Do Korean Exports Have Different Patterns over Different Regimes?: New Evidence from STAR-VECM

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Contents

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In this work we examine whether the relationships of Korean exports to global GDP and to the exchange rate change depending on whether exports are in their expansionary or their contractionary regimes. To this empirical end we incorporate the two distinct dynamic features of regime change and co-integration into a multi-variable smooth transition autoregressive vector error correction model (STAR-VECM). Our estimation results reveal asymmetries in the short-run relationships of Korea's exports to global GDP and to the exchange rate, between the contractionary and the expansionary export regimes, although their long-run relationships remain stable. Specifically, the positive effect of real global GDP on Korea's real exports is inelastic during contractionary regimes but changes to become elastic in expansionary regimes. The effect of the real effective exchange rate on Korea's real exports is positive and inelastic under contractionary regimes, but becomes negative and elastic under expansionary regimes. Our results suggest that the asymmetric properties of the relationship of Korea's exports to global GDP and the exchange rates across the different regimes should be taken into account in order to better understand the behavior of Korea's exports.

Keywords: Exports, Global GDP, Exchange rate, Regime change, Smooth Transition Autoregressive Model

JEL Classification Numbers: F14, C40, C51

Ⅰ. Introduction

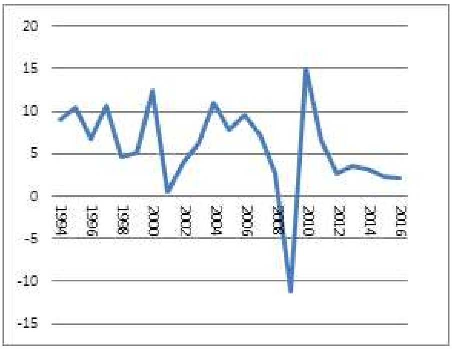
In this work we investigate the dynamic relationships of Korean exports to global GDP and to the Korean won exchange rate by allowing endogenous regime changes. It has been documented that the long-run relationship between world trade and world income, as measured by the income elasticity of trade, has weakened since the global financial crisis (Constantinescu et al., 2015). In addition, it is also argued that the short-run relationship between world trade and world income is cyclical while their long-run relationship remains stable over time (Borin et al., 2017). These recent findings motivate us to question whether the relationship between Korea's exports and global GDP also have a cyclical pattern of differing in booms and in recessions.

Since the 2008 global economic crisis we have observed a rapid contraction in global trade. The global trading volume recovered in 2010 and 2011, but has faltered since then as it is still well below its previous level. In 2016 the global trade slowdown was more pronounced. The annual rate of growth in the volume of world exports of goods slowed to 2.1% in 2016, as shown in Figure 1. According to research of the IMF, this slowdown in trade since the global financial crisis is attributable to structural changes in the relationship between world trade and world income, as represented by a decrease in the long-run income elasticity of trade.[1] In contrast, research by the OECD and others argues that this trade slowdown can be explained by cyclical factors, and that the short-run relationship between world trade and world income can weaken during recessions even though their long-run relationship remains stable.[2]

Against the backdrop of the above discussion of the changes in the relationship between world trade and world income since the global financial crisis, we focus on Korea's exports and their relationship with

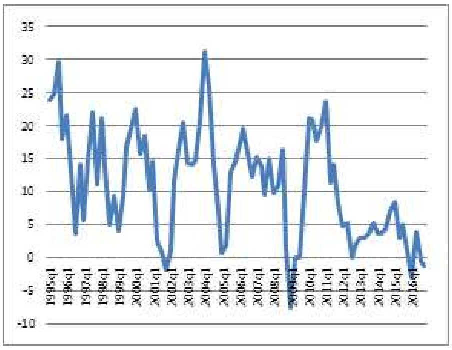
1) See Constantinescu et al., IMF working paper (2015).
2) Refer to Borin et al. (2017) and Ollivaud and Schwellnus (2015).

Figure 1. Growth of World Exports



Note: Annual % changes in volumes of exports of goods
Source: IMF World Economic Outlook (2017)

Figure 2. Growth of Korean Exports



Notes: Year-on-year % changes in real exports of goods
Sources: KITA, BOK

global income. For Korea, the rate of growth in real exports of goods has also slowed since 2012, and the average year-on-year rate even reached a minus figure in 2016, at -0.23% as shown in Figure 2. Considering the details of the discussion mentioned above, it seems like a good time to examine whether the relationship between Korea's exports and world income has changed.

Since the global financial crisis there has been a growing number of studies examining the relationship between trade and global GDP so as to better understand whether this relationship has weakened. Many of them have analyzed the long-run and short-run relationships between them using error correction models. One of the challenges in investigating this relationship is that changes in trade regimes such as its expansions and contractions have to be incorporated. According to recent studies, the income elasticities of trade are significantly different in expansions than they are in contractions (Bussiére et al., 2013; Borin et al., 2017; Ollivaud & Schwellnus, 2015). An additional challenge is that it is hard to define the changes in regime between trade expansions and contractions based simply on some exogenous measures, ignoring that the regimes could be determined endogenously. However, there have been no empirical studies that have taken both of these two challenges into account together.

We therefore investigate the dynamic relationship between exports and its fundamental determining factors (global GDP and exchange rates) by incorporating the two distinct features of endogenous regime shifting and co-integration between trade and its related factors into a Smooth Transition Autoregressive Vector Error Correction model (hereafter STAR-VECM) framework. The STAR-VECM methodology allows us to determine the boom-and-bust cycles of exports by the endogenous characteristics of the individual variables, unlike in previous studies that determine the trading cycles through ad hoc defined characteristics related to GDP. Another important advantage of using the STAR-VECM model is that it enables us to capture any asymmetry in effects across the exports' regimes.

Based on theoretical grounds, we select real global GDP and the real effective exchange rate as the fundamental factors affecting Korean exports. The results of STAR-VECM estimation reveal that Korean exports exhibit significant non-linear movements in line with the changes in regime, and that the above-mentioned fundamental factors affecting them are co-integrated with them. A look at the cumulative net effects reveals that changes in the fundamental factors Granger-cause changes in exports, and that the effects of these fundamental factors are asymmetric across the different regimes. Specifically, the positive effects of global GDP on exports are intensified under the expansionary regime. We find further that the movements of exports are longer lasting (or have a momentum property) in their expansionary regimes.

The remainder of this paper is organized as follows. Section 2 reviews the literature, and Section 3 introduces the empirical model and data. Section 4 presents the STAR-VECM estimation results, and our interpretations of them. Section 5 further studies the dynamic momentum effects of Korean exports. Section 6 then concludes.

Ⅱ. Literature Review

A large volume of literature has investigated the relationship between trade and its determinants such as income and relative prices. In the early stage of this study, Houthakker and Magee (1969) estimated the income and price elasticities of trade for advanced economies for the period from 1951 to 1966. In addition, Hooper et al. (2000) have estimated the income and price elasticities of trade for each of the G7 countries over the 1970-1995 period, using an error correction model. They find that income elasticities tend to be more stable and relatively larger than price elasticities.

