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Analysis of Impulse Response Function according to the Equilibrium Relationship between Production and Exchange Rates

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Abstract. The South Korean economy is heavily reliant on exports since resources are scarce; the majority of crude oil and raw materials are imported from other nations. As a result, exchange rate fluctuations have a significant influence on both the domestic economy and foreign shocks. In particular, in the case of manufacturing, an increase in the exchange rate can weaken the external price competitiveness of exports, so exporting companies are required to prepare various countermeasures such as short-term price adjustments and long-term cost reductions. In this regard, it is very important to understand the equilibrium level of production and exchange rate. Therefore, in this context, the purpose of this study is to analyze the equilibrium relationship between production and exchange rates by industry in the manufacturing industry, which is South Korea’s largest industry. For the analysis, data from the National Statistical Portal of Statistics Korea's "mining industry output index by industry" and the Bank of Korea's economic statistics system's "won/dollar (close price)" were retrieved from January 2000 to December 2018. In the analysis, the Impulse response function model based on the equilibrium exchange rate theory of Lucas (1982) is used.

As a result of the analysis, the existence of a long-run equilibrium relationship between exchange rates and production was different for each industry. It can be understood that the reason for this difference in existence is related to the structure of the industry. There are practical implications in that these findings may be given as an empirical basis for decision-making such as the government's monetary policy, as well as a foundation for scientific responses to exchange rate fluctuations for manufacturing operators.

Keywords: Equilibrium exchange rate, impulse-response function, granger causal test, nominal exchange rates, real exchange rates, production

1. Introduction

The purpose of this study is to discover how the manufacturing industry, Korea's largest industry, has an equilibrium relationship between production and exchange rates. An equilibrium relationship refers to a state in which profits of all companies in the full competition market are zero, no longer resulting in the entry and departure of companies.

In order to establish these conditions, the margin must be zero, and demand and supply must be equal. If excess profit occurs in the balanced state, the adjustment process to the balance occurs.

In other words, in order to obtain excess profits, new companies will enter, and existing companies will expand their facilities. This increase in production (increase in supply) results in a drop in market prices and results in a gradual shift to a balanced relationship due to no excess profit.

Furthermore, losses other than excess profits cause existing companies to leave or downsize their facilities, resulting in lower supply and higher market pricing. Through this adjustment process, it can be said that it is through the coordination process in a balanced relationship that each company receives only normal profits. In order to achieve the purpose of the research, the following research topics were established and verified. The impulse response function is used to analyze how the balance between production and exchange rates is achieved.

In general, according to existing theories, it is argued that production and exchange rates are in long-term equilibrium. These arguments are analyzed by how (depending on correlation) the adjustment process for the balanced relationship changes (by correlation) and how long the adjustment process takes place through the impulse response function that has been widely used in previous studies.

2. The Concepts and Classification System of Manufacturing Industries

Manufacturing is an industrial activity that uses physical or chemical operations to convert raw materials made up of materials or components into new products. The importance of manufacturing can be found in terms of strengthening the stability of the economy. As evidenced by the financial crisis that occurred in late 2000, the manufacturing powerhouse showed a strong side to external shocks, and even if the service economy intensifies, national economic development cannot be expected without a solid manufacturing base.

Korea's economic growth has been driven by manufacturing, and it continues to be dependent on manufacturing, despite considerable service economization.

The Korean Standard Industrial Classification is a systematic classification of industrial activities performed by production units according to similar characteristics by the National Statistical Office.

According to the 10th Korean Standard Industry Classification revised in June 2017, the nation's industries are classified as agriculture, forestry and fisheries (A), mining (B), manufacturing (C), electricity, gas, steam and air conditioning (D), water, sewage and waste disposal, raw material regeneration (E), construction (F), wholesale and retail (G), transportation and storage (H) and lodging (J) and restaurants (Information and lodging).It is divided into S-up (S), in-house employment activities, in-house consumption production activities (T), and international and foreign institutions (U). Manufacturing, the main subjects of this study, are food (10), beverages (11), cigarettes (12), textile products (13), clothing, accessories and fur products (14), leather, bags, and shoes (15), wood and wood products (16), pulp, paper and paper products (17), printing and paper products (18, coal refining), and petroleum products and cox.

3. Exchange Rate Theory and Pre-Study

3.1. Balanced exchange rate theory

There are many theories about exchange rates. However, the theory that explains production and exchange rates focuses on the equilibrium exchange rate model, which Lucas claims. Methodologically, Lucas developed dynamic, stochastic, general equilibrium models to analyze economic decision-makers operating through time in a complex, probabilistic environment.

A flexible exchange rate model with different trade goods and real impact between nations can be considered as an expanded model or generalized model of an equilibrium exchange rate model.

