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Application of Fisher's Equation on the Korea's Open Economy using System Dynamics*

Youngcheul Ahn** Kabsoo Lee***

| Contents |

| Abstract |

The goal of this paper is to find the optimal level of quantitative easing in order to overcome the economic crisis. This paper uses the system dynamics approach technically and the Fisher's equation of exchange theoretically for the diagnosis of the present Korea's economy. The simulation model is constructed through the non-linear simultaneous function for the long-term prediction. The first thing that has to be done is to find the trend functions of the determinants of the Fisher's equation, and then to construct the non-linear simultaneous function through the combination of the functions.

The results of simulation give some implications. The quantitative easing

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** First Author: Lecturer, Department of International Trade, Pusan National University.

*** Corresponding Author: Professor, Department of International Trade, Pusan National University.

is divided into natural and political monetary easing. The political monetary easing is not necessary for the reflationary policy of real estate market, but important for the betterment of trade balance that can cause the industry growth.

The log-transformed variables are used for the simulation and statistic analysis. After calculating the optimal level of money expansion, the logarithmic values are converted into the real values.

Korea's economy is small in the whole international economy, but the effect of Korea's monetary policy on the trade balance isn't diminutive. Therefore, the Korea's monetary policy can lead the industry growth in the export-oriented economy and be an alternative to solve the financial crisis in the Korea's economy by improving the Korea's trade balance.

▪ Key words: Quantitative Easing, Fisher's Equation of Exchange, System Dynamics, Trade Balance, Mundell-Tobin Effect

Ⅰ. Introduction

The global financial meltdown of 2008 resulted from the sub-prime mortgage loans in America has caused the financial crisis of not only U.S.A., but also the entire world. U.S.A. has abused the quantitative easing to overcome this problem. Following that, Japan has tried to implement the quantitative easing.

As already experienced, quantitative easing is a method of the financial protectionism and well acknowledged as the failed economic policy. Quantitative easing can be used as a method to win the trade competition through the control of real exchange rate. This increasing of exchange rate in home country brings about the decreasing of import in its own country, namely the reduction of export in trade partner country. Because of that, the quantitative easing of counter

partner country is not avoidable and results in the reduction of the world production.

In spite of these problems, quantitative easing is often very easily accepted in order to expand the domestic demand. But it results in the extreme inflation in a domestic market. Furthermore it maybe widens the gap between the real GDP and potential GDP. Therefore it is important to find the optimal level of quantitative easing. For calculating the optimal level of quantitative easing, the things such as follows have to be considered: inflation, gross domestic product, unemployment and money quantity besides the exchange rate and trade balance.

The purposes of this research are as follows. The first is to conduct a study on the effects of Korea's quantitative easing on its economy. The second is to examine the relationship between price level and trade balance. This research uses the simple fisher's equation of exchange (Bernanke et al. 1999, 1347) to achieve these purposes theoretically and the system dynamics approach developed from the work of Forrester (1958, 37; 1961, 398) to research technically. This approach can construct a dynamic nonlinear simultaneous equations model (Sterman 1985, 17; 1989, 321) to explain the complex feedback system accompanying delayed time (Schmitt-Grohé & Uribe 2004, 757). The dynamic nonlinear simultaneous equations model needs the combination of the abstracted variables induced from real data sets and is made by simulation program named the power-Sim studio 10. The GA (graphic analysis) program is used to find the trend line of respective variables and to construct the simulation model.

In conclusion, this paper studies the optimal level of the quantitative easing for a country economy through the example of its effect on the Korea's economy. The excessive quantitative easing in Korea can worsen the economy and aggravate the crisis through the declining in

production in its own economy and finally worsen the trade partner's economy through the aggravating the partner's trade balance. Therefore the importance of finding optimal increment of money should always be emphasized.

II. Theoretical Background and Previous Research

Irving Fisher (1935, XV) has thought one of the causes of the suffering is the instability of money and tried to verify the correlation between the money instability and quantitative easing. Summer (1990, 719) has argued that increased wage and price flexibility can be easily destabilized and Irving Fisher had proved it through the study of Phillips Curve.

H. G. Monissen (1999, 2) asserted Irving Fisher has changed his mind about the cause of the financial crisis and thought the business fluctuations can be stabilized by banking reform with the 100 % reserve requirement. He reused the simple fisher's equation to determinate the optimal price and output and to design the monetary policies that handle the quantitative easing. He made the following model with a simple Fisher's equation (Fisher 1911, 296) and three constraint functions.

$$m + v = p + y \tag{1.1}$$

$$y = y^{P} + \lambda(p - p^{e}) \tag{1.2}$$

$$v = \bar{v} + \gamma(p - p_{-1}) \tag{1.3}$$

$$p^{e} = \alpha p_{-1} + (1 - \alpha)p^{e}_{-1} \tag{1.4}$$

This is a log-transformed model of Fisher's equation of money. The function (1.1) as the Fisher's equation of exchange has following variables; m: money supply, v: velocity of money, p: price index, y: gross domestic product. The first constraint functions (1.2) is a Lucas's aggregate supply function and has variable y^P, potential GDP, and p^e, expected price level, and the third constraint function (1.4) is a simple version of adaptive expectations and has a variable p_{-1}, price level of the previous period, and p^e_{-1}, expected price level of the previous period. In the constraint functions, α, λ and γ are the parameters. λ shows a coefficient based on an economy's sensitivity to price shocks as the relationship between the GDP loss and Inflation error, $\frac{y-y^p}{p-p^e}$, γ implicates the relationship between the money velocity error and changed rate of inflation, $\frac{v-\bar{v}}{p-p_{-1}}$ and α means error adjustment coefficient that shows the correlation between the changed rate of real inflation and that of expected inflation, $\frac{p^e-p^e_{-1}}{p_{-1}-p^e_{-1}}$.