Most previous studies find that the long-run relationship between trade and its determinants varies depending upon the period, implying that it is critical to consider the dynamic movement of the relationship across the booms and recessions. Irwin (2002) investigates the long-run elasticity of world trade with respect to world GDP for the 1870-2000 period using auto-regressive distributed lag regression, and finds that the elasticity estimates increase after 1950, suggesting that trade grew more rapidly than income, and particularly after 1950. Escaith et al. (2010) estimate the long-run import elasticities with respect to GDP based on an error correction model using the quarterly data of 24 OECD countries for the period from 1971 to 2009. They find that the elasticities increased in the 1990s but decreased in the 2000s, explaining this by the fact that the internationalization of production in the 1990s brought about a transition from the steady state in the 1980s to a new one in the 2000s, with trade elasticities in consequence rising during the transition phase. They additionally conduct an analysis for each country, and their estimates of the long-run trade elasticities for Korea are 1.83 for the 1990s and 2.06 for the 2000s, which suggests that the responsiveness of Korea’s imports with respect to its GDP increased in the 2000s relative to the 1990s. Bussiére et al. (2013) estimate trade elasticities with respect to import intensity-adjusted demand (IAD), rather than GDP, for 18 OECD countries for the period from 1985Q1 through 2011Q4. They show that the income elasticity of imports becomes greater during recessions, and particularly during the global financial crisis, suggesting that trade elasticities vary over the business cycle, with their magnitudes increasing during recessions and crises.

More recent studies covering the period since the global financial crisis have shown that the relationship between trade and income has weakened during this time. Constantinescu et al. (2015) examine the relationship between world trade and world income based on an error correction model using both annual data for the 1970-2013 period and quarterly data for the 1991-2013 period. Their annual data analysis finds that the long-term elasticities of trade with respect to income are 1.3 for the 1970-1985 period, 2.2 for 1985-2000, and 1.3 for 2000-2013, with their explanation for this being that the increase in the long-run trade elasticity in the 1990s was attributable to accelerated international production, but that the elasticity declined in the 2000s as this process slowed down. The results of their quarterly data analysis reveal further that the elasticity has decreased to 0.68 since the global financial crisis compared to 1.49 before it, suggesting that the link between income and trade has weakened since the 2000s and even more so since the crisis. These studies' findings, that the long-run relationships between trade and its determinants vary depending on the time, suggest a critical need for considering the dynamic movements of the relationship between trade and its determinants across booms and recessions.

However, more recent studies argue that the short-run elasticities could decrease in recessions and increase in booms, while the long-run elasticities remain stable. Ollivaud and Schwellnus (2015) show that the long-run income elasticity of world trade has not declined much since the global financial crisis, while the short-run elasticity has fallen below its long-run trend. They also argue that cyclical movements have appeared in the past as well, with the short-run elasticity declining to below the long-run elasticity during recessions. In addition, Borin et al. (2017) find that the income elasticity of trade is cyclical due to the high volatility and pro-cyclicality of trade flows, which implies that the short-run elasticity is below its long-run trend when the rate of real GDP growth is below its long-run trend. They suggest, therefore, that the forecast error on trade could be magnified when GDP growth is less than expected. These recent studies reveal a necessity for distinguishing the relationships between trade and its fundamental factors in booms from those in recessions.

As for the evidence from Korea, many empirical studies explored the relationship between Korean trade and its determinants, with most of the studies before the global financial crisis showing Korean trade to be responsive to income although the magnitude of responsiveness varies over time. Sim (2006) finds, using an autoregressive distributed lag error correction model for the 1990Q1-2006Q2 period, that the income and price elasticities of imports are 2.7 and -0.88 respectively for the period after the Asian financial crisis. Shin and Kim (2007), using VAR for the period from 1990 to 2005, also find that the responsiveness of Korean exports to world GDP increased after the Asian financial crisis, while their responsiveness to the exchange rate decreased. Seo and Kang (2016) analyze the determinants of Korea's real exports for the 1988M1-2006M12 period using an error correction model, and find that the short-run income elasticity of exports is 1.2. Baak (2011) examines the long-run relationships between Korean exports and the exchange rate and the world trade volume for the period 1992Q1-2009Q4, with his results from a fully modified OLS showing that the income and price elasticities decreased during the 2000-2008 period compared to the entire sample period. Chung et al. (2008) find, using an error correction model for the period from 1988Q1 to 2008Q2, that the long-run income elasticity of Korean exports is 3.6, while their price elasticity is inelastic, suggesting that Korean exports respond very sensitively to world GDP and insensitively to the real effective exchange rate. Kang (2014) investigates the income elasticities of imports for Korea while considering the extensive margins due to new goods in order to address estimation bias, using product-level annual data for the 1997-2010 period. His panel regression estimates the income elasticity of imports at 1.34 without the extensive margin, and 1.26 with the extensive margin.[3)]

Recent studies covering the global financial crisis period show that the responsiveness of Korean exports to foreign GDP has weakened since the crisis. Kang and Chung (2015), using an error correction model for the period from 1991Q1 to 2014Q3, find the income elasticities of Korean exports to have been approximately 1.8 in the long run and 1.2-1.8 in the short run before the global financial crisis, but that they have fallen to 1.4 and 0.6 respectively since the crisis. Their price elasticities turn out to be mostly insignificant, regardless of the period. They point out that the main reasons for the decline in income elasticity are the structural slowdown in world trade, the structural changes in the Chinese economy along with its growth slowdown, and an increase in offshoring.

Overall, these studies show that the relationships between Korean exports and its determinants has weakened since the 2000s, or that they have varied over the business cycle, revealing that trade elasticities change depending on the economic regime. In this context, it is important to rigorously investigate the relationship of Korean exports to its fundamental factors by incorporating the variations in the relationship over the different economic regimes. To this end we employ a Smooth Transition Autoregressive Vector Error Correction model (STAR-VECM) that appropriately estimates the relationship between exports and their determinants, by incorporating endogenous regime shifting of exports.

3) Empirical studies with Korean data (Lee & Yi (2005)) estimate the trade elasticities by sector or product category, with an emphasis on the differences in trade structures and in the responsiveness to income and relative prices by sector. Cardarelli and Rebucci (2007) point out that aggregate data analysis might yield biased results due to not considering the differences across sectors. Analysis using sectoral level trade data could therefore provide complementary information, enabling a better understanding of the mechanism behind the aggregate data analysis results. We leave sectoral level data analysis to future research.

Ⅲ. Empirical Model and Data

1. Smooth Transition Autoregressive Vector Error Correction Model (STAR-VECM)

Given the significant evidence of co-integration between endogenous variables related to exports,[4] the most appropriate model is one in which the endogenous variables are linked by a linear long-run equilibrium relationship, and in which adjustment toward the equilibrium is nonlinear and can be characterized by a slow regime switch triggered by the dependent variable's own past values.[5] Here the regimes are determined by the size and sign of the deviation from the equilibrium relationship. Therefore, in the empirical analysis we fully take into account non-linearity, co-integration and regime changes.

