Epidemic models for U.S. financial subprime mortgage crisis in 2008 influencing on Korean corporations

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Chang Hyeong Lee

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Abstract

A financial crisis can spread like a contagious disease to both domestic sectors including demand market and foreign markets which are linked to one country with various aspects. This work mainly focuses on contagious phenomenon which is observed in Korean corporations enlisted in KOSPI & KOSDAQ index right after U.S financial shock in 2008. To set up the model, we use SIR epidemic model to detect epidemic dynamics in Korean corporations after shock. In addition, EDF model is also applied to analyze the degree of contagion within individual business. Using corporate fundamental data from KRX and FSS, including stock price, total market value, and current liabilities from Jun. 2008 to Jun. 2010, we observe contagious features resulted from U.S. financial crisis - EDFs are rising or show sustained level within infected corporations. We also presume parameters including contact rate and recovery rate to identify epidemic model of U.S. financial crisis which especially affected business sector in Korea. Further research is needed to identify the individual movement of certain sector or individual corporations from a view of agent-based model.

Contents

List of Figures

List of Tables

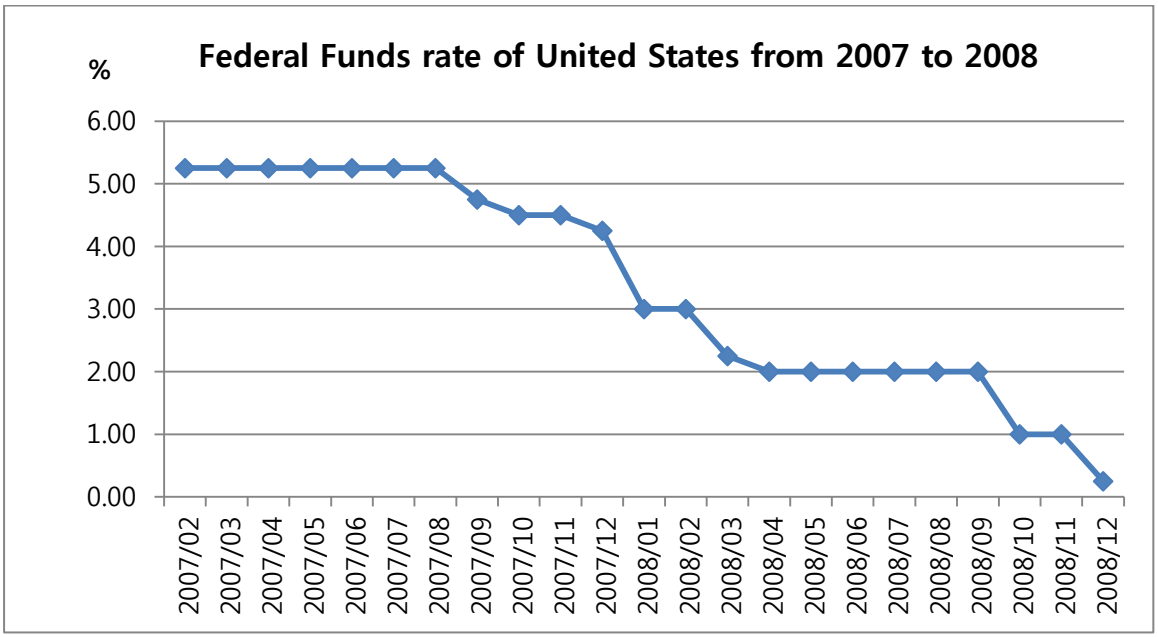
I. Introduction

Financial Sectors of each country are globally connected with each other and there are a variety of sizes, instruments, and participants. In that sense, financial industry is very inter-correlated market so one can affect the others both directly and indirectly. Therefore if there's an outbreak of financial crisis in one sector within a country or in a global world, we can easily anticipate that crisis can affect the other sector or country. This effect looks like contagious diffusion among the financial sectors so each financial sector can be infected by financial crisis. U.S. Subprime Mortgage crisis in 2008 is a typical example of financial crisis. In fact, there were many financial crises before 2008, such as 1995 Mexican crisis, 1997 Asian crisis including Indonesia, Malaysia, the Philippines, South Korea and Thailand, and 1998 Russian crisis[1]. However U.S. financial crisis is very recent crisis that affected numerous countries in the world, and the size of impact was so big that contagion of crisis could be easily detected.

Subprime Mortgage crisis has very unique characteristics compared to other crisis before because its process were gradual and spreads slowly. Many financial experts said that it was the worst case of financial crisis ever so we can conjecture that those crises were very significant. 2008 financial crisis rooted in subprime mortgage loan. Mortgage loan in U.S. can be classified into 3 groups : Prime, Alternative A, and subprime. Prime stands for mortgage loans which can be lent to private borrowers with high credit rank. Alternative A has borrowers that have mid-level credit rank. Subprime is served to persons who have low-level credit rank and they belong to lower-income group.

The price of houses in U.S. had increased rapidly since 1990's due to law interest rate and relaxation of regulations. Financial institutions had enlarged their loan coverage to lower-income group using subprime mortgage. However, these melting-up housing market in U.S. had collapsed down gradually from 2006. There are several reasons why the U.S. financial crisis occurred and became global, crucial, like epidemic.

Firstly, there was over-liquidity of dollars in the global financial market. U.S. government had retained low interest rate for very long time so the money supply in the market was so huge. Therefore the enormous dollar money supply made the depreciation for dollar value in the global financial market. Indeed, this made the nation's current account balance be worse.



* Sourced by ECOS, Bank of Korea

<Figure 1> Low interest rate retained in United States from 2007 to 2008

The second reason is the mortgage financial products. Many financial engineers at that time were trying to invent fancy financial product especially focusing on mortgage. Mortgage-backed securities (MBS) were certain kinds of the financial products which are pooled from many mortgages. So their profit source could be generated from mortgage interests. These kinds of work are called securitization. There were also Collateralized debt obligation (CDO) which came from various kinds of MBSs and Asset-backed securities (ABSs). All these financial products were very fragile and risky when the housing market went to recession. As the price of houses went down in 2006, so many borrowers could not pay for their loan interests. Naturally, tons of MBSs and CDOs were fall into

insolvency and the securities did not make profit any more. At that time, the Lehman Brothers, which had 4th largest size of total assets among financial institutions in U.S., had tons of MBSs and CDOs so the company had fall into very crucial financial difficulties within the company. In addition to that, many MBSs and CDOs contained subprime mortgage loans at that time. Therefore the more housing price dropped, the more severe troubles generated within the company. After all, Lehman Brothers did a huge layoff and finally made an application for bankruptcy protection to the New York Court in September 2008. It became the opening act of U.S. financial crisis in 2008.

Lastly, the network structure of global financial market brought the diffusion of U.S. financial crisis faster. Recent financial world are very inter-correlated market so the certain part of changes can impact another part effectively because of the network structure. After the Lehman's application for bankruptcy protection, many countries' stock index dropped rapidly and severely. The credit rating for U.S. financial institutions dropped as well and this generated the credit crunch among the financial institutions. Therefore investors who invested their dollar money, tried to recollect their fund from all over the world. It became indeed global financial crisis. There were also so many financial derivatives, like swaps, options, and futures so they carried huge risks to each financial sector within each country. Incorrect pricing of risk generated the chaos in financial market and various kinds of financial institutions, including investment banks, insurance companies and savings banks, were gone. Therefore it was like epidemic spreads among the countries.

Panic and chaos also proliferated among people along with financial crisis due to unprecedented situation. After painful experiences of that, U.S. government were trying to aid financial sectors so it made special actions like, releasing bailout to financial market, prohibition for short stock selling, improving financial solvency of each institutions, and so on. Finally, it became very crucial to find more comprehensive and fundamental way to prevent and detecting financial crisis in advance. If we could track the phenomenon of financial crisis effectively beforehand, then it might be a good solution for preventing and coping with financial crisis. Therefore the research on analyzing and modeling of

financial crisis can carry an important meaning. In this study, epidemic models, including Susceptibles - Infectives-Recovered (SIR) model, are applied to analyze the financial crisis. [7]

