Propósitos y Representaciones
ISSN 2307-7999
e-ISSN 2310-4635

Jan. 2021, Vol. 9, SPE(1), e886
Special Number: Educational practices and teacher training
http://dx.doi.org/10.20511/pyr2021.v9nSPE1.886

RESEARCH ARTICLES

Investigating the Financial Crisis of the Iranian Stock Exchange Using Transfer Entropy Method and comparing it with the Dow Jones Financial Market

Investigando la crisis financiera de la bolsa de valores iraní utilizando el método de transferencia de entropía y comparándolo con el mercado financiero Dow Jones

Arefeh Mohaghegh
Department of Accounting,kish International Branch, islamic Azad University, Kish Island, Iran
ORCID: https://orcid.org/0000-0003-4456-3668

Mohsen Hamidiyan
Assistant Professor, Faculty Member, Department of Accounting, Islamic Azad University, South Tehran Branch
ORCID: https://orcid.org/0000-0003-4456-3668

Seyed Ali Hosseini Esfidvajani
Assistant Professor, Faculty Member of Shahid Beheshti University
ORCID: https://orcid.org/0000-0001-7202-9337

Gholamreza Jafari
Professor, Faculty Member of Shahid Beheshti University
ORCID: https://orcid.org/0000-0002-4310-6716

Received 02-08-20 **Revised** 04-10-20 **Accepted** 01-11-21 **On line** 01-17-21

***Correspondencia**

Email: hamidian_2002@yahoo.com

Citar como:

Arefeh Mohaghegh, Mohsen Hamidiyan, Seyed Ali Hosseini Esfidvajani, Gholamreza Jafari (2021). Investigating the Financial Crisis of the Iranian Stock Exchange Using Transfer Entropy Method and comparing it with the Dow Jones Financial Market. *Propósitos y Representaciones, 9* (SPE1), e886. Doi: http://dx.doi.org/10.20511/pyr2021.v9nSPE1.886

Summary

The focus of the present study is on the financial markets of Iran. In fact, the purpose of the present study is to examine the critical state of the Iranian stock market and compare it with one of the famous American markets called Dow Jones. The purpose of the financial crisis is to examine the effect of the interaction of companies within a market. According to modern financial theory, crisis is a phenomenon of market orientation and finding a negative preferred direction among companies. The stock market data of 180 companies of this market that were active during the period of 2008 to 2019 were used to investigate the financial crisis of the Iranian Stock Exchange. The results show that the average transfer entropy for 180 firms in the Iranian stock market is more random. That is to say, the observed declines do not correspond to the time periods of the crisis in the stock market. Although transfer entropy seems to be a good indicator for determining the period of crisis in the US Dow Jones market, it cannot be an indicator for determining the financial crisis for the Iranian stock market.

Keywords: Financial Crisis, Iranian Stock Exchange, Entropy Method, Dow Jones Financial Market

Resumen

El enfoque del presente estudio está en los mercados financieros de Irán. De hecho, el propósito del presente estudio es examinar el estado crítico del mercado bursátil iraní y compararlo con uno de los famosos mercados estadounidenses llamado Dow Jones. El propósito de la crisis financiera es examinar el efecto de la interacción de las empresas dentro de un mercado. Según la teoría financiera moderna, la crisis es un fenómeno de orientación al mercado y de encontrar una dirección preferida negativa entre las empresas. Los datos del mercado de valores de 180 empresas de este mercado que estuvieron activas durante el período de 2008 a 2019 se utilizaron para investigar la crisis financiera de la Bolsa de Valores de Irán. Los resultados muestran que la entropía de transferencia promedio para 180 empresas en el mercado bursátil iraní es más aleatoria. Es decir, los descensos observados no corresponden a los períodos de tiempo de la crisis en el mercado de valores. Aunque la entropía de transferencia parece ser un buen indicador para determinar el período de crisis en el mercado estadounidense Dow Jones, no puede ser un indicador para determinar la crisis financiera del mercado bursátil iraní.

Palabras clave: Crisis financiera, bolsa de valores iraní, método de entropía, mercado financiero Dow Jones

Introducción

A financial-economic crisis generally pertains to any extensive imbalance in domestic and international economic markets affected by endogenous and exogenous market factors (Hassanzadeh & Kianvand, 2010). A financial crisis commonly alludes to a situation in which a substantial number of assets lose their value. The depression and unemployment crisis can be among the undeniable consequences of a financial crisis. Reinhart and Rogoff (2009) argue that a financial crisis is an equal threat-opportunity situation with domestic or international roots or stemming from the private or public sectors. Besides, in pre-capitalist societies, a crisis would emerge as a result of several exogenous factors like flood, famine, and drought. However, in a market-based society (i.e., the capitalist system), a chain of endogenous factors contributes to the disruption and heterogeneity of the overall functioning of the system. Being intrinsically based on contradiction and imbalance, the market system continuously confronts a crisis. Hence, the crisis reproduces itself spirally. A crisis cycle is a period from the onset of a crisis to the onset of a subsequent crisis, which can be subdivided into four stages – crisis, depression, recovery,

prosperity (boom). The first and foremost important stage of the cycle is the "crisis" that leads to the devastation of some productive forces (forces of production) and the bankruptcy of a large number of economic institutions and enterprises. Following the termination of the crisis and depression, retrogression winds down whereas interest rates are still trivial, industrial production and trade are limited, prices and wages are low, and the unemployment rate is high. Following a reduction in costs and competition over market dominance, firms are encouraged to resume production and use all technical means to realize this goal. Thus, the demand for capital goods booms and the cycle enters its third stage, i.e., recovery. Here, firms are constantly updating their fixed assets, trade is booming, production is reaching pre-crisis levels, the unemployment rate is declining, and interest rates, wages, and prices are rising. This trend continues as production enhances even more than the pre-crisis situation. Now, the cycle enters its fourth stage, i.e., prosperity (boom). Here, production is rapidly booming again; however, declining interest rates are preventing continued prosperity, and this is where the community experiences another crisis (Soheili & Mirzaei Rashtoo, 2013).

