public, undermining trust in global financial markets (Manos Matsaganis, 2011) [3]. The situation in Greece developed on an unforeseen scale shortly after the start of the international financial crisis of 2007–2008, coinciding with weak global economic development, and quickly extended to other nations, resulting in another global recession.

2.2 Contagion

Contagion refers to the spread of an economic crisis from one market or region to another, which may occur at both domestic and international levels. In the European sovereign debt crisis, different types of contagion have been suggested, including interbank contagion, currency crisis contagion and financial market contagion.

Payment systems and the interbank market are two examples of how banks connect. These different connections have the potential to contagion.

McAndrews and Roberds (1995) [4] and Freixas and Parigi (1998) [5] used a locational model of payment systems to study contagion in net and gross payment systems. If one institution fails, a chain reaction occurs, and the bank will be vulnerable to contagion. Transactions are settled in central bank currency one-to-one in the general system. There is no risk of contagion, but banks must maintain large reserves.

Allen and Gale (2000) conducted a study that concentrates on a contagion platform that arises from the overlapping claims that different banking system regions or sectors have on one another via interbank markets [6]. When one region experiences a banking crisis, the value of the other regions' claims on the afflicted region diminishes. If the spillover effect is strong enough, it has the potential to cause a crisis in neighboring regions that, in the worst-case scenario, becomes a contagion.

When we discuss contagion in currency crises and international markets, we generally refer to three basic theories: Monsoonal effect, spillovers, and pure contagion. Masson (1999) distinguishes between the three theories [7]. Monsoonal effects will occur when industrial countries undergo major economic shifts that influence emerging economies. When there are links between regions, the spillover effect arises. Pure contagion implies that the expected change is unrelated to fundamentals and is tied to multiple equilibria.

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3 MODEL AND METHODOLOGY

3.1 Description of crisis contagion

This research identifies a factor, the stock index from 2005 to 2015, which can explain a significant portion of the variation in the weekly exchanges of the five major stock markets, namely the stock markets of Greece, Germany, the United Kingdom, the United States, and Hong Kong. Multiple coefficients were employed in this study to estimate the correlation between Greece and other countries, including Pearson correlation, Rank correlation and Copula function.

1)Pearson Correlation: Firstly, we employed the Pearson correlation coefficient $\rho(1)$, which has a higher sensitivity to linear dependence. It is a covariance-based linear measure and takes value in [-1,1]. It has two conditions: (1) linear relationship between two variables; (2) X_1 and Y_1 are jointly normal. However, it cannot provide a precise estimation for non-linear dependence. If X_1 and X_2 are independent, then $\rho(X_1, X_2) = 0$, but it should be well known to all users of correlation that the converse is false: the uncorrelatedness of X_1 and X_2 does not imply their independence in general, which may be its drawback.

$$\rho = \frac{\sum_{i=1}^{n}(X_1 - \underline{x})(Y_1 - \underline{Y})}{\sqrt{\sum_{i=1}^{n}(X_1 - \underline{x})^2}} \sqrt{\sum_{i=1}^{n}(Y_1 - \underline{Y})^2} \tag{1}$$

2)Rank Correlation: Subsequently, two rank correlations, namely the Spearman correlation $\rho_s(2)$ and Kendall coefficient τ (3) were employed to measure non-linear dependence. Compared to Pearson correlation, rank correlation can suit more data. Rank correlations are simple scalar measures of dependence that depend only on the copula of a bivariate distribution and not on the marginal distributions, unlike linear correlation, which depends on both.

$$rho(a, b) = \frac{\sum_{i=1}^{n}(X_{a,i} - \overline{X}_a)(Y_{b,i} - \overline{Y}_b)}{\left\{\sum_{i=1}^{n}(X_{a,i} = \overline{X}_a)^2 \sum_{j=1}^{n}(Y_{b,j} = \overline{Y}_b)^2\right\}^{1/2}} \tag{2}$$

Where $\overline{X}_a = \sum_{i=1}^{n}(X_{a,i})/n$, and $\overline{Y}_b = \sum_{j=1}^{n}(X_{b,j})/n$, where n is the length of each column.