Lucas proposed a more general exchange rate model by replacing the money demand function with the monetary and cash constraint assumptions within the utility function.

The basic framework of the theory of balanced exchange rates is like finding an optimal point of consumption in microeconomic theory. Important assumptions of this model are as follows.

First and foremost, there are two countries, one that produces just X-goods and the other that produces only Y-goods. Consumers in both countries share the same wealth and trade with one another, and there are no trade barriers.

Under these circumstances, consumers in each country will determine the consumption of X and Y goods, which can bring maximum utility, and goods not produced in their own countries will be consumed through trade. The relative price between the two goods (the relative value of the foreign commodity Y material expressed as the X material of its own product), i.e., the real exchange rate, is determined by the preference of consumers. For example, if consumers prefer X goods, the price of X goods will rise relatively and the relative price will fall. On the contrary, if consumers prefer foreign goods relatively, the price of Y goods will rise relatively and the relative price will rise. Hence, the model was developed to represent the nominal exchange rate that resembles the monetarism model in appearance.

The nominal exchange rate can be represented by introducing demand and supply for money into the model, which is represented by a combination of relative monetary volume, relative monetary demand, and real exchange rates. The effect of money volume or demand for money on the exchange rate is comparable to the result of the monetarism model.

For example, an increase in the amount of local currency, as in the monetary stock model, causes an excess supply of local currency, raising the price of other currencies and thus raising the nominal exchange rate, whereas an increase in real demand for local currency causes excess demand for local currency, causing the nominal exchange rate to fall. However, the effect on the nominal exchange rate of the relative price, or real exchange rate, differentiates the balancing theory from the monetarism model. Unlike the monetarism model, a change in the real exchange rate results in a change in the nominal exchange rate. In other words, if the relative price changes for some reason, the nominal exchange rate changes accordingly.

For example, the production of domestic product X has increased dramatically through technological innovation. The relative increase in the supply of domestic products compared to other countries' products will lead to an increase in the price of foreign products and thus the nominal exchange rate will rise in nominal exchange rates. If domestic products fall relatively, domestic and foreign consumers' consumption of domestic products will increase, thereby boosting exports of domestic products. In other words, the Lucas (1982) equilibrium model suggests that exchange rates have an equilibrium relationship with currency volume and industrial output. Therefore, this study wants to analyze the existence of an equilibrium relationship between exchange rates and production in the manufacturing sector.

3.2. Exchange rate flow path

The effect of exchange rate fluctuations on production is explained in terms of supply and demand. A firm's production is determined by how efficiently the factors of production are used in addition to the amount of labor, capital stock, and input of intermediate goods, which are one of the factors of production. If the exchange rate rises, the price of imported raw materials will inevitably arise. An increase in the price of imported raw materials is rippled by an increase in the cost of production factors. This process reduces the factor input in production, resulting in a decrease in total supply.

On the other hand, if the scale of production expands and profits increase due to the increase in exports, the supply capacity of production expands, and consequently the total supply increases. When the exchange rate rises, if the exporting company receives the export payment in international currency, the profit converted into the domestic currency, that is, the foreign exchange profit, can have a positive effect on the operation of the company.

However, if the exchange rate rises, the price of imported raw materials and technology introduction costs will rise, which is likely to reduce corporate investment and increase the economic burden on new companies. In this case, as the company builds a stable profit structure, the R&D investment cost and the motivation for technological innovation can be reduced. In addition, as the exit of marginal firms is delayed due to temporary profitability improvement, productivity may decrease in the long run.

In other words, in the case of a company that inputs a lot of intermediate goods or raw materials in the production process, an increase in the exchange rate leads to an increase in costs, which may result in a decrease in profits and a decrease in the company's investment. As such, an increase or decrease in the exchange rate affects the production and profit of a company, so an empirical analysis is needed.

Such studies have been carried out for a long time, Harris, Richard G.(2001), Chang, dongku, Choi, yeongjun (2005), Byung-chang Lee (2006), Sylviane Guillaumont Jeanneney and Ping Hua (2006), Robert Dekle and Kyoji Fukao(2009), Kwon, SunHee (2013) and Lee, Woong-Ho (2016 studies are representative.

Harris (2001) analyzed the effects of exchange rate fluctuations on productivity through panel data of 18 industries in 14 OECD countries from 1970 to 1997. As a result, it was shown that, if the exchange rate rises, productivity can be increased in the short term, but productivity can be decreased in the long term. Also, Harris (2001) analyzed that the widening of the productivity gap between Canada and the US in the 1990s caused the Canadian dollar exchange rate to remain high against the US dollar for a long time, leading to a contraction in investment due to an increase in the price of imported goods.