Over the past few years, research and educational centers have conducted a vast array of studies on financial crises in various academic disciplines using different methods. A considerable number of studies have also been carried out on the "entropy" method. Nonetheless, they have failed to address the financial crisis that plagued the Tehran Stock Exchange (TSE) using the "entropy transfer" method and to compare it with the Dow Jones financial market. Previous studies have dealt with financial crises, often from other perspectives, or have failed to compare the TSE data and the Dow Jones Index data. Notwithstanding, it is vital to discuss the financial crisis in Iran, considering the existing economic situation and inflation. Given the above, the main question that this research seeks to answer is: "Can the financial crisis faced by the TSE be estimated by using the transfer entropy method and then compared with the US financial market?"

Literature Review

Financial Crisis

A financial crisis is a situation where a substantial number of financial institutions/assets suddenly lose a considerable part of their value. There are various kinds of financial crises. In the literature of experimental economics, financial crises can generally be subdivided into extensive categories, including the independent debt crisis, the balance of payments (BoP) crisis, the currency crisis, the banking crisis, the foreign currency reserve crisis, the exchange rate crisis, the stock market crash (crisis), and the like (Bonis et al., 1999). It is worth noting that the present study deals with the financial crises faced by various countries rather than a global financial crisis (GFC). Following rapid growth in the financial network literature, experimental works can be separated into two categories. The first category focuses on research based on "financial network data" to identify and understand their characteristics. For example, Weistrofer (2013) used statistics of the integration of the Bank for International Settlements (BIS) banking section for international settlements to assess the extent to which boundaries are being confronted, and proposed a number of vulnerability measures. For instance, similar to entropy, the borrower concentration, formulated based on the Herfindahl Index, means that two measurement actions suggest the degree to which a loan is diverse. The borrower concentration ratio may principally be interpreted as a higher contagion risk. Hale (2012) established a global financial network in banks and determined the systemic effect of depressions and banking crises on the global banking network.

Concepts of Entropy and Entropy Transfer

Entropy is generally referred to as the degree of uncertainty in a set of information. The concept of "entropy," introduced in physics, has its roots in the 19th century. Clausius (1867) was the first person to provide an introduction to a mathematical quantity, *S*, on an intuitive understanding of Carnot [cycle], and called it "entropy." It expressed the heat transfer in thermal processes by Equation $dS = dQ/T$, where Q is the temperature, and T is the absolute temperature at the transfer location (Reddy and Sebastian, 2009). Entropy is a random variable defined in terms of its probability distribution, which can be applied to an acceptable degree of randomness or uncertainty suggesting the number of bytes required to exchange the message. The entropy of

a system is associated with the amount of information contained therein. A more orderly system can be defined with fewer information bytes, while a less orderly one requires more information bytes to be described (Fatemi, 2001).

Dow Jones Index

In the stock market, traders often take advantage of various indices to calculate the market value of different companies. Dow Jones Industrial Average (DJIA) is one of the most prominent global financial indices, which is regarded as the major valuation criterion for a large number of investors. DJIA is a free market index published by the Wall Street Journal. It was first introduced on May 26, 1896, which includes a list of the top (preferred) 30 stocks on the New York Stock Exchange (NYSE). It is used to compare speculations and evaluate the performance of enterprises. It differs from the Fortune 500 and the S&P 500 in this respect. Moreover, the Dow Jones is a price-weighted index, meaning that higher-priced stocks have a greater effect on the index value. The firm includes 30 stocks in various sectors including materials, consumer goods, finance, healthcare, industry, oil and gas, technology, telecommunications, and public services. Nevertheless, it can be subdivided into several sub-indices to facilitate performance monitoring. They rest on the premise that firms are regarded to be of high, medium, or low value. High-value stocks make up the majority of the index (i.e., 70%). Firms continuously differ in terms of the Dow Jones Index. The last firm to be added to the list was Cisco in June 2009. In addition to Cisco, only six other companies have been added to this list over the past decade: Bank of America (2008), Chevron (2008), and Craft (2008), Pfizer (2004), Verizon (2004), and Trolls Insurance (2009). Furthermore, General Motors has been considered one of the leading firms since 1907. Nonetheless, this period terminated when it was removed during the 2009 Financial Crisis (International Trading Broker (ITBFX), 2018).

Research Background

Lim et al. (2008)

addressed the 1997 Asian Financial Crisis on the performance of eight Asian stock markets. Evidence suggested a negative correlation between market returns and the financial crisis.

In their study, **Babecky et al. (2012)** identified leading indices contributing to the emergence of crises. They employed two scales, namely continuous and discrete, to create a dependent variable. For the continuous scale, the composite dependent variable (i.e., simple arithmetic mean) consists of GDP, unemployment, and fiscal deficit, regarded to be the actual crisis cost. For the discrete scale, the dependent variable includes the probability of a crisis. According to the research findings, among the major risk factors in developed countries are housing prices, stock price index, credit growth, and some global variables such as private credit. In a study, **Fosberg (2012)** explored the impact of GFC on corporate capital structure. According to his analysis, corporate capital structure has undergone considerable changes as a result of the financial crisis and depression during the first decade of the 21st century. Particularly, the amount of liabilities associated with the capital structure of representative companies has enhanced by an average of 5.5% from 2006 to 2008. When the adverse effects of the financial crisis were resolved, corporate capital structure returned to pre-crisis levels at the end of 2010. After the elimination of depression trails from the corporate capital structure, it became clear that almost all (i.e., 5.1%) changes in liabilities (debts) were due to financial crises. **Sensoy et al. (2014)** addressed the strength (power) and direction of information flow between exchange rates and stock prices in a number of emerging countries by exploiting the new concept of "entropy transfer effects" (i.e., a surrogate nonlinear causality method) using symbolic coding. According to analyses, before the 2008 Crisis, there was only a low level of interaction between the two variables, and exchange rates generally affected stock prices. In times of crisis, there is a robust interaction between the two variables. In the post-crisis era, this robust interaction continues and stock prices commonly influence exchange rates. **Stosic et al. (2016)** reviewed the impact of financial crises on foreign exchange markets (Forex or FX) using the "time-dependent block entropy method" and measured the entropy evolution for different exchange rates. The results indicated a considerable increase in exchange rate entropy as a result of financial crises, indicating FX volatile dynamism. In accordance with phenomenological expectations, with large liquidity and trading volume, Forexes are more stable and at the same time recover from crises faster than markets with small liquidity