In a linear time series, this type of behavior is captured by a linear vector error-correction model (VECM) (Engle and Granger, 1987).[6] Escribano and Mira (2002) extend the linear VECM to a general nonlinear VECM by employing the Near Epoch Dependence (NED) concept suggested by Gallant and White (1988) and Wooldridge and White (1988). Particularly, they reveal that the nonlinear VECM can be theoretically structured by integrating a smooth transition autoregressive model (STARM), among numerous potential nonlinear parameterizations.[7]

In our preliminary tests we find robust evidence favoring a smooth transition dynamics model over a linear VECM, using nonlinearity tests. We therefore incorporate nonlinearity into the VECM, following recent advances in nonlinear models. We integrate a smooth transition

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4) For exports (y_t^1), there are two endogenous variables— real global GDP (y_t^2) and the real effective exchange rate (y_t^3). The results of the preliminary test for co-integration is reported in the next section.

5) There are two kinds of nonlinear regime-switching models based on the speed of transition between states: the threshold autoregressive model (TARM) by Tsay (1989), and the smooth transition autoregressive model (STARM) by Luukkonen et al. (1988), Teräsvirta and Anderson (1992), and Teräsvirta (1994). The STARM allows a smooth transition between states while the TARM assumes a sudden change between states with a discrete jump.

6) See also Johansen (1995) and Hatanaka (1996).

7) For the detailed proof, refer to Section 5 in Escribano and Mira (2002).

mechanism into the VECM to allow for a nonlinear characteristic, giving us what is called a smooth transition autoregressive vector error-correction model (STAR-VECM).[8] This model can be considered as a special kind of vector smooth transition autoregressive model (STARM).

In the following, we explain the specifications of the STAR-VECM based on exports. For the three integrated variables of the log of exports (y_t^1), the log of real global GDP (y_t^2), and the log of the real effective exchange rate (y_t^3), a general form of the smooth transition vector error-correction model (STAR-VECM) is as follows:

$$
\begin{aligned}
\Delta y_t^1 &= \left[\phi_0 + \alpha_1^1 z_{t-1} + \sum_{j=1}^{4}\sum_{i=1}^{4}\phi_i^j \Delta y_{t-1}^j\right] + \left[\rho_0 + \alpha_2^1 z_{t-1} + \sum_{j=1}^{4}\sum_{i=1}^{4}\rho_i^j \Delta y_{t-1}^j\right] \bullet F(\Delta y_{t-d}^1) + \varepsilon_t^1, \\
\Delta y_t^2 &= \left[\phi_0 + \alpha_1^2 z_{t-1} + \sum_{j=1}^{4}\sum_{i=1}^{4}\phi_i^j \Delta y_{t-1}^j\right] + \left[\rho_0 + \alpha_2^2 z_{t-1} + \sum_{j=1}^{4}\sum_{i=1}^{4}\rho_i^j \Delta y_{t-1}^j\right] \bullet F(\Delta y_{t-d}^2) + \varepsilon_t^2, \qquad (1) \\
\Delta y_t^3 &= \left[\phi_0 + \alpha_1^3 z_{t-1} + \sum_{j=1}^{4}\sum_{i=1}^{4}\phi_i^j \Delta y_{t-1}^j\right] + \left[\rho_0 + \alpha_2^3 z_{t-1} + \sum_{j=1}^{4}\sum_{i=1}^{4}\rho_i^j \Delta y_{t-1}^j\right] \bullet F(\Delta y_{t-d}^3) + \varepsilon_t^3.
\end{aligned}
$$

where Δy_t^1 is the log difference (or growth rate) of real exports, Δy_t^2 the log difference (or growth rate) of the aggregated real GDP of OECD countries, Δy_t^3 the real effective exchange rate of the Korean Won, $F(\Delta y_{t-d}^i)$ the transition function, and Δy_{t-d}^i the transition variable. $z_t = \beta v_t$, for some vector β, denotes the error-correction term. That is, z_t is the deviation from the equilibrium relation given by $\beta' v_t = 0$. $F(\Delta y_{t-d}^c)$ is the transition function, and Δy_{t-d}^c is a common transition variable.

For the STAR-VECM, we specify two types of the transition function, $F(\Delta y_{t-d}^c)$: the logistic smooth transition vector error correction model (LSTAR-VECM) and the exponential smooth transition vector error

8) For a more general discussion, see Granger and Swanson (1996). Also, for an early empirical example of nonlinear error-correcting mechanisms, refer to Escribano (1987), and Escribano and Pfann (1998).

correction model (ESTAR-VECM). The LSTAR-VECM is more appropriate to describe a stochastic process that is featured by an alternative set of dynamics of either the small or the large value of the transition function. In the LSTAR-VECM, the transition function is defined by the logistic function as follows:9)

$$F(\Delta y^{c}_{t-d}) = \left[1+\exp\left\{-\gamma(\Delta y^{c}_{t-d}-C)\right\}\right]^{-1},\ \gamma > 0. \tag{2.1}$$

In contrast, the ESTAR-VECM is more appropriate for generating another dynamic of both large and small magnitudes of the transition variable. In the ESTAR-VECM the transition function is given by:10)

$$F(\Delta y^{c}_{t-d}) = 1-\exp\left\{-\gamma\left(\Delta y^{c}_{t-d}-c\right)^{2}\right\},\ \gamma > 0. \tag{2.2}$$

Selection between LSTAR and ESTAR can be decided based on the test shown in Appendix 2.

The adjustment parameter, γ, represents in both models the speed of transition between the two states: the greater the value of γ, the faster the change between the states. The model degenerates to the conventional threshold autoregressive model (TARM) of Tsay (1989) as the value of γ approaches infinity. The model degenerates to a linear AR model, where

---

9) The logistic function, $F(\Delta y^{c}_{t-d})$, has a value between 0 and 1, based on the degree and direction by which Δy^{c}_{t-d} deviates from c, the shifting value of the transition variable. The estimated value of c defines a transition between the two regimes: $0 < F(\Delta y^{c}_{t-d}) < 0.5$ (the lower regime) for $\Delta y^{c}_{t-d} < c$, and $0.5 < F(\Delta y^{c}_{t-d}) < 1$ (the upper regime) for $\Delta y^{c}_{t-d} > c$. When $\Delta y^{c}_{t-d} = c$, $F(\Delta y^{c}_{t-d}) = 0.5$ so that the current dynamics of Δy (or the growth rate) is halfway between the upper and the lower regimes; especially, when Δy^{c}_{t-d} takes a large value (i.e., $\Delta y^{c}_{t-d} \gg c$), $\exp\{-\gamma(\Delta y^{c}_{t-d}-c)\}$ is close to 0. As a result the value of $F(\Delta y^{c}_{t-d})$ approaches one, and the dynamics of Δy are generated by both ϕ^{i}_{j} and ρ^{i}_{j} in equation (1). In addition, for a small value of Δy^{c}_{t-d} (i.e. $\Delta y^{c}_{t-d} \ll c$), $\exp\{-\gamma(\Delta y^{c}_{t-d}-c)\}$ approaches to a large number. Then the value of the transition function $F(\Delta y^{c}_{t-d})$ approaches 0, and the dynamics of Δy_t are generated by only the ϕ^{i}_{j} parameter in equation (1).

