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Identifying path of Global Financial Crisis Contagion Direction on Industries of Iran Stock Market

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Abstract
Simultaneous understanding of volatilities and changes in financial markets is very important to optimize the portfolio and risk management methods. The 2008 financial crisis led into devaluation of most assets, increased volatilities and endangered several institutional investors' survival. When the stock market' correlation is highly enhanced, risk and return management with the classic portfolio theory becomes severely challenging. In this study, to manage systematic and non-systematic risks by investors and policymakers in case of similar financial crises, the Effect of global financial crisis contagion is examined through the path of S&P500 global index, and DFM regional index of different industries of Iran Stock Market is examined using DFGM contagion test and stochastic Ornstein Uhlenbech process. The results show that Dubai Stock Market has an important role in crisis expansion into different sectors of Iran Stock Markets so that the fundamental contagion effects are channelled via this direction. Also, according to the results, the starting point of the global financial crisis contagion was the basic metals industry, and the contagin happened in metal ores and petroleum products sectors with different rates. Finally, the global financial crisis is spread into different industries of Iran Stock Market via financial links and not trough commercial ones. Identifying the direction of contagion of financial crisis provides an opportunity for investors to apply hedging and asset allocation strategies optimally.

Keywords: Stock Market, Global financial crisis, DFGM contagion test, Ornstein-Uhlenbeck process.
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Introduction

Financial crises are generally recurring phenomena and their effect is not limited to the original economy and markets, as they spread into other countries' economies via different channels. Financial crisis concept refers to a condition in while many financial entities or assets suddenly lose a considerable part of their value. Financial crisis includes several kinds such as payment balance, circulating currency, debt, banking, international reserves and equity market (Bonis et al, 1999). The concept, despite an increasing number of studies on financial contagion, does not have a globally recognized description, and it is visible especially in different approaches of contagion effect test.

World Bank (2013) provides several definitions for the contagion: World Bank's three main definitions are suggested as below:

Broad definition: "contagion is the transfer of shocks between countries or the effect of general spillover between countries."

Restrictive definition: "contagion is the transfer of shocks to other countries or their correlation, without any basic relation between countries and existing shocks. This definition is wholly known as excessive co-movement, which is described by herd-like behavior."

Very restrictive definition: "contagion happens when countries' correlation during a crisis is increased compared to the peaceful period."

Forbes and Rigobon (2002) consider the contagion effect as a considerable increase in intermarkets links which is made up by a country or a group of countries being hit by shocks," and describe the concept as "shift contagion". The description is admitted and applies by many scholars. Forbes and Rigobon explain that if markets indicate a high positive correlation during stability, and it is maintained ever after being hit by a shock, this can not be necessarily a sample of contagion. A significant co-movement of markets (positive correlation) aftershocks should be stabilized in order to include contagion; otherwise high level of correlations existence is due to powerful links between markets. This is considered as "mutual dependence". The financial crisis in 2008 which initiated by the US subprime mortgage crisis, was the worst and most severe crisis experience in the world since the Great Depression in the 1930s. The event led some advanced economies into an unforeseen recession as global equity markets crashed. The emerging stock markets were not on the safe side, since equity prices drastically dropped in these countries, especially on September 2008, when Lehman Brothers

collapsed and two debt crises occurred in Dubai and Europe and further lowered equity prices (Habiba Al Mughairi, 2016). Scholars and market participants were mainly worried after 2008 financial crisis about the contagion effect and crisis transfer to different markets. As an example, the financial crisis lowered capital market investment in the UAE and Saudi Arabia and subsequently their equity markets' indices heavily lost their value. Despite the fact that most of the listed companies in Iran's Stockmarket did not have a direct financial transaction with international companies, the global recession which lowers products' prices in the world and then in Iran, affects manufacturing companies' competitive capacity in the country and brings negative expectations on equity returns. By the start of the financial crisis, the Tehran Stock Exchange total index had an almost negative trend and the price index of the crisis-stricken stock was hit by tangible volatilities (Keshavarz, 2013). In this way, identifying financial crises contagion direction into stock markets different sectors to integrate exchange's indices aiming at creating convergence and reaching relative stability in Iran's stock markets sectors via an appropriate approach and supportive policies is applying reducing crisis effects and to manage systematic and non-systematic risks. Due to such considerations, analyzing and evaluating contagion starting point and rate of contagion for financial crises in different sectors of the stock exchange and the co-movement of these sectors are truly important to create a more transparent understanding of diversification and portfolio risk management benefits and applying hedging strategies for investors and policy markets. The research aims at the identification of financial crisis contagion direction for stock exchange sector to manage portfolio risk.

Based on the provided evidence, these questions can be asked if the financial crisis affects the return and price index volatilities in different sectors of the national exchange. Which sectors of Tehran Stoch Exchange price index are affected by financial crisis contagion? Where is the starting point of financial crisis contagion? Is the contagion rate of different sectors in the Exchange identical?

The current study is different from previous ones on financial crisis contagion by several means. Initially, it reviews financial crisis contagion direction in different sectors of Iran's equity market, considering the role of Dubai Stock market in the contagion transfer. The study is justified as different sectors can act differently under financial crisis effect; as a result, different sectors' systematic and non-systematic risks are identified before and after financial crises contagion, which have important outcomes for asset allocation and portfolio risk evaluation. Besides,/ in the recent decade equity markets

have partly changed into a premium channel for investors' portfolio optimized management. Also, this is the first measure that Dubai Stock market is considered as the financial crisis contagion channel into Iran's Exchange different sectors. Dubai Stock market is selected as the financial crisis contagion channel as there are similar economic, political and geographical features with Iran, and the commercial transaction volume is considerable between Dubai and Iran.