and trading volume. Besides, according to analyses, periods of economic uncertainty occur when entropy values are low, which may be seen as a means of predicting financial crises. In a study, **Rummel (2017)** studied 153 companies listed on the Nasdaq Stock Market and compared the information flow between various industries using the entropy transfer method. The results suggested that sustainable consumer industries and financial industries provide the largest amount of information on the economy as a whole. With a one-day delay, he found out that the introduction of a delay variable would result in a substantial increase in the transfer entropy in all industries, except energy. However, the highest increase (103%) is linked to technology considering the average (28%). Furthermore, after a one-day delay, he demonstrated that the additional delay usually reduces transfer entropy yet not uniformly, indicating that the movements are mainly affected by two-day trends. **Lee & Park (2019)** measured the extent to which highly connected financial networks are diverse by applying the entropy of the network. Due to the altered time of network entropy, there has been a decrease in the global diversity of the World Financial Network following the emergence of foreign claims of international banks since the 2007-2008 Financial Crisis. However, foreign claims are majorly focused on original countries among the 20 ones that have reported them. This change is clearly observed due to an unprecedented decline in measurement due to network entropy. The results suggested a promising potential for the network entropy across the financial market. **Abdullah et al. (2013)** investigated the relationship between the entropy of financial statements and earnings variability in various industries listed on the TSE in the form of three models. To this end, changes in financial statement items are measured based on the entropy formula and the effect of these changes on earnings variability. Accordingly, it will be demonstrated that changes in these items will lead to earnings variability. The information under investigation is associated with 14 industries listed on the TSE in the 2000-2010 period. The results indicated a relationship between the entropy of financial statements and earnings variability in a few industries and companies listed on the TSE. Nonetheless, research hypotheses were rejected since the number of these industries and companies was limited. In a study, **Arab Salehi et al. (2015)** analyzed the major causes that contributed to the emergence of GFC in two sections. The first section reviews current factors and perspectives on the "major causes of emergence" and the second one analyzes the "major causes of the transfer of the crisis throughout the world" by employing the complexity approach. Factors that have contributed to GFC include rising bubbles due to real estate loans, overused financial derivatives, extreme optimism in risk assessment, poor corporate governance, self-interestedness (profit-mindedness), poor regulation across the market, etc. The present research has examined the financial crisis from different perspectives, including macroeconomic, accounting and financial, regulatory and legal, corporate governance, and the like. Therefore, it provides a thorough summary of the GFC. In a study, **Arab Salehi et al. (2017)** explored the impact of the GFC on the degree to which earnings are managed in 130 companies listed on the TSE. This study measures and expresses earnings management indices by taking advantage of the extent of earnings (income) smoothing and the modified Jones model. The findings demonstrated a decrease in the degree to which earnings are managed in companies listed on the TSE during the GFC. **Abdullah et al. (2018)** checked the effect of the entropy of the liquidity and leverage ratios on identifying companies listed on the TSE, suspected of fraudulent financial reporting. For this purpose, variations of liquidity and leverage ratios were measured based on the entropy formula followed by examining the effects of these changes on the likelihood of fraudulent financial reporting. The results showed the significance of the tested models. In the two hypotheses tested, the entropy of total debt ratios and operating funds to debt were significant, and other variables tested in the hypotheses were rejected. In a study, **Bayani & Mohammadi (2019)** identified the factors influencing the emergence of financial crises in the Iranian economy by defining uncertainty in crisis models using the "Bayesian Model Averaging (BMA)" approach. In this study, 62 variables influencing the financial crisis were entered into the model. Finally, 12 unresolved variables affecting the financial crisis were identified using the BMA. These included budget deficit or surplus, deviations of the unofficial exchange rate from the official exchange rate, inflation rate, the ratio of foreign debt (external loan or debt) to foreign assets held by the central bank, the rising currency ratio (liquidity/monetary base), the ratio of exports to GDP, the ratio of imports to GDP, the ratio of government spending to GDP, the ratio of budget deficit to

GDP, the ratio of liquidity to foreign assets held by the central bank, growth rate of credits granted to the private sector, and inflation rate. According to the results, the "financial crisis index" in the Iranian economy is a multidimensional problem because it is affected by variables such as financial policy, monetary policy, and foreign exchange policy.

Método

This is a practical research project in purpose and exploratory in nature, which falls into the retrospective studies using old information based on real information published by TSE (TSE Price Index (TEPIX)), Central Bank of I.R.I. (inflation), and information obtained from the Dow Jones Index. The data needed to conduct the research were collected from websites affiliated to TSE and central banks of I.R.I. and America. Excel is used to sort and classify data and draw diagrams. The statistical population consists of all companies listed on the TSE/OTC during a period of 11 years from 2009 to 2018. TEPIX and stock prices have been used according to the research objective, indicating the average changes in all companies listed on the TSE.

3.1. TSE Price Index (TEPIX)

Stock market indices are generally considered as a set of important criteria. Analyzing them can help assess the status of the stock market in the past and present from different aspects and even predict the future trend of the stock market by using graphic methods. Therefore, given the vital role played by stock market indices in investor decision-making, the fluctuations in these indices are naturally crucial for investors. There are a variety of stock market indices, each of which shows the stock market status in a particular way; therefore, investors should carefully consider the functions of each of these indices in analyzing stock market indices. The total index in TSE is known as TEPIX, one of the most widely used indices among market participants and investors, reflecting general price levels and dividends of companies listed on the TSE. In other words, changes in TEPIX indicate the average return on investment (ROI) in the stock market. An important point in reviewing this index is the degree to which TEPIX changes. For example, a TEPIX rising from 80,000 to 120,000 units in the course of one year indicates that the average stock market return has been equal to 50% over the past year. According to the TEPIX calculation formula, the larger the companies and the more capital they have, the more impact they will exert on the TEPIX. The diagram presented in Figure 1 shows the TEPIX data and inflation based on the information published by TSE and the Central Bank of I.R.I.

