Journal of Global Information Management
Volume 27 • Issue 4 • October-December 2019

The Investigation of Dependence Between the Internet Measurement and Globalization

Bruce Qiang Sun, SUNY Buffalo State, Buffalo, USA
Tina Ting Swan, SUNY Buffalo State, Buffalo, USA
Yan Lu, The University of New Mexico, Albuquerque, USA
Lorena Mathien, SUNY Buffalo State, Buffalo, USA

ABSTRACT

Under the new measurement for the internet supplied from the Cooperative Association for Internet Data Analysis (CAIDA), the authors relax the orthogonal and normality condition with the methodology based on empirical codependence structures and marginal distributions. The nonparametric dependence between the diffusion of the internet and different globalization indices is examined using a panel of 10 countries, as long as error terms do not follow multivariate Gaussian distributions. The model selections are ranked and the authors find the best dependence model. The empirical dependence of the Internet diffusion on the globalization is further demonstrated from the dynamic copula analysis.

KEYWORDS

Copula, Distance, Globalization, Gravity Equation, Internet

1. INTRODUCTION

In recent years, there have been a large number of investigations on the relationship between technological advances and globalization. One of the most interesting topics is that, as the driving force, how do the emergence and rapid development of the Internet technology and its applications impact on globalization, or do they impact on each other? Although there are still debates, some facts and arguments have been generally accepted. The growth of the Internet has accelerated the dissemination of global information all over the world, which enables more effective and convenient communications among international decision-makers. Companies improve their productivity and competitiveness with more efficient and smooth processing of transactions. Furthermore, the E-commerce on the Internet has been more competitive, giving consumers more diverse choices. Therefore, all of these have greatly boosted the globalization including the economic and political interactions, technology and capital flows and international social welfare.

The Internet can be defined as an innovative communication that enables the dissemination, exchange, storage and analysis of data and all kinds of global information. While the multi–national flows of information, trade and capital are key elements to globalization, the Internet plays an

DOI: 10.4018/JGIM.2019100109

innovative role on the global economy and politics. To measure the Internet development across countries, many researchers use data from the Internet Software Consortium (ISC) to count how many web hosts are attributed to each country by counting top-level host domain names. As they point out, however, this may not be a very good measure, since there is no necessary correlation between a host's domain name and where the site is actually located. Generally, there are two concerns need to be addressed: First, there are still confusions and debates on the exact measurements on the development of the Internet on the globalization and vice versa. Second, there are also debates on whether the statistical algorithms, tools and analytical models can give exact description and understanding of their dependence relation.

As to the measurement of globalization, there are many indicators published periodically in the past decade. The popular ones that researchers frequently applied are listed below. The World Development Indicators (WDI) from the World Bank are published quarterly, including more than 900 indicators organized in different sections, such as, financial sector, trade, world view, environment, economy, markets, and global links. The Organization of Economic Cooperation and Development (OECD) puts together special groups of experts to evaluate the processes of globalization in almost all dimensions. They publish the OECD Handbook on Economic Globalization Indicators in response to increasing demands for better measures to the trends of globalization, with a conceptual and methodological framework for gathering quantitative information and constructing indicators. The International Monetary Fund (IMF) also supplies various indices to illustrate the international flows of goods, capital, and people. Different from the above measurements, the KOF Swiss Economic Institute has devised a composite index of globalization, the KOF Globalization Index. The index measures the social, economic, and political dimensions of globalization. It observes the globalization of a set of countries over a long-term period. The economic globalization index measures the extent of cross-border trade, investment and revenue flows in relation to GDP; the index also measures the social dimension of globalization in the cross-border personal flows as well as the size of the resident foreign population, and cross-border information flows; and finally, it provides the cultural and political proximity to the global mainstream.

The measurements of the Internet are much more relying on the development of information technologies. So far researchers have very limited sets of measures, and sometimes they have been even contradictive to each other. Abramson (2000) states that measurement of telecom traffic flows helps pin down and address the uneven patterns of globalization. However, Internet traffic statistics are still estimated based on extremely thin data sets. Huang and Sun (2016) present a way to measure the diffusion of the Internet. It relied on the access of the Internet connections and infrastructures in the countries. The gathered data gave an effective way with insight into the complexity of a large, heterogeneous, and dynamic worldwide Internet topology. We found the significant and positive relationship between the Internet distance and different globalization indices. The dynamic panel causality analysis demonstrates further the impact of the Internet diffusion on the different indices of globalization. Thus the first concern in the above has been generally addressed in our previous paper (2016).

