BILATERAL TRADE AND ECONOMIC GROWTH: THE EMPIRICAL EVIDENCE BETWEEN U.S. AND SOUTH KOREA

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Abstract
This paper analyzes the relationships between bilateral trade and economic growth in the U.S. and Korean economies. Using quarterly data from 1990 to 2008, the theoretical procedures utilize Ordinary Least Square (OLS) and Seemingly Unrelated Regression (SUR) models under the static model assumption, an Impulse Response Function (IRF) and Forecast Error Variation Decomposition (FEVD) under the Vector Autoregressive (VAR) model, and Granger causality tests. Empirical results indicate a causal relationship between bilateral export growth and economic growth for the U.S. and Korean economies. The export-led growth (ELG) hypothesis is strongly supported by the results of Granger causality tests on Korean exports.

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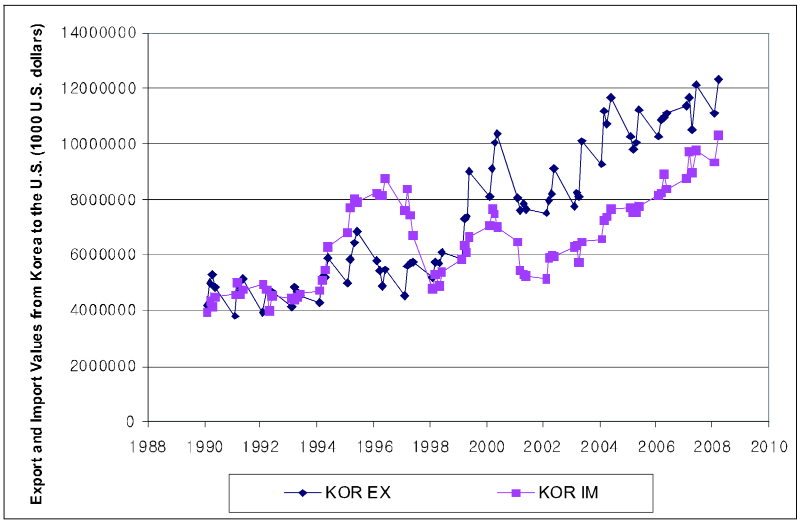
I. Introduction

The relationship between export and economic growth has been the subject of considerable interest in recent years (Feder, 1982). According to the export-led growth (ELG) hypothesis, export activity leads economic growth. That is, exports directly affect the production of goods and services for nations. Another approach to export and economic growth is the growth-driven export (GDE) hypothesis which postulates a reverse relationship and hypothesizes that economic growth itself induces trade flow (Konya, 2006). There is a vast amount of empirical literature on this issue. Almost all of these previous papers are concerned with the relation between total exports and economic growth in developed or developing countries. Based on this literature review, it is apparent that the impact on economic growth of bilateral trade between developed and developing countries has rarely been examined to this point.

South Korea is an example of a nation that followed the development strategy which promotes exports following the cessation of the Korean War (1950－53). During the period from 1953 to 1961, the Korean economy experienced a slow recovery from the war and depended on U.S. assistance. From 1962 to 1966, the "Export First" ideology in South Korea was established in the first Five-Year Economic Development Plan. The effects of this policy played an important role in Korean economic development, averaging an annual real GDP growth rate of 9.2% between 1962 and 1979. Moreover, annual economic growth has been over 7% since the beginning of the 1980s.

In this situation, trade between the United States and South Korea is a vital component in the development of the South Korean economy. Figure 1 and 2 show trends of export and import values from Korea to the United States and South Korea's major trading partners, respectively. The United States is Korea's second largest export market and third largest import market. For the United States, Korea is the seventh largest export market and seventh largest source of imports. In 2005, the United States share of Korean exports and imports were 14.5% and 11.7%, respectively.

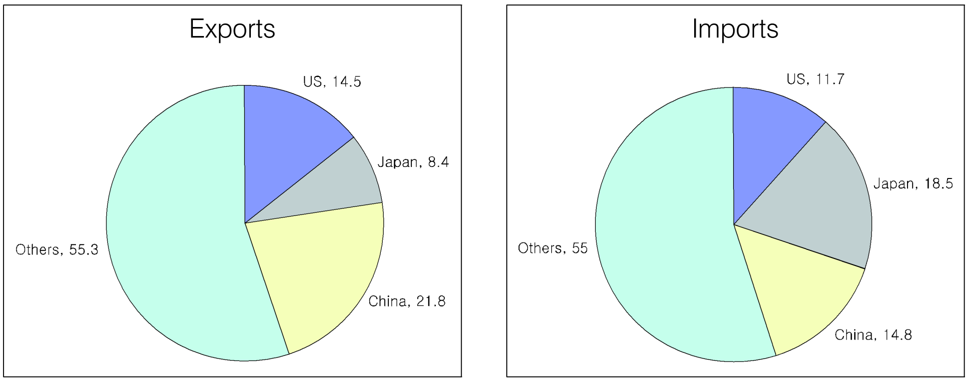
FIGURE 1. Trends of Export and Import Values from Korea to U.S.



Source: www.costoms.go.kr.

Note: KOR EX and KOR IM indicate the export values and import values from Korea to the United States, respectively.

FIGURE 2. Korea's Major Trading Partners, 2005 (in percentages)



Source: www.costoms.go.kr.

Despite Korea's impressive growth record, it remains unclear whether the export promotion policy itself significantly contributed to this success (Hutchison, 1987). Even if the trade dependence between the United States and Korea has decreased since the middle 2000s, bilateral trade between the United States and South Korea is considered to have been a positive factor in both the

U.S. and Korean economies. Based on this, the objective of this paper is to analyze the relationships between bilateral exports and economic growth for both the U.S. and Korean economies. This paper is organized as follows. First, a literature review is conducted. These papers mainly invoked the Granger causality condition with respect to exports and economic growth. Second, the data and methodology are examined and explained, noting especially that the methodologies employed include (a) ordinary least square (OLS) and seemingly unrelated regression (SUR) models using panel data, (b) the unit root test and cointegration for estimated variables, (c) the impulse response function (IRF) and forecast error variance decomposition (FEVD) for the vector autoregressive (VAR) model, and (d) the Granger causality test. Third, empirical results show how bilateral exports have contributed to economic growth in the U.S. and Korean economies and also how the ELG hypothesis is supported by the evidence with respect to theoretical procedures. Finally, the paper concludes with a summary of results and their implications.

II. Review of Literature

A number of studies have been undertaken using the works of Granger (1969), Hsiao (1979), and Sims (1972). These studies tested the causality between export and economic growth but did not examine in a uniform fashion the ELG and GDE hypotheses.

Feder (1982) analyzed the sources of growth for semi-industrialized countries using the period 1964－73. Empirical growth models were used which included non-exports and labor/capital stock. He concluded that economic growth has been generated by increases in the aggregate level of labor and capital, as well as the reallocation of resources.

Sharma and Norris (1991) investigated the causal relationship between growth and exports in five industrialized countries (Germany, Italy, Japan, United Kingdom, and U.S.) using a VAR model. They estimated VAR models which included four variables (output, labor, capital, and exports) from 1960 to 1987. They determined that Germany and Japan are valid candidates that support the ELG hypothesis and that these two countries experienced innovations in factor inputs.

Marin (1992) estimated the causal linkages between exports and productivity for four developed countries (Germany, United Kingdom, U.S., and Japan) based on cointegration and Granger causality. According to his results, world output could be linked to productivity independent of exports with the exception of the United States, which might be an indication of international increasing returns to scale.