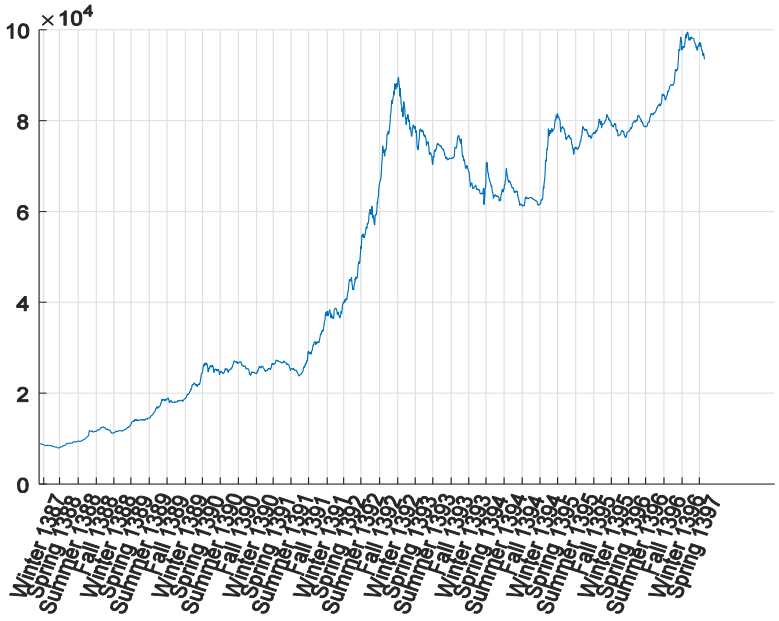


Figure 1. TEPIX from winter 2008 to spring 2018

3.2. Primary Concepts of Entropy Transfer

(A) The entropy of a random variable *X* is usually shown with $p\ (x)$, as a probability function, defined by Shannon (1948) as follows:

$$H\ (X) = \ H\ (p)\ = -\sum_{x} p(x)\log p(x) = \ E[log\{1/p(x)\}]$$

where the logarithm bases are 2 and 0; therefore, the logarithm is set to 0.

The entropy is measured in bits as follows:

$$0\ \leq\ \mathrm{H(X)}\ <\ \infty$$

If the logarithm is considered with base *e*. Then, the entropy is typically measured. The entropy of a dynamical system shows the degree to which it is disrupted, as described in thermodynamics. Furthermore, the information required to predict the next measurement is accompanied by a certain accuracy. As explained in information theory, entropy does not measure some system realization distribution but rather provides some information on system fluctuations over time in frequency or phase space.

3.3. Data Sorting and Preprocessing

The present research uses the stock price data of 180 companies listed on the TSE from 2008 to 2018, as well as the all-share index data of the Dow Jones Market from 1991 to 2019. This data cannot be used directly and need to be corrected. First, companies with active presence were considered throughout the period. Second, the working (business) days during which all the companies were present were considered simultaneously. Third, if a number is not recorded as a price for a number of companies on some days, another number is considered instead resulting from the interpolation or averaging of the previous day's [closing] price and the next day's price. Furthermore, to remove possible trends in data series, the logarithmic efficiency of the data was calculated according to Gibrat's law, which successfully makes data stationery.

$$S(t) \equiv \ln Y(t + \Delta t) - \ln Y(t)$$

3.3. Adjacency Matrix Calculation

The adjacency matrix should be calculated upon market data classification to provide a graphical model to examine the relationship between companies operating in the market. The entries of the adjacency matrix include transfer entropy for two companies operating in a market that determines the amount of information transferred from Firm *i* to Firm *j*. In other words, the fact that the entries are not equal to 0 suggests a direct relationship between the two companies in the market, with the magnitude of that number indicating the size and intensity of this relationship. The adjacency matrix is not necessarily symmetric, meaning that the amount of information transferred from Firm *i* to Firm *j* varies with its inverse. Hence, this paper seeks to derive a directed and weighted graph for the financial market over a certain interval. The transfer entropy is a function of three parameters, including *k*, *l*, and *w*, indicating the time delay (memory) of the destination series, the time delay of the source series, and the time window in which transfer entropy is obtained, respectively. Here, it is assumed that no information is transferred from a company to itself (transfer = zero), i.e., the main diagonal [elements] of the adjacency matrix is equal to 0.

$$T_{I\to J} = \sum p(j_{n+1}, j_n, i_n) log \frac{p(j_{n+1}, j_n, i_n)p(x_n)}{p(j_n, i_n)p(j_{n+1}, j_n)}$$

$$\begin{bmatrix} 0 & T_{X_1\to X_2}(k,l,w) & \dots & T_{X_1\to X_N}(k,l,w) \\ T_{X_2\to X_1}(k,l,w) & 0 & \dots & T_{X_2\to X_N}(k,l,w) \\ \vdots & \vdots & \vdots & \vdots \\ T_{X_N\to X_1}(k,l,w) & T_{X_N\to X_2}(k,l,w) & \dots & 0 \end{bmatrix}$$

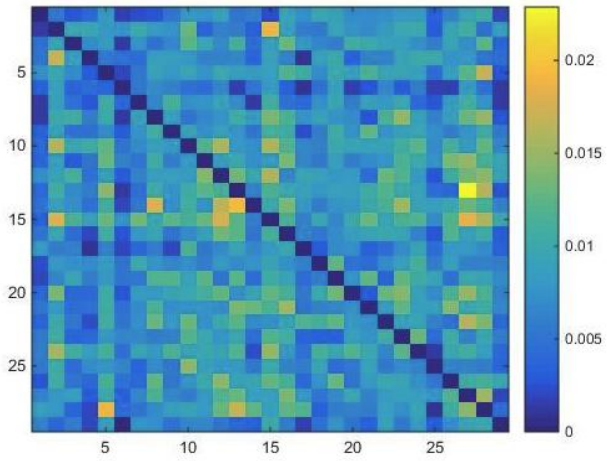


Figure 2. Adjacency matrix obtained from entropy transfer in Dow Jones market with 30 companies in a time window

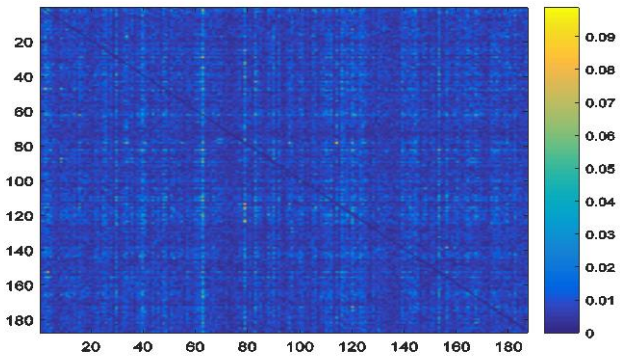


Figure 3. Adjacency matrix obtained from transfer entropy in TSE with 180 companies in a time window