$$\tau = \frac{2K}{n(n-1)} \tag{3}$$

Where $K = \sum_{i-1}^{n-1} \sum_{j=i+1}^{n} \xi^*(X_{a,i}, X_{a,j}, Y_{b,i}, Y_{b,j})$, and
$$\xi^*(X_{a,i}, X_{a,j}, Y_{b,i}, Y_{b,j}) = \begin{cases} 1 \ if \ (X_{a,i} - X_{a,j})(Y_{b,i} - Y_{b,j}) > 0 \\ 0 \ if \ (X_{a,i} - X_{a,j})(Y_{b,i} - Y_{b,j}) = 0 \\ -1 \ if \ (X_{a,i} - X_{a,i})(Y_{b,i} - Y_{b,i}) < 0 \end{cases}$$

3)Copula Functions: Since the aforementioned correlation measures (linear and rank correlations) fail to capture tail dependence, which provides measures of extreme dependence, they can understate the probability of extreme events that lead to large losses, for instance, the European Sovereign Debt Crisis. As such, we applied 4 copula functions, including Gaussian

copula, Student's T copula, Clayton copula, and Gumbel copula, to examine the tail dependence during the crisis.

Copula functions could link marginal distributions together to form the joint distribution. For any random variables $X_1, X_2, ..., X_p$, we need copula functions to join marginals to their joint distribution as:

$$F(x_1, x_2, ..., x_p) = C[F_1(x_1), F_2(x_2), ..., F_p(x_p)]$$

If each $F_j(x)$ is continuous, C is unique. From a modeling perspective, copula allows us to separate the modeling of the marginal distributions $F_j(x)$ from the dependence structure.

3.2 Causes of Contagion

There may be many reasons for expecting a crisis to take place in time. Contagion causes can be theoretically classified into three types (Masson, 1999) [7].

The first category emphasizes a shared source for crisis occurrence, such as measures implemented by industrial countries that have similar consequences on emerging markets. Examples include the early 1980s Latin American debt crisis, which was precipitated by an increase in interest rates in the United States, and the 1973 oil crisis, which was precipitated by an oil embargo declared by the Organization of Arab Petroleum Exporting Countries. This category is known as "monsoonal effects" (Masson and Mussa, 1995) [8], and it refers to basic economic shifts in industrial countries that lead to crises in emerging markets.

The second category implies that a financial crisis in one country may have a substantial effect on the macroeconomic fundamentals in other emerging markets. It is referred to as "spillovers" since it stems from the interdependence of emerging countries. The Canada-US trade connection exemplifies it; the effects of a slight U.S. slowdown are compounded by Canada's reliance on the U.S. market, as the United States is Canada's primary export market.

The final category involves a financial crisis in a single country that is not unrelated to macroeconomic fundamentals and is solely the result of market sentiment and investor behavior. According to Masson (1999), the term "contagion" is only applied to this category [7]. Contagion, according to this definition, arises when there is a comovement, even though there are no global shocks and interdependence and fundamentals are not involved. One prominent example is that the crisis may lead investors to reassess the fundamentals of other countries, even if it does not result in a change in the risk tolerance of investors.

3.3 Transmission Model

1)Liquidity Theory: A transmission model is proposed based on the liquidity theory to explain the correlation analysis and to find out the reasons for contagion, which underlies comparisons between the real situation in Greece, Macau and the model at the conclusion.

According to liquidity theory, consumers can save for future consumption by investing in two types of assets: a short liquid asset and a long illiquid asset. To explain the essential concepts, time is divided into three periods indexed by $t= 0,1,2$. For $t=0,1$ the short asset allows one unit of the good at date t to be converted into one unit of the good at date $t+1$, whereas the long asset allows one unit of the good at date 0 to be converted into R (R= Return rate) >1 unit of

the good at date 2. Despite the fact that the short asset matures after one period, it offers a low return. The long asset matures in two periods but pays a higher return. At the midpoint, each unit of the long asset can be prematurely liquidated to produce $0 < r < 1$ unit of the consumption good. In practice, assets are more likely to be liquidated by sale, while the liquidation value is determined by the market price.
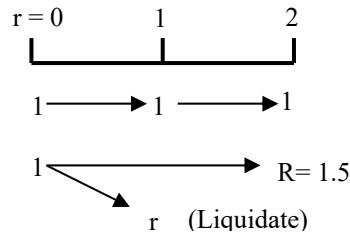

Figure 1. Two Types of Assets

2)Liquidity Preference: Generally, there are two types of consumers in the assumption, the early consumers who only consume at date 1 and the late consumers who only consume at date 2. Here we assume λ indicates the likelihood of being an early customer, and $1-\lambda$ represents the chance of being a late consumer. The consumer is uncertain about whether he is an early or late consumer until the beginning of date 1, while λ can be thought of as a measure of consumer liquidity preference. From a larger scale, λ varies from region to region.