In this paper, we will endeavor to look into the second concern, which will answer one of the most fundamental questions in the related global research. Many researchers believe that, whether there does exist the dependence relationship between the Internet and globalization needs to be checked with new hard evidence from the real data. We will check the nonparametric dependence between the diffusion of the Internet and different globalization indices using the same panel of 10 countries[1]. We relax the orthogonal and normality condition in the panel time series analysis. The empirical results of the panel time series analysis show that the error terms do not follow multi-Gaussian distributions, so it is necessary to explore the relationship among the time-series variables cross-sectionally. We can apply copula methods and make model selections to search the detailed dependence structure which has better fit to the dataset, in order to supply the full description and explanation of the dependence relation. We will also derive the optimal parameters for several standard parametric copulas, corresponding to empirical copulas of the panel time series. The model selections will be ranked to find the best dependence model. Finally, the results show that the shock from the annual cycles can be forecasted, and the prompt reflection can be traced by the traffic fluctuations.

2. LITERATURE REVIEW

Globalization can be understood as the global development of communication technologies and capital movements. It has several fundamental elements, such as information flows, international trade, foreign direct investment, short term capital flows, and movements of labor. Borcuch and Kaczor (2012) conclude that the impact of the Internet on globalization has diversified aspects. The positive impact of the Internet on globalization includes the modernization and improvement in online business.

Totonchi and Manshady (2012) make an investigation on the relationship between globalization and the Internet at firm levels. They find that the relationship between globalization and the Internet commerce is complex and varied. Aydina and Savrulb (2014) investigate the relationship between globalization and E–commerce. Their results indicate that linear models may not be enough to show the relation between globalization and Internet. Goldfarb and Blum (2006) use the gravity equations to measure the international electronic commerce. They show the gravity equations hold in the case of digital goods that are consumed over the Internet and have no trading costs, but the effects of distance on electronic commerce mainly focus on the digital goods that depend on the taste. Lee-Chu-Tseng (2012) claimed that the Internet infrastructure affects workplace reform significantly. N'DAa, Robin, and Tribunella (2009) used data of two time points, 1990 and 2000, and over 100 countries, to find the codependence between technology and economic freedom.

On the other hand, Aas (2004) states that understanding and quantifying dependence is at the core of all modeling efforts. The linear correlation coefficient, which is the most used measure to test dependence, is only a measure of linear dependence. It has many drawbacks to exploit the complicated relations among factors. It is a meaningful measure of dependence if random variables are well represented by an elliptical distribution. Outside the world of elliptical distributions, however, using the linear correlation coefficient as a measure of dependence may lead to misleading conclusions. Hence, Adam, Ding and Li (2015) consider using alternative methods for capturing co-dependency. One class of alternatives are copula-based dependence measures. Dowd (2008) discusses the uses of copulas for modeling multivariate density functions and explains how copula methods can be applied to the study of macroeconomic relationships. He suggests that copulas are well suited to the study of the relationships among the macroeconomic factors. Shaw, Smith and Spivak (2012) measure and model the dependency within capital models by the consideration of copulas. In this paper, we will apply the copula theory and make the model selections to estimate what kind of nonparametric dependence structures have better fits and prove the relationship between globalization indicators and Internet measurements.

The rest of the paper is organized as follows. Section 3 is devoted to a summary of the Internet measurements and the KOF Globalization indicators. We present an empirical examination that describes the behavior of cross–country Internet, using the empirical copulas to see the joint distribution of the relationship and demonstrate how the empirical data can be regressed by nonparametric models. Section 4 concludes the paper.