The present study is organized into five sections. The first section provides a theoretical background and review literature on financial crisis contagion. In the second section, the methodology of DFGM models and Ornstein-Uhlenbeck process is described, as well as the research model to identify the path of financial crises contagion in the industries of Iran Stock Market. In the third section, the data description is presented. Section four is dedicated to the research model in order to identify the path of the global financial crisis contagion in the industries of Iran Stock Market. And finally, the last section is the conclusion

Theoretical background and previous studies

1. Theoretical background

Several theories have been provided in financial literature about different transfer channels of shocks and contagion; these can be categorized into two major groups. The first group of theories is concentrated over fundamental bases (such as common shocks, trade linkages and financial linkages). The other part explains contagion occurrence based on investors' behaviors, (including liquidity and incentive problems, information asymmetry, market coordination problem and investor reassessment). The financial contagion may happen by a spillover of financial markets' inter-dependence, which is visible during financial crises. Kaminsky and Reinhart (1996) indicate this crisis expansion as a contagion based on a foundation. Volatility transfer of financial crises cannot be solely related to evident changes in the macroeconomy, but the result of investors' behaviors or other financial entities. King and Wadhwari (1990) encourage investors during a national crisis to transfer their capital to other markets. This kind of contagion is usually the reason for international behaviors such as financial drift, herd behavior, uncertainty and risk aversion inclination. Such risks can be either local (internal) which originate from an individual country to affect other countries' economic foundations, or general (global) which affect more than one country or market simultaneously (Bekart et al, 2014).

Forbes and Rigobon (2000) introduced a profitable distinction between non-crisis contingent theories and crisis contingent theories. The former point out the international transfer of shocks, regarding the fact that transfer process changes aftershocks occurrence.in other words,

These theories refer to the cases in which a complete transfer has accomplished via economic linkages between countries or investors' signaling viewpoint determines four main channels: trade spillovers, financial linkages, common external factors and learning trade spillovers originate from the fact that when a country is facing with a considerable devaluation of its currency, other countries will bear losses by decreasing their competitive capacity comparing the first country. Moreover, if the currency exchange rate's drop causes economic activities recession in a country, the export of trade partners will further decline. The process has been formulized by Gerlach and Smets and some experimental measures, including works by Eichengreen, Rose and Wyplosz confirm the issue. when investors act to modify their portfolio after a shock occurrence, financial linkages may lead to the contagion of shocks. Investors will have to transfer their positions into the other country's markets for risk management or liquidity goals. The viewpoint is provided by Baig and Goldfajn, Business and Mulder and Valdes.

The common external factors provided by Masson have been defined as major economic shifts the industrial countries which arise in emerging markets. Such common shocks include a rise in international interest rates, changes of mutual exchange rates between large economies and drop of global demand. The shocks can bring asymmetrical effects on national economies.

Learning is a wake-up call for investors when a crisis happens in a country (Goldstein) so that their tendency and risk aversion of the countries with macroeconomic structure and similar policies are reevaluated.

Financial markets linkages make a markets' crisis spread to other markets, or even cover the whole economy. The stock market is of the most important financial markets in a country, and are applied as an index to indicate national economic status. Therefore, in financial crises stock markets are affected differently but related (Hartman et al.)

2. Previous studies

Forbes and Rigobon (2002) point out international shocks transfer regardless of the changes in the transfer process aftershocks occurrence by differentiating between non-crisis contingent and crisis-contingent theories. In other words, these theories indicate cases in which economic linkages between countries or

investors' signaling are completely determined.

Wang and Thi (2006) use the bi-variate GARCH-DCC model to evaluate the existence of contagion between Thai and Chinese economic zone's stock markets. Their samples were Shanghai, Hong Kong, Taiwan and Bangkok's exchanges indices from 21 February 1992 until 15 November 2000. The result shows a sign of contagion effects during the Asian crisis in the region. The contagion happened in an exceptional economic growth period, i.e., investors should specifically consider the neighboring countries' events, and when economic, financial and market information is neglected, endogenous financial shock rise.

Malik and Hammouded (2007) evaluated the volatility contagion mechanism between the USA and Persian Gulf's countries stock and crude oil global markets by using multi GARCH model and daily data between 1994 and 2001. They found out that the oil market is indirectly affected by the US and Saudi Arabis's stock markets news. For Saudi Arabia, there is a significant spillover of volatilities toward global oil market as the largest peto-exporter. On the other hand, Persian Gulf countries' stocks are recipients of volatilities from the global oil market.

Beiere et al. (2012) review the changes in global correlation in a large complex of crises between 1978 and 2010, but as mentioned by the scholars, econometrically it is difficult to separate contagion and globalization.

Abdullah Yalam (2012) revises the UK'S role in affecting the transfer of global financial crises from the USA to Turkey by using DFGM and FR models. Besides, the significance of the UK Stockmarket in DFGM model is more precise than in the FR model, and the global financial crisis is transferred by financial linkages in Turkey rather by trade linkages.

Emenike Kaluo (2014) studies fluctuation transfer between stock markets and the currency in Nigeria between January 1996 and March 2013 by using multivariate Garch model in the framework of BEKK. The outcomes indicate a reciprocal relationship between stock and currency markets, manifesting the effects of information flow in the currency market toward the stock market and vice versa.

Fry and Shiao (2015) review volatility contagion originated from the global crisis in 2008-2009 from the US banking sector to the global stock markets and banking sectors. The results from the extremal estimation model indicate volatility contagion from the US banking sector to the intended sectors.

Sclip et al. (2016) review the dynamic correlation of volatilities between stock and sukuk international markets by using multivariate GARCH models, symmetrical with dynamic conditional correlations (DCC) and student's t-distribution. The results show there is a high correlation between the USA and the UAE's Sukuk and Stock markets. Also, the fluctuation linkage between Sukuk and regional markets' indices is higher amid global financial crisis they found out that diversification benefits, including in Sukuk with considerably lower fluctuation than equities can be achieved in a well-diversified portfolio.

Dahiru A. Bala (2017) reviewed stock return volatilities spillovers in emerging and developed markets by multivariate GARCH models. Also, the global financial crisis (2007-2009) effects on the stock market's volatilities interactions were estimated by MGARCH models and through dummy variables of the financial crisis to evaluate their effect on volatility and spillover. The results indicate a correlation between emerging markets which is lower comparing the developed markets' correlation and increasing during the financial crisis.

Roy and Roy (2017) evaluate financial contagion in assets markets of India. The findings show that the financial contagion rate is large among these markets. Also, VAR model results show that the stock market transfers fluctuates, while bond, currency and gold markets are the recipients.

Korniyenko et al. (2018) review the global financial system's dependence and shock-contagion exposure though the most important contagion transfer channels, including debt and stock issuing relations between countries based on network analysis. They found out with the occurrence of the global financial crisis, the financial network structure has changed. Among central countries, most of the contagion is transferred from the USA and its financial system. While, among European countries, the UK has had the least effect on shocks transfer and the highest effect is related to the Eurozone.