3)Complete Market & Incomplete Market: Uncertainty about liquidity preferences generates an excess demand for liquidity, which is why banks are required since they have a comparative advantage in providing liquidity. Increasing market liquidity is a good way to start when it comes to banks overcoming liquidity misallocation. We have two types of markets based on liquidity: complete and incomplete markets, which differ by transaction direction; the complete market is two-way while the incomplete market is one-way.
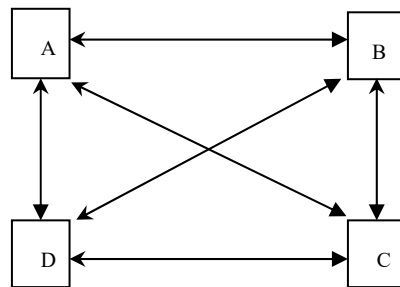
Figure 2. A Complete Market
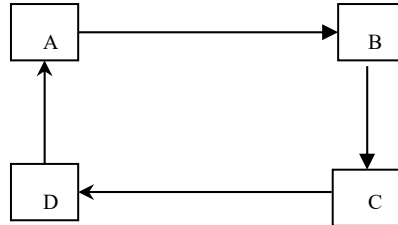
Figure 3. An Incomplete Market

4 EMPIRICAL APPLICATION

4.1 Identification of Crisis Period

We investigate the Gross Domestic Product (GDP) of Greece from the first quarter of 2000 to the fourth quarter of 2015 to determine the duration of the European Sovereign Debt Crisis. We then discovered that the crisis lasted for 6.5 years, from 2008 Q3 to 2015 Q2. During the crisis, three financial shocks occurred in total. The first financial shock began in 2008 Q3, where the GDP of Greece dropped in two consecutive quarters, coupled with the effects of the Subprime Mortgage crisis. It ended in 2009 Q3, indicated by the decrease of loss rate.

4.2 Correlation Analysis

1)Data Collection: We chose the HSI (Hang Seng Index) in Hong Kong, the GDAXI in Germany, the ATG (Athens General Composite Index) in Greece, the FTSE (Financial Times Stock Exchange 100 Index) in the United Kingdom, and the DJI (Dow Jones Industrial Average) in the United States as stock indexes.

2)General Situation: Pearson Spearman and Kendall: Different correlation coefficients are displayed respectively in the following tables Table 1 shows that all coefficients between Greece and Hong Kong or Greece and Germany have drastically decreased. Pearson coefficients between Greece and the United States, on the other hand, perform inversely, while the other two coefficients marginally decrease. In table 2, on the other hand, all coefficients decrease. As a result, during the pre-crisis period, there was a correlation of stock indexes between all countries (a decline) in the general condition.

TABLE 1. PEARSON SPEARMAN AND KENDALL

	Greek & HK		Greek & German		Greek & USA	
	Pre	Post	Pre	Post	Pre	Post
Pearson	0.6659	0.3826	0.7293	0.4469	-0.0120	-0.0410
Kendall	0.4115	0.2531	0.4848	0.3171	-0.0261	-0.0037
Spearman	0.5712	0.3757	0.6553	0.4604	-0.0390	-0.0054

TABLE 2. PEARSON SPEARMAN AND KENDALL

	Greek & UK		German & HK		German & Spain	
	Pre	Post	Pre	Post	Pre	Post
Pearson	-0.0999	-0.0804	0.6692	0.5283	-0.2234	-0.0804
Kendall	-0.0815	-0.0243	0.3919	0.3388	-0.0857	-0.0511
Spearman	-0.0754	-0.0331	0.5498	0.4839	-0.1240	-0.0750

3)Extreme situation: Copula Function:

TABLE 3. COPULA FUNCTION

	Greek & HK			Greek & German			Greek & USA		
	Pre	Post	AVP%	Pre	Post	AVP%	Pre	Post	AVP%
Ga	0.6228	0.3880	0.38	0.6873	0.4468	0.35	-0.1009	-0.0203	-0.80
St	0.6346	0.4240	0.33	0.7160	0.4768	0.33	-0.0772	-0.0224	-0.71
Gu	1.7067	1.3074	0.23	1.9482	1.3882	0.29	1.0000	1.0000	0.00
Al	1.2937	0.5939	0.54	1.6501	0.6792	0.59	0.0000	0.0000	0.00