10) For a large or small value of Δy^{c}_{t-d}, the value of $\exp\{-\gamma(\Delta y^{c}_{t-d}-c)^2\}$ approaches zero, and the value of the transition function approaches one. The dynamics of Δy_t are generated by both ϕ^{i}_{j} and ρ^{i}_{j} in equation (1). When the value of Δy^{c}_{t-d} is close to c, the value of $\exp\{-\gamma(\Delta y^{c}_{t-d}-c)^2\}$ approaches 1 and the value of the transition function approaches 0. In these cases the dynamics of Δy_t are generated only by the ϕ^{i}_{j} parameters in equation (1).

the ρ_j^i parameters become unidentifiable, if γ approaches zero and the value of the transition function $F(\Delta y_{t-d}^c)$ approaches zero. In specifying the STAR-VECM, the past value of the dependent variable is chosen as the common transition variable in $F(\Delta y_{t-d}^c)$.

2. Data

We employ quarterly data retrieved from various public data archives. Korea's real exports (y_t^1) are the total value of export of goods, sourced from the Korea International Trade Association (KITA), adjusted by the export price index from the Bank of Korea (BOK). Global GDP (y_t^2) is retrieved from the data archive of the OECD as the aggregated real GDP of the OECD member countries. The real effective exchange rate (y_t^3) is obtained from the Bank for International Settlements (BIS).

We choose a data range running from the first quarter of 1994 through the fourth quarter of 2016 for all variables. To eliminate seasonality in our GDP and trade data, we use seasonally adjusted real GDP data and adjust the trade level data series with X11-ARIMA. Each variable is then transformed into its logarithm, and the quarterly change of each variable is obtained as its quarterly log difference.[11)]

Table 1 presents summary statistics on the log differences (or growth) of the variables:

Table 1. Summary Statistics (1994 Q1 – 2016 Q4)

Log difference (or growth rate) of the following variables	Mean	Standard Deviation
Real Exports (Δy_t^1)	0.0304	0.0859
Global real GDP (Δy_t^2)	0.0054	0.0487
Real effective exchange rate of Korean Won (Δy_t^3)	-0.0008	0.0524

11) For each time-series the Dicky-Fuller test is conducted to confirm the non-stationarity of the data; the results are not reported in the paper due to a space limitation, but are available upon request.

Ⅳ. Estimation Results

1. Preliminary Tests: Co-integration and Benchmark Linear VECM Estimations

In this section we present the estimation results of the co-integration relations, after which the linear vector error correction model (VECM) estimation results are provided. These empirical results are the benchmarks for our nonlinear STAR-VECM estimation in the next section.

The co-integration relationship between the log of real exports (y_t^1), the log of real global GDP (y_t^2), and the real effective exchange rate of the Korean Won (y_t^3) is specified as follows:

$$y_t^1 = \beta_0 + \beta_1 y_t^2 + \beta_2 y_t^3 + \varepsilon_t \tag{3}$$

The results of co-integration estimation are reported in Table 2, which shows significant co-integration relationships. The long-run linear relationship between exports and global GDP is found to be significant and positive, consistent with the theoretical expectation. The long-run relationship between exports and the real effective exchange rate is negative, indicating that an appreciation of the Korean Won raises the relative price of Korean exports and thus causes them to decline. In sum, the long-run relationships between exports and the fundamental factors affecting it are estimated to be significant and consistent with theoretical expectations.

Table 2. Co-integration Equations of Korean Exports

This table shows the estimation result of equation (3) where y_t^1 is the log of real exports, y_t^2 the log of the aggregate real GDP of OECD countries, and y_t^3 the real effective exchange rate of the Korean Won.

	y_t^1
β_0	-75.2709*** (-48.5215)
β_1	4.9512*** (56.7281)
β_2	-0.0232*** (-3.1312)
Adj.R^2	0.9734
SER	0.1140
LLV	71.4422

Notes: The values in parentheses below the regression coefficients are the heteroskedasticity robust t-statistics; SER is the standard error of regression, and LLV the log likelihood value. *, **, and *** represent significant at 10%, 5%, and 1% level, respectively.

In the following our linear vector error correction model (VECM) estimation results are summarized. By following standard VECM specifications, the export VECM estimation is specified in equation (4):

$$
\begin{aligned}
\Delta y_t^1 &= \left[\phi_0 + \alpha_1^1 z_{t-1} + \sum_{j=1}^{3}\sum_{i=1}^{4}\phi_i^j \Delta y_{t-i}^j\right] + \varepsilon_t^1, \\
\Delta y_t^2 &= \left[\phi_0 + \alpha_1^2 z_{t-1} + \sum_{j=1}^{3}\sum_{i=1}^{4}\phi_i^j \Delta y_{t-i}^j\right] + \varepsilon_t^2, \\
\Delta y_t^3 &= \left[\phi_0 + \alpha_1^3 z_{t-1} + \sum_{j=1}^{3}\sum_{i=1}^{4}\phi_i^j \Delta y_{t-i}^j\right] + \varepsilon_t^3.
\end{aligned}
\tag{4}
$$

where Δy_t^1 is the log difference (or growth rate) of real exports, Δy_t^2 the log difference (or growth rate) of real global GDP, and Δy_t^3 the log difference (or growth rate) of real effective exchange rate of the Korean Won.

The results of estimation of our linear VECM in Table 3 show that the fundamental factors (global GDP and REER) have significant effects on (or

Granger cause) exports. In addition, the error correction term (z_{t-1}) in the estimation has a negative and significant coefficient, indicating that exports have a dynamic tendency to recover their dynamic equilibrium, long-run relationship state.

Table 3. Estimation of Linear VECM: Exports, Global GDP and Exchange Rate (1994 Q1 – 2016 Q4)

This table shows estimation results of equation (4) where Δy_t^1 is the log difference (or growth rate) of real exports, Δy_t^2 the log difference (or growth rate) of real global GDP, and Δy_t^3 the log difference of real effective exchange rate of the Korean Won.

	Real Exports (Δy_t^1)	Real Global GDP (Δy_t^2)	REER (Δy_t^3)
ϕ_0	0.0275*** (0.0050)	0.0031 (0.7771)	−0.0080 (0.4524)
α_1	−0.0843* (0.0764)	0.0046 (0.6430)	0.0018 (0.8485)
ϕ_1^1	−0.4094** (0.0011)	−0.1567 (0.1937)	0.1679 (0.1474)
ϕ_2^1	0.0793 (0.5420)	−0.2114 (0.1108)	0.0320 (0.7988)
ϕ_3^1	0.0010 (0.9936)	0.1002 (0.4404)	0.0059 (0.9622)
ϕ_4^1	0.4335*** (0.0002)	0.0933 (0.4182)	0.1420 (0.2002)
ϕ_1^2	4.7645*** (0.0045)	1.4952 (0.1049)	−0.1525 (0.1834)
ϕ_2^2	−3.4842* (0.0799)	−1.0651 (0.5894)	−2.3305 (0.6500)
ϕ_3^2	−0.3700 (0.8557)	2.4455 (0.2958)	1.0354 (0.7577)
ϕ_4^2	−1.5981 (0.3059)	1.6518 (0.6553)	2.1942* (0.0833)
ϕ_1^3	−0.0284 (0.7856)	0.2977** (0.0105)	0.1975* (0.0719)
ϕ_2^3	0.1081 (0.3128)	−0.2898** (0.0136)	−0.1625 (0.1420)
ϕ_3^3	0.0026 (0.9800)	0.3353*** (0.0048)	0.0707 (0.5235)
ϕ_4^3	0.1188 (0.2520)	−0.3072** (0.0106)	−0.1025 (0.3633)
adjusted R^2	0.7073	0.12243	0.042402

Notes: The values in parentheses below the regression coefficients are the heteroskedasticity robust t-statistics; SER is the standard error of regression, and LLV the log likelihood value. *, **, and *** represent significant at 10%, 5%, and 1% level, respectively. The full results for all parameter estimates are not presented due to space limitations, but are available upon request.