3.4. Calculation of the Transfer Entropy on Corporate Price Index Data

First, corporate price index data needs to be detrended using the log-returns method. To this end, the price of each day must be divided by the price of the previous day followed by the calculation of the log, since there is a daily data timescale. Thus, the overall trend of the index is removed and only daily fluctuations remain. To calculate the transfer entropy from a time-series, first, the detrended data are divided into *s* intervals, each of which is assigned a number or symbol. Here, the interval 3 is considered, equivalent to whether the price index is either rising or falling or staying in the current price. If the data is properly divided, the transfer entropy will be a descending function relative to the variable *k* as the memory declines, resulting from an increase in the time delay in the data in natural processes. Here, it is assumed that the effects of Company *X* itself should not be taken into account when calculating the information transferred from Company *Y* to Company *X*. Given this assumption, it would be better to assume the variable *K* as large as possible so that no company receives information from itself. Nevertheless, the problem

is the limited size when calculating the time-series and delayed distribution function, which affects the results. To overcome this problem, a time-series with a delay *k* is made from the time-series for each company and the amount of mutual information is calculated for these two time-series:

$$M_{IJ}(\tau) = \sum p(i_n, j_{n-\tau}) log \frac{p(i_n, j_{n-\tau})}{p(i)p(j)}$$

The Mutual Information Diagram is drawn for a firm in terms of *k* in the figure below. As expected, the resulting diagram is a descending function of the time-delay *k* because a decrease occurs in the transferred information or the system memory following an increase in time delay. Therefore, according to the diagram, the ideal time delay is where the mutual information [transfer] is equal to 0 or has a local minimum. Thus, the optimal value for time delay is calculated for each company.

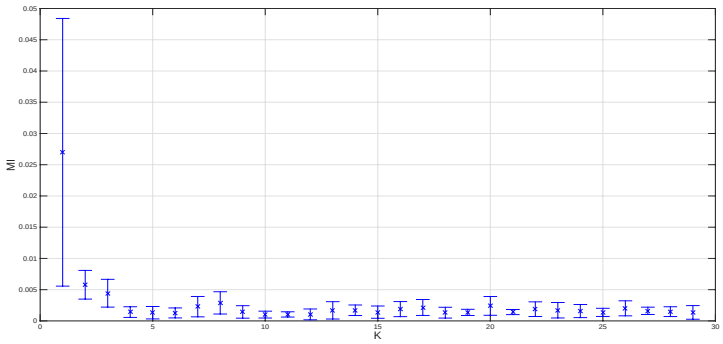


Figure 4. Mutual information for a company in terms of *k*

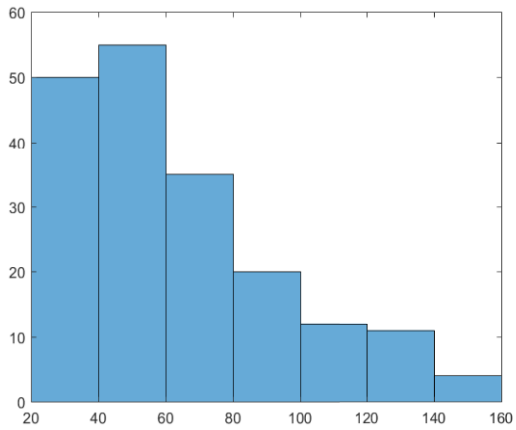


Figure 5. Time delay histogram of 180 companies listed on the TSE

According to the time delay histogram, the time delay (or memory) in the companies operating in the stock exchange changes from 20 to 160 days; therefore, the corporate memory distribution function is no longer Gaussian, known as non-Gaussian. Nonetheless, the time delay of 30 companies operating in the Dow Jones market indicates a Gaussian behavior, and the average

goes to the variable l in the information transfer entropy following the time delay of the destination series *k*, indicating the source time-series memory. Many research studies consider the value of l to be 1 or *k* to avoid computational complexity. Here, its value is considered equal to *k*.

The statistical index is based on the entropy of information transfer between companies, suggesting the degree to which information flows between companies over a given interval. Hence, to obtain this statistical index, a specific interval is considered in the data. It is calculated for the intended interval by considering the time delay at the information destination, the optimal classification of transfer entropy, and the adjacency matrix of the companies. Ultimately, the average information transferred across the market is determined over a time period by averaging the entries of the adjacency matrix. This quantity, known as the average *w*-day market information, is related to the past *w* days, which is displayed on the last day of the window. Moving this window during a one-day-step time-series leads to a new series, each point of which shows the average transferred information associated with the past *w* days.

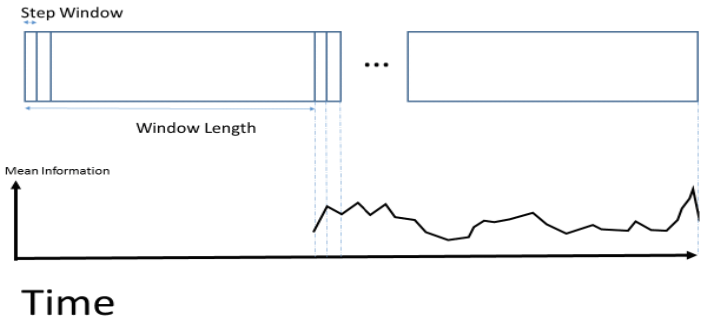


Figure 1: Procedure of considering windows over time and moving them over the time-series

w, the window length, can be seen as a scale length of the system in which there is significant information. Different window lengths can be considered; therefore, the amount of information transferred between companies varies. Nonetheless, a window length is regarded as acceptable where maximum information is transferred. The number associated with the displaced information or the average transfer entropy of the adjacency matrix is obtained for different windows. An increase and then a decrease is observed in the transferred information as a result of an increased window length. Furthermore, the desired output suggests that the diagram peak occurred over window 70. This means that the maximum amount of information is transferred between companies operating in the stock market on a 70-day scale. Notwithstanding, the optimal window or scale was obtained within 200 days to transfer maximum information in the Dow Jones market.