3. COPULA ANALYSIS AND ESTIMATION

3.1. The Data and Empirical Problem

We continue using the datasets downloaded and processed from the CAIDA, one of the channels of the National Supercomputing Center (NSC), to measure the connectivity and the performance of the Internet by collecting raw files from activated monitors across ten countries for ten years. There are four variables discussed in the empirical results. The first is data length, which represents the length of the signal sent from the source IP address to a specific destination IP address. This variable gives us an opportunity to check the efficiency of the information transformation when we change the size of the length or the ratio of the signal length to the number of the hops across countries. The second is RTT. We will count how many round trip times (RTTs) can be attributed to each starting hop in each country by counting million-seconds for each destination. This is the most stable variable supplied by CAIDA. The third is HopDistance. This counts how many hops before the signal successfully goes through from the source to many destinations. This is an alternative way to test the stability and the efficiency of information traveling. It's expected that the HopDistance will be large when the number of hops increases and the recursive hops appear, which signals that the information traveling is unstable and inefficient. The last one is Reply TTL, which measures the forward IP paths to record each hop from a source to many destinations by incrementing the so-called "time to live" (TTL) of each IP path and recording replies from each router (or hop) leading to the destination hosts. This is also an alternative way to compare the connectivity of the Internet, instead of only counting how many web hosts are attributed to each country by counting top-level host domain names.

There are ten countries we used in this paper. They are the United States, the United Kingdom, China, Japan, Canada, Korea, France, Sweden, Netherland, and New Zealand. All the files are daily–accumulated records of each monitor from the round-trip tracing within a month. We inherited the data of the ten countries from our published works. CAIDA only collected the data from these ten countries at that time. By examining the variables of data length of sending message, RTT, Hopdistance, and TTL, we can see that, for data length, the message sending out to multiple destination has been increased; RTT, Hopdistance, and TTL have deceasing trends, indicating that the rounding time for the message echoing back to resource gets decreased. This confirms there exists significant improvement in the stability and efficiency of the information traveling, and the connectivity of the Internet across time in different countries is enhanced during the time period. These improvement resulted from greater increments in hosts located in developing countries than in developed countries due to substantial upgrades in hardware and franchises.

The KOF Index of globalization, economic globalization, social globalization, and political globalization are downloaded from the KOF website, which was introduced by Dreher (2003), and is updated and described in details then, Gaston and Martens (2008). The overall index covers the economic, social and political dimensions of globalization. Economic globalization is characterized as long distance flows of goods, capital and services as well as information and perceptions that accompany market exchanges; while political globalization is characterized by a diffusion of government policies, and social globalization is expressed as the spread of ideas, information, images and people. To proxy the degree of political globalization, the methodology follows A.T. Kearney (2001), employing the number of embassies and high commissions in a country, the number of international organizations to which the country is a member and the number of UN peace missions a country participated in. The KOF Index of Globalization measures globalization on a scale of 1-100, where the underlying variables enter in percentiles.

In Huang and Sun (2016), the fundamental empirical problem from the derived logarithmic gravity equation is:

$$\ln x_{ij} = constant + lny_i y_j + (1-\sigma)\rho \ln d_{ij} + (1-\sigma)\ln I_i I_j - (1-\sigma)\ln p_i p_j$$

where x_{ij} is a measurement of globalization index between region *i* and *j*. The d_{ij} is the geographic distance, and $I_i I_j$ is the Internet measurement between region *i* and *j*. In this paper, we only concentrated on the influence of the Internet on the globalization, especially globalization of the integration from the international service aspects. Originally The y_i is the nominal income of consumers in region *i*, and p_{ii} is the price of goods consumed by j consumers and are from in region i. The coefficient ρ is a correlation coefficient, and σ is the elasticity of substitution between all goods.

Considering the gravity equation again, with distance variables dropped, the geographic distance remains the same across countries, which can be treated as fixed constants in the estimation equation. The price-adjusted income level disappears as in the previous literature[2]. We set up:

$$\Delta X_{it} = \delta_0 + \delta_1 \Delta X_{i,t-1} + \delta_2 \Delta I_{it} + \delta_3 \Delta I_{i,t-1} + u_{it} \tag{3.1}$$

where the subscript i and t denote the ith country, $i = 1, ..., 10$, and the tth year, $t = 1, ..., 10$. The X_{it} is the first-differenced KOF index of globalization, financial and economic globalization, social globalization, or political globalization for country i, in year t, measured as the variables and weights defined in Dreher (2003). In this paper, they were the measurements for the bandwidth estimations of the cross-traffic travelling distance, RTT or other closed-form measurements, for instance, Data Length, HopDistance and TTL, and the lagged terms of X_{it}, I_{it}, u_{it}. The error terms are assumed as multi-Gaussian and orthogonal to the group of variables for identification. so the identification issue have been posted. On the other hand, as long as the error terms do not follow the multi-Gaussian distribution, copula theory is an alternative for estimating the relationship between the globalization and the diffusion of the Internet.