In the end, the exchange rate rises as a factor to increase the price of imported raw materials, which increases the cost of the company. Therefore, exporting companies try to increase export competitiveness by lowering export prices. On the other hand, if the exchange rate falls, manufacturers with a high proportion of exports will try to strengthen their export competitiveness through productivity improvement. The relationship between exchange rate and production was investigated by Dong-gu Jang and Young-jun Choi in 2005 using the model of the non-tradable goods to examine “the asymmetric effect of an increase in the exchange rate on the traded and non-traded goods sectors” in the free open economic environment after the financial crisis in 2008.

As a result of the analysis, after the subprime crisis, the rise in the exchange rate led to an increase in the relative prices of traded goods.

Hence, it was suggested that this acted favorably on the trade goods sector along with the rapid liberalization after 2008, causing a sharp increase in the production of trade goods and weak production and demand for non-traded goods (Chang et al., 2005). In other words, it has been suggested that an increase in the exchange rate increases the production of traded goods and decreases consumption, while decreasing the production and increasing consumption of non-traded goods.

The effects of exchange rate fluctuations can be divided into positive and negative effects. As for the positive effect, an increase in the exchange rate leads to an increase in exports, which leads to an increase in aggregate demand and an increase in production. In addition, productivity may increase due to technological improvements in the process of expanding production as demand increases. On the other hand, higher exchange rates may have a negative effect of increasing raw material prices and component costs, resulting in reduced component input and thus decreased production. Moreover, importing capital goods will lead to a drop in investment, which will also serve as a factor in the production cut.

In 2006, Lee Byung-chang's study focused on the phenomenon of improvement in labor productivity in the manufacturing industry, while the nominal exchange rate of the won and dollar has generally been on the decline since the subprime crisis. Therefore, using panel data from19 industries in the manufacturing industry for the period 1993 to 2003, the effects of long-term fluctuations in exchange rates on productivity were analyzed. As a result, before the financial crisis, the effect of exchange rate fluctuations on productivity was insignificant. However, after the sub-prime crisis, the long-term and short-term trends were opposite. In the short term, it increases productivity, but in the long term, it decreases productivity (Lee 2006).

Sylviane Guillaumont Jeanneney and Ping Hua (2006) used productivity data from 29 Chinese provinces from 1993 to 2001 to examine the influence of exchange rate levels on productivity.

As a result, the exchange rate appreciation improved the efficiency of technology utilization in the long run. However, it was suggested that slowing technological progress, it may act as a constraint on productivity growth (Sylviane et al., 2006). Robert Dekle and Kyoji Fukao (2009) were to try to better understand the relationships among Japanese productivity growth, the Japan-U.S. real exchange rate, and long-run economic outcomes, such as Japanese employment. They made the following conclusions. As the yen appreciated starting in 1985, Japanese “competitiveness”--defined as the ratio of U.S. average costs to Japanese average costs—sharply declined. However, the decline in Japanese competitiveness differed among industries. In industries where Japanese productivity growth was relatively high, the decline in Japanese competitiveness was much smaller. A comparison of the actual real exchange rate with this paper’s long-run equilibrium benchmark shows that the Japanese real exchange rate was near equilibrium in 2003, when the nominal yen-dollar exchange rate was around 120 yen to the dollar (Dekle et al., 2009). The recent rapid appreciation of the yen to below 90 yen to the dollar, owing to the Global Financial Crisis is thus clearly excessive, and has resulted in large profit and employment losses for Japanese manufacturers. They suggested that a return of the yen-dollar rate to above 120 should help restore profitability to Japanese manufacturers. Finally, it was concluded that exporting companies have doubled their efforts to improve productivity in order to reduce production costs, as the productivity of exporting companies deteriorated due to the increase in the yen-dollar exchange rate.

In 2013, Kwon, Sun-Hee conducted a study comparable to that of Robert Dekle and Kyoji Fukao (2009). Kwon, Sun-Hee (2013) used yearly data from 1970 to 2007 to perform a panel analysis on the effect of exchange rate fluctuations on productivity, focusing on the manufacturing industry, which is sensitive to imports and exports. In addition, as the industry was divided into domestic and export industries, it was examined how sensitive each industry's productivity was to changes in the exchange rate. Then, it was checked whether the influence of the exchange rate on production cost and Total Factor Productivity (TFP) changed by classifying it into the pre-crisis period and the entire period. As a result of the analysis, it was suggested that if the exchange rate falls, there will be an effect of reducing production costs, but this will act as a factor that puts pressure on the profitability of the company.

In this situation, it was found that firms increase total factor productivity as a self-help measure for cost reduction. In addition, as a result of analyzing the domestic demand industry and the export industry, it was suggested that the domestic industry is less sensitive to the volatility of the exchange rate than the export industry. On the other hand, as a result of analyzing the relationship between productivity and industry concentration, it was suggested that if the market concentration of an industry increases, companies do not try to improve productivity. It was also suggested that one of the important ways for a company to maintain profitability in the face of such exchange rate changes is to focus on technological improvement (Kwon 2013). In fact, it has been suggested that exchange rate changes have a significant effect on the productivity of traded and nontraded goods.