Ghartey (1993) tested the causal relationship between exports and economic growth for Taiwan, the United States, and Japan from 1960 to 1990. He selected the optimal lag for the VAR model employed, using Hsiao's procedure which includes the minimization of final prediction error criterion (FPE). He mentioned that Taiwan's case exhibits evidence for "exports causing economic growth," while the United States provides evidence for "economic growth causing exports," and Japan provides evidence for "bilateral feedback between exports and economic growth."

Kwan and Kwok (1995) argued that previous causality studies for exports and economic growth did not clearly distinguish between exogeneity and causality. They also mentioned that causality analysis needs to address the issues of (a) validity and efficiency of existing impact estimates, (b) whether or not export growth helps forecast output growth, and (c) whether the relationship between exports and economic growth is structurally stable. With these concepts, they analyzed the exogeneity and causality between export growth and output growth for the Chinese economy in the period from 1952 to 1985. They found that both export growth and output growth in China are strongly exogenous and Granger causal.

Jin and Yu (1996) re-examined the ELG hypothesis using six expanded variables (exports, economic growth, capital, employment, labor, and production) in a VAR model for the U.S. economy. Instead of using a Granger causality test between export and economic growth, they used the IRF which is based on the moving average representation of the VAR procedure. They found that the IRF results did not appear to support the ELG hypothesis because the U.S. economy has been growing mainly as a result of domestic capital formation independent of growth in exports.

Riezman and Whiteman (1996) attempted to ascertain the evidence for or against the ELG hypothesis including imports in the period 1950–90. They followed the standard methods of detecting ELG using Granger causality tests and applied statistical tools which measure the conditional linear feedback and the FEVD. The FEVD procedure permits investigation of the nature of ELG with a flexible time horizon and provides a tool on how to analyze just how much of the variance of economic growth can be attributed to innovations in export growth.

Shan and Sun (1998, 1999) analyzed a new growth theory where the ELG relationship considers exports, energy input, imports, output, labor, and capital using 1978－1996 Chinese-U.S. time series data. Their results supported bidirectional causality between exports and economic growth in China because the feedback effect was found within the VAR procedure. In addition, Granger causality is found between exports and economic growth in the United States.

Glasure and Lee (1999) examined the ELG hypothesis for Korea in five variables (real GDP, exchange rate, government spending, money supply, and exports) using the VAR procedure and vector error correction (VEC) models for the period from 1973 to 1994. They utilize Granger causality for export growth and economic growth. According to their results, the VEC model detects bilateral causality between export growth and economic growth, while it is not detected through other procedures.

Dawson (2005) investigated the ELG hypothesis including agricultural and non-agricultural exports in less developed countries. In particular, they examined the contribution of agricultural exports to economic growth using Solow's production function. Their results support the ELG hypothesis, and reaffirmed that agricultural exports have an important role to play in the engine of growth in less developed countries.

This paper attempts to analyze the relationship between bilateral exports and economic growth for the U.S. and Korean economy. The theoretical procedures follow the works of Granger (1969), Hsiao (1979), and Sims (1972) with respect to the optimal lag selection for FPE on the VAR model, the IRF and FEVD procedure, and the Granger causality tests.

III. Data and Modeling

1. Data

The data for this analysis are obtained from the U.S. Department of Commerce,

TABLE 1. Descriptive Data

Variables	Observations	Mean	Std	Min	Max
Log(US GDP)	74	9.9546	0.1197	9.7571	10.154
Log(US Consumption)	74	9.7893	0.1289	9.5754	10.0062
Log(US Investment)	74	9.1496	0.14	8.8943	9.3528
Log(US Government)	74	9.2284	0.1163	9.0634	9.4578
Log(US Export)	74	6.8003	0.1099	6.5993	7.015
Log(US Import)	74	6.843	0.1501	6.581	7.09
Log(KOR GDP)	74	8.1235	0.1142	7.9448	8.3528
Log(KOR Consumption)	74	7.9588	0.2199	7.4856	8.2765
Log(KOR Investment)	74	8.144	0.2062	7.695	8.4439
Log(KOR Government)	74	7.8882	0.2899	7.3983	8.9652
Log(KOR Export)	74	6.843	0.1501	6.581	7.09
Log(KOR Import)	74	6.8003	0.1099	6.5993	7.015

TABLE 2. The Definitions of Variables

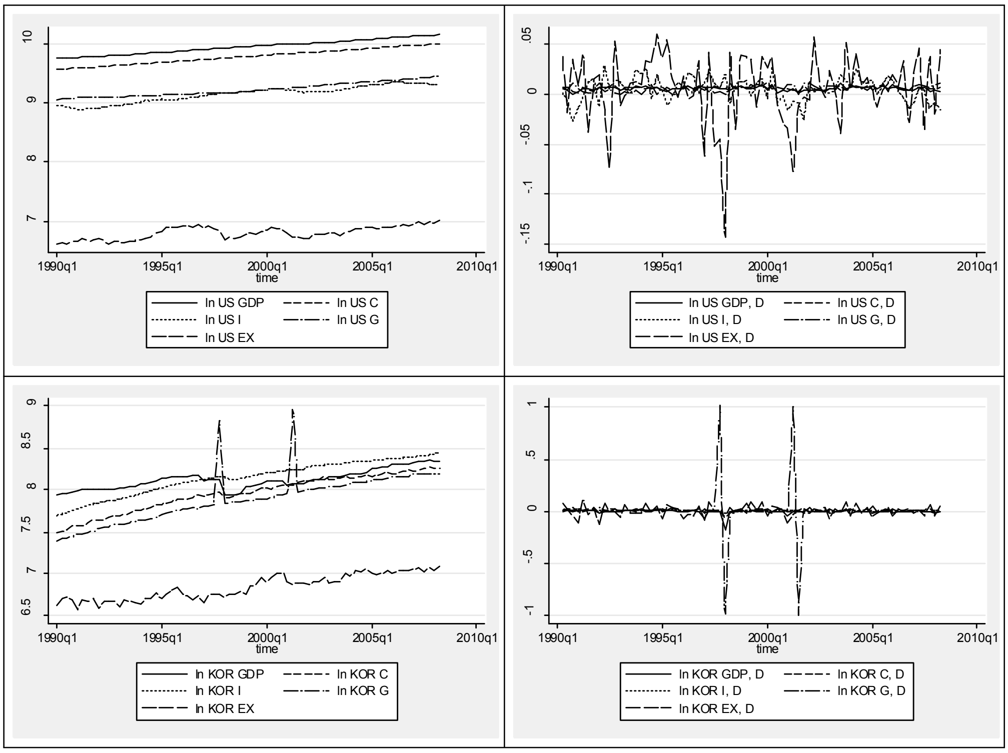
Variables	Definitions
TIME	**Quarterly data from 1990.q1 to 2008.q2**
US GDP	**Real gross domestic product for the U.S (thousand of current U.S. dollars)** Source: U.S. Department of Commerce (Bureau of Economic Analysis)
US C	**Consumption for the U.S. (thousand of current U.S. dollars)** Source: U.S. Department of Commerce (Bureau of Economic Analysis)
US I	**Investment for the U.S. (thousand of current U.S. dollars)** Source: U.S. Department of Commerce (Bureau of Economic Analysis)
US G	**The U.S. government consumption and investment (thousand of current U.S. dollars)** Source: U.S. Department of Commerce (Bureau of Economic Analysis)
US EX	**Total export values from the U.S. to Korea (thousand of current U.S. dollars)** Source: Korea Customs Service (www.customs.go.kr)
US IM	**Total import values from Korea to the U.S. (thousand of current U.S. dollars)** Source: Korea Customs Service (www.customs.go.kr)
KOR GDP	**Real gross domestic product for the U.S (thousand of current U.S. dollars)** Source: Korean Statistical Information Service (www.kosis.kr)
KOR C	**Consumption for the Korea (thousand of current U.S. dollars)** Source: Korean Statistical Information Service (www.kosis.kr)
KOR I	**Investment for the U.S. (thousand of current U.S. dollars)** Source: Korean Statistical Information Service (www.kosis.kr)
KOR G	**The U.S. government consumption and investment (thousand of current U.S. dollars)** Source: Korean Statistical Information Service (www.kosis.kr)
KOR EX	**Total export values from Korea to the U.S (thousand of current U.S. dollars)** Source: Korea Customs Service (www.customs.go.kr)
KOR IM	**Total import values from the U.S to Korea (thousand of current U.S. dollars)** Source: Korea Customs Service (www.customs.go.kr)

Korean Statistical Information Service and the Korean Customs Service and include variables such as real GDP, consumption, domestic investment, government expenditure, and bilateral export/import values. The quarterly data covers the period from the first quarter of 1990 through the second quarter of 2008. The specific explanations and definitions of estimated variables are shown in Tables 1 and 2.