TABLE 4. COPULAFUNCTION

	Greek & UK			German & HK			German & Spain		
	Pre	Post	AVP%	Pre	Post	AVP%	Pre	Post	AVP%
Ga	-0.1041	-0.0556	-0.47	0.6176	0.5147	0.17	-0.1552	-0.0864	0.44
St	-0.1130	-0.0617	-0.45	0.624	0.5379	0.14	-0.1498	-0.0872	0.42
Gu	1.0000	1.0000	0.00	1.6864	1.5119	0.10	1.0000	1.0000	0.00
Al	0.0000	0.0000	0.00	1.1884	0.8967	0.25	0.0000	0.0000	0.00

We employ squared euclidean distance (SED) to determine the best copula function between each country. The copula function is better suited if the value generated is lower. We located the best copula for each situation by employing the squared euclidean distance (SED). The Gaussian copula is best used in Greece and Hong Kong.

In Greece and Germany, Student's T copula is most suitable employed. Clayton copula and Gumbel copula appear to have the same value between Greece to the USA and Greece to the UK. In Greece and Germany, the Gumbel copula is best used.

TABLE 5. SQUARED EUCLIDEAN DISTANCE

	Greek & HK	Greek & German	Greek & USA	Greek & UK	German & HK
	Post				
Ga	0.0483	0.0545	0.0598	0.0497	0.0458
St	0.0487	0.0444	0.0603	0.0514	0.0399
Gu	0.0539	0.0577	0.0564	0.0443	0.0394
Al	0.0904	0.1546	0.0564	0.0443	0.1301

4.3 Reasons for Contagion

This study has therefore identified a high correlation between Greece and the stock markets of Hong Kong and Germany during the European Sovereign Debt Crisis, whereas Greece and the United States (U.S.) and the United Kingdom (U.K.) have a low correlation. In the next stage, we aimed to establish why the connection between Greece and Hong Kong, Germany was formed, as well as to investigate the reasons for the low correlation between Greece and the US and UK, based on the recent theoretical literature on contagion in financial networks, and estimate it using data on export proportions.
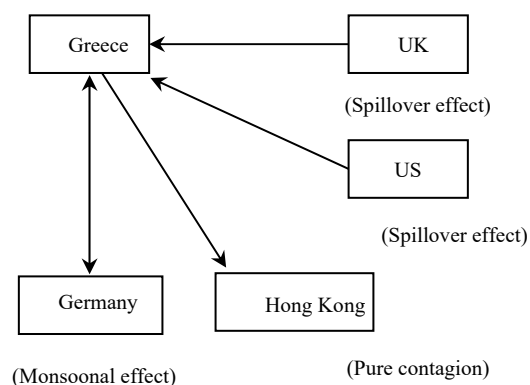
Figure 4. Contagion STRUCTURE

1)Greece and Germany: The confluence of speculative crises may have been driven by advances in industrial economies via monsoonal effects involving trade flows (Masson, 1998) [9]. The Mexican crisis, for example, was exacerbated by a rise in U.S. short-term rates beginning in March 1994, indicating that major economic upheavals in industrial countries could lead to crises in their neighbors.

As a result, during the European Debt Crisis, the connection between the Greek and German Stock market may be driven by a monsoonal effect. Because Greece and Germany are both Eurozone members, they implement the same currency and fiscal policies as the rest of the European Union, which may result in a monsoonal effect if primary economic policies shift. Spillover effects are another probable explanation for the crisis's coincidence, given Germany's position as the world's second-largest exporter.

2)Greece and the United States: Greece's exports to the United States account for a sizable part of regional exports, implying a large potential for spillover effects. According to Table 6, the United States fluctuated between the 5th to 7th primary export partners of Greece from 2005 to 2008

TABLE 6.   GREECE'S FOREIGN TRADE DATA BETWEEN 2005 AND 2008 (%)

	Exports to US	Imports from US
2005	5.02% (6th)	3.57%
2006	4.57% (7th)	2.08%

2007	5.19% (7th)	2.86%
2008	5.54% (6th)	2.47%

3)Greece and the United Kingdom: Similarly, high export rates with developed countries may contribute to the existence of spillover effects. As seen in Table 7, the United Kingdom contributed to a major fraction of Greek exports.