Exchange rate fluctuations have a positive (+) effect on production cost and a negative (-) effect on productivity, these contents were suggested to be consistent with economic theory and conclusions of previous studies. The exchange rate affects the productivity of the domestic manufacturing industry because exchange rate changes have a substantial impact on the external competitiveness of domestic companies. Therefore, if domestic companies improve total factor productivity through technological advances, they will be able to see the effect of reducing production costs in preparation for exchange rate fluctuations. If each industry does not spare an investment in technological innovation such as management technology, R&D, the introduction of new technology, and information technology, this will also help to improve productivity.

Therefore, it was suggested that since there is a limit to stabilizing the exchange rate through monetary policy due to the opening of the capital market, it is necessary to focus on improving the productivity of each industry.

In 2016, Lee, Woong-Ho classified the ripple effect of exchange rate fluctuations into 8 industrial groups according to the size of the direct rate of return, indirect rate of return, and the forward chain effect index, and analyzed the characteristics of each industry group. As a result of the analysis, in the analysis of the ripple effect on the manufacturing industry in South Korea due to exchange rate fluctuations, the industries with a direct rate of return of less than 10% were the printing and recording media reproduction industry (18), the metal processing product manufacturing industry (25), the furniture manufacturing industry (32), and the other manufacturing industry (33) had very few factors of price fluctuations in response to exchange rate fluctuations (Lee 2016). However, the industry in the manufacturing of coke, briquettes, and petroleum refineries (19) has a rate of return of over 70%, suggesting that price fluctuations are large according to exchange rate fluctuations. In addition, it was suggested that more policy considerations are needed in industries with a large ripple effect through this industry-related analysis.

The preceding studies have shown that exchange rate fluctuations can affect productivity through several channels. However, in the case of the domestic economy, it is difficult to find an analysis of the effect of exchange rate fluctuations on total factor productivity in the manufacturing industry. Also, it is not well known how the structure and characteristics of the market, such as the degree of foreign dependence on of the manufacturing industry or the concentration of industries, change these relationships. Therefore, the relationship between exchange rates and corporate productivity is an interesting research project both theoretically and empirically. In theory, productivity is an important factor that determines the competitiveness of the nation's economy, by extension, businesses, and industries. Given that increasing productivity means reducing costs and increasing production, companies focus on developing technologies through education and R&D investments to increase the productivity of human and physical capital. From a long-term perspective, technological development is the deciding factor driving economic growth.

4. Research Design

4.1. Collecting data

This study retrieved and evaluated the "Industrial Mining Industry Production Index" from the National Statistical Portal's survey on mining and manufacturing trends, as well as the "won/dollar (end price)" of the Bank of Korea's economic statistics system, from January 2000 to December 2018.

A sample of total time series data was obtained by classifying the 10th Korean Standard Industry Classification Table. Finally, since the data in this study are monthly data, it is analyzed after conducting a seasonal adjustment (X12- ARIMA).

4.2. Research model

4.2.1. Unit root test

In the case of unusual time series data with unit muscles, cumulative random shocks have a lasting effect on the prediction. Therefore, the stability of the time series data should be verified and the normality of the time series 2 data should be ensured through the near-unit test to solve these problems. A Dicky Fuller (DF) test is typical of the verification methods to ensure the stability of time series data. If the unit root is an abnormal time series variable, the DF test should be performed because the stability test needs to be used to analyze the presence of the variable's normality, since it affects the future cumulative impact of the impact. The DF test is a way to verify that the regression coefficients for and are equal to 1. However, since there are possibilities and intercepts of a linear trend, we would like to set up a model through the following expression process.

$$H_0 : \rho = 1$$

$$H_a : |\rho| < 1 \tag{1}$$

$$y_t = py_{t-1} + \varepsilon_t \tag{2}$$

$$y_t = a + py_{t-1} + \varepsilon_t \tag{3}$$

$$y_t = a + \gamma_t + py_{t-1} + \varepsilon_t \tag{4}$$

Through the process of the above formula, the statistics for the test shall be according to $\gamma = \frac{\widehat{\rho}}{se(\widehat{\rho})}$, and the above four process formulas shall be modified to the following formula for convenience.