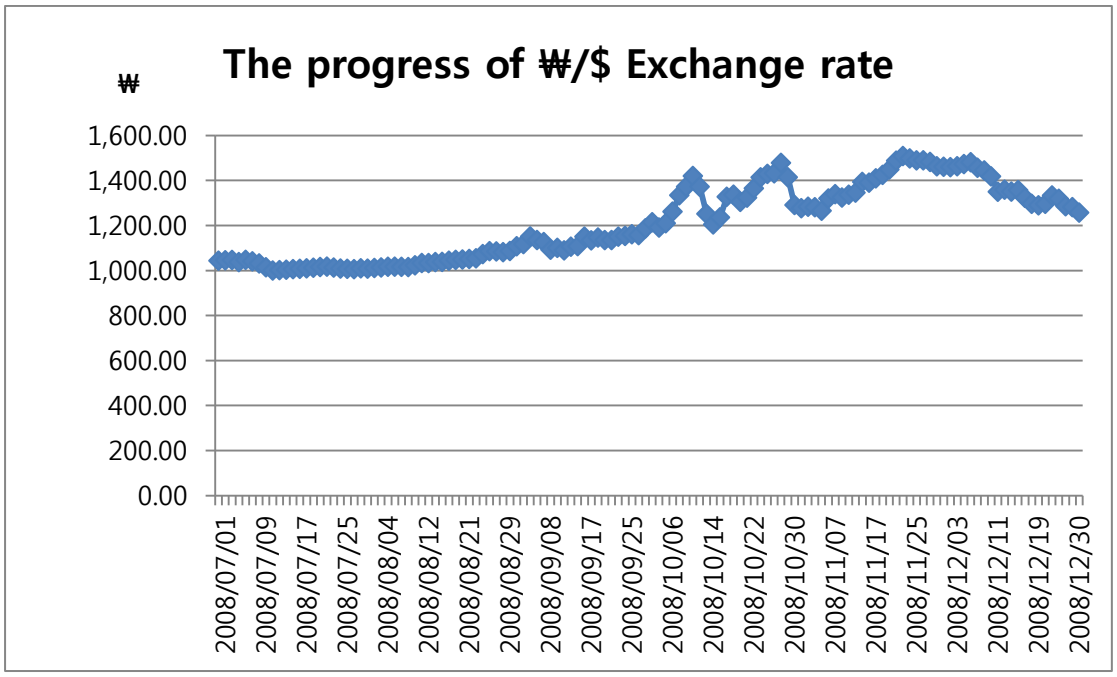
1-1. Background of research

The impact of U.S. financial crisis in 2008 was so huge that almost every country and every financial sector were being attacked. Although the hit to Korean financial market was not a direct shot, but the influence was noticeable. The Korean stock index, KOSPI (Korea Composite Stock Price Index) dropped, like all other country right after U.S. crisis. However the financial situation in Korea was not worrying before the Lehman Brothers collapsed. Korea experienced foreign exchange crisis in 1997 so that gave a big lesson to Korea. Therefore foreign exchange reserves had been cumulated and managed well till 2007. At that time, foreign exchange reserves were 262 billion dollars. Korean banks also had maintained the BIS capital adequacy ratio up to above 12% level and this level was comparable to other international banks in good health. There were also compulsory regulations on accounting principle among the businesses so the degree of transparency in financial sectors and businesses were high at that time.

However, the U.S. financial crisis affected Korean exchange rate and credit matters. The Korean Won/Dollar exchange rate increased a lot and credit crunch had been prevailed among the financial and business sectors. In fact, Eastern Europe, South America, and Asia were experiencing the same crisis effect at that time. Although a grave situation, like national nonpayment, major big banks' collapse, did not occur at least before 2008, Korea has own particular problems within the nation such as recession in real estate market, insolvency in savings banks, and excessive level of household debt, and failures in exchange hedge among small and medium-sized businesses resulted from KIKO (Knock-in Knock-out) products.

The price of raw materials, crude oil and grain had dropped rapidly right after U.S. financial crisis. Especially, the risen price of crude oil affected Korean oil market severely because the cost of oil was

very important to consider in Korean economy. KOSPI also dropped sharply to 1,388 point on September 16 in 2008, right after application for bankruptcy protection from Lehman Brothers. KOSPI then also dropped 10% in October to below 1,000-point level. Foreign investors continued net sale more than 3.6 billion dollars at that time. The Korean Won/Dollar exchange rate also increased sharply due to foreign dept. As a result of U.S. financial crisis, the demand for dollars went through the roof and many banks and businesses tried to buy dollars for stocking up liquidity. Foreign buyers started to doubt about the ability of repayment of foreign debt from Korea so national CDS (Credit Default Swap) premium jumped over the moon. All these aspects pulled the Won/Dollar exchange rate up to 1,400 on October 23 in 2008. In addition to that, many small and medium-sized businesses suffered from KIKO contract due to unexpected rises in exchange rate. This was the failure of foreign exchange hedging for many businesses.



* Sourced by ECOS, Bank of Korea

<Figure 2> The drift of Korean Won/Dollar exchange rate from July to December in 2008

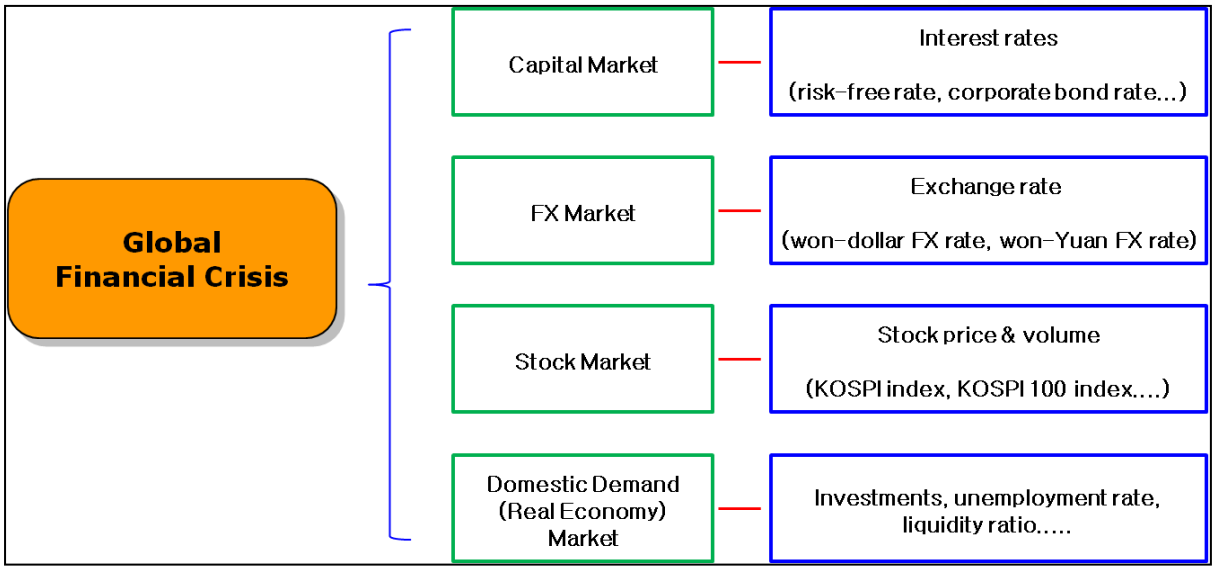
U.S. financial crisis in 2008 also impacted real economy sector in Korea. First of all, a sensation of

fear that insolvency would be severe as time went by, diffused within whole real market in Korea. The interest rate on a loan, especially mortgage loan, increased a lot so many households suffered from that rising. In addition, the net value of assets, including real estate and stocks, dropped seriously so people didn't want to consume. In other words, the private consumes dropped as well so real economy bogged down. Like trigger effect, many businesses reduced employments and investment due to the rising uncertainty and this accelerated the impact of crisis in Korea.

Korean economy sector grew -3.4% in 1st quarter in 2009 compared to the same period last year. Especially manufacturing industry grew -9.1% and construction industry grew -6.3% in 4th quarter in 2008 compared to the same period last year. Manufacturing and construction was major businesses in Korea so we can estimate the huge degree of impact from U.S. financial crisis from those figures. Exports and imports dropped as well due to the decrease of demand for product globally.

Fortunately, Korean economy was resilient to financial crisis from outside because Korea once had an experienced IMF crisis in 1997. Since 1997, most of businesses and banks did severe restructuring process while they are in the middle of crisis. This gave strengths for them to react more effective during the crisis. Therefore Korean economy could recover quickly compared to other counties.

Consequently, global financial crisis could impact through several different channels[2] : interest rate, exchanged rate, stock and export sector. Figure 3 shows that structure. The impact would be total directional and simultaneous so well-organized remedy plan would be needed. The study in this paper relates those plan and tactics for deal with financial crisis in the future.



<Figure 3> The Channels for diffusing financial crisis to Korean economy

There were also a variety of remedies and solution plan for easing U.S. financial crisis all over the world. U.S. firstly moved into action. Right after the crisis, several big financial firms in U.S. collapsed including Lehman Brothers. Fannie Mae and Freddie Mac are nationalized and AIG got a relief loan from government. These all happened within just 10 days. It was so fast. Most funds were centered at safe assets like gold and Treasury bills. Dow Jones Index dropped 450 points at once. The interest rate of short-term inter-bank loan went up by almost double. These effects were not limited to U.S. The first action for dealing with crisis in U.S. was banning for short selling.

Short selling was prohibited among most financial institutions right after crisis because short selling was very risky investment actions so it could harm and spread the risks more. SEC (Securities and Exchange Commission) also banned short selling for a limited time. In fact, short selling could make security market more efficient. The price of securities in the financial market could be settled efficiently by inflection of whole information including short selling. After United Kingdom and U.S. banned the short selling, other countries including France, Germany, Canada, Australia, Singapore, Japan and Korea also banned the short selling. Short selling mostly damaged to hedge fund. Many firms which sourced from hedge fund had been trouble with financing their fund due to banning the

short selling. U.S. Government released TARP (Troubled Asset Relief Program) plan and this plan was for curing the financial crisis. According to the plan, U.S. government would buy toxic assets, like mortgage loans or bonds from risky financial institutions. In fact, fund needed was so huge that it is almost 700 billion dollars. This TARP plan was realized after passing the Emergency Economic Stabilization Act of 2008. China also came up with a new-pump-priming policy on November 11th in 2008. G20 also discussed the plan for cooling down the financial crisis. EU also chose the steps to stimulate the economy with 200 billion €. Japan and Korea also offered the stabilization plan on December 2008. Indeed, the impact of U.S. financial crisis in 2008 was so huge that a lot of countries all over the world suffered from that and its diffusion was so fast and global.