Patrick Olufemi Adeyeye et al. (2018) evaluate the global financial crisis on emerging stock markets behaviors by providing some evidence of efficiency and volatility in the stock market of Nigeria during different periods. The studies timeline was between July 2004 and December 2014, and the results show that the price is not a martingale, including Nigerian stock market as an efficient market.

Walid Mensi (2019) reviews the global financial crisis and dynamic simultaneous changes between oil prices and different sectors in Saudi Arabia’s market by applying the wavelet analysis approach and VaR scale. The results indicate significant simultaneous changes between crude oil and

different exchange sectors during the time with different frequencies. These changes intensify at the same time as a result of 2008-2009 global financial crises. Between 15 sectors petrochemicals is affected the most, and hospitality and tourism are affected the least by oil price changes. Besides, banking, agriculture and food industries, telecommunication, media and publishing and hospitality and tourism are not affected by the recent oil price drop after mid-2014.

Keshavarz Haddad and Meghareh Abed (2012) review 2008 financial crisis contagion effect in the US between 2006 and 2009 over Tehran Stock Exchange's broad index, industry index, financial intermediary, as first and second markets indices of the Exchange by applying DFGM contagion test. The results indicate that the global crisis has spread to Tehran Stock Exchange's total index. Also, the 2008 financial crisis in the US affects index and first market indices and decreased the value of these indices; however, was not effective on financial intermediaries and the second market indices.

Seyyed Hosseini et al. (2013) used time-series data from oil-dependent countries' stock markets between 2006 and 2010 to study the constant conditional correlation volatility contagion with the long-term memory and the constant conditional correlation model to find out that volatility contagion fro, global oil markets to Dubail and Tehran markets, and also the contagion happen from Dubai market to Tehran.

Elmi et al. (2016) reviewed the effect of the structural changes of volatilities on momentum transfer and the spillover between gold market and iron stock market in a period between 2007 and 2013, by using a common algorithm of iterate cumulative sum of squares (ICSS), and also a modified algorithm of ICSS. The findings show that momentum and of intermarket fluctuations are reciprocal between studied markets and an incorrect determination of structural changes may lead to a misdirection of momentum and spillover evaluation in the variables of the research.

Fattahi et al. (2017) review the contagion in Iran's financial markets using a combination of Ornstein- Uhlenbeck process and converting continuous wavelet between 2008 and 2017. Findings show that the starting point of contagion in Iranian financial markets was oil market and the rate of stock market synchronization with the oil market is higher than with other markets, and after that, respectively currency and gold markets are placed. Also, they found out that there is a considerable correlation between oil market and other financial markets in the short–term; however, the correlation is only available between oil market and two markets of stock and currency in the long run and

after oil sanctions against Iran in 2012, the correlation between oil markets, and currency and stock markets increase in the mid-term.

Methodology

1. Interdependence model

Before designing the contagion model, asset markets interdependence model during the non-crisis period were used as a hidden factor model of asset return for contagion direction test. This model is originated from financial factor models based on orbitrage theory, in which asset return by common factors series aka systematic risk (non-diversifiable) and a series of special factors aka non-systematic risk (diversifiable) are determined (Sharpe, Solnik). Similar models of hidden common factor are used by Corsetti et al (2001, 2003), Dungey and Mrtin (2001), Dungey et al (2005), Forbes and Rigibon (2002) and Bekaert et al (2005).

In this part, and to simplify the contagion model, the number of studied assets is considered as 3. Extending the model to N assets or asset group is simple. Let's presume three assets return during the non-crisis period as follows:

$$\{x_{1.t}.x_{2.t}.x_{3.t}\} \quad (3)$$

All return average is regarded as zero. The returns could be from currency or stock markets in each country or a mixture of both markets in an individual or some countries the following trivariate factor model is a dynamism summary in three processes during crisis period:

$$x_{i.t} = \lambda_i w_t + \delta_i u_{i.t} \quad i = 1.2.3 \quad (2)$$

The variable w_t indicates common shocks in which it affects all assets' return with the coefficient. The shocks can show financial shocks by changes in risk aversion of international investors or changes in global financial aids (Cizeau et al, Rigobon, Mahien and Schotman). Generally, it indicates hidden market foundations which determine assets average return in international markets during the "normal" period aka non-crisis period. The variable is usually considered as a global factor which may be visible or invisible. For detailed goals, the hidden stochastic process' global factor is determined by the variance 1, and the average of zero:

$$w_t \sim (0.1) \quad (3)$$

The factor's features will be discussed later to calculate richer dynamism, including automatic correlation and time-varying volatilities. The terms $u_{i.t}$in the second equation are the unique factors of a special asset market. Special shocks role is determined in asset return functions with coefficients$\delta_i > 0$. These factors are presumed a stochastic process with zero average and variance of 1:

$$u_{i.t} \sim (0.1) \tag{4}$$

To complete the model, all factors are considered as independent:

$$E[u_i . u_{j.t}] = 0. \quad \forall_{i \neq j}. \tag{5}$$

$$E[u_{i.t} . w_t] = 0. \quad \forall_i. \tag{6}$$

To emphasize the interrelations between three assets' return in equation 2 amid the non-crisis period, the covariance's are calculated with the following relation:

$$E[x_i . x_{j.t}] = \lambda_i \lambda_j. \quad \forall_{i \neq j}. \tag{7}$$

Also, the variance includes:

$$E[x_{i.t}^2] = \lambda_i^2 + \delta_i^2. \quad \forall_i \tag{8}$$

Equation 7 indicates that each dependency between asset returns is only the result of common shocks' effects with identical effects overall markets. The following relation:

$$\lambda_1 = \lambda_2 = \lambda_3 = 0 \tag{9}$$

Will lead to independent asset markets, which determine all movements with specific shocks. The hypothesis used by Mahien and Schotman (1994) is that $\lambda_i \lambda_j$is considered equal to the constant value of L for$i \neq j$.

2. Contagion experimental model

Contagion is defined by simultaneous transfer of local shocks to another country or market after being conditional on common factors existing in a non-crisis period and indicated in equation 2. The description is based on Masson (1999)'s definition which separated asset market shocks into common spillovers originated from some identifiable channels and contagion. As indicated later, the definition is based on other approaches like the one of Forbes and Rigobon, in which contagion is depicted by an increase of

correlation amid crisis period.