2. Unit Root and Cointegration Tests

The data must be tested for unit roots and cointegration vectors. As shown in Figure 3, neither series appears to be stationary in levels. In addition, they appear to group around a common trend, an indication that they may be cointegrated.

FIGURE 3. Trends of Variables for the Korean Economy



Note: The definitions of variables are the same as Table 2. These graphs are obtained from the selected data of authors.

TABLE 3. Results of Unit Root Test

	ADF in Levels Lag(0)		ADF First Differences Lag(0)	
	Without Trend	With Trend	Without Trend	With Trend
Log(US GDP)	0.0002 (0.11)	−0.0861* (−1.83)	−0.7662*** (−6.54)	−0.7671*** (−6.49)
Log(US C)	0.0004 (0.27)	−0.1408** (−2.41)	−1.1164*** (−9.40)	−1.1181*** (−9.36)
Log(US I)	−0.0114 (−1.08)	−0.027 (−0.63)	−0.7469*** (−6.32)	−0.7547*** (−6.36)
Log(US G) †	−0.0133*** (−4.24)	−0.0058 (−0.31)	−0.8344*** (−6.94)	−1.0543*** (−8.74)
Log(US EX)	−0.0529 (−1.35)	−0.1092* (−1.99)	−1.0461*** (−8.74)	−1.0456*** (−8.67)
Log(US IM)	−0.0572 (−1.40)	−0.4759*** (−4.68)	−1.4239*** (−13.30)	−1.4237*** (−13.22)
Log(KOR GDP)	−0.0203 (−0.71)	−0.0799 (−1.65)	−0.9142*** (−7.68)	−0.9157*** (−7.63)
Log(KOR C) †	−0.0224** (−2.66)	−0.1023** (−2.34)	−0.9852*** (−8.22)	−1.0507*** (−8.73)
Log(KOR I) †	−0.0195*** (−4.83)	−0.0578*** (−2.87)	−0.5394*** (−5.09)	−0.6752*** (−5.76)
Log(KOR G) †	−0.3428*** (−3.92)	−0.9655*** (−8.08)	−1.5001*** (−14.49)	−1.5006*** (−14.40)
Log(KOR EX)	−0.0572 (−1.40)	−0.4759*** (−4.68)	−1.4239*** (−13.30)	−1.4237*** (−13.22)
Log(KOR IM)	−0.0529 (−1.35)	−0.1092* (−1.99)	−1.0461*** (−8.74)	−1.0456*** (−8.67)

Notes: t-values are in parentheses. * indicates 90% confidence level. ** indicates 95% confidence level. *** indicates 99% confidence level. † indicates stationary variables in terms of ADF results

Given the annual nature of the time-series data, it must be pre-tested for stationarity and for the existence of a cointegration vector before we move on to specification of the model. The system equation is then estimated using ordinary least square (OLS). A unit root test is conducted to determine the order of integration of the variables under consideration. The test employed for testing the order of integration is the Augmented Dickey-Fuller (ADF) test. This procedure's results reject the null hypothesis of non-stationary for all variables, when first difference variables are used. Table 3 indicates that the variables are stationary of order 0. In Table 4[1], the results of the Engle-Granger (EG)[2] test, which determines the presence of unit roots among the residuals from regression model, are presented. The null hypothesis of the E-G test is that the residuals are non-stationary. With respect to the results in Table 4, we conclude that the residuals are stationary, which means that the dependent and explanatory variables of each regression model are cointegrated. Also, we can call the estimated equation the static relationship function and interpret these parameters as long-run parameters.[3]

3. Empirical Model for the ELG hypothesis

The first equation specified attempts to determine how bilateral trade contributes to economic growth for both the United States and Korea. To analyze the impacts of trade on GDP, the national income equation (based on macroeconomic theory) is introduced and is specified as

(1) $Y = C + I + G + (EX - IM)$

where Y is GDP, C is consumption, I is investment, G is government expenditure, EX is exports, and IM is imports.

To assess this empirical procedure, the following expanded national income equation using a log-log equation is specified as

(2) $Log(GDP_{it}) = \alpha_0 + \alpha_1 Log(C_{it}) + \alpha_2 Log(I_{it}) + \alpha_3 Log(G_{it}) + \alpha_4 Log(EX_{ijt}) + \alpha_5 Log(IM_{jit}) + \varepsilon_t$

where GDP_{it} is the real GDP for country i in period t; C_{it} is the consumption for country i in period t; I_{it} is the investment for country i in period t G_{it} is the government expenditure for country i in period t EX_{ijt} is the export value from country i to country j in period t IM_{jit} is the import value from

1 See page 18
2 See Engle and Granger (1987)
3 See page 650 in Greene(1990)

country j to country i in period t; and ε_t is the error term.

The objective of this paper is to investigate the causality between the logarithms of bilateral export values and real GDP in the U.S. and Korean economies. Before testing for causality between exports and GDP, a panel data approach, based on the OLS and SUR procedures, is used. The SUR model used herein was developed by Zellner (1962) and is a procedure for analyzing a system of multiple equations. An econometric model may contain multiple equations which are independent of each other on the surface. This approach has two advantages: first, it does not require joint hypotheses for all panel data and allows for contemporaneous correlation; and second, lag structure does not need to be pre-tested (Zellner, 1962).

4. The Impulse Response Function (IRF) and Forecast Error Variance Decomposition (FEVD) for Trade on GDP

The vector autoregressive (VAR) procedure is one of the most successful, flexible, and easy to use models for the analysis of multivariate time series (Greene, 1990, pages 586-590).The main advantage of the VAR model is that one does not need to specify the variables in terms of endogenous and exogenous, since all are endogenous. However, the problem with the VAR model is choosing optimal lag length.

There are several ways to choose the optimal lag length, including the log-likelihood ratio test (LR), Akaike Information Criterion (AIC), Schwartz Criterion (SC), FPE, etc.. Lütkepohl (2006, page 140) mentioned that the LR test is cumbersome and requires a normality assumption for the disturbances. The lag length of the level vector autoregressive system is determined by AIC and SC as follows:

$$AIC = Log\,|W\,| + \frac{\qquad}{T}$$

(3) $$SC = Log\,|W\,| + \frac{N^2 q}{T} Log(T)$$

where W is the estimated residual covariance matrix, N is the number of equations, q is the number of coefficients per equation and T is the sample size.