3.2. The Model and Identification

In this section, we will use copula theory to check the dependence relation of the Internet measurement and the Globalization indexes, and in the meantime, to fix the problem that the linear or log-linear estimation might not be the correct way if the error terms in (3.1) are not multivariate Gaussian[3].

The identification is one of the basic steps for estimation if we want to use the data to capture the correlations between the variables interested. In our empirical model above, we assume that the unobservable error terms follow multi-Gaussian distribution conditional on the Internet variables. However, the dependence relations in the regressions rely heavily on the multivariate distribution of errors conditional on the explanatory variables. The (weak) orthogonal conditions between the error terms and the explanatory groups are the fundamental for consistency and efficiency issues, which can lead to the potential bias in the maximum likelihood estimation. Furthermore, the marginal distributions do not follow Gaussian either, which can be seen from figures in the appendix, so the dependence correlation between globalization and the diffusion of the Internet should not be measured by the traditional linear correlation statistics. According to Aas (2004), the linear correlation coefficient is only a measure of linear dependence. It is a meaningful measure of dependence if random variables are well represented by elliptical distributions, whereas our statistical analysis and figures show they are clearly not elliptically distributed. Outside the world of elliptical distributions, however, using the linear correlation coefficient as a measure connectedness across countries of dependence will lead to misleading conclusions.

We use ρ^{-} to denote the sample correlation coefficient. By our derivation for examining empirical Equation (3.1), we see that $\rho^{-}(X_k, I_l) = -0.07$. If (X_k, I_l) are Gaussian distributed, X_k and I_l would be dependent in multiple Gaussian distribution. Our empirical data shows that (X_k, I_l) are not multivariate Gaussian, and the hypothesis that their marginal distributions are normal can be simply rejected. so $\rho^{-}(X_k, I_l) = -0.07$ alone is far from sufficient to say that X_k and I_l are independent or not. Therefore, we would use a different setting of correlations to check the dependence of them. For empirical observation $\left\{X_k\right\}_{k=1}^{NT}$ and $\left\{Y_l\right\}_{l=1}^{NT}$ of cross-sectional time series $\{x_k\}$ and $\{y_l\}$, the Kendall's τ is defined as:

$$\tau = \frac{2}{NT\left(NT-1\right)} \sum_{0 \le k,l < \tau \le NT} sign\left[\left(X_k - X_\tau\right)\left(Y_K - Y_\tau\right)\right]$$

It is an indicator to measure the difference between the probabilities of cordance and concordance. When X and Y are independent, the theoretical expectation of τ is zero. In the sequel, we turn our attention to the copula approach for the dependence analysis of the variables $\left\{X_t^i\right\}$ and $\left\{I_t^j\right\}$. The earliest paper explicitly relating copulas to the study of dependence among random variables appeared in Schweizer and Wolff (1981). Copulas allow us to separate the effect of the dependence from the effects of the marginal distributions.

3.3. The Empirical Copula

To demonstrate that the variables we examined in (3.1) are closely dependent, we measure the error between the empirical copula derived from the variables $\{X_t\}$ and $\{I_t\}$ and the standard copulas. We shall show that empirical copula is close to the Frank copula, i.e. $\{X_t\}$ and $\{I_t\}$ can be statistically regarded as dependent relationship as Frank model.

Given observations $\left\{X_k\right\}_{K=1}^{NT}$ and $\left\{Y_l\right\}_{l=1}^{NT}$ of random variables, a commonly used empirical distribution of X and Y are defined by:

$$\bar{F}\left(x\right) = \frac{1}{NT}\sum_{k=1}^{NT} 1\left\{x \ge X_k\right\}, \quad \bar{G}\left(y\right) = \frac{1}{NT}\sum_{l=1}^{NT} 1\left\{y \ge Y_l\right\}$$

where 1 is the indicator function that takes value 1 when its logical argument is true and zero when its logical argument is false.