Korean government also did remedy policy for dealing with financial crisis. The response was a little bit submissive, but Korean government and BOK (Bank of Korea) struggled to push liquidity into financial market. BOK supplied 37.7 billion dollars in December 2008 and Korean government contracted $30 billion currency swap with U.S., China and Japan for each. Despite those efforts, money did not circulated to real economy due to credit uncertainty of corporate businesses and aversion of loans from banks for their own liquidity.

Korean government used a fiscal policy widely. It arranged a revised supplementary budget in the size of almost 29 billion dollars in April 2009. It also pre-executed that budget for job-sharing, stabilization of housing market and public welfare stability. By these constant efforts, Korean economy could get recovered quickly. Korean government also reformed of tax system for activating economy. It reduced corporate and income tax rate and gave tax incentive for promoting R&D from businesses. It also supplied more lands and houses to private sector for stabilizing housing market in Korea.

The financial authorities in Korea did monetary policy actively. They cut off the base interest rate to 2.0% in 2008. They also bought RP from the financial market for supplying liquidity. These

measures progressed very quickly so financial market had been stabilized quickly either. Korean stock Index went back to 1,400 point as well. They also banned short selling temporarily and set up the stabilization fund for bond market. In addition, they made the new improvement plan for auditing system of derivative market. In that plan, they focused on reforming monitoring system, Enhancing protection for investors, prevention of insolvency from financial institutions and resettlement of auditing system for derivative market in Korea.

In foreign exchange market, Korean government announced the plan for supplying foreign currency liquidity to foreign exchange market. It supplied foreign fund in the size of almost 56 billion dollars to the market from October 2008 to February 2009. After the currency sway with U.S., the Korean Won/Dollar exchange rate fell down to 1,260 in December 2008. The government also settled up the new system for monitoring the soundness of foreign fund the financial institutions had. It also tried to promote the soundness and transparency of Korean economy to foreign market for developing good image of Korea. This could help the foreign investors get attracted by the good and safe image of Korean financial market. Government set up the special task force team and it held many investment information sessions for foreign investors in many countries.

Private sectors, including banks and investing companies were also trying to prevent post-crisis on their own. Banks expanded their own capital to the total level of 16 billion dollars from October to December 2008 so BIS ratio could drop back to the level of 12.3%, which is the level before the financial crisis. Business restructuring process was progressed on actively. Actually construction and ship-building industry damaged significantly from financial crisis. Therefore Korean government had to solve this insolvency problem for resolving the market uncertainty which could be generated from insolvent enterprises. It supplied the liquidity to construction and ship-building enterprises and set up the new restructuring program for those companies. These procedures were all applied to both major companies and small and medium-sized companies.

Until now, we can estimate the seriousness of impact from U.S. financial crisis in 2008 which was generated from subprime mortgage. As I mentioned it before, the impact was so worldwide and fast so it looks like epidemic disease. If one sector in certain area 'infected' from financial crisis, then it can easily diffused and moved to another region through various channels. Post-crisis plan is, of course, very important that it can cure and solve the damages from crisis effectively. However, if we can detect and recognize the crisis with relevant models, then it also can be very helpful to act proactively against financial crisis. Therefore I think setting up the financial modeling for financial crisis is very meaningful in that sense. In this paper, I utilize basic epidemic models (SIS and SIR model)[7] which are generally used to analyze spreads of infectious diseases, like plague, measles, cholera, or dengue fevers, and so on. The spread of financial crisis is very similar to that of infectious disease so this application is expected to explain diffusing phenomenon of financial crisis. If the U.S. financial crisis is the big shock, then it can impact to any countries all over the world. I pick Korean market, especially focusing on corporate business industry in Korea. I want to analyze the degree of impact which was given to Korean enlisted businesses due to the U.S. financial crisis by using the epidemic model. I also use EDF (Empirical Default Frequency) model [8] to estimate the degree of insolvency of each businesses. If crisis shock impact the Korean businesses, then many companies are expected to infected, recovered and died as time goes by. Therefore this paper focuses on analyzing those epidemic dynamics among Korean businesses after U.S. financial crisis and this is my objective of study.

1-2. Existing research

(1) Dynamics of the contagion of financial crisis

There is actually few preceding research which dealt with this theme, The idea that financial crisis

can be transmitted to other countries is relatively a new concept for economists. Although Great Depression certainly had contagious elements, this concept is taken seriously only recently with the Mexican Crisis of 1994. This crisis is followed by East Asia Crisis, and Russian Crisis which are to some degree contagious. However none of these crises was as wide spread as the 2008 crisis. Another prominent feature of the 2008 crisis is that it began in a highly developed country. It spread across countries through financial and other economic links very quickly. These facts point out that for understanding the last global crisis not only identifying the channels through which the crisis is transmitted to but also the dynamics the dispersal are important. In this study it is our aim to model the dynamics or transmission. In that regard we adopt a widely used mathematical model of epidemics.

The last three decades stands witness to a great wave of integration. Financial, trading and communication/social networks spread becoming a significant and integral part of daily life. As these networks grew countries became more interdependent. The benefits of being a member of the networks increased and new benefits emerged. However networks are channels that also spread the problems of one member to others. Contagion is basically the transmission the crisis through the links between the members. Networks that are so essential in today's world also cause disasters like financial crisis to spread to other countries. Networks existed long before economics or any other branch of science discovered them. Contagion also is not a new phenomenon. Although the phenomenon of financial contagion is old the topic itself is began to be investigated only since 1990's. There is a myriad of definitions of contagion and no established consensus on one definition. Each definition emphasizes certain face of the phenomenon. These definitions are classified into five groups by Pericoli and Sbracia (2003) who provides a good summary of the literature on contagion. The classifications are as follows:

- One occurrence of financial crisis can increase probability of a financial crisis in another market.

- The asset prices from one market where financial crisis started to diffuse can affect other assets.

- Having in commons in changes of asset prices cannot be accounted by fundamental elements.

- The contagion is getting larger through the link of markets after a shock in a financial market.

Another interesting definition of contagion is provided by Edwards (2003). He limits the spread economic situation beyond what the size range and shock is international transmission has been pre-expected. Edwards looks this definition is consistent with the epidemiological literature that have more experience in infected cases clearly. Although for this paper Edwards' definition is vital, it is only so in the repercussions. Such a definition indicates that economy can be perceived as a network and biological analogy of contagion is similar to the spread of financial crises. However this study takes a broader view of the phenomenon; contagion is the transmission of the crisis in a network, through the links between the members.

In this study our purpose is not to introduce a new model to explain contagion, the channels of transmission or how individual's behave raises the possibility of "catching" the crisis. The goal of that research is to account for the dynamics of the financial crisis contagion. In order to do this we adopt a well known epidemiological model. This study is certainly not the first time biological models are used in social sciences: diffusion of innovations the spread of cultural foods and outbreak of political and social unrest had been modeled by adopting biological models (Dodds and Watts, 2005). In this study we reinterpret SIS model to explain how financial crisis spread through to close knitted links of economics network that is vital yet prevalent in our world. SIS model is based on SIR model which divides population into three groups

(S) Susceptible : who are currently not infected but have possibility of containing the disease

(I) Infective : who are infected and have possibility of deliver the disease

(R) recovered : who are recovered from the disease .

Although we do not utilize this fact, it is the rationale behind using two different sub populations.

Subpopulation 1 contains developed countries while subpopulation 2 includes developing countries. Each of these subpopulations are divided further into 2 groups of susceptible $S_i, i = 1,2$ and infective $I_i, i = 1,2$. The SIS model itself is basically a system of differential equations which show rates of transfer from one state (or) to the other. The basic two population SIS system is as follows

$$\frac{dS_1}{dt} = -k_{12} S_1 I_2 + \alpha_1 I_1$$
$$\frac{dI_1}{dt} = k_{12} S_1 I_2 - \alpha_1 I_1$$
$$\frac{dS_2}{dt} = -k_{21} S_2 I_1 + \alpha_2 I_2$$
$$\frac{dI_2}{dt} = k_{21} S_2 I_1 - \alpha_2 I_2$$
$$t>0$$

The recent crisis draws attention to the dynamics of the spread of the commutable crisis. Of late research papers are also focused not only the channels of the spread but also the progress of contagion. This paper suggests that biological models of spread of infectious diseases fallow a similar pattern to the spread of crises. The SIS model for two dissimilar groups, addressed in this study, exhibits the aggregate exposure to neighbor countries that is already succumbed to crisis. In that respect is suitable to model the transmission of the crises among countries via the network that is embedded in daily economic political and social interactions.