Another criterion for the optimal lag selection is the FPE by Hsiao (1979 and 1981) and is specified as follows:

$$(4)\quad FPE = \left[\frac{(T+N)}{(T-N)}\right] \times \left[\frac{RSS}{T}\right]$$

where RSS is the residual sum of squares of the equation. Here, the lag length of the VAR procedure is selected by the minimum of the FPE. Suppose p is the optimal lag length of the dependent variable y with the VAR specified as follows:

$$(5)\quad y_t = \sum a_i y_{t-i} + \sum b_j x_{t-j} + \mu_t \quad \forall i \ \ and \ \ j = 1,2,...,p$$

This paper follows Hsiao's method[4] in which the minimum of the FPE and AIC is used to determine the optimal lag length of the VAR model. The export-led growth (ELG) hypothesis is tested using the impulse response function (IRF) and forecast error variance decomposition (FEVD) based on the moving average representation of the vector autoregressive (VAR) procedure (Jin and Yu, 1996). In addition, the bilateral VAR model of lag order p is as follows:

$$(6)\quad x_t = \alpha_{2,t} + \sum_{i=1}^{p} \beta_{2,i} x_{i,t-i} + \sum_{i=1}^{p} \gamma_{2,i} y_{i,t-i} + \varepsilon_{2,i,t}$$

where y is the real GDP in period t, x is the export volume in period t, $_{1,t,t}$ and $_{2,t,t}$ are uncorrelated disturbances.

The IRF shows the effect on the adjustment path of variables, such as trade, on GDP. Another way to analyze the effect of various shocks is through the FEVD. Therefore, if we investigate the relationship between exports and economic growth, the VAR procedure indicates whether exports and economic

4 Hsiao(1979 and 1981) mentioned that 'the FPE criterion balances the risk due to the bias when a lower order is selected and the risk due to the increase of variance when a higher order is selected.' He also noted that 'choosing the order of the lags by minimum FPE is equivalent to applying an approximate F test with varying significance level.'

growth are related; the IRF analysis shows how export and economic growth react to dynamic shocks; and the FEVD procedure gives information about the sources of volatility (Green, 1990, pages 595-605). This paper is based on the VAR of optimal lags for bilateral exports on GDP. We estimate the IRF and the FEVD for the dynamic relationships between bilateral exports and GDP.

5. Testing for Granger Causality

Causality by Granger (1969) is inferred when lagged values of a variable *x* have explanatory power in a regression of a variable y on lagged values of *y* and *x* (Greene, 1990, page.592). To test the causality between bilateral exports and GDP, we perform the Granger causality test by estimating the bilateral VAR procedure. Applying the optimal lag (*p*) in equation (5), we obtain the bilateral VAR as follows:

$$x_t = c_0 + c_1 x_{t-1} + c_2 x_{t-2} + ... + c_p x_{t-p} + d_1 y_{t-1} + d_2 y_{t-2} + ... + d_p y_{t-p} \quad (7)$$

The Granger test is based on the F-statistics[5] for the joint hypothesis and is as follows:

$$H_0 : d_1 = d_2 = ... = d_p = 0 \quad (8)$$

Therefore, the null hypothesis means that *x* does not cause *y* in the first regression of equation (7) and that *y* does not cause *x* in the second regression of equation (8).

[5] Lütkepohl(2006) cites important roles for F-statistics, one of which is that "the asymptotic chi-square distribution is often a poor approximation to the small sample distribution of the causality test. Therefore, an F-version is preferred which is obtained in the usual way by dividing the chi-square statistic by degrees freedom." (page. 320)

IV. Empirical Results

1. Estimation Results of the OLS and SUR for Bilateral Exports to GDP

The purpose of this empirical investigation is to analyze the effects of bilateral exports on economic growth for the U.S. and Korean economies in terms of the ELG hypothesis. We test the causal relationships between bilateral exports and economic growth using the IRF and FEVD procedures, and the Granger causality test. In this section, we analyze the relationship between bilateral exports and economic growth using the OLS and SUR procedures under the static model.

Table 4 shows the estimated results of the equation (2) for the ELG hypothesis under the static model. The results of the first column are based on the dependent variable with the U.S. GDP using the OLS procedure. The effect of exports from the United States to Korea is positive and statistically significant, but inelastic. That is, a one percent change in exports from the United States to Korea increases U.S. economic growth by 0.015%. Also, other factors, such as consumption, investment, and government expenditures, are also positive and statistically significant while the effects of these factors are larger than those of exports from the United States to Korea.

The results of the second column include the dependent variable of Korean GDP in terms of the OLS procedure. The effects of exports from Korea to the United States is also positive and statistically significant, but inelastic. This implies that a one percent increase in Korean exports to the United States increases Korean GDP by 0.164%. Other factors, including consumption, investment, and government expenditures, are also positive and statistically significant.

The results of the third column present results regarding the relationship between bilateral exports and economic growth in the United States and Korea using the SUR procedure. The effects of the explanatory variables exhibit the same results as the previous techniques. Based on the ELG hypothesis, the impact of exports from Korea to the United States are larger than those of exports from the United States to Korea. Even if exports have a positive influence on economic growth in both countries, the impacts of exports are different between the two countries, with Korean exports having more influence on Korean economic growth than that of U.S. exports on U.S. economic growth.

The OLS and SUR results imply that the U.S. and Korean economies exhibit positive correlation between bilateral exports and economic growth. However, the results of both the OLS and SUR procedures do not imply causal relationships but show the static relationships between bilateral exports and economic growth. In the next section, the causal relationships between bilateral exports and economic growth using the VAR model in terms of IRF and FEVD, and the Granger causality test will be examined and discussed.

TABLE 4. Estimated Results of National Income Equation for U.S. and Korea

Explanatory Variables	Dependent Variable (Log(US GDP))		Dependent Variable (Log(KOR GDP))		
	OLS	OLS robust	OLS	OLS robust	SUR
Intercept	0.8488***	0.8488***	2.6283***	2.6283***	1.7165***
	(34.58)	(30.88)	(5.33)	(5.35)	(20.57)
Log(US C)	0.7295***	0.7295***	–	–	0.7219***
	(32.31)	(36.94)			(33.68)
Log(US I)	0.1159***	0.1159***	–	–	0.116***
	(12.07)	(11.88)			(12.75)
Log(US G)	0.1033***	0.1033***	–	–	0.1142***
	(6.23)	(7.24)			(7.26)
Log(US EX)	0.015***	0.015***	–	–	0.0152***
	(5.36)	(5.17)			(5.67)
Log(US IM)	−0.0223***	−0.0223***	–	–	−0.0242***
	(−5.23)	(−5.29)			(−5.96)
Log(KOR C)	–	–	0.9144**	0.9144**	0.8762**
			(2.08)	(2.13)	(2.11)
Log(KOR I)	–	–	0.9169*	0.9169**	0.8886**
			(1.98)	(1.99)	(2.02)
Log(KOR G)	–	–	0.0074	0.0074	0.0143
			(0.20)	(0.41)	(0.41)
Log(KOR EX)	–	–	0.164*	0.164*	0.1691*
			(1.78)	(1.90)	(1.91)
Log(KOR IM)	–	–	0.6621***	0.6621***	0.6641***
			(8.09)	(9.89)	(8.47)
R-squares	0.9998	0.9998	0.8256	0.8256	0.9216
Observations	74	74	74	74	74
Breusch-Pagan	0.81	–	0.23	–	–
	p-value:0.3677		p-value:0.6351		
Engle-Granger	–	−0.3456***(−3.84)	–	−0.2049***(−2.83)	−0.3731***(−4.08)

Notes: t-values are in parentheses. * indicates 90% confidence level. ** indicates 95% confidence level. *** indicates 99% confidence level

2. Results of IRF and FEVD for the VAR Model

Appendix A shows optimal lag length selection for the VAR procedure under the five selection criteria. With respect to the minimum of the FPE and AIC, the VAR models for U.S. consumption determine an optimal lag of 9 quarters, the VAR models for the Korean export and consumption determine an optimal lag of 6 quarters, the VAR models for the Korean government expenditure and U.S. imports determine an optimal lag of 5 quarters, the VAR model for U.S. exports and Korean imports determine an optimal lag of 3 quarters, and the VAR model for U.S. investments, U.S. government expenditures, and Korean investments determine an optimal lag of 2 quarters.