2. STAR-VECM Estimation Results

In each estimation the model selection between ESTAR and LSTAR is decided based on the procedure of Teräsvirta and Anderson (1992), and the LSTAR model has been chosen under 10% significance level in every STAR estimation.[12)] First we present the results for all parameters of the Korean export STAR-VECM estimation, in Table 4.[13)] It should be noted that the significance of the γ-parameter is crucial in estimating the STAR model, because it is evidence of the validity of the STAR model specification compared to the other regime-switching models such as the Markow switching model.[14)]

We see that the value of the γ-parameter, representing the speed of regime shifting, is positive and significant at the 5% level with 4.3178 for real exports. The value of the γ-parameter shows that the growth of Korean exports undergoes a relatively slow transition between the two regimes, while the growth of global GDP and the real effective exchange rate display relatively fast and more frequent transitions between the two regimes. It should also be noted that the c-parameter indicates a halfway point between the expansionary and the contractionary phases of exports, with 0. 0779 for real exports.

12) The procedure for model selection between ESTAR and LSTAR suggested by Teräsvirta and Anderson (1992) is explained in more detail in Appendix2.

13) During the sample period 1994Q1-2016Q4, China's increased involvement in trade from the early 2000s caused dramatic changes in the dynamic pattern of Korean exports. However, our empirical model of Logistic STAR-VECM endogenously incorporates this dramatic effect in terms of regime shifting from a 'contractionary phase' to an 'expansionary phase' of exports. We estimate the conditional probability of export regime changes from contraction to expansion from 2001, when China joined the WTO. The probability of this regime shift continues above the 0.9 (or 90%) level from 2003, indicating that Korea's exports remain in an expansionary phase.

14) The γ-parameter will be infinity in the case of the Markow switching model, but the γ-parameter is zero in a linear model (or a simple VECM).

Table 4. Estimation of STAR-VECM (1994 Q1 – 2016 Q4)

This table shows estimation results of equation (1) where Δy_t^1 is the log difference (or growth rate) of real Exports, Δy_t^2 the log difference (or growth rate) of the aggregate real GDP of OECD countries, Δy_t^3 the log difference of real exchange rate of the Korean Won, $F(\Delta y_{t-d}^i)$ the transition function of LSTAR, and Δy_{t-d}^i the transition variable.

	Real Exports (Δy_t^1: LSTAR)	Real Global GDP (Δy_t^2:LSTAR)	REER (Δy_t^3: LSTAR)
ϕ_0	0.0819 (0.3344)	0.1845** (0.0170)	−0.0012 (0.9765)
α_1	−0.0256 (0.7886)	0.0568 (0.6187)	0.0494* (0.0711)
ϕ_1^1	−0.8236*** (0.0002)	1.7105 (0.3879)	0.2349 (0.1249)
ϕ_2^1	−0.0273 (0.6025)	0.0450 (0.9670)	−0.0394 (0.8633)
ϕ_3^1	−0.4202** (0.0120)	−3.1103* (0.0889)	0.4487** (0.0106)
ϕ_4^1	0.2728 (0.1105)	0.1038 (0.7692)	0.5338*** (0.0012)
ϕ_1^2	2.4494*** (0.0025)	5.3144* (0.0645)	−0.7248*** (0.0000)
ϕ_2^2	−1.5348* (0.0999)	1.9000 (0.1173)	−0.4617* (0.0913)
ϕ_3^2	−0.2700 (0.7557)	4.3774** (0.0133)	0.2992 (0.5407)
ϕ_4^2	−2.4981 (0.1305)	0.7093 (0.3840)	−0.5603*** (0.0115)
ϕ_1^3	0.65219 (0.3529)	1.4040* (0.0780)	0.7342*** (0.0006)
ϕ_2^3	0.01121 (0.2932)	−2.9010* (0.0687)	0.3857 (0.1486)
ϕ_3^3	0.5523* (0.0878)	4.9220** (0.0472)	−0.8884*** (0.0082)
ϕ_4^3	−0.2242 (0.2763)	−5.1777* (0.0641)	−0.3480* (0.0524)
ρ_0	0.0425 (0.8354)	−0.1835** (0.0208)	0.0127 (0.7736)
α_2	0.1751* (0.0699)	−0.0595 (0.6100)	−0.0520* (0.0782)
ρ_1^1	0.1843 (0.7794)	−1.8622 (0.3589)	−0.3734* (0.0949)
ρ_2^1	0.2334 (0.9017)	−0.1564 (0.8911)	−0.1995 (0.4593)
ρ_3^1	2.1018*** (0.0000)	3.3038* (0.0720)	−0.6548*** (0.0051)
ρ_4^1	−0.2785 (0.5989)	−0.1000 (0.7948)	−0.4940** (0.0351)
ρ_1^2	3.7645*** (0.0001)	−5.2816* (0.0678)	0.8280*** (0.0000)
ρ_2^2	−2.4895* (0.0889)	−2.0531* (0.0915)	0.3903 (0.2077)
ρ_3^2	−0.4800 (0.9557)	−4.3016** (0.0174)	−0.2203 (0.6761)
ρ_4^2	−1.9481 (0.2959)	−0.5767 (0.5004)	0.8781*** (0.0012)

ρ_1^3	−0.2220 (0.1542)	−1.3763* (0.0886)	−0.8029*** (0.0013)
ρ_2^3	0.3860 (0.1953)	2.5155 (0.1078)	−0.2451 (0.4613)
ρ_3^3	−2.2202*** (0.0011)	−4.4122* (0.0649)	1.0024*** (0.0051)
ρ_4^3	−0.0810 (0.6609)	5.0527* (0.0735)	0.2492 (0.2927)
γ	4.3178** (0.0336)	18.2753** (0.0206)	11.2367** (0.0463)
c	0.0779*** (0.0000)	−0.0292*** (0.0000)	−0.0242 (0.2678)
adjusted R^2	0.7511	0.4417	0.2320

Notes: The values in parentheses below the regression coefficients are the heteroskedasticity robust t-statistics; SER is the standard error of regression, and LLV the log likelihood value. *, **, and *** represent significant at 10%, 5%, and 1% level, respectively.

3. Granger Causality and Cumulative Net Effects

Given the results of the STAR-VECM estimation in the previous section, we are interested in gauging the cumulative net effect to evaluate the total net effect of a Granger-causing variable on the Granger-caused variable.