(2) Worldwide spreading of economic crisis

To build a network of world economy, susceptible to infection with variable probability of infection, which - by applying (SIR) epidemic model recovery, modeling the spread of the crisis. I will depend on the strength of the economic relations with the strength of the country and the pair of the specified country the probability of infection. The crisis caused by the large countries such as the United States, such as this, that it has the potential, such as the recent financial crisis like this, spread the world are

expected. Countries have shown that it is possible to start the global crisis. Surprisingly, we also find the GDP was much lower than Belgium. Using a k -shell decomposition method for quantifying the power diffusion (node), to obtain a measure of " centrality " as the heat spreader of the economies in the network. Where it ranks the various countries according to the shell they belong, we find out what the most central of 12. These countries are likely to expand the global crisis is the highest. Those 6, medium / small other, is a result which could not be expected otherwise. Among these 12, 6, is economical on a large scale. Further, we use our model to expand the possibilities for countries belonging to another shell in accordance with the magnitude of the crisis, and to predict risk.

Since the number of factors is large, the global economic crisis, such as a crisis of 2008-2009 recent such, is certain. In today's global economy, and a strong economic relationship between the countries, it is possible to investigate how the crisis should be propagated from the country of origin to other countries in the world it is important. Indeed, the last few decades, important crisis of some to have originated in one country. However, therefore, for the interdependence of the economy and that may be affected by diffusion, how the domestic economy of the extent of other countries is not yet clear. For example, as is normally performed in recent years currency and financial markets, where we, in order to cope with the modern economy, it uses the approach of statistical physics. More precisely, it corresponds to the country, a complex network, and nodes in the network, and displays the world economy through a link to the economic relationships between them.

II. Theoretical & Mathematical models

2.1. Epidemic models

2.1.1. Deterministic models

When dealing with large populations, as in the case of tuberculosis, compartment mathematical model or deterministic is used. In the deterministic model, partition or different subgroups, individuals in the population is assigned to each representing a particular stage of the epidemic. For example, M, S, E, I, and frequently, characters such as R are used to represent the different stages.

As a mathematical derivative, therefore the model, transition rates another is expressed is formulated with differential equations from one class. While building such a model, it must be assumed differentiable with respect to time the population size in the compartment, the epidemic process is the deterministic. In other words, the change in a population of compartment models - can be calculated using the history of only used to develop (Blauer Castillo Chavez, 2001) .

Lattice (such as square lattice of two-dimensional like this) that is done through the (cellular automata) Synchronous update (or kinetic Monte Carlo method) update a single site of asynchronous, another approach, discrete analysis of the above update and this is done through. Non-uniformity to be considered and approach the grating allows clustering.

<SIR epidemic model>

In 1927, modeling WO was considered the population they were fixed with three compartments of only Ag McKendrick and Kermack is: is affected, S a (T); infected, I is (t); and , delete, R (T). Compartment to be used for this model is composed of three classes.

- S(t) is used to represent those susceptible to disease or the number of individuals not infected with the disease at time t.

- I(t) indicates the number of individuals that are able to infect the disease to spread disease in those categories sensitive.

- R(t) is due for vaccination, or infected with either death, are used for those individuals that have been removed from the disease. Those in this category cannot be used or re-infection, it sends the

infection to others.

Based on a fixed population, N (the sum of S(t), I(t), R(t)), Kermack and McKendrick found the following equations:

$$\frac{dS}{dt} = -\beta SI$$

$$\frac{dI}{dt} = \beta SI - \gamma I \qquad \text{where, } \beta \text{ : contact rate}$$

$$\frac{dR}{dt} = \gamma I \qquad 1/\gamma \text{ : average infectious period}$$

Several suppositions were set in the formation of these equations. First, the disease must be considered to have an equal probability as individuals and all other such diseases in a proportion infection rates and contacting the individual in the population which is considered to be β. Therefore, a new infection in a unit of time of infection per can infected individuals come into contact with each other, sending a disease and people of other fractions per βN of contact with the unit time due to infection of the S / N-sensitive then βN is (S / N), the number of the βN which gives the speed of (what is left of the category-sensitive) or new infection (S / N), I = βSI (Blauer Castillo - Chavez, 2001).

For equations of the second and third, consider the population to leave the class-sensitive as equal in number to enter the class they are infected. However, entry into the class equal number Deleted infection (1 or mean recovery / mortality, / γ,, represents the average duration of infection γ) fraction, per unit time, leaving the class. These processes that occur simultaneously, which is proportional to the size of each (daily crab, 2005), in the group that are widely accepted law of mass action, the rate of contact between the two groups in the population it is called with the idea. Finally, recovery rate and infection so much faster than the time scale of death and birth, these factors are assumed to be

ignored in this model.

<The SIS model with deaths>

It can be derived from the SIR model to account for the individual to recover the immune quite ill simply easily, i.e., the individual subject as soon after they recovered SIS model. If you add those taken from the populations recovered from SIR model, delete the formula that represents the population, were infected with the vulnerable population, differential equations to obtain the following.

$$\frac{dS}{dt} = -\beta SI + \gamma I$$

$$\frac{dI}{dt} = \beta SI - \gamma I - \delta I \qquad \text{where, } \delta \text{ : death rate (mordibity)}$$

$$\frac{dD}{dt} = \delta I$$

S + I + D = C (constant)

2.1.2. Stochastic model

"Stochastic" refers to some or that a random variable. Stochastic model is a tool for estimating the probability distribution of potential outcomes by allowing random variations of more than one input after one time. Stochastic model is different exposure, by variations in the potential risks of the dynamics of disease or other illness. When these variations are important, (Trottier Philippe, 2001) as, and is used subpopulations.

Versions stochastic SIR model, continuous variables are replaced by discrete numerical values, processing speed, is substituted with a probability process. We also intended to demonstrate the potential of the process of 5 i-th. As a result, I, is a vector that holds the probability of the possible

process of all. There is such a process 3 SIR model of probability theory above : $\beta SI,\ \gamma I,\ \delta I$. For example, it is the probability that at time t, the new susceptible hosts are infected.

$$\text{P(infected)} = \beta SI$$

In this case, the value of S is down jump 1, so I jump in 1, typically, a probability that is generated, note that (it may go above 1 in total) and not the 1 , please. They give the relative probabilities for each process.

<Stochastic Simulation Algorithm (SSA)>

If p(x,t) indicates the probability that the number of population is x at time t, then it is known that the governing equation for the stochastic epidemic model is generally written as follow:

$$\frac{dp(x,t)}{dt} = \sum_{k=1}^{r} (R_k(x - V_k)\, p(x - V_k, t) - R_k(x)\, p(x,t))$$

- N(t) = S(t) + I(t) + R(t)

- P(x,t) : The probability of the state x = ($x_1, x_2, \ldots\ldots x_s$) at time t

- X = ($X_1, X_2, \ldots\ldots X_s$) : Random variable, the number of i-th population

- P(x,t) = P[X(t)=x]

- $R_k(x)$: Probability rate function for the k-th reaction at the state x

- V_k : k-th column vector of the matrix V.

- V : the matrix that denotes change of the number of population in the each compartment

If we know all possible states of x and the transition rate matrix K then the governing equation above can be written as the linear form[3] :

$$\frac{dP(t)}{dt} = KP(t)$$

It is difficult to find the general solution of governing equation of linear form above analytically so some computational algorithms to find solution were on the rise. One of the most well-known algorithms for finding solution, is Stochastic Simulation algorithm (SSA)[11]. The SSA generally is conducted to solve the master equations known as the standard exact method. Monte Carlo procedure is used for numerically generating samples of τ (time to the following reaction) and j (index of the next reaction) in exact method. The brief idea of SSA is following:

Step1. [Initialization] Setting the initial condition $x(0) = x_0$

Step2. [Monte Carlo Simulation] Generating two random numbers r_1 and r_2 from the uniform distribution to determine τ (Time until next reation) and j (Next generation index)

Step3. [Updating] $X(t+\tau) = X(t) + v_j$

Step4. [Looping] Go back to Step2.

2.1.3. Agent-based model (ABM)

Agent-based model (ABM), in order to simulate the interaction of (entity of the population, or both individual and group organization and such) autonomous agents and actions in terms of assessing their effect on the whole system it is a class of computational model. This is a combination of elements of game theory, complex systems, emergence, calculation sociology, multi-agent systems, evolutionary programming. Monte Carlo method has been used to introduce randomness. Ecological within, ABM also is referred to as the (ABM)-based model of the individual, individuals may be simpler than than completely autonomous agent back home ABM in IBM in particular.

The review of the literature of recent models of the base of the individual, agent-based model relates to a multi-agent system, that it is used for non-computing the domain of science-related, including ABM mother biology, social science and ecology shows. It is related to the agent-based modeling, but the goal of ABM, multi-agent and multi-agent system that it is because of you want to search for a description insight into the collective action of the agent to comply with the simple rules of the natural system typically different from the concept of simulation, or design drugs rather, than to solve engineering problems or practical specific.

The agent-based model, in an attempt to re-create, to predict the emergence of a complex phenomenon, it is a kind of micro-scale model to simulate and simultaneous operation, the interaction of multiple drugs. Process is one of emergence from the (micro) level under a higher system (macro) level. Thus, an important concept is that a simple action rules to generate complex operation. This principle, known as KISS, ("keep silly, simple") has been adopted by the community of modeling extensively. Central doctrine of another thing is that the whole is greater than the sum of its parts. In general, characterization and bounded rationality reasonable, such reproduction, the individual agent, recognized as their own interests, such as a simple decision-making rules and heuristic social status or economic interests, and use they It is estimated to be acting in those. The ABM agent, there is a possibility that "learning", adaptation, and regeneration occurs.