$$\Delta y_t = (p-1)y_{t-1} + \varepsilon_t \tag{5}$$

$$\Delta y_t = a + (p-1)y_{t-1} + \varepsilon_t \tag{6}$$

$$\Delta y_t = a + \gamma_t + (p-1)y_{t-1} + \varepsilon_t \tag{7}$$

Referring to formula 1 above, the null hypothesis follows $H_0 : \rho = 1$.
In addition, a DF test ($H_a : |\rho| < 1$) is performed on the basis of Equation 7 to analyze which of the above formula models is appropriate. The test statistics for conducting the DF test follow the $\gamma = \frac{\widehat{\rho}}{se(\widehat{\rho})}$ formula presented earlier and can be used to determine which model is appropriate by using the formula of $H_0 : \alpha = 0$, a significance test for the constant term. The DF test determines that the time series variable follows autoregressive (AR) and sets the assumption for the error term ε_t to be independent of each other and have the same variance. However, the appropriateness of DF verification can be distorted because ε_t , which is mostly a residual term, and has a self-correlation. Therefore, each of the three models for the DF test is calm, and the analysis is performed by adding y_{t-1} , $i = 1, ..., p$. Many analyses use this method because the test statistics for added formulas have the effect of eliminating autocorrelations.

This method is called the Augmented Dicky Fuller (ADF) test. The ADF test can test whether a time series variable has safety, and the test statistic follows $\hat{T}$. The ADF test also performs a test on the $H_0 : \rho = 1$(time series variables have unit roots) to analyze whether a variable exists unit-roots.

These ADF models are as follows.

$$\Delta y_t = (p-1)y_{t-1} + \sum_{i=1}^{p} \delta_t \Delta y_{t-1} + \varepsilon_t \quad (8)$$

$$\Delta y_t = a + (p-1)y_{t-1} + \sum_{i=1}^{p} \delta_t \Delta y_{t-1} + \varepsilon_t \quad (9)$$

$$\Delta y_t = a + \gamma_t + (p-1)y_{t-1} + \sum_{i=1}^{p} \delta_t \Delta y_{t-1} + \varepsilon_t \quad (10)$$

It is analyzed that the unit root does not exist if the unit root exists by proceeding with the above ADF verification and the DF verification at the same time, and the unit root does not exist if the result is not significant. If the unit muscle does not exist, the vector return model (VAR) is used because it is not necessary to analyze whether it is a long-term balancing relationship as a variable in a stable time series. However, analysis is performed using the Vector Error Modification Model (VECM) because the existence of unit root is an unstable time series variable and long-term equilibrium should be considered.

4.2.2. Granger causal model

Granger causal tests are a method of estimating the antecedent between each variable in the VAR and VECM models by analyzing if the values of the coefficients utilized by each variable are all zero.

Granger causal tests, one of the methods for these estimates, are a relatively simple test method using F-statistics and are used in many prior studies. These tests perform regression analysis by separating the two variables into dependent and explanatory variables and intersecting the positive variables. It tests whether there is a correlation or predictive power between the two variables. If the two variables are highly correlated with each other and autocorrelations exist in the dependent variable, the other variables may be judged equally, even if the historical time series values of one variable can account for the current value. Therefore, a Granger causal test should be performed to perform an analysis of both variables' historical time series values. The formula for Granger causal test is as follows. The above formula is the basic formula for Granger's causality test and tests whether $\beta_1 = \beta_2 = \cdots = \beta_p \equiv 0$.

$$y_t = a_0 + a_1 y_{t-1} + \cdots + a_p y_{t-p} + \beta_1 x_{t-1} + \cdots + \beta_p x_{t-p} + \varepsilon_t \quad (11)$$

$$x_t = a_0 + a_1 x_{t-1} + \cdots + a_p x_{t-p} + \beta_1 y_{t-1} + \cdots + \beta_p y_{t-p} + \mu_t \quad (12)$$

The Granger causality test analyzes the antecedent and trailing relationships of each variable. However, since they cannot analyze the effect on each other, the magnitude of the effect on each other can be analyzed using the impulse function. The impulse function is analyzed based on the above formulas <Equation 11> and <Equation 12>, and when a unit of shock occurs to one variable, the response of the other variable is examined. Therefore, the effect of one variable on another variable can be dynamically identified. The above formula is the basic formula for the Granger causal test and is tested for $\beta_1 = \beta_2 =\cdots= \beta_p \equiv 0$. Granger causal tests are to analyze the leading and trailing relationships of each variable, but since they cannot be analyzed for their effects on each other, the magnitude of their effects on each other can be analyzed using the Impulse function. The impulse response function is based on the above equations <Equation 11 and Equation 12>, and when a unit of impact occurs on one variable, the response of another variable can be examined dynamically to determine the effect of one variable on the other.

5. Empirical Analysis

5.1. Basic analysis

5.1.1. Basic statistics

Table 1 shows the results of a basic statistical analysis of the exchange rate and the growth rate of the industry's production index for each manufacturing sector. Since the time series data are from January 2000 to December 2018, the number of observations is 228 per variable.