The first model discussed here is based on factor structure developed by Dungey et al (2002, 2005). As a result, contagion from country 1 to country 2 is to be considered. Equation 2-factor model can be developed as follows:

$$y_{1.t} = \lambda_1 w_t + \delta_1 u_{1.t}$$
$$y_{2.t} = \lambda_2 w_t + \delta_2 u_{2.t} + \gamma u_{1.t} \quad (10)$$
$$y_{3.t} = \lambda_3 w_t + \delta_3 u_{3.t}$$

$x_{i.t}$ is substituted in equation 2 $y_{i.t}$to justify asset return decline during the crisis period. The term now includes contagion transfer channel which is indicated by local shocks of an asset market in country 1, and its effect is calculated by γ parameter. The main objective of all experimental models is the contagion test of statistical γ parameter's meaningfulness.

2-1.Bivariate test

Contagion bivariate tests are concentrated over changes in each pair of asset return volatilities. From equation 10; the covariance between countries 1 and 2 assets during the crisis period includes:

$$E[y_1 . y_{2.t}] = \lambda_1 \lambda_2 + \gamma \delta_1 \quad (11)$$

Comparing it with non-crisis period covariance in equation 7 indicates changes in covariance between two periods as follows:

$$E[y_1 . y_{2.t}] - E[x_{1.t} . x_{2.t}] = \gamma \delta_1 \quad (12)$$

If γ>0, an increase of asset returns covariance during a crisis is as presumed. The situation is usually pronounced in crisis data. However, it can be visible once there is a decline in covariance. Both situations are verified, as both indicate evidence of contagion via shocks' effects in equation 10. Therefore, the contagion test is calculated by the following restriction test in equation 10-factor model:

$$\gamma = 0 \quad (13)$$

This is the approach taken by Dungey et al, and Dungey and Martin. Another approach to creating the contagion test is to apply the volatility term for $y_{2.t}$ obtained by the following equation:

$$E[y_{2.t}^2] = \lambda_2^2 + \delta_2^2 + \gamma^2 \quad (14)$$

Comparing this term with equation 8, it becomes clear that changes in volatilities of two periods are only due to the presence of contagion.

$$E[y_{2.t}^2] - E[x_{2.t}^2] = \gamma^2 \quad (15)$$

As a result, the test based on equation 13 can be described as a test to indicate whether there is an increase in fluctuations or not. Equation 14 shows the proper description of $y_{2.t}$ fluctuation in the analysis of shocks effects as common, specific and contagion shocks, which are shown respectively as below:

$$\frac{\lambda_2^2}{\lambda_2^2 + \delta_2^2 + \gamma^2}, \frac{\delta_2^2}{\lambda_2^2 + \delta_2^2 + \gamma^2}, \frac{\gamma^2}{\lambda_2^2 + \delta_2^2 + \gamma^2} \quad (16)$$

This scale analysis describes the relative potential of contagion in affecting over returns' fluctuations during the crisis. As mentioned previously, the contagion potential is determined by γ parameter, which is convertible as a test.

2-2. Multivariate test

The existing contagion test is the one for reviewing the contagion between countries 1 and 2. However; this can be tested in different directions if sufficient moment conditions are available to identify the unknown parameters. As an example, equation 10 can be extended as below:

$$\begin{aligned} y_{1.t} &= \lambda_1 w_t + \delta_1 u_{1.t} + \gamma_{1.2} u_{2.t} + \gamma_{1.3} u_{3.t} \\ y_{2.t} &= \lambda_2 w_t + \delta_2 u_{2.t} + \gamma_{2.1} u_{1.t} + \gamma_{2.3} u_{3.t} \\ y_{3.t} &= \lambda_3 w_t + \delta_3 u_{3.t} + \gamma_{3.1} u_{1.t} + \gamma_{3.2} u_{2.t} \end{aligned} \quad (17)$$

Or summarized as,

$$y_{i.t} = \lambda_i w_t + \delta_i u_{i.t} + \sum_{j=1.j\neq i}^{3} \gamma_{i-j} u_{j-t} \qquad i = 1.2.3 \quad (18)$$

Theoretical variance or covariance is an extension of terms which are respectively provided in equation 14 and 11. As an example, country 1's return variance is as follows:

$$E[y_{1.t}^2] = \lambda_1^2 + \delta_1^2 + \gamma_{1.2}^2 + \gamma_{1.3}^2 \quad (19)$$

While countries 1 and 2 assets' return covariance is:

$$E[y_1 . y_{2.t}] = \lambda_1 \lambda_2 + \delta_1 \gamma_{2.1} + \delta_2 \gamma_{1.2} + \gamma_{1.3} \gamma_{2.3} \quad (20)$$

There are 6 parameters; in this case, γ_{ij} indicating contagion's potential in all asset markets. The model is not identified by itself, since there are 12 unknown parameters. But with a mixture of variance-covariance matrix experimental moments during the crisis period, 6 moments with experimental moments of variance-covariance matrix amid the non-crisis period and 6 other moments, totaling 12 moments are formed. These can be used for estimating 12 unknown parameters with generalizing moment method (GMM). In the provided model in 3 markets, the total number of unknown parameters is nine. Considering 9 unknown variable and 12 equations in the estimation of GMM, it is a metacognition model.

3. Ornstein Uhlenbeck (OU) Process

To study the correlation rate of inter-markets relations and fluctuation modeling in financial markets, OU Process is applied. OU process is an example of the Markov process in the condition's space and continuous time which has adopted features from Brownian Motion in practice. The main features of the OU model include:

1. OU process is capable to indicate motion toward a long term.
2. Long term balance value and the return rate is reviewed to the mean for studying the crises extend in the markets.
3. OU process can be applied for different time steps (time intervals).