This research concentrates on how the quantitative easing has effects on the GDP and Trade Balance of a country in the system dynamics model of the Fisher's equation. To answer this question, this research chooses the network (=graph) analysis approach that is constructed by the non-linear simultaneous function. The previous research of Ahn and Kim (2013, 372) "A nonlinear Simultaneous Equations Model Analysis on the Effect of Yuan Revaluation on Korea's Trade Balance" had used the approach by simulation. The two effects of the FTA between Korea and China on the Korea's economy are proved in the former paper. The first is the effect of tariffs reduction, and the second is the effect of the China's economic growth. Ahn and Lee (2014, 234) published a research on the effect of the

Japan's Quantitative Easing on Korea's Economy. This research had a result by which it is proved that the quantitative easing is a policy that beggars the neighbor. Angerhofer and Angelides (2000, 348) showed the international supply chain management through the system dynamics modelling.

III. Research Methodology

1. Simulation Model and Data Analysis

As mentioned above, this research uses the system dynamics modelling for the dynamic simulation of Fisher's equation model that has a form of non-linear simultaneous equations. The following Simulation model in <Figure 1> shows the Fisher's exchange equation connected with the macro-open economy. This model is a causal diagram showing stock and flow structure with the money supply which has a influence on the price index and furthermore on the GDP. In this case, the political added amount of money supply is defined as the reflation policy. This simulation provide the foundation on which optimal quantitative easing can be calculated and shows the correlations of price index and GDP with the trade balance. Even if the simulation does not provide the velocity of money in Korea, it is calculated already.

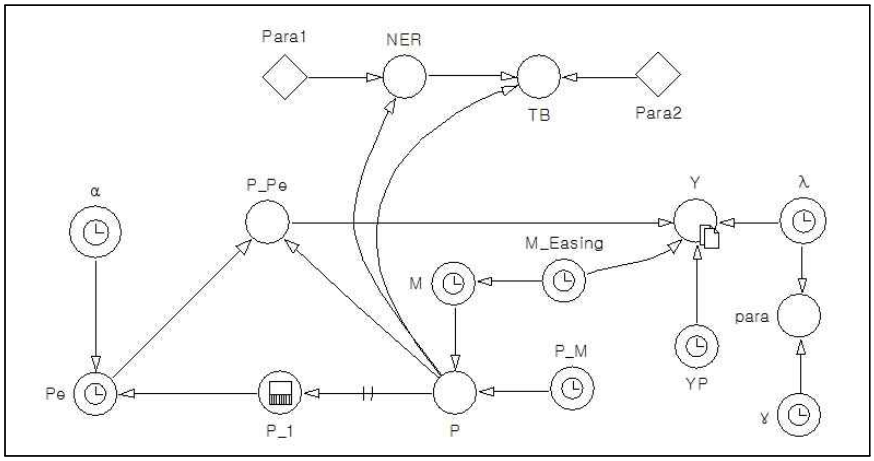
The simulation begins from the dynamic change of money which has an effect on the price index and is located in the center, M_easing.

The price index derived by M2[1] is compared with the expected

1) The reason why this paper uses M2 is because the use of the M1 shows the pattern of extreme excess liquidity especially by the expanding monetary policy.

price index. The gap between the real price index and the expected is a component which structures the GDP. M_easing in Green Box is a policy variable, which means the reflation policy. The purpose of this research is to find the optimal quantity of M_easing in Korea's open economy.

<Figure 1> Simulation Model of Fisher's Equation of Exchange



The variables in simulation model <Figure 1> are the trend functions derived from the real data by a calculation program, GA, and they are linked together in a form of the simultaneous equation. The dynamic algorithm of Fisher's equation (1) is connected with the trade balance, TB. The following <Table 1> shows the variable of simulation and present variable's notation, definition. TB is related with nominal exchange rate that is correlated with the price index.

Because of these correlations, the empirical test is required. Although the empirical test itself is not the goal of this study at all, it is necessary for the calculation of correlations parameters, Para 1 and 2, which link the trade balance with the Fisher's equation.