Table 1: Basic statistics

Sortation	Average	Median	Max	Min	Dispersion	Standard deviation	OBS
EX	0.0004	-0.0033	0.1359	-0.1405	0.0009	0.0304	228
C10	0.0025	0.0031	0.1826	-0.1934	0.0024	0.0490	228
C11	0.0064	0.0000	0.5506	-0.3932	0.0130	0.1141	228
C12	-0.0026	-0.0032	0.2248	-0.2101	0.0024	0.0487	228
C13	0.0011	-0.0054	0.1592	-0.1924	0.0035	0.0591	228
C14	-0.0028	-0.0071	0.2744	-0.1737	0.0034	0.0586	228
C15	-0.0028	-0.0075	0.2755	-0.1780	0.0034	0.0581	228
C16	0.0002	0.0011	0.1585	-0.1653	0.0023	0.0474	228
C17	0.0017	0.0018	0.1827	-0.1757	0.0017	0.0410	228
C18	0.0002	-0.0028	0.2035	-0.2047	0.0030	0.0547	228
C19	0.0020	-0.0012	0.1444	-0.1107	0.0013	0.0364	228
C20	0.0032	0.0023	0.0939	-0.1487	0.0007	0.0273	228
C21	0.0058	0.0056	0.1510	-0.1823	0.0021	0.0458	228
C22	0.0025	0.0028	0.2497	-0.2201	0.0024	0.0485	228
C23	0.0029	0.0008	0.1812	-0.2231	0.0028	0.0529	228
C24	0.0024	0.0011	0.2623	-0.1183	0.0014	0.0370	228
C25	0.0019	0.0013	0.1998	-0.2104	0.0025	0.0498	228
C26	0.0097	0.0102	0.2147	-0.2059	0.0018	0.0429	228
C27	0.0045	0.0005	0.2779	-0.1752	0.0039	0.0623	228
C28	0.0035	0.0059	0.1651	-0.1768	0.0021	0.0459	228
C29	0.0048	0.0036	0.1928	-0.2104	0.0025	0.0499	228
C30	0.0098	0.0028	0.5560	-0.3550	0.0140	0.1182	228
C31	0.0031	0.0012	0.2295	-0.2205	0.0047	0.0686	228
C32	0.0023	0.0008	0.4405	-0.2453	0.0051	0.0713	228
C33	-0.0011	-0.0012	0.2494	-0.3305	0.0041	0.0641	228

According to [Table 1], the average production growth rate of the automobile and trailer manufacturing (C30) was the highest at 0.98% and the highest in February 2009 compared to other industries (55.6%). Manufacturing of coke, briquettes, and petroleum refining (C19) recorded the lowest production growth rate (-11.07%) in July 2001.

Industries with large fluctuations were automobile and trailer manufacturing (C30), with a standard deviation of 0.1182.

5.1.2. Unit root test

The results of the Table 2 Unit Root Test showed that all time series variables rejected the null hypothesis that "the time series has unit roots" at a 1% significant level.

In other words, the sample data in this study do not have a unit root, and the data have a stable time series, so long-term equilibrium need not be considered. Therefore, in this study, we do not use the Vector Error Correction Model (VECM) but use the Vector Return Model (VAR) to conduct empirical analysis.

Table 2: Unit root test results

Period	January 2000 to December 2018		
Sortation	ADF T-Statistic	Sortation	ADF T-Statistic
EX	-15.3350***	-	-
C10	-18.9715***	C22	-15.2602***
C11	-14.4904***	C23	-13.7411***
C12	-16.9226***	C24	-21.6785***
C13	-11.7647***	C25	-13.4363***
C14	-15.7382***	C26	-13.8740***
C15	-15.6768***	C27	-26.3430***
C16	-24.0654***	C28	-13.2675***
C17	-16.8946***	C29	-25.7550***
C18	-12.6749***	C30	-13.6399***
C19	-13.5239***	C31	-16.0887***
C20	-19.2149***	C32	-12.2912***
C21	-16.5870***	C33	-13.1253***

*Note: *** is 1% significant*

5.2. Production and exchange rate relationships using impact response function models

The analysis results of the impulse response function show the degree of influence of information flow between exchange rates and regional production. After estimating the Vector Return Model (VAR), the impulse response function is used to examine what changes (response) occur over time when a unit of impact is applied to a variable.

Because the impulse response function may vary depending on how the variables are constructed, we would like to utilize the generalized impulse response function in Pesaran and Shin (1998) to utilize the functionality that is unrestricted in the composition of the variables. Therefore, this analysis examines both the exchange rate and the production index by industry in both directions.

The results of the analysis of the impact response function are presented graphically, where 'Response of A to B' shows how B affects A, showing how A reacts when B changes by one unit. Therefore, this study looks at the reactions between the exchange rate and one unit of the regional production index.