The IRF demonstrates the effect on the adjustment path of the variables. It implies that a one period shock has an impact or dies out. The FEVD shows the effects of various shock based on the decomposition of co-variance matrix of the VAR model (Reizman and Whiteman, 1996). Table 6 illustrates the estimated results of the IRF and the FEVD procedure for relationships between bilateral exports and economic growth based on the VAR model. In the IRF procedure, if values exclude zero, the effects are considered to be significant (Jin and Yu, 1996). The response effects of bilateral exports to GDP are initially positive and significant. Likewise, most of the forecast error variance in GDP is due to changes in bilateral exports. That is, positive shocks of bilateral exports for the U.S. and Korean economies create a positive reaction in their economic growth. Therefore, the IRF and FEVD results appear to support the ELG hypothesis for bilateral export growth and economic growth in the U.S. and Korean economies (See Appendix B).

Lütkepohl (2006, page 66) suggests that we must understand the differences between FEVD and Granger causality, because Granger causality and instantaneous causality are different concepts. Also, he mentioned that Granger causality is the uniquely defined property of two subsets of variables for a given process while FEVD is not unique because it is dependent on the choice of the transformation matrix. Therefore, the interpretation of FEVD is subject to similar constraints as the interpretation of IRF (Lütkepohl, 2006, page 66). In the next section, we explain and analyze the results of Granger causality test for the ELG hypothesis.

TABLE 6. The Results of IRF and FEVD for VAR Model

Steps	US EX ⇒ US GDP		US C ⇒ US GDP		US I ⇒ US GDP		US G ⇒ US GDP		US IM ⇒ US GDP	
	IRF	FEVD	IRF	FEVD	IRF	FEVD	IRF	FEVD	IRF	FEVD
1	0.0071	0	0.8176	0	0.0125	0	0.0471	0	−0.0009	0
2	0.0058	0.006	0.968	0.1006	0.0104	0.0009	0.0614	0.0019	0.0026	0.0001
3	0.0097	0.0054	1.0195	0.1232	0.0089	0.0009	0.0692	0.003	−0.0011	0.0006
4	0.009	0.0076	0.925	0.1417	0.0063	0.0008	0.075	0.0038	−0.0068	0.0005
5	0.0105	0.008	0.7312	0.1441	0.0039	0.0007	0.0802	0.0044	−0.0113	0.0026
6	0.01	0.0089	0.6956	0.1378	0.0015	0.0006	0.0853	0.0049	−0.0117	0.007
7	0.0103	0.0092	0.7084	0.1254	0.0006	0.0005	0.0902	0.0054	−0.0144	0.0102
8	0.0098	0.0095	0.6756	0.1178	0.0028	0.0004	0.0951	0.0059	−0.0165	0.0144

Steps	KOR EX ⇒ KOR GDP		KOR C ⇒ KOR GDP		KOR I ⇒ KOR GDP		KOR G ⇒ KOR GDP		KOR IM ⇒ KOR GDP	
	IRF	FEVD	IRF	FEVD	IRF	FEVD	IRF	FEVD	IRF	FEVD
1	0.0805	0	0.3966	0	0.1821	0	0.0784	0	0.2256	0
2	0.0465	0.0052	0.1502	0.0026	0.1948	0.0006	0.0901	0.1545	0.3291	0.029
3	0.0413	0.0047	0.3788	0.002	0.159	0.0009	0.0743	0.216	0.1723	0.0606
4	0.0963	0.0044	1.003	0.0028	0.1187	0.0009	0.0739	0.2271	0.0668	0.0547
5	0.0971	0.007	1.4741	0.0093	0.0816	0.0009	0.0379	0.2214	−0.0683	0.0451
6	0.1555	0.0091	1.6948	0.0211	0.0478	0.0008	0.0359	0.1998	−0.1854	0.0392
7	0.194	0.0153	1.7982	0.0343	0.0172	0.0008	0.0214	0.1886	−0.3033	0.04
8	0.2773	0.0243	1.8614	0.0477	0.0105	0.0007	0.0093	0.1767	−0.3966	0.0494

Note: ⇒ indicates that first variable is the impulse of the second variable (i.e. "A ⇒ B" implies that A is the impulse and B is the response)

3. Results of Granger Causality Test

Tables 7 and 8 present results of the Granger causality tests, including the null hypothesis that bilateral exports do not impact GDP within the U.S. and Korean economies. Table 7 presents results related to both U.S. and Korean exports, suggesting that the null hypotheses of 'Granger no-causality from these variables to GDP' can be rejected at the level of 5% statistical significant, respectively. This implies that there is Granger causality between bilateral exports and the GDP in both the U.S. and Korean economies.

Even if one were to choose the optimal lag length based on the minimum of FPE and AIC, we estimate the model using the other different lag structures on the VAR procedure because the results are not sensitive to the choice of lag length[6]. Table 7 also shows that the results of the Granger causality test are robust to different lag structures. Table 8 summarizes the results of the Granger causality test based on comparisons of each pair. If we investigate the different lag lengths in the VAR models, we conclude that the ELG hypothesis (a) is strongly supported by the evidence from the Korea economy, and (b) receives little support from the evidence of the U.S. economy. Other relationships, including investment and government expenditure on GDP, have strong evidence for the Granger causality.

TABLE 7. Results of Granger Causality (GC) Test

VAR Lags	Granger Causality Tests									
	US EX → S GDP		US C → S GDP		US I → S GDP		US G → S GDP		US IM → S GDP	
	F-statistics	p-values	F-statistics	p-values	F-statistics	p-values	F-statistics	p-values	F-statistics	p-values
1	2.79*	0.099	2.61	0.11	2.89*	0.093	2.95*	0.090	7.10***	<0.01
2	2.03	0.139	3.73**	0.029	**5.06*** **	**<0.01**	**2.96** **	**0.038**	4.38**	0.016
3	**2.83** **	**0.045**	4.86***	<0.01	6.23***	<0.01	3.78***	<0.01	6.22***	<0.01
4	1.97	0.109	2.34*	0.064	11.96***	<0.01	3.87***	<0.01	3.84***	<0.01
5	2.30*	0.055	0.85	0.519	11.77***	<0.01	3.62***	<0.01	**4.47*** **	**<0.01**
6	2.02*	0.076	0.81	0.563	11.26***	<0.01	5.85***	<0.01	5.99***	<0.01
7	1.83*	0.097	2.16**	0.05	12.35***	<0.01	6.50***	<0.01	5.26***	<0.01
8	2.04*	0.057	4.07***	<0.01	14.16***	<0.01	7.75***	<0.01	5.39***	<0.01
9	2.16**	0.038	**8.07*** **	**<0.01**	11.27***	<0.01	9.14***	<0.01	7.22***	<0.01
10	2.20**	0.032	8.00***	<0.01	9.79***	<0.01	11.46***	<0.01	9.35***	<0.01

6 Pindyck and Rubinfeld (1991, page.217) mentioned that ‘it is best to run the test for a few different lag structures and make sure that the results are not sensitive to the choice of lag length.’ Ghartey (1993) suggests to ‘select a strategy for choosing the optimum number of lags on each other when there is more than one independent variable.’