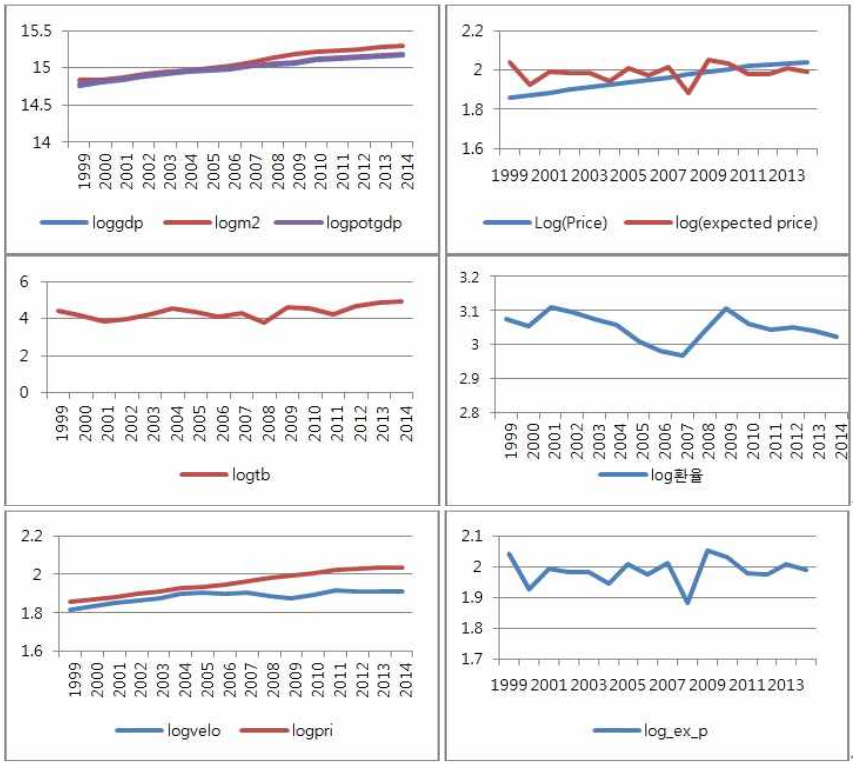
<Table 1> Variable Definitions in Green Box of Simulation Constructure

Variables	Notations	Definitions
M2	M	Money Supply combined with cash and all kinds of deposits
Qunatitative Easing	M_Easing	A policy to increase M2, printing money and issue of national bonds
Price Index	P	A consumer price index shows the level of inflation
Previous Price	P_1	Price index before 1 year
Expected Price	Pe	Price index that indicates the expectation of a economy after 6 months
Deviation of Price	P_Pe	The gab between real and expected prices
Real GDP	Y	Real gross domestic product
Potential GDP	YP	Gross domestic product under the assumption of natural rate of unemployment
Nominal Exchange Rate	NER	The exchange rate of the currencies (means the exchange rate of the same good between countries
Trade Balance	TB	The balance of trade connected with exchange rate
Parameter 1	Para1	Correlation Parameter between NER and P, β_1
Parameter 2	Para2	Correlation Parameter between NER and TB1, α_1
Parameter 3	Para3	Correlation Parameter between Y and TB2, α_2
alpha	α	Error adjustment coefficient
Lambda	λ	Coefficient based on an economy's sensitivity to price shocks
Gamma	ɣ	Coefficient between the money velocity error and changed rate of inflation

* All variables imported from real data are converted into logarithmic value.

In this paper, the change of TB provides some information about the effects of quantitative easing. If TB is positive, then the effect of nominal exchange rate on the trade balance could be positive and this result means that the quantitative easing bring a positive effect on the open macro economy in its train. The sign of each parameter has a important meaning. The plus sign means a positive correlation between explanatory and dependent variables, at the same time that the changing directions of two variables are same because this empirical function is logarithmic function.

<Figure 2> Logarithmic Variables for Fisher's equation of exchange in Korea



This research analyze 16 years of data from 1999 to 2014 after financial crisis in Korea. The main variables of this model are money

(M2), price index (P) and gross domestic product (Y), and the varibles that are necessary for the model building are the expected price index (Pe) and the potential GDP (YP). The velocity of money is calculated from index in the Fisher's equation of exchange and the potential GDP is derived from the combination of real GDP with natural rate of unemployment. The source of all data is fetched from Economic Statistics System of the Bank of Korea (ECOS).

The data set of logarithmic variables is presented in <Figure 2>. This figure 2 shows the policy of M2 increasing began after 2008, which was begun by the quantitative easing of U.S. Dollars, accepted as a way to resolve the global monetary crisis from America, but could not improve the Korea's GDP because of the expansion of the serious world financial crisis. According to the graphs, the money velocity is lower than the Inflation rate. It means the impact of money on the market is getting weaker and an easy the money policy is not working in the market so well. The figure of expected price index shows that it is not increased within a certain period of time between 1999 and 2014. It means the expectation of consumers on the business cycle did not turn around. The potential GDP shows the continuous increasing. If the gab between real and potential GDPs is ever widening, it implies the unemployment rate is getting bigger continuously. All the logarithmic functions should not overlook the simple Fisher's equation of exchange.

2. Determination of Equation for Simulation

Priorly, some trend curves of variables are derived from the curve fitting and the others are estimated from the statistic analysis. This paper uses the calculation program GA (=Graphic Analysis) for the derivation of fitted trend curves, named non-linear functions which

construct the algorithm of system dynamics modelling and the program E-Views for making an estimate of correlation parameter, Para 1 and Para 2.

The correlation parameters is derived from the following three estimation regression equations. Para 1 shows the relationship between Price index and nominal exchange rate and Para 2 between the trade balance and the nominal exchange rate. The correlation parameters of variables that are calculated by the testing of the significations are used for constructing the simulation. The following time series least squares analysis is performed to determine the parameters.

$$TB1 = \alpha_1 P + \alpha_2 NER + \varepsilon_2 \quad (2.1)$$

$$NER = \beta_1 P + \varepsilon_1 \quad (2.2)$$

<Table 2> Descriptive Statistics

Dependent Variable	Variable	Coefficient	R-squared (Adjusted R^2)
TB 1	C	5.790622	0.314353* (0.208869)
	NER	0.431166	
	P	3.18893**	
NER	C	3.447269***	0.092225 (0.027384)
	P	-0.203146	

* means coefficient is significant on the 90 % level

** means coefficient is significant on the 95 % level

*** means signification on the 99% level

The log expected price shows the regular cycle that has an influence on the whole economy. The change of price index can give an effect on the exchange rate, but Korea's price change have no significant effect on the international exchange rate. After 2008 the quantitative easing of America is making a valid result. It means the change of America's price index has a good influence on the global exchange rate. The results of least squares analysis are described in the

following statistics of <Table 2>.