Agent-based models are most often configured: (also known as the particle size of the agent, usually), agent (1) several specified in various scales; (3) Learning; heuristics (2) Decision adaptation process or law; (4) interaction topology, and (5) non-agent environment. As custom software either, or through the ABM toolkit is implemented as computer simulations ABM base, generally, the change in the individual behavior, the software, which the operation emerging overall system it can be used to test whether the effect as.

Decline analysis of the spread of infectious diseases, including the threat of biological warfare, is

widely used in biology, growth and population dynamics, vegetation ecology, ancient civilization, agent-based modeling and evolution of behavior ethnocentric, force / displacement migrate, biological applications, biomedical applications, including the immune system of the human dynamics of language selection, cognitive modeling, and inflammation. The model of the agent-based, and is used to develop decision support systems such as breast cancer. Military applications are evaluated in.

SIS and SIR epidemic models can freely be applied to ABM models. For example, we can set the subgroup of S as several agents that are differently adapted and reacting to certain stimulus or atmosphere or circumstance. These can reflect the perspectives of agent-based model. Each agent can act separately within the model.

2.2. Expected Default Frequency (EDF) model

EDF model of listed companies, represent a significant advancement and extension of credit risk model basic structural. Too unrealistic both is used in practice, too, the assumption of structural model basic, you see the problem. But still, it is worthwhile to start a description of the Black-Scholes-Merton structural model basic for two reasons, the description of our EDF model it. It provides us with a good foundation of the basic theory behind the EDF model, this can help you to advance understanding how much it represents on the standard approach EDF model it.

The credit risk model of the basic structure, the market value of the assets of the companies is based on the assumption that the development process according to the probability of the following.

$$dA = \mu A dt + \sigma_A A dW$$

, where μ is the expected growth rate of the firm's value of asset, σA is the assets volatility, and W means that a standard brownian motion. For the sake of simplicity, we assume a period of one year.

This follows from the assumption of geometric Brownian motion that the log of annual asset value is normally distributed every year.

Volatility of asset market value of assets, and point, of default: it that the distance is, as described above, it is to encapsulate the three main parts of the foregoing information is a count of the standard deviation basically, the default It is clear from this equation. You can use the terms of credit fundamental analysis, to capture the financial leverage of the Company, of the molecular formula of DD captures the business risk denominator. The amount of all three as intuitively, standardized by the business risk, distance to default of companies, is the difference between the expected asset value at the point of default and date of the horizontal line. DD is a summary of all the information on the statistics of a single that provides a ranking of default risk. Default probability of the structure basic model can be calculated as the area under the normal distribution under the point of default.

In fact, we need to estimate the third-order input for the calculation of DD. One of the important insights of credit risk modeling structured approach, asset volatility and asset value unobservable of the company, is a way that can be inferred from the observable market information. Specifically, asset volatility and asset value of the company, can be obtained from the return of the stock market. In essence, have a walk-away option shareholders: if value of the company is lower than the value of the debt, you can creditor comes to take over ownership of the company shareholders. Shareholders in limited liability, that you have is an important consideration in this regard.

Can not own a house with a mortgage, provides a useful analogy for explaining the theory underlying the EDF model of public. It is common you can say "own" your home, but since the title is held by the lending bank (you, it does not have the title.7, this is not necessarily the case in practice , and therefore won the title to the house only for you, to repay the full amount mortgage truly), I own it. In addition, the market value of the house exceeds the mortgage balance, the likelihood is low, I will have to default on your mortgage.

Followings are basic Black-Scholes equations(Merton Model)

$$C = S \bullet N(d_1) - Xe^{-rT} \bullet N(d_2)$$

$$d_1 = \frac{\log(S/X) + (r + \sigma^2/2)T}{\sigma\sqrt{T}}, \qquad d_2 = \frac{\log(S/X) + (r - \sigma^2/2)T}{\sigma\sqrt{T}} = d_1 - \sigma\sqrt{T}$$

, where C is price of call option, S is stock price, σ is volatility of stock price, T is time to maturity, and r is risk-free rate. Therefore it can derive the following equation :

$$\sigma_c = N(d_1)\sigma_s \bullet \frac{S}{C}$$

So we can derive the Black-Scholes equation like following :

$$V_E = V_A N(d_1) - V_D e^{-rT} N(d_2)$$

$$d_1 = \frac{\log(V_A/V_D) + (\mathrm{r} + \sigma_A^2/2)\mathrm{T}}{\sigma_A\sqrt{T}} \qquad d_2 = \frac{\log(V_A \quad V_D +) \quad -(\sigma^2{}_A \quad /}{\sigma_A\sqrt{T}}$$

$$\sigma_E = N(d_1) \bullet \sigma_A \bullet \frac{A}{E}$$

, where, V_E is total amount of market price from company, V_D is total liability from company, and σ_A is volatility of corporate value.

III. Application : Epidemic models in Korean enterprises by U.S. financial crisis

3.1. Data & Modeling

3.1.1. Major study objective

The financial crisis of 2007–2008 in U.S., also known as the Global Financial Crisis and 2008 financial crisis, is considered by many economists as the worst financial crisis since the Great Depression of the 1930s. It resulted in the threat of total collapse of large financial institutions, the bailout of banks by national governments, and downturns in stock markets around the world. In this work, we observe the contagious impact on Korean business sectors due to outbreak of 2008 U.S. financial crisis. The major study objective is to find epidemic diffusions in Korean enterprises affected by 2008 U.S. financial crisis by using EDF model and SIS(SIR) epidemic models. Furthermore, this paper contains such trials in terms of ABM perspective among enlisted enterprises.

3.1.2. Overview of research methodology

In this study, how it was the most trouble, had a cause connected correctly EDF model and epidemic model exactly. In fact, you can think of specific separate models of both, of course, because the model we typical models who have been widely used in the field already, but to think once this is defined ideas and decent I thought it would be required. First, the definition of shock absolutely necessary in the epidemic model, and definitions for the transition phenomenon and definition (S, I., R, D, and so on) about the state of each was also necessary. Therefore, with a focus on defining the portion thereof was subjected to the study. Shock thought be determined with reference to the time when the financial crisis of 2008 has occurred is appropriate first. The key here again is, is a partial Shock about what happened to the system about which point exactly. Stock information is included facts EDF model, stock quotes so intense variable variation changes in real time, too. It is possible to

consider the time interval is an important part. It can be seen that as an example, the stock index of almost every country of the financial crisis after the U.S. plummeted rapidly. Therefore it is necessary to precisely defined Shock, eventually, as described in the introduction of this paper, the beginning of the crisis originated in the United States in 2008, is based on the bankruptcy of Lehman • Brothers actually I was on the basis of September 15, 2008 Lehman Brothers has received filed for bankruptcy under the Shock of determination that.

Now, is important to the next, there is a definition of each State. Though it is an important part of any also, that, to see whether S, I, R, D in what state, there is a need to define in my own part of these. Given the situation, such as infectious disease spread is actually one time, the object will be people and creatures, but in the current situation, is an important part or even catch in any one object. So, is the company Samgyetang each object. The reason for this is what an important part of EDF model that determine the expected probability of corporate bankruptcy. Therefore, in order to derive the expected probability of the company dishonor itself, immediately, he grabbed the company each object. Then, it was necessary that as long as the spirit's that look at the change in estimated bankruptcy probability of companies by financial crisis originated in the United States in particular, is set to identify the extent possible to provide its effect. Therefore, in consideration of the aftermath of the impact and the magnitude of the financial crisis of 2008, almost all countries are subjected to all influence, South Korea so as to set the object to target the Korean companies under the assumption that no exception were.

In Korean companies, if you define each object really, it is important is how to select what kind of Korean companies now. On the basis of the data of the 2012 National Statistical Office, the number of companies of South Korea now stands at about 3.6 million units. Inclusion in the study of both the company of all these, the scope of the research and also become too large great difficulties continue to ensure the material. Therefore, it was thought that I needed always work to be selected in the selection. In addition, by selecting the companies just such a method which can be sampling most easily, was

that to be able to implement the EDF model, to select a company that contains the appropriate data. If you select the companies listed on the securities market today, how can I floated soon, it was going to. It is believed that if it is a listed company once, because all the information is disclosed in the Financial Supervisory Service published website, that there is no great difficulty in securing the material. Further, there was no big problem to apply the EDF model because it is the company who issues shares essentially the companies listed, and there is no great difficulty may be calculated whether the bankruptcy bankruptcy probability I thought it was.

Currently, listed securities market in Japan is divided into KOSDAQ market KOSPI market greatly. KONEX market was recently opened, is also in operation in. A total of 772 companies (31 May 2014) is listed on the KOSPI market currently, 1,004 pieces of company are listed on the KOSDAQ market. Listing and years of the size of the company, to be random sampling a company of 148 in the KOSPI market in the judgment that the target company in consideration of the industry group of all, listed on the KOSPI market, and the sampling is good were.

The following is a table showing the basic descriptive statistics of the 148 companies.