Now let $U = F(X)$ and $V = G(Y)$. The empirical copula for U and V is first defined on the lattice:

$$\Sigma = \left\{\left(\frac{k}{NT}, \frac{l}{NT}\right) : k, l = 0.1...NT\right\}$$

by:

$$C_{Empirical}\left(u,v\right) = \frac{1}{NT}\sum_{k=1}^{NT} 1\left(\bar{F}\left(X_k\right) \le u\right) 1\left(\bar{G}\left(Y_l\right) \le v\right) \quad \forall u,v$$

and then extended over $[0, 1]^2$ by a linear interpolation.

Based on the integral difference measures in Appendix B, we calculate the errors between the empirical copula and several standard copulas which can be referred from Appendix A. In the appendix, we list the empirical Copula for joint distribution, the marginal cumulative probability distribution, and the marginal distribution. It shows that the empirical copula for our interests, $\left\{X_t^i\right\}$ and $\left\{I_t^j\right\}$. And a quasi-standard parametric form. The contours of copula show some pictures for approximation from the parametric view. The marginal cumulative probability distribution, and the marginal distribution confirm that the $\left\{X_t^i\right\}$ and $\left\{I_t^j\right\}$. are not Gaussian distribution, so we need some functional form, other than Gaussian, in the estimation process for our empirical model above.

3.4. Results

In this section, we discuss the copula model of dependency, preliminarily, in nonparametric format, i.e., distributional inference, to explain the global interaction. Firstly, X_{it} and I_{it}, $i = 1, ..., N$, for all $t = 1, 2, ...T$ will be put into the variable sets without considering the orders, and the estimates of parameters can be obtained according to the dependence parameter inside the functional forms. We thus obtain a nonparametric inference for estimating the relationship between the globalization and the diffusion of the Internet.

We have nonparametric evidence supporting the relationship between the globalization and the diffusion of Internet. In the appendix, the figures showed the difference between the empirical copula and several parametric copulas. From these figures, we see that the minimum errors between empirical error and the parametric copulas are attained near those values 0.01 ~ 0.02, so that the parametri copula becomes the Frank copula. We also plot the relative differences between empirical copula and the product copula which are attained near those values 0.7 ~ 0.8, so that the parametric copula becomes the Frank copula[4]. From the smallness of the error between empirical copula and the Frank copula, we can reasonably conclude that the relationship in (3.1) are in some functional form, which is not Gaussian. It shows that the empirical copula for our interest $\left\{X_t^i\right\}$ and $\left\{I_t^j\right\}$ has the minimum error to the Frank copula in L_1, L_2 and L_∞. We can find the dependence within the values of related variables, which are significantly shown up in the estimation equation. Here, the coefficient estimates of θ are positive in all of the alternative specifications for Data length, and negative in most of the alternatives for RTT, and HopDistance. In the appendix it shows that the minimum error to the empirical copula in L_1, L_2 and L_∞, and the associated coefficients for including independent variable, Data length, RTT, HopDistance, TTL, respectively. The consistent dependence coefficients of X_{it} and I_{it} confirm that the measurable values for globalization index is adaptive to the Internet diffusion's values. So in this setup framework, the relationship we examined for series (X_{it}, I_{it}) are statistically dependent. The Internet measurement, I_{it}, has the minimum error for parametric copulas which are attained near those values 0.01 ~ 0.10 so that the parametric copula becomes the Frank copula. In addition, the relative differences between empirical copula and the Frank copula are attained near those values 0.09 ~ 1.0, in each different estimation process, Data length, RTT, HopDistance, and TTL. The dependence coefficients vary in different criterions for minimum error, and we can explain the economic meanings based on the values from different cri-terions. We can find that the movements in the diffusion of the Internet have statistically significant relationship to the globalization index. In general, we can summarize the correlation coefficients, θ, 0.21, −1.89, −0.63, 0.21 for Data length, RTT, HopDistance, and TTL, respectively, to approximate the empirical correlations between the diffusion of the Internet and the degrees of globalization across countries.