The results of <Table 2> shows that the trade balance and nominal exchange rate have no significant correlation at all. It means the nominal exchange rate under the floating exchange rate system has no effect on the trade balance because the price index of partner country also should affect the change of exchange rate under this system. And a reason why there is no significant correlation between TB and NER in Korea can be a low interest rate, which lowers the NER.

<Table 3> Equations for simulation

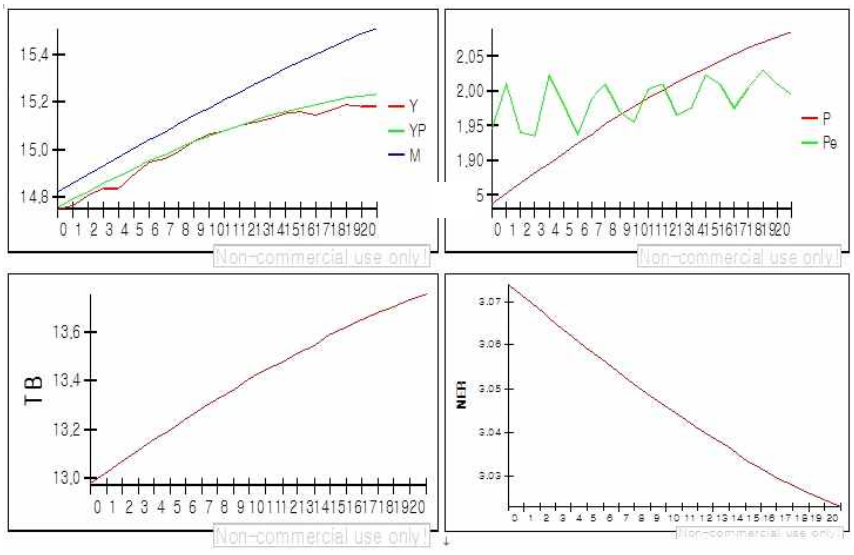
Name	Definition
Alpha	0.192*SIN(2.11*TIME+46)+0.194
Lambda	0.538*SIN(0.222*TIME+0.388)-0.127
M	(-2.75/(1+EXP(0.052*TIME)))+16.2 + M_Easing
M_Easing	STEP(0.1, 15)
MER	Para1*P+3.447269
P	P_M*M
P_1	DELAYPPL(P,1,1.82)
P_M	((0.695/(1+EXP(-0.0845*TIME)))+1.49)/ ((-2.75/(1+EXP(0.052*TIME)))+16.2)
P_Pe	P-Pe
Para1	-0.203146
Para2	3.18893
Para3	1.415276
Pe	Alpha*P_1+(1-Alpha)*(-0.0381*SIN(-1.69*TIME+18.1)+1.99)
TB_1	Para2*P+0.431166*MER+5.790622
TB_2	Para3*Y-7.878767
Y	YP+Lambda*P_Pe
YP	(1.12/(1+EXP(-0.118*TIME)))+14.2

* Time: the time distance from start time to stop time (1999-2021)

Although the correlation coefficient of NER on the TB are not significant, but positive, it means that the increasing of NER have a positive effect on the TB. Price index can has a significant positive correlation with TB. Even if it is not suitable in economy theory, Cash flow can be slowed down by the low interest rate. Then the price index could be increased and import could decreased.

Some coefficients are not significant. These are acceptable as the parameter for the simulation because the R-squared meaning the fitness of the simulation model are significant. It means it is possible to build the flow chart of simulation. The exchange rate itself could not affect the trade balance in the floating exchange rate system. But the exchange rate and price index have closely related each other. It is arguable that the quantitative easing makes the trade balance better. Now it is possible to structure the non-linear simultaneous functions for the simulation model. The equations for the simulation are included in <Table 3>.

<Figure 3> The trend curves of Variables



The curves of logarithmic variables in <Figure 2> can be compared with the trend curves derived from the given logarithmic data set by nonlinear programming in the simulation model of <Figure 3>. The trend curve of GDP in <figure 3> contains the change of price index while the trend curve of potential GDP don't contain it. The trend curve of logarithmic TB is calculated from the system dynamics modelling. The each TB is linked with the respective specific variables.