In the STAR-VECM estimation results, we calculate the cumulative net effects as follows. That of Δy_t^2 on Δy_t^1 can be calculated by adding the coefficients in the estimation equation $\Delta y_t^1 = \left[\phi_0 + \alpha_1^1 z_{t-1} + \Sigma_{j=1}^3 \Sigma_{i=1}^p \phi_i^j \Delta y_{t-i}^j\right] + \left[\rho_0 + \alpha_2^1 z_{t-1} + \Sigma_{j=1}^3 \Sigma_{i=1}^p \rho_i^j \Delta y_{t-i}^j\right] \cdot F(\Delta y_{t-d}^1) + \varepsilon_t^1$. Under the condition that Δy_t^2 significantly Granger-causes Δy_t^1, we test the null hypothesis $H_0 : \phi_1^1 + \phi_2^1 + \cdots + \phi_p^1 = 0$. We calculate the cumulative net effect by adding the coefficients of the Granger-causing variables $\Sigma_{i=1}^p \phi_i^1$ in the contractionary regime and $\Sigma_{i=1}^p \phi_i^1 + \rho_i^1$ in the expansionary regime for the cases where the null hypothesis is not accepted at least at the 10% significance level.[15)]

Based on the Granger causality test and the cumulative net effects, we examine whether and how the factors determining exports have dynamic impacts on it. Based on our estimation results, the cumulative net effects in the simple linear VECM and the nonlinear STAR-VECM are compared,

15) In calculating the cumulative net effects, we summed only those coefficients that are statistically significant at least at 10% significance level.

as presented in Tables 5:

Table 5. Comparison of (Cumulative) Net Effects on Exports between Linear VECM and STAR-VECM

The net effect of Δy_t^2 on Δy_t^1 is calculated by summing up the coefficients in the following estimation equation:
$\Delta y_t^1 = \left[\phi_0 + \alpha_1^1 z_{t-1} + \Sigma_{j=1}^3 \Sigma_{i=1}^p \phi_i^j \Delta y_{t-i}^j\right] + \left[\rho_0 + \alpha_2^1 z_{t-1} + \Sigma_{j=1}^3 \Sigma_{i=1}^p \rho_i^j \Delta y_{t-i}^j\right] \cdot F(\Delta y_{t-d}^1) + \varepsilon_t^1$,
where Δy_t^1 is the growth rate of exports, Δy_t^2 the growth rate of real global GDP, Δy_t^3 the log difference of real effective exchange rate of the Korean Won. The numbers reported are the (cumulative) net effects. Under the condition that Δy_t^2 significantly Granger causes Δy_t^1, we test the null hypothesis $H_0 : \phi_1^1 + \phi_2^1 + \cdots + \phi_p^1 = 0$. If the null hypothesis is not accepted at least at the 10% significance level, we calculate the cumulative net effect by adding the coefficients of the Granger-causing variables (Δy_t^2) $\Sigma_{i=1}^p \phi_i^1$ in the contractionary regime and $\Sigma_{i=1}^p \phi_i^1 + \rho_i^1$ in the expansionary regime. For each pair, the (cumulative) net effects in the expansionary regime when $F(\bullet) = 1$ and in the contractionary regime when $F(\bullet) = 0$ are reported. *, ** and *** denote that the null hypothesis is rejected at the 10%, 5% and 1% levels, respectively.

Linear VECM

		Granger–caused variables
		Δy_t^1 (real Korean exports)
Granger–causing variables	Δy_t^2 (real global GDP)	1.2803**
	Δy_t^3 (real effect exchange rate)	Insignificant

STAR–VECM

		Granger–caused variables	
			Δy_t^1(real Korean exports)
Granger–causing variables	Δy_t^2 (real global GDP)	Contractionary regime	0.9146**
		Expansionary regime	2.1896**
	Δy_t^3 (real effective exchange rate)	Contractionary regime	0.5523*
		Expansionary regime	-1.6679***

Notes: *: significant at 10% level, **: significant at 5% level, and ***: significant at 1% level.

Table 5 above reports a comparison between the simple linear VECM and the non-linear STAR-VECM in terms of the cumulative net effects on Korean exports. In the simple linear VECM, the net effect of real global GDP (Δy_t^2) on Korean exports (Δy_t^1) is estimated as 1.2803 at the 5% significance level. The net effect on Korean exports of the real effective exchange rate (Δy_t^3) is estimated insignificant.

However, in the results with the STAR-VECM model we find evidence that the effects on Korean exports of real global GDP (Δy_t^2) and the real effective exchange rate (Δy_t^3) change significantly over the regimes. The net effect of real global GDP (Δy_t^2) on Korean exports (Δy_t^1) is estimated as 0.9146 under the contractionary regime and 2.1896 under the expansionary regime, with significance levels of 5%. This asymmetry in effects between the different regimes reveals that the response of exports with respect to global GDP is elastic during an expansionary regime but inelastic during a contractionary regime.

The real effective exchange rate (Δy_t^3) also shows the asymmetric net effects on Korean exports over the two regimes. Compared to the negative long-run relationship between the real effective exchange rate and exports shown in Table 2, the short-run relationship also turns out to be negative (-1.6679) and elastic during the expansionary regime, but changes to positive (0.5523) and inelastic during the contractionary regime. The positive relationship during the contractionary regime might be attributable to Korean exports' high dependency on imported intermediate inputs, because a depreciated Korean won results in increased costs of the imported inputs for producing goods for export, leading therefore to a decline in exports, and this cost effect seems to be dominant during the contractionary regime.[16)]

An important finding in these results is that the positive effect on Korean exports of real global GDP (Δy_t^2) intensifies under the expansionary regime. In time series analysis, we call this the dynamic *'momentum effect'* on exports under their expansionary regime. We also find that the real effective exchange rate (Δy_t^3)'s negative impact on exports is only seen under the expansionary regime of exports (Δy_t^1) with

16) Among total Korean imports, the share of intermediate goods is approximately 48% on average for the period of 2000 to 2016, while the average shares of final goods and raw materials are 23% and 25% respectively. Also, recent studies such as Yoon and Kim (2017) find the similar results that depreciation in exchange rate decreases Korea's exports.

a larger magnitude than under the contractionary regime, which is further evidence of a dynamic *'momentum effect'* on Korean exports (Δy_t^1) under their expansionary regime.

V. Further Studies: Dynamic Momentum Effects on Korean Exports

Concerning the empirical results in the previous section, it is important to note that Korean exports reveal dynamic *'momentum properties'* in its expansionary regimes. In this section we investigate further the dynamic behavior of Korean exports using nonlinear STAR models, by examining the characteristic roots derived from the estimations. The characteristic roots are computed from the following characteristic polynomial:

$$\omega^k - \Sigma_{j=1}^{k}(\varphi_j^k + \rho_j^k F)\omega^{k-j} = 0, \tag{5}$$

where the ω's are the characteristic roots for the k^{th} order, φ_j^k is a vector of $(\varphi_1^k, \ldots, \varphi_1^k)$, and ρ_j^k is a vector of $(\rho_1^k, \ldots, \rho_1^k)$. First we calculate the roots for the regime with $F=0$, which corresponds to the lower (or contractionary) state in the LSTAR model. We next calculate the roots for the regime with $F=1$, which describes the upper (or expansionary) state in that model.