VAR Lags	Granger Causality Tests									
	KOR EX → OR GDP		KOR C → OR GDP		KOR I → OR GDP		KOR G → OR GDP		KOR IM → OR GDP	
	F-statistics	p-values	F-statistics	p-values	F-statistics	p-values	F-statistics	p-values	F-statistics	p-values
1	2.83*	0.097	3.60*	0.061	4.37**	0.04	8.70***	<0.01	1.79	0.185
2	2.53*	0.087	2.48*	0.091	**4.28****	**0.017**	8.00***	<0.01	2.87*	0.063
3	2.26*	0.089	3.17**	0.03	4.58***	<0.01	7.50***	<0.01	**4.24*****	**<0.01**
4	2.60**	0.044	8.59***	<0.01	4.31***	<0.01	5.83***	<0.01	3.25**	0.017
5	2.58**	0.034	4.45***	<0.01	4.12***	<0.01	**6.85*****	**<0.01**	2.42**	0.046
6	**2.56****	**0.028**	**3.69*****	**<0.01**	4.22***	<0.01	5.41***	<0.01	2.46**	0.033
7	2.46**	0.029	2.75**	0.015	4.33***	<0.01	5.30***	<0.01	2.54**	0.023
8	3.68***	<0.01	3.09***	<0.01	4.88***	<0.01	4.10***	<0.01	3.13***	<0.01
9	3.87***	<0.01	2.92***	<0.01	4.58***	<0.01	3.86***	<0.01	6.26***	<0.01
10	4.53***	<0.01	5.45***	<0.01	7.04***	<0.01	7.55***	<0.01	7.52***	<0.01

Note: → **indicates the Granger causality between two variables** and all variables indicate the value of logarithm. Optimal VAR orders are in parentheses. * indicates 90% confidence level. ** indicates 95% confidence level. *** indicates 99% confidence level. Boldness and underline indicate the optimal lag for VAR model based on the results of Table 4.

TABLE 8. Results of Granger Causality(GC) Test: Comparison of Each Causality Pair

Null Hypotheses	GC Wald test Statistics	p-values	Results
US EX does not Granger cause US GDP	2.83**	0.045	Weak Granger Causality
US C does not Granger cause US GDP	8.07***	<0.01	Weak Granger Causality
US I does not Granger cause US GDP	5.06***	<0.01	Strong Granger Causality
US G does not Granger cause US GDP	2.96**	0.038	Strong Granger Causality
US IM does not Granger cause US GDP	4.47***	<0.01	Strong Granger Causality
KOR EX does not Granger cause KOR GDP	2.56**	0.028	Strong Granger Causality
KOR C does not Granger cause KOR GDP	3.69***	<0.01	Strong Granger Causality
KOR I does not Granger cause KOR GDP	4.28**	0.017	Strong Granger Causality
KOR G does not Granger cause KOR GDP	6.85***	<0.01	Strong Granger Causality
KOR IM does not Granger cause KOR GDP	4.24***	<0.01	Weak Granger Causality

Note: Variable definitions are the same as in Table 2 and all variables indicate the value of logarithm. Strong Granger Causality indicates when F-value is statistically significant at 10% level and also at the all lag ranges. Weak Granger Causality indicates when F-value is statistically significant at 10% level but is not statistically significant at all lag ranges. Optimal VAR orders are in parentheses. * indicates 90% confidence level. ** indicates 95% confidence level. *** indicates 99% confidence level.

V. Conclusions

This paper analyzes the causal relationships between bilateral exports and economic growth in the U.S. and Korean economies, along with other macroeconomic factors including consumption, investment, government expenditure, and bilateral imports. Using quarterly data from 1990 : 1 to 2008 : 2, we show the evidence of the ELG hypothesis including the OLS and SUR models under static procedure, the IRF and FEVD on the VAR procedure, and the Granger causality tests. The main findings are as follows:

According to the OLS and SUR models for the relationships between bilateral exports and economic growth, the effects of U.S. exports and Korean exports on GDP are positive but inelastic. Within static procedures based on the OLS and SUR models, the U.S. and Korean economies provide evidence in support of the ELG hypothesis. However, this does not mean that bilateral exports play an important role in economic growth. That is, it is merely saying that both bilateral exports and economic growth contribute positively to each other. It provides information as to the relationships and impacts between bilateral exports and economic growth under the static model.

The results of IRF and FEVD for the ELG hypothesis indicate that the positive impacts to the percentage changes of bilateral exports provide a positive reaction in growth of both the U.S. and Korean economies, even if the effects have relatively small values. Therefore, we conclude that the U.S. and Korean economies have a positive correlation between bilateral exports and economic growth based on the IRF and FEVD procedures.

The results of the Granger causality test show that Korean export growth has strong Granger causality for economic growth in the Korean economy. Investment and government expenditure have weak Granger causality for economic growth within both countries.

In conclusion, the validity of the ELG hypothesis has been debated because the results are mixed and there is a lack of strong evidence (Jin and Yu, 1996). Shan and Sun (1999) provided the evidence of the ELG hypothesis using Granger causality in the U.S. economy and the annual data from 1980 to 1997. They asserted that exports played an important role for the U.S. economy development. Otherwise, Jin and Yu (1995) analyzed the ELG hypothesis including the estimation of IFR and FEVD in the U.S. economy and the annual data from 1959 to 1992. They argued that their findings lend support to the neutrality proposition regarding the role of exports in the U.S. economy. Based on these previous studies, this paper used three steps for verifying the ELG hypothesis: the first is the static model including the OLS and SUR procedures, the second is the IRF and FEVD methods for analyzing the response and variation between exports and economic growth, and the third is the Granger causality test for examining the evidence of the ELG hypothesis. Based on this analysis, it appears that multiple techniques (e.g., IRF, FEVD, and the Granger causality test) used together, provide evidence to examine the ELG and GDE hypotheses since each procedure provides unique and useful information. For example, the OLS and SUR procedures provide evidence as to the relationships between bilateral exports and economic growth within the same period; the IRF and FEVD show the response and variation between bilateral exports and economic growth for using the VAR procedure; and the Granger causality test indicates the direction of the cause and effect relationship between bilateral exports and economic growth.

Therefore, in light of these procedures, we conclude that the Korean economy yields evidence of the ELG hypothesis between Korean export growth and economic development. If we consider the time variations as evidence for the results of the IRF and FEVD, we conclude that the ELG hypothesis strongly supports the cases of bilateral exports. In terms of Granger causality, Korean exports give strong evidence for the ELG hypothesis. In the Korean economy, exports from Korea to the U.S. are an 'engine of growth,' and have played an important role in the economic development of Korea.

APPENDIX A. The Optimal Number of Lags for the VAR model with Common Lag-structure under Five Criteria

Lags	The VAR model for Log (US EX) to Log (US GDP)						
	LL	LR	p-values	FPE	AIC	HQ	SC
0	126.149	NA	NA	0.000071	−3.8796	−3.853	−3.8128
1	430.582	608.87	0.000	59e−09	−13.2682	−13.1885√	−13.0658√
2	432.951	4.7385	0.315	62e−09	−13.2172	−13.0843	−12.8799
3	440.172	14.441√	0.006	5.6e−09√	−13.3179√	−13.1318	−12.8456
4	441.468	2.592	0.628	6.2e−09	−13.2334	−12.9942	−12.6262
5	442.357	1.7792	0.776	6.8e−09	−13.1362	−12.8438	−12.3941
6	444.417	4.1185	0.39	7.3e−09	−13.0755	−12.73	−12.1985
7	444.831	0.8288	0.935	8.2e−09	−12.9635	−12.5648	−11.9515
8	449.518	9.3745	0.052	8.1e−09	−13.9849	−12.5331	−11.838
9	451.253	3.4588	0.483	8.8e−09	−12.9141	−12.4092	−11.6323
10	454.818	7.1306	0.129	9.0e−09	−12.9006	−12.3424	−11.4838