<Table 4> Estimated values of variables as base for the policies

period	M	P	Y	YP	Pe	alpha	Lamda
0	14.83	1.84	14.75	14.76	1.94	0.37	0.08
1	14.86	1.85	14.76	14.79	2.01	0.03	0.18
2	14.90	1.87	14.81	14.83	1.94	0.19	0.27
3	14.93	1.88	14.84	14.86	1.93	0.36	0.34
4	14.97	1.90	14.84	14.89	2.02	0.03	0.39
5	15.00	1.91	14.89	14.92	1.98	0.19	0.41
6	15.04	1.92	14.95	14.95	1.94	0.36	0.41
7	15.07	1.94	14.96	14.98	1.99	0.02	0.37
8	15.11	1.95	14.99	15.01	2.01	0.20	0.32
9	15.14	1.96	15.03	15.03	1.97	0.35	0.24
10	15.17	1.98	15.06	15.06	1.95	0.02	0.15
11	15.21	1.99	15.08	15.08	2.00	0.21	0.04
12	15.24	2.00	15.10	15.10	2.01	0.35	-0.08
13	15.27	2.01	15.11	15.12	1.97	0.02	-0.20
14	15.30	2.02	15.13	15.14	1.98	0.22	-0.31
15	15.34	2.03	15.15	15.16	2.02	0.34	-0.42
16	15.37	2.04	15.16	15.17	2.01	0.01	-0.51
17	15.40	2.05	15.14	15.19	1.97	0.23	-0.59
18	15.43	2.06	15.16	15.20	2.00	0.34	-0.64
19	15.45	2.07	15.19	15.21	2.03	0.01	-0.66
20	15.48	2.08	15.18	15.22	2.01	0.24	-0.66
21	15.51	2.08	15.18	15.23	1.99	0.33	-0.63

* Notice: The period section (0-21) means time series from 1999 to 2020.

Simulation has the following construction. Time unit is period and time step is 1, which means one year. Run time of simulation is set from 0 to 21. The year on which analysis is begun is 1999, so that the last year is 2020. This means that the time section for simulation is [1999-2020]. The estimated values of variables are represented in the

following <Table 4>. Alpha has the short-term cycle and lambda has the long-term cycle. The potential GDP is a criterion to find optimal quantitative easing. The closer the real GDP is to the potential GDP, the closer the amount of quantitative easing is to the optimal amount. The expected price index has the cyclic changes interlocking the alpha's business cycle.

IV. Application of policies and optimal Easing

1. Application of policies

The object to build the dynamic simulation model is to find the real effect of the policy on the subjective of analysis. This research has an object to find the real effect of quantitative easing, M_easing, as policy variable on the trade balance. Three scenarios can be considered as follows: scenario A: Doing nothing policy, scenario B: Quantitative easing as Reflationary policy and scenario C: Quantitative easing as export-led growth policy. The artificial policy functions from 2015 after 16 years in 1999.

1. Scenario A: "Doing nothing" is the base scenario on which the effects of policies can be measured. A role of scenario A provides a dynamic computable non-linear simultaneous equations model that is combined with the integrated quantitative easing policy.
2. Scenario B: "Quantitative Easing as export-led growth policy" is an industrialization strategy that is combined with an increasing of nominal exchange rate. By this way, the Quantitative Easing is connected with gross domestic product as a national income of

production.

3. Scenario C: “Quantitative Easing as Reflationary policy” is interlocked with the M2. Reflationary policy as a kind of economy stimulus policies has a Mundell-Tobin effect that means increasing of consumption and investment in the recession on the assumption that an economy has an enough production possibility.

The dynamic changes of variables in simulation model in the scenario A are same with the trend curve of variables as the basic framework. According to the reflationary policy of Korea in 2014, Korea's government had eased off about 40 trillion won. This policy could not increase the real GDP and just bring the high inflation. But this policy improves the trade balance. If quantitative easing comes into force till the logarithmic value of M2 become 0.1, the quantity would run into 520 trillion won.[2)]

The results of the increasing of logarithmic M2, 0.1, are described in the following <Table 5>. By the scenario B, the price index would be increased, but the GDP would be decreased. These results are indicated by <Table 5a>. If that is the case of scenario C, so called, quantitative easing as export-led growth policy, not only the price index, but also the GDP would be increased as represented in <Table 5>.

This Expansion of M2 increases the price index from 2.02 to 2.05 (= from price index 104.7 to 112) and can induce the inflation. Something that is worse than inflation is the reduction of the growth speed. The real GDP will be reduced from 15.18 to 15.17 after 5 years. It means the real reduction of the 60 trillion won. But <Table 5b> shows that trade balance based on the and price index can be better by rising from 13.55 to 13.62 (increxchange rateeasing of 5 trillion). The logical deduction obtainable from scenario B is that the quantitative easing

2) By the calculation of logarithmic value, the given value of low data is important. The amount of variation alters according to the size of given value.

without Mundell-Tobin effect can result in the inflation and the reduction of real GDP, and consequently the squandering of the nation's resources and ultimately the widening rich-poor gap and social polarization.