On the other hand, in the examination of economic, social, and political globalization, we have similar results supporting the relationship between the globalization and the diffusion of the Internet. Here, the Internet measurement, I_{it}, has the minimum error for parametric copulas are attained near those values 0.01 ~ 0.08 that the parametric copula becomes the Frank copula. Furthermore, the relative differences between empirical copula and the Frank copula are attained near those values 0.03 ~ 1.0, in each different estimation process (i.e., Data length, RTT, HopDistance, and TTL). The dependence coefficients also vary in different criterion for minimum error, and we can similarly explain the economic meanings based on the values from different criterions. Here, we can summarize the correlation coefficients, θ, 0.21, −1.05, −0.21, 1.05 for Data length, RITT, HopDistance, and TTL, respectively, to approximate the empirical correlations between the diffusion of Internet and the degrees of economic globalization across countries. For social cross–country interactions, the correlation coefficients, θ, 0.63, −1.89, −0.63, −0.21 for Data length, RTT, HopDistance, and TTL, respectively, to approximate the empirical correlations between the diffusion of Internet and the degrees of social globalization across countries. The correlation coefficients, θ, 1.05, −1.89, −1.05, −1.05 for Data length, RTT, HopDistance, and TTL, respectively, to approximate the empirical correlations between the diffusion of Internet and the degrees of political globalization across countries. The interesting point is that the coefficient estimates of θ are negative in most of the alternative specifications for interaction between TTL and social globalization, or political globalization, which is different from other globalization index measurements, so this supports this unique data sets are good alternatives to approximate the measurements of Internet diffusion, especially from the nonparametric point of view using Frank copula's functionals. Our data provides valuable input for empirically-based modeling of the Internet behavior and properties.

Based on our results, aggregate cross-sectional time series data shows consistent nonparametric evidence to provide support for the dependence between the globalization and Internet diffusion. The impact of Internet diffusion on globalization is supported not only in linear functional ways, but in the nonparametric distributional examinations. It should be noticed that the $I_{i,t}$, the current and lagged-one-period Internet diffusion both put consistent impact on the current trend of globalization, where the coefficient, θ is the dependence parameters in the theoretical model above, which support the same movement of technology growth from the Internet diffusion on the growth of the global integration. We further confirm that it will be reasonable if we use the Internet diffusion rate to calculate the network incentive, not the proxy variable which results from the global geography, local distance and neighboring price for services.

4. CONCLUSION

In this paper, we looked into the second concern in the introduction, whether there does exist the dependence relationship between the Internet and globalization. To address the concern is a part of the fundamental works in global information management. Under the examination of quasi-parametric dependence between Internet measurements and different globalization indices, the empirical derivations and results are provided with more solid background for the evaluation of financial transactions, international trades, institutional transitions and government policy.

The derived empirical results further support there exists significant and positive relationship between Internet information transferring sizes and the globalization, the fixed-time-to-length messages and instantaneous changes on globalization. We also prove the strong relationship between the information cycle rates of Internet speeds and the globalization, and the mistakes on transferring message bytes and the globalization. With comparing cross-country institutions transformation based on the influence from Internet service, we find the strong persistence in the political globalization when there is so much free flowing information.

We compute the indicators to measure the difference between the probabilities of discordance and concordance. Copulas allow us to separate the effect of the dependence from the effects of the marginal distributions. Sklar's Theorem tells us that for any two random variables with joint and marginal distribution known, the copula functions are determined if the marginal distributions are continuous. On the other hand, if we know the marginal distributions, different copulas can applied to approximate the joint distributions. This gives us an elastic framework to do the analysis of dependence relation between two random variables.

In fact, copulas can do more than merely shed light on correlations. Since copulas enable us to model the multivariate density function of the Internet measurement and globalization indicators, they shed light on their complete relationship, whereas any other correlation indicators only give us a partial picture. The best fit, Frank copula, shows how the Internet measurement and globalization index are related in their tails, as well as in their central masses. Therefore, we master the complete picture of empirical dependence relation between the Internet and globalization from this dynamic panel copula analysis.

The outcomes of our analysis also demonstrate empirically that the error terms and the explainable variables are not independent, so the identification issue can be solved by this alternative method.

On the other hand, as long as the error terms do not follow the multi-Gaussian distributions, copula theory is an efficient alternative for estimating the relationship between the globalization and the diffusion of the Internet, which confirms the significant strong relationship between the globalization and the diffusion of Internet.

REFERENCES

Aas, K. (2004). Modelling the dependence structure of financial assets: A survey of four copulas. *Samba*, *22*(4), 18. Norwegian Computing Center Research Note, Samba, Volume 22, Issue 4, December 2004, page 1-19.

Abramson, B. D. (2000). Current Statistics: Internet Globalization Indicators. *Telecommunications Policy*, Volume 24, Issue 1, 2000, pp. 69-74, 69–74.