Lags	The VAR model for Log (US C) to Log (US GDP)						
	LL	LR	p-values	FPE	AIC	HQ	SC
0	315.059	NA	NA	1.9e−07	−9.783	−9.7565	−9.7156
1	653.819	641.52	0.000	9.7e−12	−19.6818	−19.6021	−19.4794
2	645.983	20.327	0.000	8.0e−12	−19.8745	−19.7416	−19.5371√
3	650.229	8.4939	0.075	8.0e−12	−19.8822	−19.6961	−19.4099
4	657.741	15.032	0.005	7.2e−12	−19.9911	−19.7527√	−19.3847
5	661.357	7.2315	0.124	7.3e−12	−19.9799	−19.6875	−19.2378
6	663.825	4.9361	0.294	7.7e−12	−19.932	−19.5865	−19.055
7	669.722	11.796	0.019	7.3e−12	−19.9913	−19.5927	−18.9793
8	675.918	12.392	0.015	6.8e−12	−20.0599	−19.6081	−18.913
9	681.949	12.062√	0.017	6.5e−12√	−20.1234√	−19.6184	−18.8416
10	682.906	1.9125	0.752	7.2e−12	−20.0283	−19.4702	−18.6115

APPENDIX A. Continued

Lags	The VAR model for Log (US I) to Log (US GDP)						
	LL	LR	p-values	FPE	AIC	HQ	SC
0	189.929	NA	NA	9.7e−06	−5.8727	−5.8461	−5.8053
1	531.954	648.05	0.000	2.5e−10	−16.4361	−16.3563	−16.2337
2	541.817	19.725√	0.001	2.1e−10√	−16.6193√	−16.4864√	−16.282√
3	545.251	6.8682	0.143	2.1e−10	−16.6016	−16.4155	−16.1293
4	548.908	7.3134	0.120	2.1e−10	−16.5909	−16.3517	−15.9837
5	551.257	4.6992	0.320	2.3e−10	−16.5393	−16.2469	−15.7972
6	552.59	2.6646	0.615	2.5e−10	−16.4559	−16.1104	−15.5789
7	552.22	5.2603	0.262	2.6e−10	−16.4131	−16.0144	−15.4011
8	558.142	5.8442	0.211	2.7e−10	−16.3794	−16.9276	−15.2325
9	561.042	5.801	0.215	2.8e−10	−16.3451	−15.8401	−15.0632
10	562.866	3.6483	0.456	3.1e−10	−16.2771	−15.7189	−14.8603

Lags	The VAR model for Log (US G) to Log (US GDP)						
	LL	LR	p-values	FPE	AIC	HQ	SC
0	223.342	NA	NA	3.4e−06	−6.9169	−6.8903	−6.8494
1	594.594	742.5	0.000	3.5e−11	−18.3936	−18.3138√	−18.1912√
2	599.171	9.1551	0.057	3.5e−11√	−18.4116√	−18.2787	−18.0743
3	602.241	6.1404	0.189	3.5e−11	−18.3825	−18.1965	−17.9103
4	604.84	5.1966	0.268	3.5e−11	−18.3387	−18.0995	−17.7316
5	606.239	2.7974	0.592	3.5e−11	−18.2575	−17.9651	−17.5153
6	608.799	5.1213	0.275	3.5e−11	−18.2125	−17.867	−17.3354
7	610.581	3.5634	0.468	3.5e−11	−18.1432	−17.7445	−17.1312
8	615.449	9.7359	0.045	3.5e−11	−18.1703	−17.7184	−17.0234
9	617.688	4.4788	0.345	3.5e−11	−18.1153	−17.6103	−16.8334
10	623.105	10.835√	0.028	3.5e−11	−18.1595	−17.6014	−16.7428

APPENDIX A. Continued

Lags	The VAR model for Log (US IM) to Log (US GDP)						
	LL	LR	p-values	FPE	AIC	HQ	SC
0	157.42	NA	NA	0.000027	−4.8568	−4.8303	−4.7894
1	422.803	530.77	0.000	7.6e−09	−13.0251	−12.9454√	−12.8227√
2	425.37	5.1328	0.274	7.9e−09	−12.9803	−12.8474	−12.643
3	432.704	14.669	0.005	7.1e−09	−13.0845	−12.8985	−12.6122
4	432.277	5.1464	0.273	7.5e−09	−13.0399	−12.8007	−12.4327
5	442.239	13.924	0.008	6.8e−09√	−13.1325√	−12.8401	−12.3904
6	443.089	1.6986	0.791	7.6e−09	−13.034	−12.6885	−12.157
7	446.514	6.8507	0.144	7.8e−09	−13.0161	−12.6174	−12.0041
8	448.157	3.2862	0.511	8.4e−09	−12.9424	−12.4906	−11.7955
9	455.266	14.218√	0.007	7.7e−09	−13.0396	−12.5346	−11.7577
10	458.552	6.5722	0.160	8.0e−09	−13.0172	−12.4591	−11.6005

Lags	The VAR model for Log (KOR EX) to Log (KOR GDP)						
	LL	LR	p-values	FPE	AIC	HQ	SC
0	111.216	NA	NA	0.000113	−3.4129	−3.3864	−3.3455
1	244.966	267.5	0.000	2.0e−06	−7.4676	−7.3879	−7.2652
2	250.445	10.959	0.0027	1.9e−06	−7.5139	−7.381	−7.1765
3	251.159	1.427	0.839	2.1e−06	−7.4112	−7.2251	−6.9389
4	257.448	12.578	0.014	1.9e−06	−7.4827	−7.2435	−6.8755
5	261.036	7.1762	0.127	2.0e−06	−7.4698	−7.1775	−6.7277√
6	263.828	5.5842	0.232	2.1e−06√	−7.4321√	−7.0866√	−6.555
7	264.884	2.1118	0.715	2.3e−06	−7.2301	−6.9414	−6.3281
8	270.94	12.112√	0.017	2.1e−06	−7.4043	−6.9525	−6.2574
9	274.813	7.747	0.101	2.2e−06	−7.4004	−6.8954	−6.1185
10	276.489	3.3509	0.501	2.4e−06	−7.3277	−6.7696	−5.911

APPENDIX A. Continued

Lags	The VAR model for Log (KOR C) to Log (KOR GDP)						
	LL	LR	p-values	FPE	AIC	HQ	SC
0	100.285	NA	NA	0.000159	−3.0714	−3.0448	−3.0039
1	317.844	435.12	0.000	2.0e−07	−9.7451	−9.6654	−9.5427
2	318.737	1.786	0.775	2.2e−07	−9.648	−9.5151	−9.3107
3	334.401	31.327	0.000	1.5e−07	−10.0125	−9.8264	−9.5402
4	344.369	19.937	0.001	1.3e−07	−10.199	−9.9598	−9.5918
5	380.284	71.83	0.000	4.7e−07	−11.1964	−10.904	−10.4543√
6	385.812	13.056	0.011	4.4e−08√	−11.2754√	−10.9299√	−10.3983
7	388.592	3.5605	0.469	4.7e−08	−11.206	−10.8073	−10.194
8	390.204	3.2222	0.521	5.2e−08	−11.1314	−10.6785	−9.9844
9	391.363	2.3189	0.677	5.7e−08	−11.0426	−10.5376	−9.7607
10	397.378	12.03√	0.017	5.4e−08	−11.1056	−10.5474	−9.6887