<Table 5a> Time table of variables by increasing of logarithmic value of M2, 0.1

Scenario A				Scenario B				Scenario C			
period	M	P	Y	period	M	P	Y	period	M	P	Y
0	14,83	1,84	14,75	0	14,83	1,84	14,75	0	14,83	1,84	14,75
1	14,86	1,85	14,76	1	14,86	1,85	14,76	1	14,86	1,85	14,76
2	14,90	1,87	14,81	2	14,90	1,87	14,81	2	14,90	1,87	14,81
3	14,93	1,88	14,84	3	14,93	1,88	14,84	3	14,93	1,88	14,84
4	14,97	1,90	14,84	4	14,97	1,90	14,84	4	14,97	1,90	14,84
5	15,00	1,91	14,89	5	15,00	1,91	14,89	5	15,00	1,91	14,89
6	15,04	1,92	14,95	6	15,04	1,92	14,95	6	15,04	1,92	14,95
7	15,07	1,94	14,96	7	15,07	1,94	14,96	7	15,07	1,94	14,96
8	15,11	1,95	14,99	8	15,11	1,95	14,99	8	15,11	1,95	14,99
9	15,14	1,96	15,03	9	15,14	1,96	15,03	9	15,14	1,96	15,03
10	15,17	1,98	15,06	10	15,17	1,98	15,06	10	15,17	1,98	15,06
11	15,21	1,99	15,08	11	15,21	1,99	15,08	11	15,21	1,99	15,08
12	15,24	2,00	15,10	12	15,24	2,00	15,10	12	15,24	2,00	15,10
13	15,27	2,01	15,11	13	15,27	2,01	15,11	13	15,27	2,01	15,11
14	15,30	2,02	15,13	14	15,30	2,02	15,13	14	15,30	2,02	15,13
15	15,34	2,03	15,15	15	15,44	2,05	15,15	15	15,44	2,05	15,25
16	15,37	2,04	15,16	16	15,47	2,06	15,15	16	15,47	2,06	15,25
17	15,40	2,05	15,14	17	15,50	2,06	15,14	17	15,50	2,06	15,24
18	15,43	2,06	15,16	18	15,53	2,07	15,16	18	15,53	2,07	15,26
19	15,45	2,07	15,19	19	15,55	2,08	15,18	19	15,55	2,08	15,28
20	15,48	2,08	15,18	20	15,58	2,09	15,17	20	15,58	2,09	15,27
21	15,51	2,08	15,18	21	15,61	2,10	15,17	21	15,61	2,10	15,27

* Notice: The period section (0-21) means time series from 1999 to 2020.

Thus the quantitative easing policy necessitates the industrialization policy that is especially combined with employment-oriented production strategy. This policy affects the national income of production directly, so that it is called scenario C "quantitative easing as industry-led growth policy". The outputs of simulation by scenario C represent the increasing of real GDP to exceed the increasing of inflation rate from 15.15 to 15.25 that is depicted in <Table 5a>. It means that the two-thirds of all increased M2 (=340 trillion/ 520 trillion) are integrated

into the nation's wealth. The results of scenario C show that the quantitative easing with industrial policy based on the increasing of consumption and investment is more effective than the quantitative easing based on the financial vitalization. The increasing of logarithmic value in scenario C (=000013.7) is bigger than that in scenario B (=13.62).

<Table 5b> Time table of variables by increasing of logarithmic value of M2, 0.1

Scenario A		Scenario B	
period	TB	period	TB
0	12.98	0	12.98
1	13.02	1	13.02
2	13.07	2	13.07
3	13.11	3	13.11
4	13.16	4	13.16
5	13.20	5	13.20
6	13.24	6	13.24
7	13.29	7	13.29
8	13.33	8	13.33
9	13.37	9	13.37
10	13.41	10	13.41
11	13.44	11	13.44
12	13.48	12	13.48
13	13.51	13	13.51
14	13.55	14	13.55
15	13.58	15	13.62
16	13.61	16	13.65
17	13.64	17	13.68
18	13.67	18	13.71
19	13.69	19	13.73
20	13.72	20	13.76
21	13.74	21	13.78

* Notice: The period section (0-21) means time series from 1999 to 2020.

2. The Computation of optimal Quantitative Easing

This research compares the current reflation policy of this government with the optimal quantitative easing in Korea. The current level quantitative easing in Korea's economy amounts to 60 trillion won. The log-transformed value of quantitative easing is 0.012 that is

the difference between log values computed from the money supplies, 2.009 quadrillion and 2.069 quadrillion.

The optimal amount of quantitative easing should fulfill the following two conditions. First is that the variation of real price index and expected price index should be zero. Second is that the real GDP and the potential GDP have to coincide. An politically controlled optimal amount of additionally needed quantitative easing (=0.0293) is found through the computation of results and the iteration of the simulation. And it fulfills the conditions which are above listed.

The optimal quantitative easing, Δm^*, can be derived from the simple Fisher′s equation and constraint functions above mentioned, equation (1). At first, for solving the simultaneous functions of Fisher′s exchange equation, the function of the money supply is built as follow.

$$m = y^P - \bar{v} + p + (\lambda - \gamma)(p - p_{-1}) \qquad (3)$$

When it is assumed that there is no inflation by the optimal policy, price index is regarded as unchanged, so that it is removed by the difference of equation. Using the constraint functions (1.2), (1.3) and (1.4), the optimal amount of quantitative easing can be attained as follow.

$$\Delta m^* = \Delta y^P - \Delta\bar{v} - (\lambda - \gamma)\Delta p_{-1} \qquad (4)$$

Assuming that the expected price index and the one period previous price index are same, $p_e=p_{-1}$, in the constraint equation is determined as 1, and it is obtained the real GDP to be same with the potential GDP > it is obtained that the real GDP is same with the potential GDP under the optimal policy, $y=y^P$. Therefore $\Delta p_{-1}=(y_{-1} - y^p_{-1})$. Finally the optimal amount can be depicted as follow.

$$\Delta m^{*} = \Delta y^{P} - \Delta \bar{v} + \frac{\lambda - y}{\lambda} (y^{p}_{-1} - y_{-1}) \quad (5)$$

The values of the difference function (5) are regulated in the following <Table 6>. The following values give the optimal added quantitative easing Δm^{*}(=0.0293). The sum of the nature amount of quantitative easing 0.03369 and it's political amount 0.0293 is 0.063. Therefore the optimum money supply, 15.3661, in 2015 is a value that adds the natural and political variation in 2015 in comparison to money supply, 15.3031, in 2014.