Table 6 presents the characteristic roots for the contractionary and the expansionary regimes for exports. Both regimes have pairs of complex roots. This suggests that Korean exports are characterized by cyclical movements during both its expansionary and their contractionary phases, and that the STAR models well describe its asymmetric behavior.

The contractionary regime $(F=0)$ includes explosive roots, thus indicating that exports appear to be less stable in their contractionary regimes. However, the expansionary regime $(F=1)$ is more stable because it does not include explosive roots. Hence, once exports are in the expansionary regime they are more likely to remain there for a while, whereas they tend to pass through the contractionary regime quickly. This dynamic property of exports over the two distinct regimes illustrates Korean exports' *'momentum property'* in their expansionary regime.

The implications are as follows. While exports (Δy_t^1) tend to remain in their expansionary phase longer, once they are in a phase of contraction it tends to pass very rapidly. This dynamic interpretation of Korean exports demonstrates their *'momentum properties'* in their expansionary regimes.

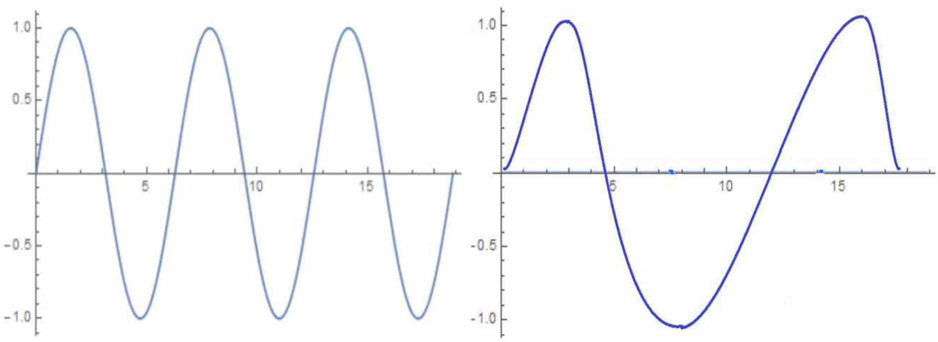
The *'momentum property'* in the expansionary regime for exports can be visually seen in Figure 3. If we take a look at graph a) in Figure 3, both the expansionary and the contractionary regimes are symmetric in terms of their individual lengths. However, we have longer or momentum expansionary regimes in graph b) of Figure 3.

Table 6. Characteristic Roots in Each Regime.

Regime	Most prominent roots	Modulus
Contractionary regime (F = 0)	−1.1451 0.0000 0.1357 ± 0.6049i	1.1451 0.0000 0.9795
Expansionary regime (F = 1)	0.6894 −0.7393 ± 0.6425i	0.6894 0.6199

Figure 3. Regime Change Patterns

a) Non-explosive roots in both regimes b) Explosive roots in contractionary regimes



Ⅵ. Conclusion

In this paper we provide new evidence that the dynamic patterns of Korean exports change across their regimes. Recent studies show that the short-run relationship between world trade and world income can change depending upon the economic cycle, even though their long-run relationship remains stable. Motivated by these recent findings, we examine how the relationships of Korea's exports to global GDP and to the exchange rate change depending on whether they are in their contractionary or their expansionary regimes. Using a Smooth Transition Autoregressive Vector Error Correction model (STAR-VECM), we incorporate the two distinct features of endogenous state changes, and co-integration between exports and the related factors determining them.

Our estimation reveals asymmetries in the short-run relationships of Korea's exports to global GDP and to the exchange rate, between the contractionary and the expansionary export regimes, although their long-run relationships remain stable. More specifically, the positive effect of real global GDP on Korea's real exports is inelastic under contractionary regimes but changes to elastic under expansionary regimes. The effect of the real effective exchange rate on Korea's real exports is positive and inelastic during contractionary regimes, but negative and elastic in expansionary regimes. Since the effects of the two determinants on Korea's exports intensify under expansionary regimes, we call them the dynamic *"momentum effects"* on exports during their expansionary regimes. Our results suggest that the asymmetric properties of the relationships of Korea's exports to global GDP and to the exchange rate, depending on whether exports are in their contractionary or their expansionary regimes, should be taken into account in order to better understand and forecast the behavior of Korea's exports related to these factors.

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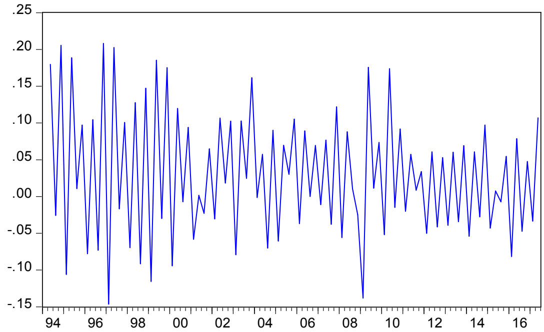
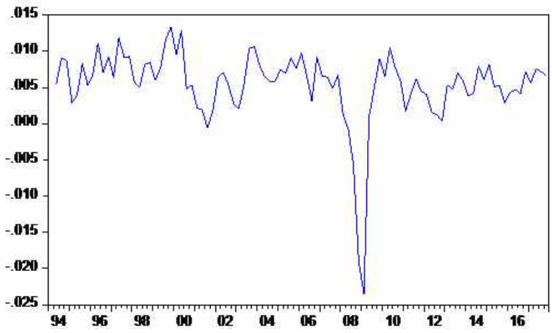
Appendix

1. Figure A1. Korea's Exports, Global GDP, and the Exchange Rate (rates of growth, 1994 Q1 – 2016 Q4)

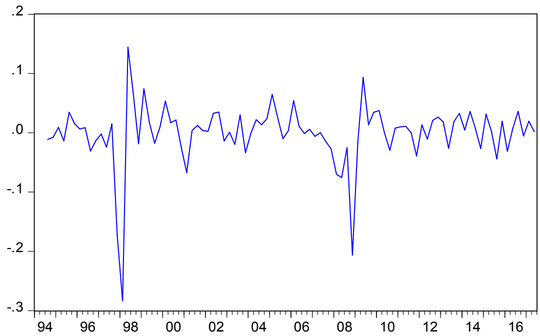
Log difference (or growth rate) of real Exports (Δy_t^1)



Log difference of real GDP of OECD countries



Log difference of real effective exchange rate of Korean Won (Δy_t^2)



2. Linearity test, and choice of STAR model between LSTAR and ESTAR

We conduct the linearity test to see whether the linear VECM model is more appropriate than a nonlinear STAR alternative. Following Teräsvirta and Anderson (1992), we estimate the following auxiliary regression:

$$\begin{aligned}\widehat{\varepsilon}_t = \phi_0 + \sum_{d=1}^{k}\sum_{i=1}^{k}\phi_i \bullet \Delta y_{t-i}(\Delta y_{t-d}) + \sum_{d=1}^{k}\sum_{i=1}^{k}\gamma_i \bullet \Delta y_{t-i}(\Delta y_{t-d})^2 \\ + \sum_{d=1}^{k}\sum_{i=1}^{k}\kappa_i\phi_{1,i} \bullet \Delta y_{t-i}(\Delta y_{t-d})^3,\end{aligned} \tag{A.1}$$

where $k = 4$, and the linearity test becomes $H_{01} : \phi_i = \gamma_i = \kappa_i = 0$, for all i.