Anderson, J., & Wincoop, E. (2003). Gravity with Gravitas: A Solution to the Border Puzzle, The American Economic Review, 1 March 2003, Vol.93(1), pp.170-192 doi:10.1257/000282803321455214

Andres, L., Cuberes, D., Diouf, M. A., & Serebrisky, T. (2007). The diffusion of the Internet: A cross-country analysis, Telecommunications Policy, 2010, Vol.34(5), pp.323-340

Antonelli, C. J., & Honeyman, P. (2000). Wiretapping the Internet. SPIE Conference on Enabling Technologies for Law Enforcement and Security, November 2000. 2027(42), pp.107911-107920, Boston, MA.

Aydin, E., & Savrul, B. K. (2014). The Relationship between Globalization and E-Commerce: Turkish Case. Procedia - Social and Behavioral Sciences, 15 September 2014, Vol.150, pp.1267-1276 doi:10.1016/j.sbspro.2014.09.143

Bhandari, A. K., & Heshmati, A. (2005). IZA, zur Zukunft der Arbeit Institute for the Study of Labor, Discussion Paper No. 1578, April 2005, pp. 1-47, Bonn, Germany.

Blum, B. S., & Goldfarb, A. (2006). Does the Internet Defy the Law of Gravity? Journal of International Economics, 2006, Vol.70(2), pp.384-405 doi:10.1016/j.jinteco.2005.10.002

Borcuch, A., Pilat-Borcuch, M., & Swierczynska-Kaczor, U. (2012). The Influence of the Internet on globalization process. Journal of Economics and Business Research, 01 June 2012, Vol.XVIII(1), pp.118-129.

Clarke, G. R. G., & Wallsten, S. J. (2006). Has the Internet Increased Trade? Developed and Developing Country Evidence. Economic Inquiry, July 2006, Vol.44(3), pp.465-484 doi:10.1093/ei/cbj026

Ding, A.A. & Li, Y. (2015). Copula correlation: an equitable dependence measure and extension of Pearson's correlation. Cornell University, Simons Foundation, arXiv:1312.7214 [stat.ME], 14 August, 2015, pp.1-45, Ithaca, New York.

Dowd, K. (2008). Copulas in Macroeconomics. Journal of International and global Economic Studies, 1(1), June 2008, pp.1-26.

Dreher, A. (2003). Does globalization Affect Growth? Does globalization affect growth? Evidence from a new index of globalization, Applied Economics, Volume 38, Issue 10, 2006, pp.1091-1110.

Dreher, A., Gaston, N., & Martens, P. (2008). Measuring globalisation gauging its consequences, New York, Springer, 2008, First Edition. doi:10.1007/978-0-387-74069-0

N'Da, K., Robin, A., & Tribunella, T. (2009). Economic Freedom and the Impact of Technology on Productivity. Journal of Global Information Management, July-Sept, 2009, Vol.17(3), pp.42-58

Freund, C. L., & Weinhold, D. (2004). The Effect of the Internet on International Trade. *Journal of International Economics*, *62*(1), 171–189.

Huang, T. T., & Sun, B. Q. (2016). The Impact of the Internet on Global Industry: New Evidence of Internet Measurement. *Research in International Business and Finance*, Research in International Business and Finance, May 2016, Vol.37, pp.93-112 doi:10.1016/j.ribaf.2015.09.008

Lee, Y. C., Chu, P. Y., & Tseng, H. L. (2012). Cross-National and Cross-Industrial Comparison of ICT Enabled Business Process Management and Performance. *Journal of Global Information Management*, *20*(2), 44–66.

Rauch, J. E. (1999). Networks versus markets in international trade. *Journal of International Economics*, *48*(1), 7–35.

Totonchi, J., & Manshady, K. (2012). Relationship between Globalization and E-Commerce. *International Journal of e-Education, e-Business, e-Management and e-Learning*, *2*(1) International Journal of e-Education, e-Business, e-Management and e-Learning, Vol. 2, No. 1, February 2012, pp. 83-87.

Schweizer, B., & Wolff, E. F. (1981). On nonparametric measures of dependence for random variables. *Annals of Statistics*, *9*(4), 879–885.