<Table 6> The given value of determination variables

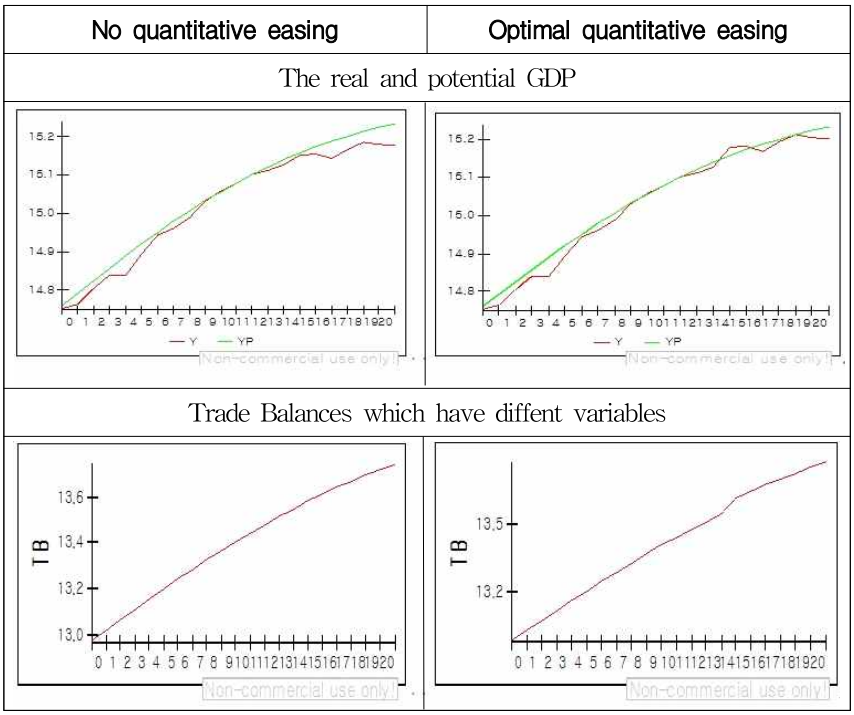
Varable	Δy^{P}	$\Delta \bar{v}$	λ	y	y^{p}_{-1}	y_{-1}
Value	0.018372	0.0057	-1.2338	-0.4202	15.1675	15.15517

By converting the logarithmic value into the real value, the real optimal money supply can be calculated. The optimal money supply in 2015 is 2.327 quadrillion won, and the natural increasing of that is 151.7 trillion won. Therefore the politically added quantitative easing needed for the optimal economy control is about 175 trillion won. This result can be interpreted: If the government has the reflationary policy with Mundell-Tobin effect, Korea needs still more quantitative easing.

The <Figure 4> shows how the optimal amounts of quantitative easing fulfill the conditions. The optimal quantitative easing with Mundell-Tobin effect changes the money supply after 2015 (=period 14). Through this change, the real GDP approaches the potential GDP. The trade balance would be increased. The real GDP and trade balance by the optimal quantitative easing have a bigger positive change than those by no quantitative easing. Of course, the quantitative easing with Mundell-Tobin effect gives the more efficient result than that with

demand policy.

<Figure 4> Comparison between policies



* Notice: The period section (0-21) means time series from 1999 to 2020.

V. Conclusion

The goal of this paper is to find the optimal level of quantitative easing in order to overcome the financial crisis. But the reason why it is not easy to find it is found in the complexity of macro-economic variable. To resolve the problem like national debt and slump, the quantitative easing is required. But this policy can result in the polarization and be ended just with the leaving high-inflation.

Furthermore this itself is a intervention of government into market and can make a bias in market sector.

Despite the above mentioned factors, quantitative easing is accepted by the decision-makers, especially at the time of international financial crisis, even if that leads to the «beggar my neighbor».

Recently many countries, particularly America and Japan have carried out the quantitative easing and actually achieve the same result. America is bailed out of the unemployment and high-inflation problems. Japan has some effect of the betterment of trade balance and the activating stock markets.

Korea as trade partner country is faced with the worsening of trade balance against America and Japan, and suffers from international financial crisis. At this time, the quantitative easing become one of alluring policies. But the damages from quantitative easing also should be considered enough, and the optimal level of that have to be decided.

This paper used the simulation-approach to find the optimal policy level, 0.0293 (=175 trillion won) considering some variables that are combined each other. This result give us many conclusions to be explained.

1. The present amount of quantitative easing is not enough. After the 40 trillion won 2014, several added easing is implemented. But this easing is short of the optimal level. If this easing is a policy not to consider the industry led policy but to pull the demand, it can be inefficient and just increases the price index. Because it is possible not to be invested into firm, but to be pocketed. If the GDP can be increased and the industry's development can be led through the rational control and public investment of the eased money, the more easing is needed.
2. The policy to stimulate domestic demand can increase the import and cause the worsening of trade balance. But the quantitative easing policy with industry-led growth can lower the price of the

import-goods, that is to strengthen international competition power. It will bring about the betterment of trade balance. Furthermore it will promote respective competition of partner countries in the international trade.