OU process is determined for the variable x_t by the stochastic differential equation:

$$dx_t = \theta(\mu - x_t)dt + \sigma dW_t \quad (21)$$

θ is a positive value which indicates the return rate to the mean, and μ is the balanced value to which the process moves, and σ is the OU process fluctuation and W_t Wiener process. We will be able to determine different indices reaction to the big changes in each market via θ using the OU process for financial markets modeling. In this study, θ shows the speed in which financial markets react to the events after the occurrence. It should be reminded that there is a latency in markets reactions, and the larger return rate indicates more influence over markets from such happenings. As a result, with dependence modeling, each pair of markets with the OU process and the estimation of its parameters, the larger amount of θ indicated more dependence

of market pair. Process fluctuation σ indicates some information about dependence issue and markets differences during the time so that the small number ofσ indicates both markets relationship. On the other hand, the long-term mean of μprovides us with more information to compare each pair of the market. Also, the definite amount μ is measured based on dependence for evaluating, so that with a binary grouping of different markets the issue will be surveyed if financial and economic transactions will be able to create groups with a similar long-term mean (Ivanov et al, 2016). OU process has been applied in the experimental results section in two forms, initially to reach an expected correlation between markets pairs, and as a result to determine the starting point of contagion between markets, and consequently by reaching the return rate to the mean the markets' adaptability speed will be calculated.

4. Research Model

Reviewing the global crisis shocks, the S&P500 Index is initially used as an international index, including crisis shocks. To test the contagion DFGM model is used. Therefore, to find out the contagion, the following equation system is estimated by GMM model:

$$sp_{3,t} = \lambda_3 w_t + \delta_3 u_{3,t}$$

$$DFM_{2,t} = \lambda_2 w_t + \delta_2 u_{2,t} + \gamma_{2,1} u_{1,t} \qquad (23)$$

$$\sum_{i=1}^{30} Industry\ Index_{i,t} = \lambda_3 w_t + \delta_3 u_{3,t} + \gamma_{3,1} u_{1,t} + \gamma_{3,2} u_{2,t}$$

In the above relation, w_t indicates global factor or normal shocks whose effects are shown with coefficients. In other words, the factors indicate the financial market's fundamental factors which determine assets average return in international markets at their stability. Also, the above relation shows a specific factor and for each market, a specific asset and effect indicated as the coefficient. The factor has a stochastic process with zero mean and variance of 1.

Moreover, it is required to point out that in DFGM approach all factors are categorized into two groups:

The first group includes factors which indicate systematic risk, and such risks may not be hedged by diversification. w_t Samples are in this category. The second group is comprised of nonsystematic risk which can be buffered by diversification. The samplesu_{it} are among this group.

Data analysis

In this study, weekly market data of Dubai Financial Market (DFM), United States' Market (S&P 500), the European exchanges (FTSE 100) and TSE's 30 blue-chips is used between June 2005 and June 2010. As Solar year's weeks do not concur with the Georgian calendar's one, and main data are reported on a daily basis, Wednesdays are taken as the beginning of the solar years' weeks. As a result, the solar years' weekend holidays will be equal to the weekend holidays of the Georgian calendar, and holidays coincide in both systems after weekly averaging. In financial studies, more concentration is placed on price returns, instead of prices, as return series indicate better statistical features than price series. These are regarded as a complete and scaleless criterion to review an investment opportunity (Noushin Bordbar et al., 2016). To calculate price return in this research, the difference between consecutive prices logarithm of stock price index I used. The net price return normal logarithm is calculated as below:

$$r_t = \ln(P_t) - \ln(P_{t-1}) = \ln\frac{P_t}{P_{t-1}} \quad (24)$$

To estimate DFGM contagion model over data, it is crucial to know the starting and closing points of the crisis for index data of S&P500, FTSE 100 and DFM. The points can be reached by such data review. Several econometric methods for identifying the structural breaking point and in this study the iterated cumulative sum of squares (ICSS) logarithm is used which is provided in section 3-1 with results reported in table 4-2.

Table 4-1.Unit Root Test Results

	Dickey-Fuller	Dickey-Fuller with breaking point
Holdings	-18.78837***	-19.6226***
Computer	-20.83128***	-21.76667***
Chemicals	-17.62856***	-18.40241***
Petroleum	-18.74011***	-20.65944***
Base Metals	-17.15884***	-17.95153***
Engineering	-20.05272***	-20.5022***
MetalOre	-17.37357***	-17.86925***
Non-Metal Ore	-11.07064***	-18.03595***
Ceramic & Tile	-16.58038***	-17.56176***
Metal Products	-18.49484***	-19.54434***
Communication Equipments	-20.25987***	-22.8108***
DFM	-20.17435***	-21.09498***
FTSE100	-22.53871***	-23.27716***
S&P500	-23.67343***	-24.82341***

Note: the test is used for weekly data calculation with 99% meaningfulness level.
Source: Research findings

Table 4-2. Structural Breaking Test Results in ICSS

	S&P500	FTSE100	DFM
Crisis beginning	2008/09/24	2008/01/10	2008/01/10
Crisis end	2009/03/25	2009/12/16	2009/12/23

Source: Research findings

The structural breaking tests estimate crisis peak point and in fact, find the point with the most changes. Crisis period is the one which includes all crisis shocks. For a more precise estimation, it seems better to consider the crisis period from a couple of earlier time periods. On the other hand, international entities and the World Bank announce the crisis climbing and starting point as15 September, with Lehman Brothers' bankruptcy on 13 September. To increase the model's accuracy and consider all crisis shocks, the starting point is taken as 25 August 2008 and the finishing point s 19 October 2009.

Table 4-3. Markets Descriptive Statistics

	Pre Crisis			Period Crisis			Post Crisis		
	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum
Holdings	-0.26	11.9	-9.9	-0.15	8.1	-8	0.67	16.1	-8
Computer	-0.17	14.2	-18.9	0.72	13.9	-5.8	0.82	14.5	-10.8
Chemicals	-0.23	11	-12.5	-0.17	6.8	-8	0.68	16.7	-7.1
Petroleum	0.00	7.8	-5.4	0.19	15.7	-9.4	0.67	20.4	-41.4
Base Metals	0.73	12.1	-6.3	-0.61	8.3	-17.8	0.64	15.5	-6.9
Engineering	-0.48	7.5	-9	1.5	12.3	-5.3	0.53	18.1	-16
MetalOre	0.72	11	-7.9	-0.51	11.9	-13.8	0.67	17.8	-13
Non-Metal Ore	-0.25	4.2	-6.2	0.25	2.8	-3	0.75	18.5	-12.3
Ceramic & Tile	-0.23	6.8	-15.9	0	6.4	-15.5	0.62	19.2	-9.2
Metal Products	-0.21	5	-18.4	0.91	15.7	-13.1	0.57	15.9	-14.8
Communication Equipment	-0.57	13.6	-48.4	0.58	30.7	-18.8	0.51	61.8	-21.9
DFM	-0.07	8.9	-9.3	-1.32	11.3	-23.8	0.03	16.3	-19
S&P500	0.03	3	-4	-0.27	6.5	-16.6	0.2	8.7	-9.5
FTSE100	0.02	3.7	-7.8	-0.08	5.8	-11.9	0.07	5.9	-11.2
Observation	163			65			504		