Shaw, R. A., Smith, A. D., & Spivak, G. S., Measurement and Modelling of Dependencies in Economic Capital, British Actuarial Journal, Volume 16, Issue 3, 21 February 2012, pp. 601-699

Shriram, A., Murray, M., Hyun, Y., Brownlee, N., Broido, A., & Fomenkov, M. (2005). Comparison of Public End-to-End Bandwidth Estimation Tools on High-Speed Links, Passive and Active Network Measurement Workshop (PAM), Mar 2005, Vol. 3431, pp. 306-320.

Singh, N., & Boughton, P. D. (2005). Measuring Website Globalization: A Cross-Sectional Country and Industry Level Analysis. Journal of Website Promotion, Vol.1(3), 3–20. doi:10.1300/J238v01n03_02

ENDNOTES

1 Since 2008, CAIDA starts to change the algorithms to supply a different dataset for Internet measurements. Considering the consistence of the project, and also avoiding the huge volatility of economic indicators in the financial crisis around 2008, we continue to use the same dataset to carry out the investigations.

2 To compare with the previous literature, we firstly run the level–valued estimations, and test the Auto–Regressive error terms for AR(1), AR(2). Our results show that there exist large significant error correlations for the dynamic panel data described in section 3.1.

3 The empirical model is derived in Huang and Sun (2016). Freund and Weinhold (2004) include year-fixed effects to control for changes in competitiveness. They use fixed-effect or fixed-difference approaches for linear models, which sacrifices the dynamic attributes of panel data. This is one of the reasons why their results from panel data regression are not goodpoor, although still better than the estimations from cross-sectional least–square regressions. They also explain that the intuition for their results follows from the fact that Internet hosts are not perfect proxies for the Internet connectedness across countries.

4 We did not include the figures for economic globalization, social globalization, and political globalization in this paper. The formats look similar to the figures here, and readers can refer the details by request.

APPENDIX A: COMMONLY USED STANDARD COPULAS

We list a few commonly used copulas here for reference. The produce copula models independent random variables and is given by $C_I(u, v) = u\, v$; The Frechet-Hoeffding upper bound copula is $C_U(u, v) = \min(u, v)$; The Frechet-Hoeffding lower bound copula is $C_L(u, v) = \max(u+v-1, 0)$, for any copula C, there holds $C_L(u, v) \leq C\left(u,v\right) \leq C_U\left(u,v\right)$.

The Gaussian copula $C_{Gaussian}(u, v; \theta) = \Phi_G(\Phi^{-1}(u_1), \Phi^{-1}(u_2); \theta)$, where $\theta \in [-1, 1]$, $\Phi(\cdot)$ is the distribution function of N(0,1) variable and Φ_G is the distribution function of Normal variable function with zero mean and covariance matrix $[1, \theta; \theta, 1]$. The Clayton copula is:

$$C_{Clayton}\left(u, v; \theta\right) = \left(u^{-\theta} + v^{-\theta} - 1\right)^{\frac{1}{\theta}}$$

where $\theta > 0$, The Frank copula is:

$$C_{Frank}\left(u, v, \theta\right) = -\frac{1}{\theta}\log\left(1 + \frac{\left(e^{-\theta u}1 - 1\right)\left(e^{-\theta u}2 - 1\right)}{e^{-\theta} - 1}\right)$$

the Gumbel copula is:

$$C_{Gumbel}\left(u, v; \theta\right) = \exp\left(-\left(-logu_1^{\theta} - logu_2^{\theta}\right)\frac{1}{\theta}\right)$$

and the FGM copula is $C_{FGM}(u, v; \theta) = u_1 u_2(1 + \theta(1 - u_1)(1 - u_2))$.

APPENDIX B: DIFFERENCE MEASURES WITH MODELS

We will use the following integral difference to measure the error between the empirical copula and the target copulas: The L^1 error $\|\cdot\|_L$ is:

$$f - g_{L_1} = \int_0^1 \int_0^1 \left| f\left(u, v\right) - g\left(u, v\right) \right| dudv$$

and the L^2 and L^∞ errors are:

$$f - g_{L_2} = \left(\int_0^1 \int_0^1 \left| f\left(u, v\right) - g\left(u, v\right) \right|^2 dudv \right)^{\frac{1}{2}}, f - g_\infty = \sup_{0 \ll u, v \ll 1} \left| f\left(u, v\right) - g\left(u, v\right) \right|$$