3. It will create the job. This time is regarded as the time of the turning point of economic change. Many mass media report the future and environment industries. It means human being is standing in front of the new life style and new life standard, so that we need new working force that is fit for those and can create the new thing for future. The public investment through the quantitative easing can dominate the market in this area in advance.

As a result, the optimal level of quantitative easing is not the final level in a situation. It hangs on the efficiency of governmental policy. Some years ago, Korea was a country of the fast growing countries. If Korea can overcome the slow growth through the more quantitative easing, the expansion of the optimal quantitative easing level can be preferable.

| References |

Ahn, Y. C. and C. Kim (2013). "A Nonlinear Simultaneous Equations Model Analysis on the Effect of Yuan Revaluation on Korea's Trade Balance." *Korea Trade Review.* Vol. 38. No. 2, pp. 369-389.

Ahn, Y. C. and K. Lee (2014). "The Study on the Effect of the Japan's Reflation on Korea's Economy." *Northeast Asian Economic Research.* Vol. 26. No. 1, pp. 233-259.

Akkermans, H. A. (1995). "Developing a logistics strategy through participative business modeling." *International Journal of Operations & Production Management.* Vol. 15. No. 11, pp. 100-112.

Angerhofer, B. J. and M. C. Angelides (2000). "System Dynamics Modelling in supply Chain Management: Research Review." J. A. Joines, R. R. Barton, K. Kang and P. A. Fishwick (ed.). *Proceeding of the 2000 Winter simulation Conference,* pp. 342-351.

Bernanke, B. S., G. Mark and G. Simon (1999). "The financial Accelerator in a quantitative business cycle framework." J. B. Taylor and M. Woodford (ed.). *Handbook of Macroeconomics.* Vol. 1, pp. 1341-1393.

Fisher, I. (1911). "The Equation of Exchange, 1896-1910." *The American Economic Review.* Vol. 1. No. 2, pp. 296-305.

_____ (1935). "Stabilised Money: A History of the Money." London: George Allen & Unwin LTD.

Forrester, J. W. (1958). "Industrial Dynamics: A Major Breakthrough for Decision Makers." *Harvard Business Review.* Vol. 36. No. 4, pp. 37-66.

_____ (1968). "Industrial Dynamics-After the First Decade." *Management Science.* Vol. 14. No. 7, pp. 398-415.

Monissen, G. H. (1999). "Monetary Policy and Monetary Reform: Irving Fisher's Contributions to Monetary Macroeconomics." *Wuerzburg Economics Papers.* No. 11, pp. 81-107.

Radulescu, D. and M. Stimmelmayr (2010). "The impact of the 2008 German corporate tax reform: A dynamic CGE analysis." *Economic Modeling.* Vol. 27, pp. 454-467.

Schmitt-Grohé, S. and M. Uribe (2004). "Solving dynamic general equilibrium models using a second-order approximation to the policy function."

Journal of Economic Dynamics and control. Vol. 28, pp. 755-775.

Scott, Summer (1990). "Price-Level Stability, Price Flexibility, and Fisher's business Cycle Model." *Cato Journal.* Vol. 9. No. 3, pp. 719-727.

Sterman, J. D. (1985). "A Behavioral Model of the Economic Long Wave." *Journal of Economic Behavior and Organization.* Vol. 6, pp. 17-53.

_____ (1989). "Modeling Managerial Behavior: Misperceptions of Feedback in a Dynamic decision Making Experiment." *Management Science,* Vol. 35. No. 3, pp. 321-339.

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국문초록
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시스템 동학기법을 이용한 피셔 방정식의 한국 개방경제에 대한 적용

안영철
(부산대학교 무역학부)
이갑수
(부산대학교 무역학부)

본 연구의 목적은 경제위기 극복을 위하여 양적 완화의 최적수준을 찾는 것이다. 양적 완화 정책을 한국 경제에 적용하기 위하여 한국 경제의 현재 상태를 진단한다. 또한 정책의 동태적 적용을 위하여 이론적으로 피셔의 교환방정식을 이용하고 기술적으로는 시스템 동학기법을 사용한다.

이러한 목적에 부합하기 위하여 해야 할 일은 피셔방정식 결정변수들의 추세 방정식을 찾는 것이며 이 방정식들의 결합을 통해서 비선형 연립방정식을 구성하는 것이다.

양적 완화는 자연적 완화와 정치적 완화로 나뉘어진다. 정치적 완화는 실질 자산 시장의 경기 부양 정책을 위하여 반드시 필요한 것은 아니지만 산업성장을 야기할 수 있는 무역수지의 개선을 위하여 중요한 의미를 가질 수 있다. 시뮬레이션과 통계분석을 위하여 변수들의 로그로 전환된 방정식들이 사용된다. 통화확대의 최적수준을 계산한 뒤, 로그값들은 실제값으로 전환된다.

한국 경제는 국제 경제에 있어서 작고 한국의 통화정책이 무역수지에 미치는 효과는 적지 않다. 따라서 한국의 통화정책은 수출지향적 경제에서 산업성장을 이끌 수 있다. 또한 한국의 무역수지를 개선시킴으로써 한국경제에서 금융위기를 해결할 수 있는 대안이 될 수 있다.

▪ 주제어: 양적 완화, 피셔 교환방정식, 시스템 동학, 무역수지, 먼델-토빈 효과