(unit : ₩1,000)

Year	Number of Companies	Avg. Total Market value	Avg. Size of Debt	Avg. Volatility of Stock price
2008	148	3,979,548	1,173,989	47.21%
2009	148	3,093,738	1,236,224	53.45%
2010	148	3,237,969	1,295,806	38.16%

<Table 1> Basic descriptive statistics about enlisted companies in KOSPI Korea

<Hypothesis setting>

The set of hypotheses required to set the direction of the research and the purpose of this study. It can

be seen to hypothesize two large.

1. 2008 U.S. financial crisis will impact Korean industry so increase companies' EDF

2. The pattern of EDF from each company seems to have the diffusion of epidemic disease and it can be expressed as effective and relevant epidemic model.

It is possible to hypothesize home that affect not only the financial markets of South Korea and the company of the spot market by Shock if appropriate, the expected probability of dishonor that companies that change. Also, is the core of the second hypothesis If you look at the aspect of EDF change of their respective companies, and be able to see after being expressed by an epidemic model the diffusion of these phenomena.

<*Status defining*>

The key Epidemic model is, the definition of that it is transferred to the state of the D and R from the I state thing that we need each object, and also transition to the I from the state of S. In the case of a person, you can go to resolve the problem that keep close tabs on the process of prognosis Become a infection to disease simply, you can recover, such as passed away, but the target is because companies who, in that portion definition of decent is required. Therefore, in this study, was defined as follows: the transition phenomenon of each.

- S → I : When the value of EDF increased or sustained compared to last month

- I → R : When the value of EDF decreased(recovered) to the level of infected point in the time line

- I → D : When the value of EDF became 1 and lasted eventually.

I think since the time that happened financial instrument that originated in the United States, to investigate the EDF of their respective companies, and let's take a look at the transition of the EDF value. As described in the portion of the hypotheses, it is possible to predict if a company is affected by the Shock later Shock then the default probability will increase also intended to affect the default risk of the company. Therefore, based on the time when the financial crisis originating in the United States broke out, on a monthly basis, if you look at the transition of the EDF of each company, it is possible to find out how to react to the effects of shock such .

The important point here is to set the time line exactly. For the actual share price is a variable that changes in real time, even in a very short time interval, there is no great difficulty in order to measure its variability. However, the necessary variables, because there are many variables to stock prices than in calculating the value of EDF, (eg, time , day , day , etc.) If you set a time line to time too short, the value of the EDF computation is very difficult. First , in a variable to be used to calculate the value of the EDF, in the case of total liabilities of each company , announced cycle nature of the public announcement of material company , there is no data of quarterly only be generated . Thus, also, in the process to get the actual data, set an appropriate timeline will play an important role in the process of estimating the value. Therefore, it is set to Timeline minimum 1 month in order to ensure effectively the value of the variables required for the calculation process of the EDF.

3.1.3. Data collection

It is possible to secure a useful data of the financial data for various progression effective study and the hypothesis was the most important. Therefore, it was an effort to ensure the data provided by agencies with a public trust force in the country. First, the data on stock prices and company information material listed company of each, can be obtained quotes from the article website (kind.krx.co.kr) Korea Exchange Website and (www.krx.co.kr). For the measurement of variability, time line of stock-related data, using the stock quotes of 148 listed companies up to June 29, 2010

from June 29, 2007. And I was able information about the delisting a listed company corporate name even gets through this websites.

How to calculate the variation of the stock price for the need to calculate the stock price movement to be used to calculate the processing of the EDF in connection with stock quotes which is diverse. Usually, price fluctuations, and fluctuations days can be distinguished, the standard deviation of the degree of variation of (stock index) or stock price of day change during the day day and variability (Inter-day Volatility) in (Intra-day Volatility) a method in measuring the variation during the day, is a method for measuring the degree of variation of (stock index) or stock occurring during the day. Therefore, in this study, a method of measuring the daily variation, measures the variability of such are as follows.

$$Volatility = \sqrt{\frac{\sum (R_t - R_m)^2}{T-1}}$$

$$R_t = \frac{P_t - P_{t-1}}{P_{t-1}}$$

$$R_m = \sum R_t / T$$

P_t : The stock price at time T

In addition, in order to determine the EDF value, it was necessary to value corresponding to the current liabilities of each company. The value of that variable, was secured by using the (dart.fss.or.kr) Financial Supervisory Service published material financial website published material of Korea has focused all. For the sake of uniformity, the Company has used the current liabilities of the company, you have used the material of debt in June 2010 up to (half-year) in June 2008 from the (half). The production time of Company Announcements article because at the earliest, no matter how it is quarterly, to ensure the exact value of current liabilities of each month is that it is very difficult. Because if not financial officer of the company internal ensuring these values is almost impossible to calculate the average value for each section, it is applied to the calculation model of the EDF.

Data on Muu~ihomu rate of return is required Otherwise, we use the data of the rate of return on one-year government bonds Bank of Korea Economic Statistics System from (ecos.bok.or.kr), 2010 June from June 2008 I relative to the data rate of return every month to the moon.

For details on how to calculate the EDF, I have introduced in the first half. Using the methods set Iterative, calculated values of the EDF monthly each company.

3.2. Analysis & Results

3.2.1. Trial on deterministic epidemic model

As described above, the epidemic model, there are two. Stochastic model and Deterministic model has is the two , but for the estimation of the appropriate parameter estimation, let's implement before the deterministic model to target the 148 companies company that is incorporated into KOSPI200 index first in first I was made . For Parameter estimation, you have not mentioned above. However, it occupies a most important part in the epidemic model, is this just parameter estimation. It is possible it is necessary to estimate the proper reaction coefficients, it is possible to implement the model, while watching the resulting value, and comparative analysis of the difference between the actual value. Epidemic model to address the disease actually can be found by using the document information parameter of these, in the present study, we cannot Through existing research to obtain information about the parameters', it is necessary to devise new .

First, we determined the values of all EDF company each 148 in the manner previously described. Descriptive statistics about the EDF value of the company is as follows.

Year	Number of Companies	EDF				
		Average	Max	Min	Median	Stand. Dev.
2008	148	0.1159	1.0000	0.0000	0.0000	0.3204
2009	148	0.0981	1.0000	0.0000	0.0000	0.2927
2010	148	0.0691	1.0000	0.0000	0.0000	0.2538

<Table 2> Basic descriptive statistics about the EDF value of 148 enlisted companies

It is very crucial that identifying the parameters from each company's EDF value effectively. Let's take a look at the deterministic models that I mentioned it before.

<SIS model>

$$\frac{dS}{dt} = -\beta SI + \gamma I$$
$$\frac{dI}{dt} = \beta SI - \gamma I - \delta I$$
$$\frac{dD}{dt} = \delta I$$
$$S + I + D = C \text{ (constant)}$$

where, β : contact rate

γ : revocery rate

δ : death rate (mordibity)

<SIR model>

$$\frac{dS}{dt} = -\beta SI$$
$$\frac{dI}{dt} = \beta SI - \gamma I - \delta I$$
$$\frac{dR}{dt} = \gamma I$$
$$\frac{dD}{dt} = \delta I$$
$$S + I + R + D = C(\text{constant})$$

where, β : contact rate

γ : revocery rate

δ : death rate(mordibity)

I tried to estimate each parameters from two models in following way.

- contact rate(β) : ratio of cumulated infected corporations with DD below -19.74, to total corps

※(-19.74 is the average DD value of infected corporations in October 2008, which was beginning of financial crisis)

- recovery rate(γ) : (average time taken till returning to S)$^{-1}$

- mordibity(δ) : ratio of bankrupted corporations among infected corporations within 1 year

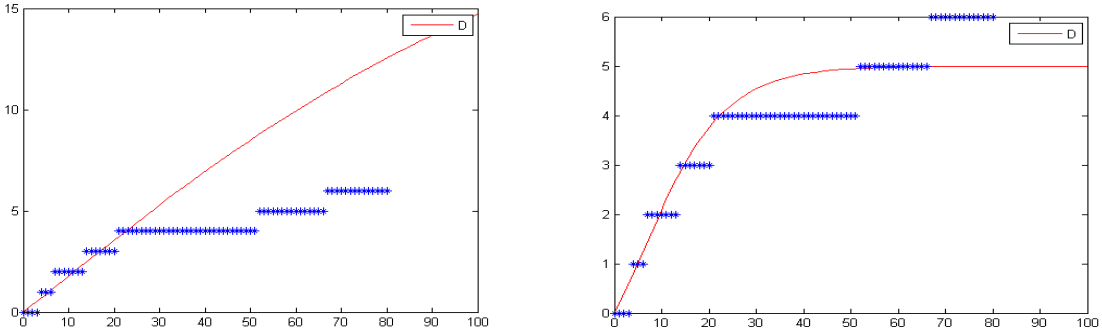
B	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF
Corporations	2009. 09	2009. 10	2009. 11	2009. 12	2010. 01	2010. 02	2010. 03	2010. 04	2010. 05	2010. 06					
	Phase 15	Phase 16	Phase 17	Phase 18	Phase 19	Phase 20	Phase 21	Phase 22	Phase 23	Phase 24		Contact rate		Recovery Rate	0.193548
[유] 후성[K]	0	0	0	0	0	0	0	0	0	0		0.002054419			
[유] LG패션[K]	0	0	0	0	0	0	0	0	0	0				morbidity	0.0098039
[유] 아모레퍼시픽[K]	0	0	0	0	0	0	0	0	0	0					
[유] 더베이직하우스[K]	0	0	0	0	0	0	0	0	0	0					
[유] 유니드[K]	0	0	0	0	0	0	0	0	0	0					
[유] 대웅제약[K]	0	0	0	0	0	0	0	0	0	0					
[유] 휴켐스[K]	0	0	0	0	0	0	0	0	0	0					
[유] 세종공업[K]	0	0	0	0	0	0	0	0	0	0					
[유] S&T모티브[K]	0	0	0	0	0	0	0	0	0	0					
[유] 일진디스플[K]	0	0	0	0	0	0	0	0	0	0					
[유] 두산인프라코어[K]	0	0	0	0	0	0	0	0	0	0					
[유] 롯데쇼핑[K]	0	0	0	0	0	0	0	0	0	0					
[유] 현대글로비스[K]	0	0	0	0	0	0	0	0	0	0					
[유] GS[K]	0	0	0	0	0	0	0	0	0	0					
[유] 강원랜드[K]	0	0	0	0	0	0	0	0	0	0					
[유] SBS[K]	0	0	0	0	0	0	0	0	0	0					
[유] 엠씨스퓨트[K]	0	0	0	0	0	0	0	0	0	0					