Source: Research findings

Table 4-3 reports return descriptive statistics of (Iran) Tehran Stock Market different sectors, S&P500, FTSE 100 and DFM indices. The sample period is of three sectors: pre-crisis period (20 June 2005 until 3 September 2008), crisis period (25 August 2008 until 19 October 2009) and the post-crisis period (21 October 2009 until 3 June 2019). The descriptive statistics indicate that mean returns of S&P 500, FTSE 100 and DFM indices in the crisis period are declining. In the pre-crisis period, most of the Iranian sectors enjoy positive mean returns.

5.Research Paradigm Estimation

To understand the relative measures of crisis contagion between stock markets in the first step of table 5-1, variance and covariance of pre-crisis and financial crisis periods are reported.

Table5-1 Pre-crisis and Crisis Periods Variance and Covariance

Market	Pre-crisis Period			Crisis Period		
	Covariance		Variance	Covariance		Variance
	S&P500	DFM		S&P500	DFM	
S&P500	1		1.844	1		14.91
DFM	0.435	1	11.158	14.238	1	37.11
Metal Products	-0.089	-0.375	3.797	1.871	3.960	15.53
Holdings	-0.193	-1.110	5.056	3.127	4.230	8.27
Chemicals	-0.167	0.359	5.073	1.916	5.357	8.18
Food	-0.011	-0.846	3.004	1.925	1.648	4.42
Petroleum	-0.148	-0.968	3.260	2.753	8.081	23.01
Base Metals	-0.664	-0.411	6.817	3.053	6.219	16.53
Engineering	-0.132	-0.429	7.072	1.754	2.877	12.37
Metal Ore	-0.433	-1.788	9.537	1.866	5.272	19.52
Non-metal Ore	0.095	-0.203	1.224	0.996	0.410	1.63
Computer	0.226	0.412	3.920	0.542	0.498	13.69
Ceramic & Tile	0.056	0.202	5.633	-2.010	-3.760	6.03
Communication Equipment	-0.466	0.920	18.180	-1.990	5.210	46.80

Source: Research findings

Table 5-1 indicates covariance structure for different sectors of stock returns in the stock market, besides S&P500 and Dubai Stock Market's indices during the crisis and pre-crisis periods. The table shows a significant increase in stock return variance and covariance during the crisis period. As an example, American markets return variance, as the origin of contagion with considerable variance changed from around 1.84 in the pre-crisis period to over 14.91 during the crisis period. This variance for Dubai Stock Market reaches from around 11.61 in the pre-crisis period to more than 37.11 during the crisis period. Also, this variance has shown a relative big growth for sector of Iran's Stock Market with the highest amount in petrochemical, metal products and base metals, increasing from around 3.26, 3.80 and 6.81 in the pre-crisis period to above 23, 15.50 and 16.53 during the crisis. Besides variance, covariance among returns of different sectors and stock index in S&P and Dubai increases during the crisis period and this effect is based on a contagion interdependence. Moreover, the result indicates evidence of crisis transfer confirmation via financial linkages. For the pre-crisis period, all amounts of covariance among different sectors indices with S&P and Dubai are below1.5 per cent. During the crisis period, the highest covariance was respectively between petrochemical (8.08), base metal (6.22) and metal ore (5.27) sectors and Dubai Stocks, while the lowest covariance refers to non-metal ore and Dubail Stock at 0.41. DFGM test provides abundant information about the shock transfer mechanism. Table 5-2 indicates variance analysis of stock return during pre-crisis and crisis periods, and sector-based crisis is estimated by using DFGM test and GMM model. The table shows a relative role of each factor in the mentioned model of equation 23, estimated for pre-crisis and crisis periods.

Table 5-2. Pre-Crisis and Crisis Periods Stock Return Variance Analysis Results

Components	Pre-crisis Period					Crisis Period				
								Contagion from:		
	World	Country	S&P500	DFM	Total	World	Country	S&P500	DFM	Total
S&P500	13.63	86.37	-	-	100	13.63	86.37	-	-	100
DFM	23.56	76.44	-	-	100	12.88	65	22	-	100
Metal Products	1.96	98.04	-	-	100	0.45	22.36	27.53	49.66	100
Holdings	9.4	90.6	-	-	100	4.96	47.86	17.62	29.56	100

Chemicals	0.2	99.8	-	-	100	0.11	54.75	0.77	44.37	100
Petroleum	5.85	94.15	-	-	100	2.04	32.81	24.97	40.18	100
Base Metals	10.46	89.54	-	-	100	4.18	35.76	23.89	36.17	100
Engineering	1.66	98.34	-	-	100	1.51	89.32	5.97	3.2	100
Metal Ore	18.37	81.63	-	-	100	8.61	38.26	10.63	42.5	100
Non-metal Ore	0.7	99.3	-	-	100	0.47	66.04	12.37	21.12	100
Computer	6.11	93.89	-	-	100	4.75	72.88	13.56	8.81	100
Ceramic & Tile	0.38	99.62	-	-	100	0.236	61.14	18.47	20.154	100
Communication Equipment	0.076	99.924	-	-	100	0.01	11.92	11.1	76.97	100

Source: Research findings

The pre-crisis period's results indicate that risks are essentially diversifiable in different sectors so that their factor has more than 80 per cent effect on the general fluctuations. Among different sectors, the lowest non-systematic risk belongs to metal aores, a symbol of the sector's high systematic risk.

During the crisis period, metal products, holdings, chemical, petroleum products, based metals, metal ores and communication equipment experience significant contagion effects, evidenced by the fact that contagions linkages between S&P and Dubai stocks are improving (49.66 per cent total fluctuation in metal products as a contagion originated from Dubai stock market and 27.53 per cent fluctuation from S&P constituents. However, the crisis periods, results indicate the fundamental contagion. This has an important role in transfers from S&P to Dubail (22.01) and base metals (23.89) and metal products (27.53), snd from Dubail stock market to petroleum products (85.67), communication equipment (76.97). The preliminary analysis shows that contagion effects transfer from S&P and Dubai to Iran's stock market different sector and Dubai stock market has an important role in shock transfer from S&P to Iran's stock market different sectors. Contagion test result indicating the null hypothesis and no contagion is reported in table 5-3.