This analysis focuses on the primary metal manufacturing industry (C24), electronic component manufacturing (C26), automobile manufacturing (C30), and food and beverage manufacturing (C11), which are representative industries that affect each other as a result of Granger's relationship verification.

According to Fig. 1, in the analysis of the impulse response function of the primary metal manufacturing industry (C24), the effect of the exchange rate caused a negative (-) reaction after 2 years, and then recovered, showing continuous results after 10 months.

According to Fig. 2, the manufacturing of electronic components, computers, images, sound, and communications equipment (C26) can see a negative (-) response over a period of three months before recovering, resulting in a continuous relationship from 10 months.

According to Fig. 3, it can be seen that the automobile and trailer manufacturing industry (C30) showed a negative (-) response until the 2nd period, changed to a positive (+) during the 4th period, and continued to show a balanced relationship after 10 months.

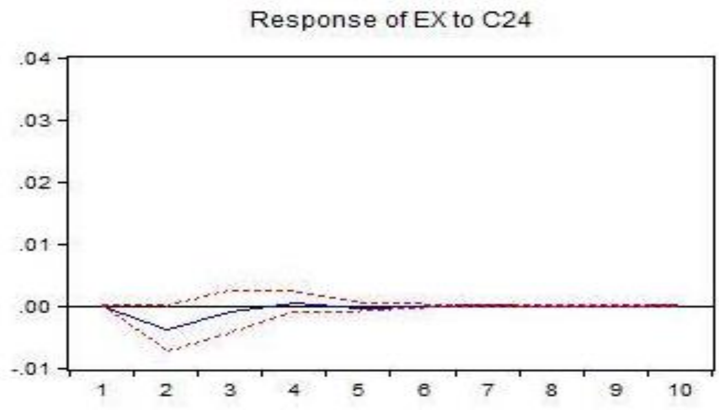

Fig. 1: Analysis of primary metal manufacturing production and shock response function of exchange rate

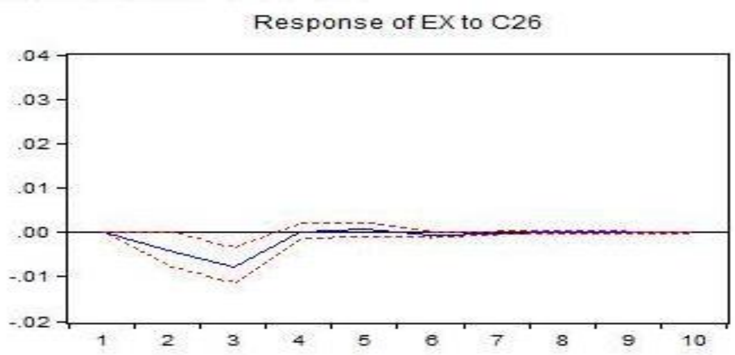

Fig. 2: Analysis of the impulse response function model of electronic component manufacturing and exchange rate

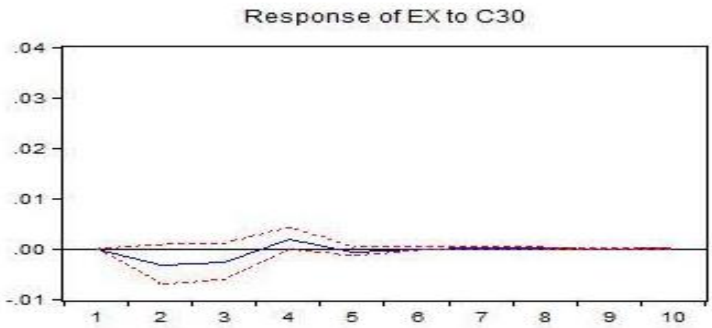

Fig. 3: Analysis of the impulse response function of automobile manufacturing production and exchange rate

According to Fig. 4, among industries where the exchange rate and production do not have a Granger causal relationship, the food manufacturing industry (C10) showed a positive (+) response in three periods after two periods of absence. It can be seen that the trade-off continues to occur after 10 months after it has changed negative (-) in four periods.

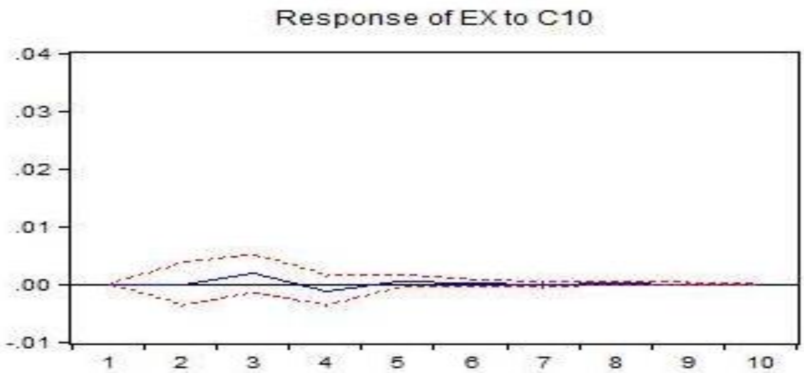

Fig. 4: Analysis of the impulse response function of food manufacturing production and exchange rate

According to Fig. 5, beverage manufacturing (C11) showed a positive response in two periods. It can be seen that the trade-off continues to occur after 10 months after it has changed negative (-) in four periods.