<Figure 4> The Excel image contains the partial result of EDF and the estimated parameters

Estimated parameters like this way, are $\beta = 0.002054419,\ \gamma = 0.193548,\ \delta = 0.0098039$.

I tried a simulation to find the harm of epidemic model by using the ODE45 function of Matlab based on the parameter that has been estimated. As a result, it was decided to obtain a result of the transition of the D values over time as follows.

<SIS model> <SIR model>



* Progress of the true number of bankrupt companies after financial crisis

<Figure 5> The results of 2 kinds of deterministic epidemic model based on estimated parameters

As shown, it is possible to determine the time variation of the number of failed firm (D) in connection with each model. Blue dots are those which issues a bankruptcy during that period in fact, shown by period the number of my company.

It's no time if discussed with respect to the definition of bankruptcy. In this study, we have determined that it is reasonable to look to be a company that has been delisted the concept of bankruptcy. I may ensure that the company's bankruptcy account for a large part of the company delisted in fact, there are various reasons to delisting. For example, a case is a delisting due to mergers and acquisitions, resulting entity of the company is changed, for example, if the holding company is changed to a subsidiary, since the distance far from the dishonor of fact, and delisting by these events I have excluded companies that have become. The following is a table summarizing the reasons for the company was delisted in fact during that period.

The rank based on frequency	**The reason why delisted**
1	Going final bankruptcy (Non-payment)
2	Encroachment of total capital
3	Audit opinion disclaimer
4	Didn’t submit the documents for public announcement

<Table 3> The reasons why companies are delisted from 2008 to 2010

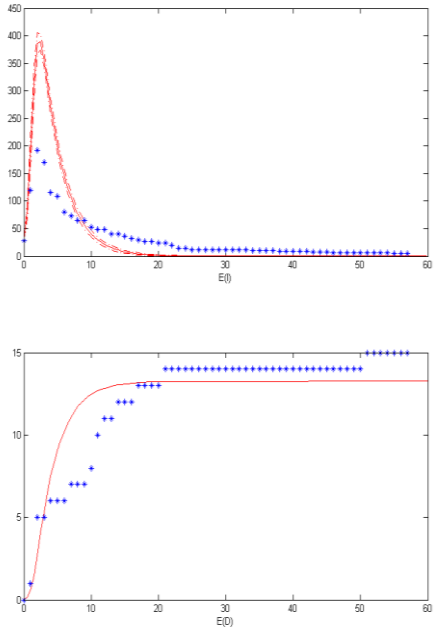
You are tracking relatively well companies bankruptcy occurs during the 20 months 10 months occurred is shock at SIS model so that it can be observed from the results, in 20 months, an increase of dishonored company model I can rate is to ensure that more rapidly than actual.

On the other hand, the SIR model, dishonored number of companies actually has a tracking relatively well up to 24 months or so, and shows the result converges to a constant level in the model thereafter.

3.2.2. Trial on stochastic epidemic model

This time, it was tried to the simulation using a stochastic model that is different from the previous section. The number of samples increased to 602 companies, I was based on the company stock to the KOSPI market all are listed. The analysis model, I was using the method of SSA (Stochastic Simulation Algorithm). Stochastic model can, as mentioned above, different results depending on the probability results as usual instead of out comes out. Therefore, it is necessary to perform the simulation to ensure proper iteration number. If it is usually SSA model, number of iterations of 1000 that need to be known. Also in this study, SIR model and SIS model also was repeated 1000 times. The more number of companies to increase, change occurs in the value of each parameter. Result of estimation of the parameters in the method of the previous section is, $\beta = 0.004214,\ \gamma = 0.3134,\ \delta = 0.006667$. The followings are the result of SSA simulations of two epidemic models.

<SIR model>



* Progress of the true number of infected and bankrupt companies after financial crisis

<Figure 6> The SIR result of stochastic epidemic model using SSA

It appears when viewed from the results, first, by comparing the model and the D value and the value of the actual I, and have a tracking than if the SIR model than the SIS model.

However, the maximum value whereas the 200 degree when the value of I from the actual SIR model, the maximum value of the model can be observed that the 400 about twice this. Of course, it is included within the scope of the variance of the value is indicated by a dotted line, and view the individual range of the dispersion. It can be seen In view of the reasons these companies exist as an object of each first, but has different properties relative to human. For example, entity of the company is made up of a myriad of variables. In other words, the elements affected by the bankruptcy probability and financial structure of the company are present in various ways in the interior of the

company. I think people than show the reaction sick when I saw the reaction of shock, the probability that there is a case to react a little more slowly is included this. The time it takes to change default probability and financial structure of the company to move to be able to apply the concept of the incubation period for the person, that is, one that can latency period corresponding to the entity present separately. So, as has been predicted by the model, I value a number of, ie, is assumed that company of infection level of infected person is not born, less than it is born.

It is believed that if you look at it compared to the previous Deterministic model, D value, ie, both models also have tracking relatively well the number of bankrupt companies in the SIR model.

3.2.3. Trial on Agent-based model

I tried to challenge the ABM model this time. In fact, the problem of applying to the Company SSA model described above is that it is necessary to premise that the company is a uniform state. For example, to represent differential equation chemical reactions , in the place where the reaction takes place, the elements of each reaction is simultaneously and uniformly all chemical reactions occurring at that time , the assumption that that react with each other at an early also time ,can be satisfied. The same is true when you epidemic model to the spread of disease. Interaction with those who do not and those who have the disease, those people have a uniform health all, assume that to each other interaction under the same conditions in each place there is a need.

However, in the case of a company, it is impossible to apply the premise. Diverse too, factors affecting the company, as described above, it’s unique too considering that basic physical it currently has the each company. Therefore, it might moiety capable of the same Shock from outside to respond to each company are all different. Therefore, there is a sense to attempt to try to apply the epidemic model collected in the company of each other homogeneous by the division properly. This part, I was left as an exercise for the future of this paper. First in this case, when each company make assumptions and are heterogeneous with each other, agent this - I think I will try to implement the

time of the based model.

It also is intended to define the agent of each, what is needed to be sure when you applied the regular ABM model, you can define the area in which the agent acts. Finally, I define the law of interaction how each agent about what to the interaction.

In this study, we saw in the first agent, is defined as a single agent of each company, for each company each have a value of DD uniquely at a particular point in time. Also, Wrapper must using methods minimum spanning tree of (MST)[21] for placement in space this company , and define the distance companies , and placed the company appropriately accordingly. Placing the company in accordance with the method of the MST, network map of the single is configured, each company is represented on each node . And it will be defined as follows: the distance between the nodes.[20]

$$\text{Distance} = \sqrt{2(1-\rho)},\ \text{where } \rho \text{ is correlation coefficient}$$

By using a parameter obtained before enough to be able to interact nodes connected to each other now (companies) to each other to deform in response (S, I) in the state of the reporting company , as such ,defined . ,, I tried a simulation easy to set up the ABM model in this way. The law of interaction associated with the transition is as follows. I saw in 1 month time unit is here.