Table 5-3. DFGM Contagion Test Results

Test Contagion from the Host country to Recipient		Host country			
		S&P500	DFM	Both**	Joint
Recipient	DFM	13.61***	-	33.63***	48.01***
	Metal Products	7.77***	21.01***		
	Holdings	3.81**	7.33***	20.72***	23.90***
	Chemicals	0.01	3.33*	15.04***	18.35***
	Petroleum	9.55***	10.72***	38.23***	38.70***
	Base Metals	13.40***	9.98***	40.13***	41.32***
	Engineering	6.20***	6.38***	31.00***	31.04***
	Metal Ore	4.80***	7.80***	25.39***	28.07***
	Non-metal Ore	0.03	6.86***	14.75***	22.10***
	Computer	6.12***	9.15***	28.85***	29.36***
	Ceramic & Tile	1.93	3.23*	17.92***	20.72***
	Communication Equipments	17.46***	20.84***	43.75***	44.16***

*. [*], [**], [***] is meaningful at 90%, 95% and 99% confidence level

** Contagion test from S&P to Dubai stock market and Iran's different sectors.

* OPEC oil index as an extra conditional variable is used for financial crisis contagion test.

Source: Research findings

The first row of Table 5-3 indicates the host country with contagion originating place and the first column show Iran's different sectors and Dubai stock market with potential contagion receiving.

Based on the results in Table 5-3, the following hypotheses about contagion will be discussed:

The first hypothesis test indicates no contagion between all markets. Regarding the first hypothesis testing with DFGM test, the contagion hypothesis of the financial crisis from S&P to Dubai market, from S&P to different sectors of Stock Market and from Dubai market to different sectors' index of Stock Market simultaneously. Based on these results the null hypothesis indicating no contagion is rejected and the hypothesis of contagion existence from S& P to Dubai and Iran's stock market sectors are accepted. The hypothesis test statistic is providing in Table 5-3 under "common" row.

Second hypothesis test indicates no contagion from the host to the other two markets commonly. The results show, concerning the first hypothesis with DFGM test to analyze contagion from the host country (S&P) to Dubai stock market and Iran's Stock Market sectors are rejected at the same time, and as a result, the parallel hypothesis indicating financial crisis contagion to both

markets is accepted. The hypothesis test statistic is shown in table 5-3 under "both" row.

Third hypothesis test shows no contagion between both markets. Concerning the first hypothesis with DFGM test the contagion from S&P to Dubai market or Iran's stock market sectors, and also contagion from Dubai stock market as the crisis transfer channel to Iran's stock market sectors is reviewed. The results show financial crisis contagion from the host country (S&P) to Dubai stock market, from the host country (S&P) to metal products, holdings, petroleum products, based metals engineering, metal ores, computer and communication equipment sectors separately. Also, the results confirm financial crisis contagion from Dubai stock market to metal products, holdings, petroleum products, based metal engineering, metal ores, computer, communication equipment, chemical, non-metal ores, and tile and ceramic sectors.

After confirming financial crisis contagion effects and its direction, the channel in which financial crisis is transferred is looked for. In this situation, the commercial linkages between three countries are reviewed since some findings in the literature indicate that crisis is transferred via commercial linkages (Bekaert et al) of financial linkages (Van Rijckeghem and Weder).

Table 5-4. Foreign Trade between 2004 and 2009 (USD million)

	Customs Import				Customs Export			
Year	UAE	% of the total	USA	% of the total	UAE	% of the total	USA	% of the total
2004	6093	17.20%	1178	3.30%	1226.1	17.90%	100.49	1.50%
2005	7683	19.60%	1227.5	3.10%	1545	14.80%	105	1.00%
2006	9349.48	22.40%	1217.37	2.90%	1728.11	13.30%	109.48	0.80%
2007	11508.7	23.80%	1126.04	2.30%	2166.02	14.10%	87.92	0.60%
2008	13491.36	24.10%	2097.92	3.70%	2322.18	12.70%	65.61	0.40%
2009	16187.07	29.30%	1453.17	2.60%	2934.34	13.40%	94.95	0.40%

Source: Central Bank of Iran

Table 5-4 shows Iran-UAE import/export data, as well as the figures between Iran-USA during 2004 and 2009. Despite the increase in imports from the UAE in many years, the figures were the highest in 2009, while the imports from the USA was very low. Iran and the UAE had the highest amount of foreign trade in 2009. Foreign trade between the USA and Iran in 2008 was at the highest. Therefore, based on import-export figures of table 5-4, there is a possibility of global crisis transfer via commercial channels.

However, it is impossible to accurately figure out the contagion channel only with import and export amount review. Then by using the import and export percentage between the USA and UAE from Iran's total trade, the commercial channel is reviewed. The amount of import and export from the USA is very low and as a result, the foreign trade relations between both countries is very low comparing their total trade. For example, for the period between 2004 and 2009 the average US export to Iran was 0.29 per cent, and the average US import from Iran was 0.05 per cent, and also in the same period, the average UAE's export to Iran was 22.7 per cent and the average import of the country from Iran was 14.4 per cent. The results indicate that there is a weak possibility of financial crisis transfer via the commercial channel.

Ornstein Uhlenbeck Model Estimation

To find the starting point of financial crisis contagion in Iran's stock market sectors and modeling it, the meaningful relationship between both markets (S&P and Dubai with Iran's market), and also estimation of synchronization rate for both markets, Ornstein Uhlenbeck process is used. It should be also noted that the Jack-Knife Resampling method is applied to find both markets' correlation and obtaining data series related to both markets' correlation. Based on the related calculations of mean return rate for different market pairs, the starting point of contagion occurs in the market with the highest among other markets; as a result, it can be found out by the mean return rate market pairs in Table 5-4 that the contagion starting point happens in the market with relatively larger numbers in its related column.