Given that linearity is not accepted for all of the sample, we next specify an appropriate STAR model to capture the nonlinear dynamics of each variable. According to Teräsvirta and Anderson (1992), the linearity test may be used to deliver a sequence of nested hypothesis tests H_{04}, H_{03}, H_{02} for the choice between the LSTAR and ESTAR alternatives. The sequence of nested tests for the coefficients in equation (A.1) above implies:

$$\begin{aligned}&H_{04} : \kappa_i = 0, && i = 1, \cdots, k \\ &H_{03} : \gamma_i = 0, \text{ given all } \kappa_i = 0 && i = 1, \cdots, k \\ &H_{02} : \phi_i = 0, \text{ given all } \kappa_i = 0 \text{ and all } \gamma_i = 0 && i = 1, \cdots, k\end{aligned} \tag{A.2}$$

Rejection of H_{04} implies selecting the LSTAR model. If H_{04} is not rejected and H_{03} is rejected, the ESTAR model is chosen. Not rejecting H_{04} and H_{03} and rejecting H_{02} leads to an LSTAR model. If none of the null hypotheses are rejected, then the linearity cannot be rejected and so the linear model should be chosen.

〈Abstract in Korean〉

국면전환을 고려한 수출변화에 관한 실증연구

김세완*, 최문정**

본 연구에서는 우리나라 수출과 그 결정요인(글로벌 GDP 및 환율) 간의 관계가 수출의 확장-수축기 국면전환에 따라 어떻게 변화하는지를 살펴보았다. 이를 위해 수출의 확장-수축기 간 동태적 국면전환과 변수 간의 공적분 관계를 고려한 분석방법인 평활전이 자기회기 벡터오차수정모형(STAR-VECM)을 도입하였다. 추정결과, 우리나라 수출과 글로벌 GDP 및 환율 간에는 안정적인 장기균형관계가 유지되나 이들 간의 단기관계는 수출의 국면전환에 따라 비대칭적인 것으로 분석되었다. 글로벌 GDP 증가가 우리나라 수출증가율을 상승시키는 영향은 수출의 확장기에는 탄력적인 반면 수축기에는 비탄력적으로 나타났으며, 실질실효환율의 절하가 수출증가율을 상승시키는 영향도 확장기에는 탄력적이나 수축기에는 그렇지 않은 것으로 나타났다. 본 연구는 우리나라 수출의 국면에 따라 주요 결정요인의 영향력이 비대칭적으로 나타날 수 있음을 보여주고 있어 수출 전망시 이에 대한 고려가 필요함을 시사한다.

핵심 주제어: 수출, 글로벌 GDP, 환율, 국면전환, 평활전이 자기회기 모형

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2	미국 장기시장금리 변동이 우리나라 금리기간구조에 미치는 영향 분석 및 정책적 시사점	강규호·오형석
3	직간접 무역연계성을 통한 해외충격의 우리나라 수출입 파급효과 분석	최문정·김근영
4	통화정책 효과의 지역적 차이	김기호
5	수입중간재의 비용효과를 고려한 환율변동과 수출가격 간의 관계	김경민
6	중앙은행의 정책금리 발표가 주식시장 유동성에 미치는 영향	이지은
7	은행 건전성지표의 변동요인과 거시건전성 규제의 영향	강종구
8	Price Discovery and Foreign Participation in The Republic of Korea's Government Bond Futures and Cash Markets	Jaehun Choi·Hosung Lim·Rogelio Jr. Mercado·Cyn-Young Park
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10	인구 고령화와 정년연장 연구 (세대 간 중첩모형(OLG)을 이용한 정량 분석)	홍재화·강태수
11	예측조합 및 밀도함수에 의한 소비자물가 상승률 전망	김현학
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13	Failure Risk and the Cross-Section of Hedge Fund Returns	Jung-Min Kim
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16	바젤Ⅲ 은행 경기대응완충자본 규제의 기준지표에 대한 연구	서현덕 · 이정연
17	우리나라 대출 수요와 공급의 변동요인 분석	강종구 · 임호성
18	북한 인구구조의 변화 추이와 시사점	최지영
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22	글로벌 금리 정상화와 통화정책 과제: 2015년 한국은행 국제컨퍼런스 결과보고서	한국은행 경제연구원
23	The Effects of Global Liquidity on Global Imbalances	Marie–Louise DJIGBENOU–KRE · Hail Park
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25	Deflation and Monetary Policy	Barry Eichengreen
26	Macroeconomic Shocks and Dynamics of Labor Markets in Korea	Tae Bong Kim · Hangyu Lee
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3	Spillovers from U.S. Unconventional Monetary Policy and Its Normalization to Emerging Markets: A Capital Flow Perspective	Sangwon Suh · Byung-Soo Koo
4	Stock Returns and Mutual Fund Flows in the Korean Financial Market: A System Approach	Jaebeom Kim · Jung-Min Kim
5	정책금리 변동이 성별·세대별 고용률에 미치는 영향	정성엽
6	From Firm-level Imports to Aggregate Productivity: Evidence from Korean Manufacturing Firms Data	JaeBin Ahn · Moon Jung Choi
7	자유무역협정(FTA)이 한국 기업의 기업내 무역에 미친 효과	전봉걸 · 김은숙 · 이주용
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7	국면전환 확산과정모형을 이용한 콜금리 행태 분석	최승문 · 김병국

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11	인구구조변화가 인플레이션의 장기 추세에 미치는 영향	강환구
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26	고령화가 대외투자에 미치는 영향	임진수 · 김영래
27	인구고령화가 가계의 자산 및 부채에 미치는 영향	조세형 · 이용민 · 김정훈
28	인구고령화에 따른 우리나라 산업구조 변화	강종구
29	인구구조 변화와 재정	송호신 · 허준영
30	인구고령화가 노동수급에 미치는 영향	이철희 · 이지은
31	인구 고령화가 금융산업에 미치는 영향	윤경수 · 차재훈 · 박소희 · 강선영
32	금리와 은행 수익성 간의 관계 분석	한재준 · 소인환
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6	직업훈련이 청년취업률 제고에 미치는 영향	최충·김남주·최광성
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12	Uncertainty Shocks and Asymmetric Dynamics in Korea: A Nonlinear Approach	Kevin Larcher · Jaebeom Kim · Youngju Kim
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14	Central Bank Reputation and Inflation-Unemployment Performance: Empirical Evidence from an Executive Survey of 62 Countries	In Do Hwang
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제2018 –17	E–money: Legal Restrictions Theory and Monetary Policy	Ohik Kwon · Jaevin Park
18	글로벌 금융위기 전·후 외국인의 채권투자 결정요인 변화 분석: 한국의 사례	유복근
19	설비자본재 기술진보가 근로유형별 임금 및 고용에 미치는 영향	김남주
20	Fixed–Rate Loans and the Effectiveness of Monetary Policy	Sung Ho Park
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