1. Influential logic : I influence S which is connected with by changing DD like followings:

$$\text{DD-}\left(\frac{\beta}{\text{Number of nodes connected to the I}} \times \frac{1}{\text{distance}}\right)$$

2. S → I : When DD of S becomes below -19.74

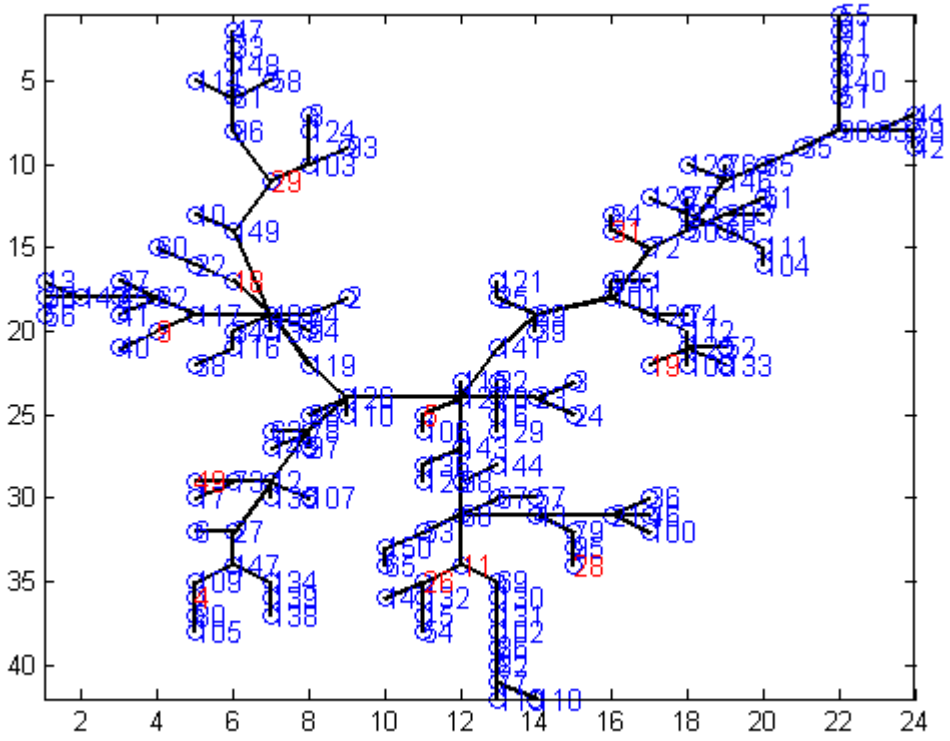
   (-19.74 is the average DD value of infected corporations in October 2008)

3. Recovery of I : I gets DD by the amount of ($\gamma \times \text{DD}$) as time unit goes by

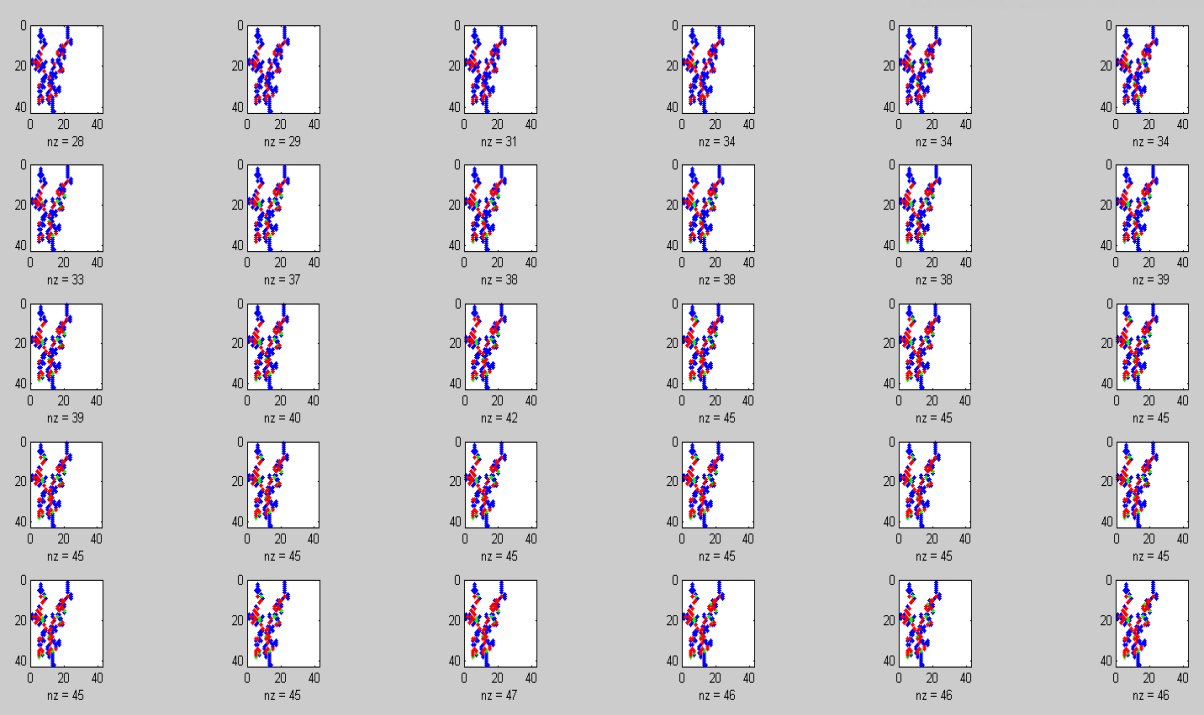
4. I → R : When DD of I becomes above -19.74

5. Death of I : If there's 3 time units after becoming I and DD does not recover to the level of firstly getting infected time

It is up to the state of Death since the let applying the Death rate, company control as described above is not present. The results are followings:



<Figure 7> The abstract shape of connected nodes for companies based on MST method



* (Blue : S, Red : I, Green : R)

<Figure 8> The result of ABM model containing 148 companies

This is the 148 companies' result and nz means the number of I as time unit goes by. The story obvious , but when it can be seen I many as time passes around about I to which the node is connected more , the occurrence of many, 6 months have passed , the total number of I is ,I look to thirty-four. You can see it is judged to think mathematically this result, and try to estimate in the case of a company about 600 companies , shall I of about 135 or so occurs within six months, but this value is it can be seen that some, there is a difference between value of I from case 600 companies actually. As described above, since it is a result reflecting the characteristics of the agent of each, ABM model will be observed that the transfer to I occurs more gradually from S. And, there is no reason why the value of D occurs, seems the number of the whole company at 148, company to satisfy the conditions of D from a relatively small and disappear over time. In order to observe the company up to the state of Death, attempt to increase the number or company, take longer time horizon are required.

IV. Discussion

There are some limitations on this study. First, the most difficult part of the part to predict is the parameters. And also, without If we attempt to measure the parameter, optionally, only be produced and inevitably an error between the actual data, it is a task not easy to predict the parameters which are most similar to the actual value. Therefore, in order to improve these parts should be included in the model to more companies. In this study , it was to be included in the target companies listed on the stock exchange of Korea, the future, the study of subsequent attempts back on and then the incorporation together also company listed on the KOSDAQ market is appropriate .

In addition, there is room for improvement points from the ABM point of view, the value of DD only one is dependent type definitions of company. It would be nice to resolve this portion, it's try to analyze individual industry groups each. Because they share the characteristics of the industry of its own way, companies belonging to the manufacturing and construction is that you can predict the parameters, you can define in its own way the characteristics of the agent only of each, to be analyzed in more detail, there is an advantage that can be. If you want to extend the analysis to account for part of these, there is room for improvement is the result.

V. Conclusion

I want to gather the results came out on the basis of the three attempts of the present study. First , the results of the analysis of the US financial crisis in 2008 with the Deterministic epidemic model, the results came out by the SIR model and SIS model also predicts relatively well the companies that went bankrupt real. But , as can be seen from the results, if is this SIS model , over time , errors and failed firm actual number of addition is larger , failed firm actual number of is maintained at a

constant level , whereas there is a tendency , in the SIS model , and is showing the form that continues to increase. The reason would need to be approached from the standpoint of the selection of the model more fundamental.

The financial crisis in the U.S. that occurred in 2008, there is no precedent in fact, it was the financial crisis that occurred on a large scale. Of course , then the financial crisis emerged in Europe in 2010 or later , the crisis , he was spread all countries of Europe , in terms of influence and scale , the proportion of the U.S. financial crisis of 2008 occupied ,the very large. So we can act as a large impact, which can affect the Korean financial crisis time in the United States. Therefore, a portion may be I it is assumed in the SIS model go S again, requires a house capable financial crisis several times erupted in fact, affect the industry of Korea followed, it is to be. And, therefore, to describe in epidemic models of financial crisis , the actual result , which is considered rather than the SIS model , person of the SIR model is suitable also disprove that kind of part .

Was analyzed using the SIR model again in stochastic epidemic model analysis using the method of SSA was an attempt for the second time , Similarly , the number of failed firm 's correctly predicts relatively ,it is possible to see. However, if you look at the transition of the I value, it is possible to see the error of being present many ways from the number of firms in the state of I real. However , the pattern in the form of reducing a certain level rises to the financial crisis originating in the United States affect the Korean company by using the stochastic SIR epidemic model that similar to the pattern of I value the fact has been observed ,it is , presenting the evidence that can explain the effect of giving the model.

Agent was the last attempt - reported to the agent of each company, based model, which assumes that you have a property that is specific to each agent. It is possible that there is little if they have the same conditions all the companies actually even influence factors that affect companies such as different portions of the reaction according to the situation of the company are all different. In this

approach, it is defined as an attribute of the specific values of the DD of each company, by using the parameters derived from the two studies prior to define the change in the value of DD, and on the state transitions of each agent, I was in the new definition. And analysis was performed by connecting to the network by using the minimum spanning tree the agent to define the space.

The results of the analysis , as expected, changes in the value of I is able to see that model than the previous two, come on gradually , It can be observed visually that the center of the (I), transition occurs infected company node is connected with more space .

VI. References

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