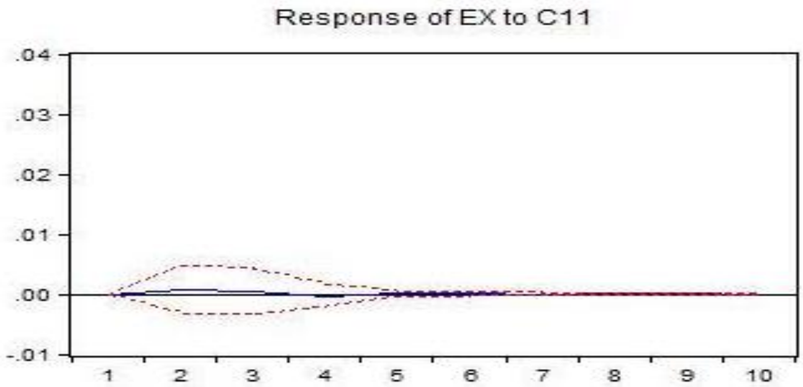

Fig. 5: Analysis of the impulse response function of beverage manufacturing production and exchange rate

Overall, in the shock response function, the exchange rate and production were generally found to be in a balanced relationship after 10 months, and the exchange rate and production were in a long-term balanced relationship.

6. Conclusion

The purpose of this study is to discover how the equilibrium link between the production and exchange rate of Korea's largest industry, manufacturing, exists on an annual and periodic basis. Korea is a country of trade and manufacturing-oriented growth and is sensitive to changes in exchange rates. In other words, changes in exchange rates will result in excess profits or losses for the entity. As a result of these changes in profit margins, the output will also change with the adjustment process of the existing Balanced Relationship. Therefore, the nation's manufacturing industries raised the need to examine whether Lucas is following the theory of exchange rate equilibrium. It also looked at how Korean industry production varies depending on exchange rate changes based on the exchange rate delivery route. While previous studies generally looked at the industry as a whole to see if it conforms to these theories and currency dispersion paths, this study looked at the relationship between exchange rates and production, divided by industry among manufacturing industries according to the trend of industrial structure diversification.

This relationship is based on the impulse response function and the sofa model, and the results are as follows. First, the exchange rate and production differed by industry on whether long-term balanced relationships existed or not. The primary metal manufacturing industry (C24) and the electronic parts manufacturing (C26) were analyzed to have a long-term equilibrium relationship between exchange rates and production, and the automobile manufacturing (C30) was found to exist in part.

Food and beverage manufacturing (C10) and beverage manufacturing (C11) were analyzed to have no long-term equilibrium between exchange rates and production. The reason for this difference in existence can be identified as related to the structure of the industry. Food and beverage manufacturing supported Lee Choong-yeol's claim that "light industry has a weak response to most shocks" since import share was comparatively low, which is not strongly tied to the macroeconomic variable foreign exchange rate.

In general, the short-term balance adjustment process appeared primarily, and it was determined that the short-term adjustment was made as a result of a change in the exchange rate, not a change in production facilities, but a change in pricing as a result of production adjustment. Other primary metals manufacturing (C24) and electronic components manufacturing (C26) were found to control the balance of production and exchange rates through adjustment of production facilities. The long-term balance of automobile manufacturing (C30) has been gradually disappearing due to external factors, but in general, automobile manufacturing has been found to follow the long-term balance in the past. One of the implications of this study is that it attempted to study whether there was a balanced relationship between the existing production and exchange rate theories by year and cycle. In addition, there are academic implications as the previous studies revealed that production and exchange rates exist in a long-term balanced relationship differ from the previous results when analyzing them by industry, and that there are differences in the application of component cost paths among existing exchange rate dispatch routes.

It is believed that practical implications exist in that these studies can provide empirical grounds for the government's decision-making (currency policy, etc.) and in foreign exchange rates can be made to investors investing in the nation's manufacturing sector. The limitation of this study is that the analysis was conducted around the cost of the production element, and the import was not considered due to the export. In other words, it was not possible to explain various spillway routes considering the competitive route among the exchange rate dispatch routes. In addition, existing prior studies argued that there was a public nature in each industry in a large framework. For example, it is necessary to analyze what changes exist between construction and manufacturing. Future research should enhance and continually investigate this.

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