Lags	The VAR model for Log (KOR I) to Log (KOR GDP)						
	LL	LR	p-values	FPE	AIC	HQ	SC
0	104.327	NA	NA	0.00014	−3.1977	−3.1713	−3.1302
1	373.212	537.77	0.000	3.6e−08	−11.4754	−11.3956√	−11.273√
2	378.312	10.2√	0.037	3.4e−08√	−11.5098√	−11.3769	−11.1724
3	381.454	6.2839	0.179	3.5e−08	−11.4829	−11.2969	−11.0107
4	383.724	4.5391	0.338	3.7e−08	−11.4289	−11.1897	−10.8217
5	385.743	4.0395	0.401	4.0e−08	−11.367	−11.0746	−10.6249
6	387.978	4.4693	0.346	4.2e−08	−11.3118	−10.9663	−10.4348
7	390.202	4.4489	0.349	4.5e−08	−11.2563	−10.8577	−10.2443
8	391.861	3.3174	0.506	4.9e−08	−11.1832	−10.7313	−10.0363
9	393.455	3.1869	0.527	5.3e−08	−11.108	−10.603	−9.8261
10	397.176	7.4435	0.114	5.5e−08	−11.0993	−10.5411	−9.6824

APPENDIX A. Continued

Lags	The VAR model for Log (KOR G) to Log (KOR GDP)						
	LL	LR	p-values	FPE	AIC	HQ	SC
0	58.1005	NA	NA	0.000594	−1.7531	−1.7265	−1.6856
1	152.529	188.86	0.000	0.000035	−4.579	−4.4993	−4.3766√
2	158.292	11.525	0.021	0.000033	−4.6341	−4.5012√	−4.2968
3	162.763	8.9413	0.063	0.000033	−4.6488	−4.4627	−4.1765
4	162.243	4.9598	0.291	0.000035	−4.6013	−4.3621	−3.9941
5	170.88	11.275	0.024	0.000033√	−4.6525√	−4.3601	−3.9103
6	173.408	5.0547	0.282	0.000035	−4.6064	−4.2609	−3.7294
7	176.258	5.7018	0.223	0.000036	−4.5705	−4.1719	−3.5586
8	177.463	2.4087	0.661	0.00004	−4.4832	−4.0313	−3.3363
9	178.722	2.5188	0.641	0.000044	−4.3975	−3.8925	−3.1157
10	184.912	12.379√	0.015	0.000041	−4.4659	−3.9078	−3.0492

Lags	The VAR model for Log (KOR IM) to Log (KOR GDP)						
	LL	LR	p-values	FPE	AIC	HQ	SC
0	146.06	NA	NA	0.000038	−4.5018	−4.4752	−4.4344
1	273.559	255	0.000	8.0e−07	−8.3612	−8.2814√	−8.1582√
2	277.391	7.664	0.105	8.1e−07	−8.3559	−8.223	−8.0186
3	283.232	11.682	0.020	7.6e−07√	−8.4135√	−8.2274	−7.9412
4	283.92	1.3764	0.848	8.5e−07	−8.31	−8.0708	−7.7028
5	284.11	0.3791	0.984	9.6e−07	−8.1909	−7.8985	−7.4488
6	287.517	6.8145	0.146	9.8e−07	−8.1724	−7.8269	−7.2953
7	288.23	1.4255	0.840	1.1e−06	−8.0696	−7.671	−7.0571
8	289.283	2.1069	0.716	1.2e−06	−7.9776	−7.5257	−6.8307
9	296.363	14.159	0.007	1.1e−06	−8.0738	−7.5688	−6.792
10	301.136	9.5459√	0.049	1.1e−06	−8.0979	−7.5398	−6.6812

Note: √ indicates the optimal number of lags.
LL: The value of the natural logarithm of the likelihood
LR: Likelihood ratio test statistics (each test at the 5% levels)
FPE: Final prediction error criterion
AIC: Akaike information criterion
HQ: Hannan-Quinn information criterion
SC: Schwarx information criterion

APPENDIX B

In this paper, we investigate a positive reaction between bilateral exports and GDP using impulse response function (IRF) and forecast error variation decomposition (FEVD). In Table 6, positive shocks of bilateral exports create a positive reaction in economic growth. IRF, in particular, is the analytic tool to look into the effect how one variable contributes to the change of another variable based on one standard deviation. If one shock has strongly or continually contributed to effects on variables, this implies that it causes unstable shocks with respect to a specific economic period. Also, in Table 3, the estimated variables of US GDP, US EX, KOR GDP, and KOR EX are non-stationary variables and therefore, we need to re-examine the IRF using the first difference. Table 9 and Figure 4 show the IRF results using the first difference, respectively.

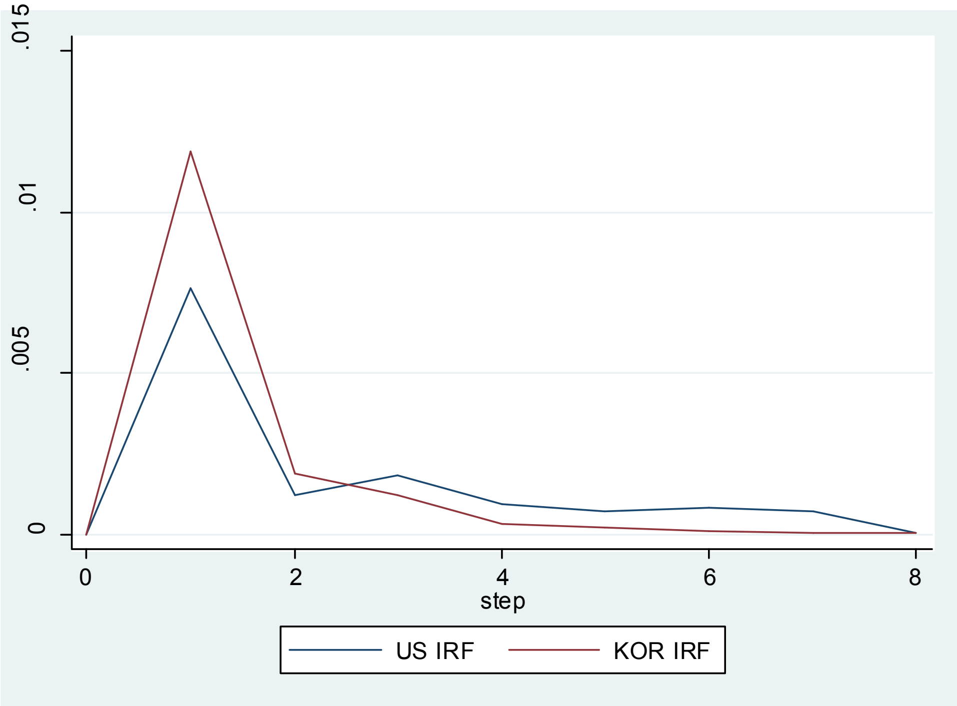
The shapes of corresponding impulse responses in the two lines are quite similar and approach some zero value. That is, a feature of the IRF is that they do die out to zero when time span after the impulse increases. Therefore, this reflects the stationarity of the system where one-time impulse has temporary effects, and this result supports the ELG hypothesis for bilateral exports and economic growth in the U.S. and Korea.

TABLE 9. Results of IRF for the First Differential VAR Model

Steps	D.US EX ⇒ .US GDP	D.KOR EX ⇒ .KOR GDP
	IRF	IRF
1	0.0076	0.0119
2	0.0012	0.0019
3	0.0018	0.0012
4	0.0009	0.0003
5	0.0007	0.0002
6	0.0008	0.0001
7	0.0007	0.00005
8	0.00005	0.00003

Note: D.US EX, D.US GDP, D.KOR EX and D.KOR GDP denote the first differential variables of the U.S. exports/GDP and Korea exports/GDP, respectively.

FIGURE 4. Results of IRF for the First Differential VAR Model



Note: US IRF and KOR IRF denote the results of impulse response function in the U.S. and Korea, respectively.

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