TABLE 7. GREECE'S FOREIGN TRADE DATA BETWEEN 2005 AND 2008 (%)

	Exports to UK	Imports from UK
2005	6.69% (3rd)	4.14%
2006	5.85% (3rd)	4.09%
2007	5.38% (4th)	3.65%
2008	4.55% (4th)	3.43%

4)Greece and Hong Kong: Table 8 illustrates that the importance of Hong Kong for Greece's export market is significantly lower in the case of Greece and Hong Kong. This preliminary quantification, therefore, suggests that there may have been a role for pure contagion effects, that is, the simultaneous occurrence of crises which is not linked to changes in observed macroeconomics fundamentals, but the market sentiment and investor confidence may have played a role, which may be led by Greece and Hong Kong's similar reliance on port trade.

TABLE 8. GREECE'S FOREIGN TRADE DATA BETWEEN 2005 AND 2008 (%)

	Exports to HK	Imports from HK
2005	0.32%	0.29%
2006	0.21%	0.19%
2007	0.22%	0.21%
2008	0.23%	0.15%

4.4 Reflections and Suggestions for Macau

There are many explanations for the outbreak of the European Sovereign Debt crisis. Despite the fact that underlying financial and macroeconomic imbalances were more severe, Greece's decision-makers are to blame for economic mismanagement, as mentioned in the literature studies. While a long-term fiscal deficit is considered as the primary cause of domestic weakness during the Greek crisis, inadequate expenditure allocation in the welfare system is one of the central reasons for the increase in government spending.

Europe has long been recognized for its sound but costly social welfare policies. While the information on Greece's economic status is not yet available, the country remains committed to the welfare system of the EU's developed countries, resulting in massive economic overruns and continuous debt. In Macau, a similar situation exists. Former Macau Chief Executive Cui Sai On stated in his 2017 "Policy-Address" that Despite a 35% decrease in gaming fees, the Macau government is still paying money to citizens as welfare for the ninth year in a row.

Permanent residents in Macau are entitled to MOP 9,000 per person, while non-permanent residents are entitled to MOP 5,400. Furthermore, pensions and pensions for senior citizens are MOP 3,450 per month and MOP 8,000 per year, respectively, and a monthly electricity subsidy of MOP 200 is maintained. The total cost of welfare was more than MOP 11.7 billion.

Commonalities exist between Greece and Macau in terms of industrial structure. Greece's industry is dominated by service industries. Taking 2014 as an example, the output value of the service industry reached 80.6% of GDP, while the output value of agriculture and industry was relatively low, accounting for only 3.5% and 15.9% respectively (Central Intelligence Agency, 2015). According to DSEC (Government of Macao Special Administrative Region Statistics and Census Service, 2019), the service industry accounts for 95.7% of the total while the gaming industry accounts for 50.6% of the service industry. This figure demonstrates how Greece and Macau are overly reliant on the service industry. Based on Greece's experience, this could result in low industrial competitiveness and long-term current account deficits. The peculiarities of Macau's industrial structure have resulted in an increase in the Macau economy's ability to withstand risks, especially during an emergency, such as a pandemic.

While the cause of the association between Greece and Hong Kong is pure contagion, it serves as a caution to Macau, while likewise provides a high degree of social benefits but is highly reliant on a single economic industry. Therefore, suggestions are given in this study. For long-term development, it is essential to create a diversified industrial structure. The development of the Greater Bay Area provided an opportunity for Macau to eliminate its unified structure. While Macau has limited resources, the substantial resources of the Greater Bay Area will promote Macao's economic development. When there is a sufficient wealth surplus, the Macau government should reinforce the existing welfare system as a crisis prevention tool. The use of public funds in the pension system should be considered as an alternative in order to reduce government spending.

5 CONCLUSION

We measured the correlation between Greece and other countries such as Germany, the United Kingdom, the United States, and Hong Kong using the Pearson correlation coefficient, Spearman correlation coefficient, and Kendall coefficient. Following that, four copula functions, including Gaussian copula, Student's T copula, Clayton copula, and Gumbel copula are used to examine the tail dependence. The empirical results indicate that contagion is evident between the stock market of Greece and that of Hong Kong and Germany, but attributing to different reasons: the mode of contagion for Greece and Germany is the monsoonal effect, while the cause of correlation for Greece and Hong Kong is pure contagion, which has significant implications for Macau: they both provide high social welfare and over-rely on the service industry [10], meaning that a similar crisis may occur in Macau. Therefore, As a result, as a crisis prevention measure, additions and adjustments to the current situation should be supplied. Macau should diversify its sectors for long-term economic development by working in tandem with the development of the Greater Bay Area. Furthermore, the government should make adjustments in the social welfare system in order to avoid following the disastrous road of Greece.

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