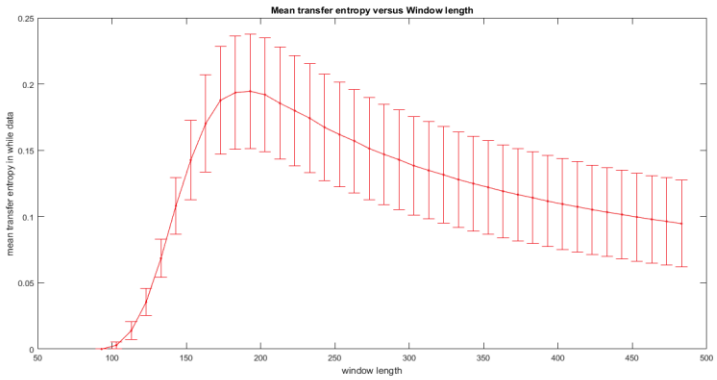


Figure 6. Average information transferred for 30 companies operating in the Dow Jones market across different scales

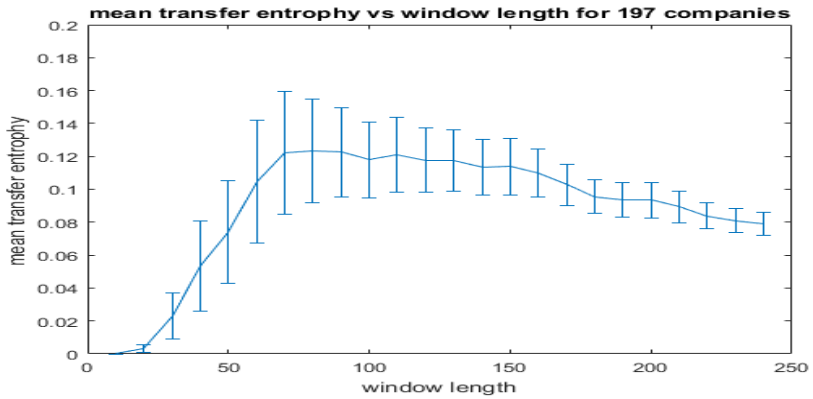


Figure 7. Average information transferred for 180 companies listed on the TSE across different scales

Thus, a 70-day time scale is considered as the optimal window length to calculate the adjacency matrix. By determining the transfer entropy variables, namely *k*, *l*, and *w*, a significant number is obtained for transfer entropy or the amount of information transferred over time. The average 70-day TSE information can be obtained by calculating the adjacency matrix in 70 days and averaging all entries, which is displayed on the last day of the window. That is, the information is related to the last 70 days. A new series is created by moving this 70-day window in a one-day-step time-series, each point of which displays the average information transferred over the past 70 days.

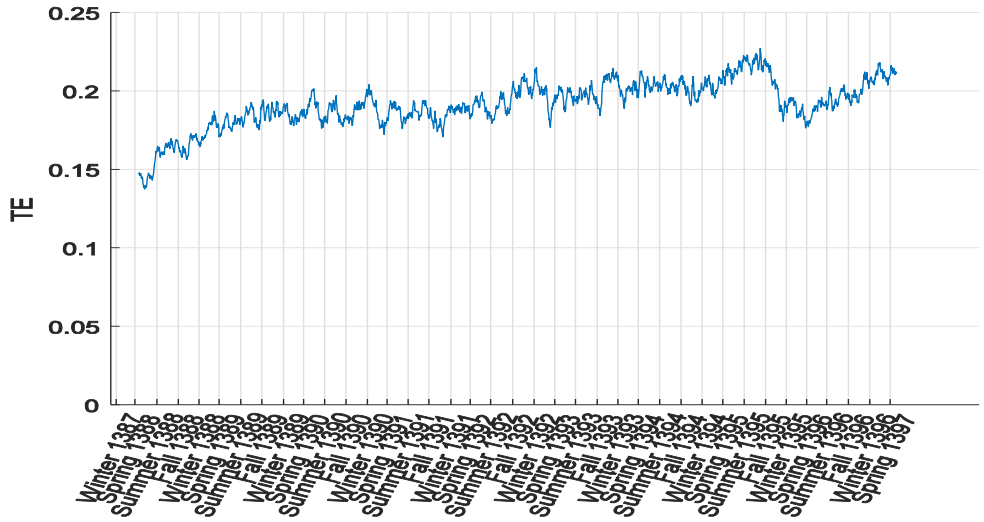


Figure 8. Average transfer entropy or transferred information for 180 companies listed on the TSE over the last 80 days

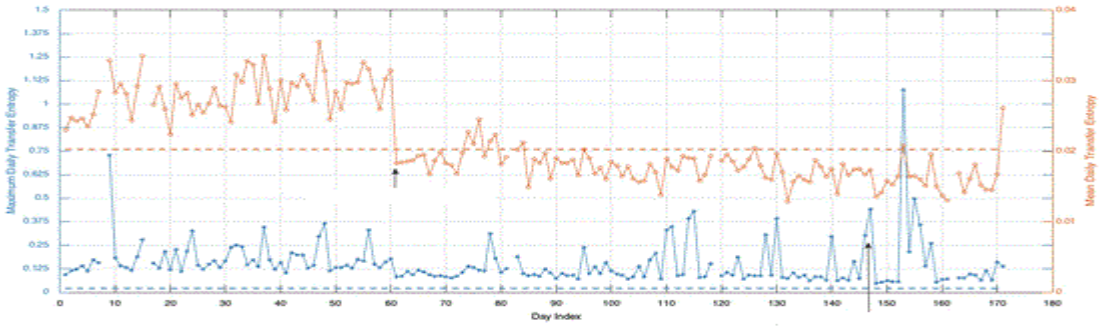


Figure 9. Average transfer entropy or transferred information for Dow Jones Index

Regarding the Dow Jones Index, based on entropy measurements, some protection measures must be taken when comparing simple system data with real complex systems. Following an increase in Dow Jones entropy, what is likely to be described as the first measure is a step-by-step transfer, as studied in complex systems. However, this is certainly due to a drop in prices on the NYSE.