5-4. Ornstein Uhlenbeck Related Parameter Calculations

GROUP 1	θ	μ	σ
MULTIDISCIPLINARY/S&P500	1.7350	0.0900	0.0022
CHEMICAL/ S&P500	-	-	-
PETROLEUMP/ S&P500	5.4100	0.0580	0.0040
BASICMETAL/ S&P500	5.5000	0.1000	0.0027
ENGINEERING/ S&P500	2.9300	0.0330	0.0026
METALORE/ S&P500	2.4600	0.0630	0.0028
NONMETALLIC/ S&P500	-	-	-
COMPUTER/ S&P500	3.6300	0.0280	0.0035
CERAMICS/ S&P500	-	-	-
METAL PRO/ S&P500	2.4300	0.0430	0.0025
COMMUNICATION/ S&P500	3.6800	-0.0221	0.0027
GROUP 2	θ	μ	σ
MULTIDISCIPLINARY/DFM	2.1200	0.0850	0.0026
CHEMICAL/DFM	2.1600	0.1181	0.0024

PETROLEUMP/DFM	2.4400	0.1150	0.0030
BASICMETAL/DFM	2.9000	0.1200	0.0034
ENGINEERING/DFM	1.8400	0.0340	0.0024
METALORE/DFM	1.5600	0.0560	0.0024
NONMETALLIC/DFM	1.4100	0.0500	0.0019
COMPUTER/DFM	2.1200	0.0388	0.0024
CERAMICS/DFM	1.8200	-0.0030	0.0019
METAL PRO/DFM	1.5900	0.0314	0.0019
COMMUNICATION/DFM	2.7600	-0.0100	0.0031

Source: Research findings

Based on results from Table 5-4, the return rate to basic metals means is relatively calculated with higher amounts. It can be observed that basic metals have more relationship with Dubai stock market, and based on the mentioned theoretical fundamentals, the estimated return rate to the mean points out the financial crisis contagion starting point from Dubai stock market channel to Iran's market is basic metals, and about S&P market, the rate of return to the mean for basic metals is relative with higher amounts; as a result, based on the estimated amounts of return rate to the mean, the starting point of financial crisis contagion from S&P channel to Iran's market is basic metals. By such results, it can result that basic metals sector index is the starting point of financial crisis contagion in Iran's market sectors, which is among high systematic risk sectors based on DFGM.

Model analysis of table variance

In the last part of this section, to show the difference between the contagion rate of the markets, the amount of long term mean (μ) and process volatility (δ) can be used. Regarding the first and second columns of table 5-4, basic metals index has the highest relationship with Dubai and S&P markets. Considering the mentioned point in the previous line about the difference of markets compatibility rate, it cannot be accurately figured out if S&P market is highly related to metal ores or petroleum products?

However, it can be viewed by comparing two columns of the long term mean and process fluctuation that the lowest amount of volatility is related to the market pair of S&P-metal ores, and on the other hand the highest amount of long-term amount is also related to the pair of S&P-metal ores. Therefore, it can be stated that after the pair of S&P-basic metal index, the relationship between S&P market with metal ores market is stronger than the relationship with petroleum products.

Generally, if all calculated parameters are considered, they can be

categorized as follows:

Group 1: the group is with a relatively high amount for the mean return rate (ɵ) and a relatively high amount for the long-term mean (μ). The group's indices usually have a strong correlation with S&P and Dubai markets and it seems that the large changes in S&P and Dubai markets are absorbed relatively faster. The group's appropriate indices include petroleum products, metal ores and chemicals. For markets with such indices, the high level of spillover expected effects can be presumed.

Group 2: the group is with a relatively low mean return rate (ɵ) and yet a high amount of long-term mean (μ). It can be presumed that he accepted spillover is available, but it takes longer to absorb shocks and also strong factors exist that can affect index return dependence. The group's appropriate indices include holdings, metal products, engineering and non-metallic ores.

Group 3: the group is with a relatively low mean return rate (ɵ) and relatively lower long-term mean (μ). This means that the expected time for the reaction against changes in S&P and Dubai markets is high and the market's revisions are mostly formed by internal financial factors and economic processes in Iran. The group's appropriate indices include computer, ceramic and tile and communicative equipment.

Finally, and based on calculations related to OU process it can be concluded that between studied indices in this research, basic metal is the contagion starting point between indices in the capital market of Iran, and it can be stated that outside market economies challenges and crises are transferred to Iran by basic metal index.

Conclusions

This study reviews the global financial crisis contagion effect via international indices of the S&P and regional index of Dubai market on different sectors of Iran's securities exchange. Based on the received experimental results, the following issues can be stated:

1- As indicated in the contagion test result of international S&P index on different sectors of Iran's securities exchange. Contagion test parameters for metal products, holdings, petroleum products, basic metals, engineering, metal ores, computer and communication equipment has a meaningful relationship, and this means the contagion of crisis happens from the global market to the mentioned sectors. Also, the contagion test result from Dubai regional index to different sectors of Iran's securities market indicates that

contagion test parameters for metallic products, holdings, chemical, petroleum products, basic metals, engineering, metal ores, non-metal ores, computer, ceramic and tile and communication equipment has a meaningful relationship; and this means crisis contagion is from the regional market to the mentioned sectors and it indicates Dubai stock market role in the crisis spread to different sectors of Iran's securities exchange.

2- The experimental findings show that pre-non-systematic risk crisis period for the sectors with crisis contagion is very high so that these sectors' factor has more than 80 per cent role in the general volatility. Among different sectors, the lowest non-systematic risk is related to metal ore sectors, indicating high systematic risk in the sector.

During the crisis period, metal products, holdings, chemical, petroleum product, basic metals, metal ores and communication equipment experience major contagion effects, documented by contagions linkages of S&P and Dubai market being developed. However, the results from crisis period indicate major contagion; contagion has an important role in contagions from the US to Dubai and from basic metal and metallic product, and from Dubai stock market to petroleum products and communicates equipment. The preliminary analysis indicates that contagion effects are transferred from the US and Dubai to Iran's stock market different sectors and Dubai stock market has an important role in transferring the crisis to Iran's stock market sectors.

3- Stochastic modeling results of OU process show that mean return rate of basic metal index among different sectors has the highest amount, and this indicates that the financial crisis contagion starting point from S&P and Dubai stock market to Iran's exchange different sectors is basic metals, and also aftermarket pair S&P-basic metals, the relationship between S&P and metal ore market is stronger than the relationship with petroleum products market.

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