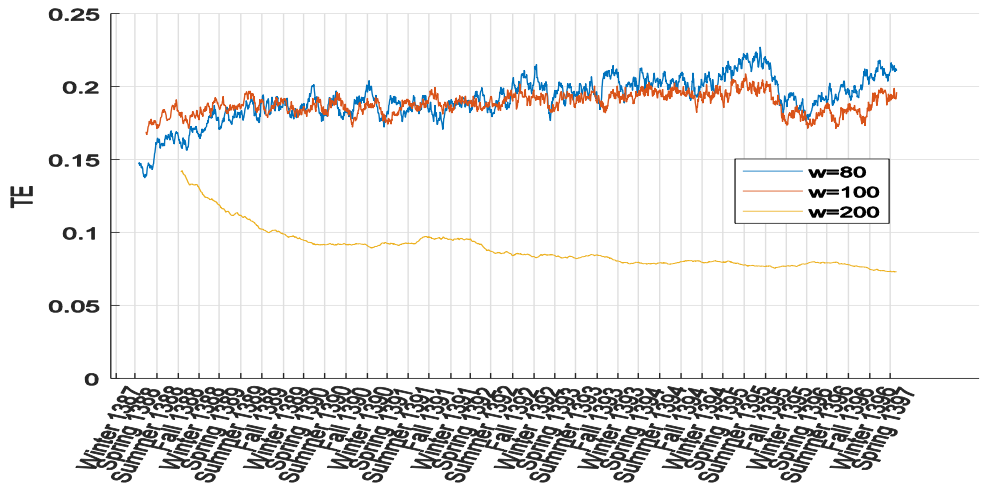


Figure 10. Average time-series of information transferred over different scales or time windows for 180 companies listed on the TSE

The following figure shows the average transfer entropy for 180 companies listed on the TSE over time. Here, the specified rectangles represent the periods of "crisis" or "decline in TEPIX" following adjusted inflation. It seems that the "average transfer entropy" mainly indicates a random behavior. That is to say, the declines observed do not correspond to periods of crisis in the stock market. Although transfer entropy can apparently be an appropriate index for determining the period of crisis in the Dow Jones market, it cannot be suitable for determining the period of crisis for TSE.

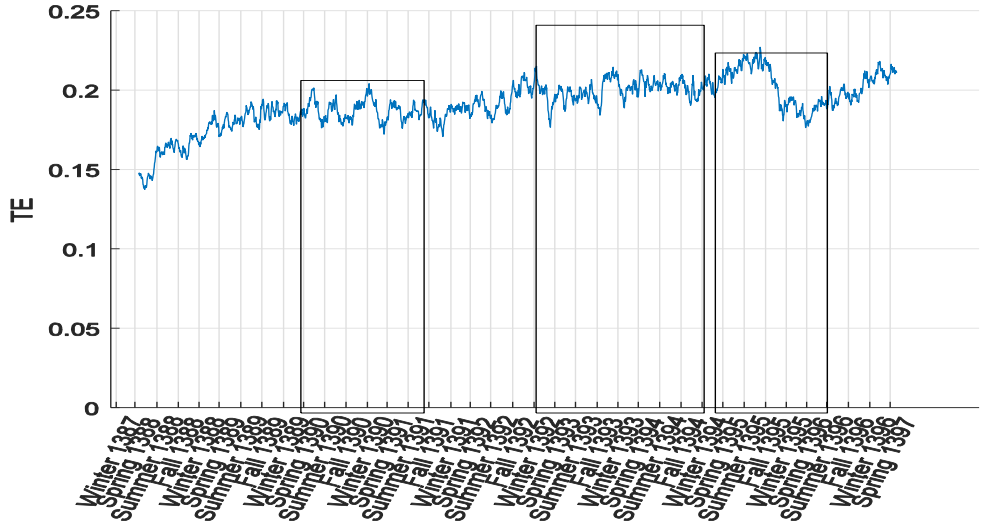
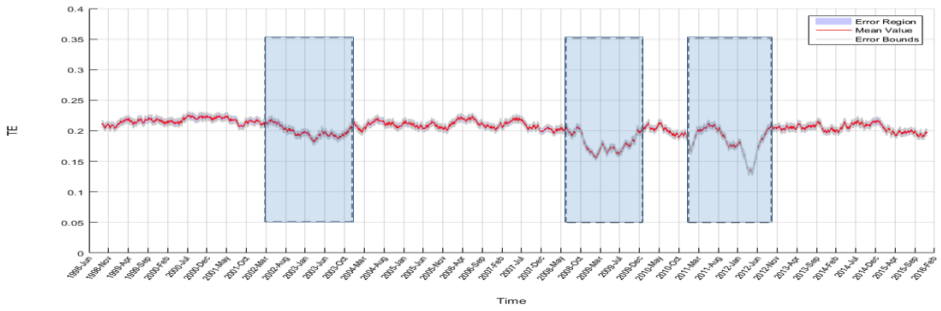


Figure 11. Average transfer entropy for 180 companies listed on the TSE over time for the optimal time window. Black rectangles indicate periods of crisis or decline in TEPIX.



Conclusion

The emergence of financial crises in stock markets is generally unavoidable, confirmed by the experience of these markets worldwide. Most GFCs have attracted the attention of researchers and government officials due to their pervasiveness (e.g., the 2008-2007 Crisis) and have been investigated from various angles. Nevertheless, despite the domestic ups and downs experienced by TSE over the last few years, no research has been conducted on TSE financial crisis using the entropy transfer method and its comparison with the Dow Jones financial market. Inflation seems to be one of the key factors contributing to the concealment of these crises domestically. Hence, the present research used the entropy transfer method. An entropic analysis is usually regarded as a new domain in financial markets, capable of being widely used in marketplaces. It is worth noting that transfer entropy is a model-free method for detecting asymmetric statistical dependence. Correlations allow for the calculation of the magnitude and flow of information in financial markets. The delay variable has also been introduced to determine industries willing to advance collective movements in the stock market and the duration of their effectiveness.

The results suggest that the entropy transfer method is inappropriate for TSE data. It should be noted that transfer entropy determines the amount of information transferred and nonlinear dynamic relationships. Thus, it proves the existence of a promising procedure for identifying directed information.

Based on TSE evidence, the average transfer entropy for 180 companies listed on the TSE mainly indicates a random behavior. In other words, the declines observed do not correspond to periods of crisis in the stock market. Although transfer entropy can apparently be an appropriate index for determining the period of crisis in the Dow Jones market, it cannot be suitable for determining the period of crisis for TSE. Furthermore, the results of this research are inconsistent with those of the research conducted by Romer (2017) and Tang and Shang (2017). On the other side, synchronous with popular financial crises, the average information transferred between companies is drastically reduced for the Dow Jones Index. The 2001 Crisis in the US markets, as a result of the 9/11 events, exacerbated distrust in its domestic financial markets, with its adverse effects lasting two years, including the 2001-2003 Crisis and the 2008 Crisis in the US and European financial markets. The 2012 financial crisis was also confirmed by the distribution function of input, output, and total information. Following a defined order quantity within the system, it approaches 0 (tending to be disordered) in critical areas, from a positive value (order phase). The average information transferred plays a role similar to the order quantity. Under normal circumstances, there are a number of causal relations between companies, linking different industries and firms. Nonetheless, once the market enters a phase of depression (recession) and crisis, the amount of information transferred between companies decreases, resulting in diminished causal relations, and companies continue to operate independently. That is, the system suffers from increased disorder (clutter) and chaos.

Finally, it is recommended to explore various industries to specify those with the largest amount of information on the economy as a whole, compare the results of each industry, and determine the type of delay in different industries, whether different, uniform or random. The

introduction of the “delay variable” to study information flow allows for expanded applications of entropy transfer in econophysics. Transfer entropy does not necessarily determine the intensity and direction of information flow, rather it predicts the duration. This leads to a better understanding of the underlying factors of market movements, including GFCs.

Referencias

Abdollahzadeh, Salam, Faghandoust Haghighi, Kambiz, Arad, Hamed. (2013). Entropy Investigation of Financial Statements and their Impact on Profit Changes in Tehran Stock Exchange Industries, 13 (52), 133-93. (in Persion).

Abdollahzadeh, Salam, Mohammadi Moqarrani, Atallah, Noroush, Iraj, Amini, Peyman. (2018). Investigating the Impact of Liquidity and Leverage Entropy Rates on Identifying Suspected Firms in Financial Reporting. Audit knowledge. ۱۸(۷۲), 96-79. (in Persion).

An international trading broker(2018). A Network Analysis of Global BankingJ. Financ. Stab. 9, 168–184.

Arab Salehi, Mehdi, Rahrodi Djerjerdi, Alireza, Hamidian, Narges. (2015). Investigating the Causes of Global Financial Crisis Occurrence and Dissemination with Emphasis on Complexity Approach. Accounting Research, 5 (3), 31-50. (in Persion).

Babecký, J., T. Havránek, J. Matějů, M. Rusnák, K. Šmídová & B. Vašíček. (2012). Leading Indicators of Crisis Incidence: Evidence from Developed Countries. Czech National Bank, mimeo.

Biani, Azra, Mohammadi, Timur. (2019). Factors Affecting Financial Crises: A Bayesian Averaging Approach. Journal of Quantitative Economics, 16 (2), 180-150.(in Persion).

Bonis, R.D., A. Giustiniani & G. Gomel. (1999). Crises and Bail Outs of Banks and Countries: Linkages, Analogies, and Differences. The World Economy, Vol. 22, pp: 55-86.

Castrén, O.; Rancan, M.(2013). Macro-Networks: An Application to the Euro Area Financial Accounts; ECB Working Paper No. 1510; European Central Bank: Frankfurt am Main, Germany.

Fatemi Adel, Sorting Univariate Distributions by Entropy and Variance (2001). Master of Science Degree in Mathematics and Statistics, Tehran University of Teacher Education. (in Persion).

-Fosberg, R, (2012), “Capital Structure and Financial Crises", working paper, William Paterson University.

-Hale, G. (2012). Bank Relationships, Business Cycles, and Financial Crises. J. Int. Econ. 88, 312–325 .

Hasanzadeh, Ali and Mehran Kianvand. (2009). The Global Financial Crisis, The OPEC World Oil and Strategic Market, Economic News, New Volume, Seventh Year, No. 126. (in Persion).

Lee, D., & Park, H. (2019). Measuring Global Financial Linkages: A Network Entropy Approach. Sustainability, 11(17), 4691.

Reinhart, C. M. & K. S. Rogoff. (2009). This Time is Different. New Jersey: Princeton University Press.

Anbari, M., Bagheri, R., & Davodi, H. (2013). Survey of Social factors Effective on discontinuation of innovation in rural areas (Case Study: Drip irrigation Technology in Lorestan). *Journal of Science and today's world*, *2*(5), 451-464.

Rummel, C,. (2017). Governor's School for Science & Mathematics, Transfer Entorpy within the Nasdaq Stock Exchange, South Carolina Junior Academy of Science. 76.

-Sensoy, A., Sobaci, C., Sensoy, S., & Alali, F. (2014). Effective transfer entropy approach to information flow between exchange rates and stock markets. Chaos, Solitons & Fractals, 68, 180–185.

Soheili, Kiomars and Azar Mirzaei Rashno. (2012). Investigating the Relationship between the Global Financial Crisis and Economic Growth in Iran, M.Sc. in Economics, Razi University of Kermanshah. (in Persion).

-Stosic, D., Stosic, D., Ludermir, T., de Oliveira, W., & Stosic, T. (2016). Foreign exchange rate entropy evolution during financial crises. Physica A: Statistical Mechanics and Its Applications, 449, 233–239.

Davodi, H., Iravani, H., Fami, H. S., & Ameri, Z. D. (2017). Affecting Factors on Water Resources' Sustainability in case of small holding farmers, Alborz province, Islamic Republic of Iran. Advances in Bioresearch, 8(3).

-Thomas Schreiber, T., (2000). Measuring Information Transfer, Physical review letters 85(2), 461. Upper, C.; Worms, A. Estimating Bilateral Exposu.

Weistro_er, C.; Mo¨bert, J.(2010). Monitoring Cross-Border Exposure: A Primer on how to Exploit the BIS Banking Statistics; Deutsche Bank Research Current Issues; Deutsche Bank Research: Frankfurt am Main, Germany.