Accounting for the Sources of the Recent Decline in Korea's Exports to China

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Contents

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Following a two-decade period of double-digit growth, South Korean exports to China have declined since 2013. We investigate the sources of this recent decline using two complementary methodologies, an accounting decomposition and a model-based decomposition. First, we decompose the changes in Korea's exports to China as a share of output into within-industry and between-industry effects using disaggregated industry-level data. Our results show that during the high export growth period of 1990-2009, the within effect dominated; in the export slowdown period of 2010-2014, the within effect contributed to the slowdown in that individual sectors, on net, exported a smaller fraction of their output to China. Second, we apply a dynamic multi-sector, multi-country general equilibrium model to decompose the shocks that cause the decline in Korea's exports to China. The results reveal that in 2013-2016 China experienced a sharp reduction in its desire to accumulate capital and to consume manufactured goods. All else equal, these forces would imply fewer imports by China from Korea of manufactured goods. Given that Korea's exports to China are highly concentrated in manufactured intermediate and capital goods, these shocks could, in principle, explain most of the decline in Korea's exports to China during this period.

Keywords: Korea, China, Export decline, Shocks, Decomposition

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Ⅰ. Introduction

Following a two-decade period of double-digit growth, South Korean exports to China, measured in U.S. dollars, have declined since 2013. The dollar value of Korean exports to China in 2016 was 14.7 percent lower than it was in 2013.[1] This fact is doubly surprising given that both economies have experienced solid GDP growth during this period.

At the same time, Korea's exports to the world have declined, as seen in Figure 1. Moreover, global trade has declined, as well. This suggests the possibility that the decline may be mirroring declines in Korea's trade overall, as well as the global decline in trade.

The goal of our project is to understand the sources of Korea's decline in exports to China during the past several years. To what extent are there Korea-specific, China-specific, or bilateral-specific factors driving this decline? To what extent are global factors driving this decline? What are these factors? In turn, what fundamental forces are driving these factors?

We address these questions with two methodologies, both involving decompositions. The first decomposition is a "within-between" accounting decomposition of Korea's sectoral exports to China. This decomposition will indicate whether a significant fraction of sectors now ships a smaller fraction of their output to China (within effect), or whether a greater share of output is concentrated in sectors that ships little to China in the first place (between effect).

The second decomposition is a model-based "shock" decomposition. This decomposition starts with a parameterized dynamic general equilibrium model of trade. The model is used to recover the shocks, that explain, or account for, the data. The advantage of this approach is that, in principle, it can address all of the questions raised above. Our model and decomposition will draw from Eaton et al. (2016, hereafter "EKNR")[2]. The authors of this paper develop a dynamic, multi-sector, multi-country

1) Also, the dollar value of Korean goods exports to China in 2016 declined by 9.3 percent compared to the previous year.

2) In turn, EKNR's decomposition draws from Chari, Kehoe, and McGrattan (2007).

framework to account for, and explain, the large drop in global manufactured goods trade during the Great Recession. They find that the most important force was a decline in the marginal efficiency investment, which reduced the demand for capital goods.

We apply a version of their framework to study Korea's decline in exports to China. Our framework will be simplified relative to EKNR in terms of the number of countries and sectors, and also on the specification of dynamics. We will employ a "Solow-model" specification for investment, rather than having investment based on the intertemporal Euler equation. Overall, though, our framework draws from EKNR — the key distinction is in the application.

Our two decompositions complement each other, and together, help us better understand the overall pattern and the sources of the recent decline in Korea's exports to China. The accounting decomposition uses highly disaggregated data to decompose the overall decline. In particular, the manufacturing sector consists of approximately 240 industries. Hence, this decomposition can show the importance of disaggregated manufacturing industries. By contrast, the model-based decomposition is considerably more aggregated, and cannot distinguish between the within and between forces for manufacturing. On the other hand, the model-based decomposition can suggest the causal forces behind the export decline, as well as the channels through which the causal forces operate, which the accounting decomposition cannot. Finally, to the extent that the accounting decomposition reveals that within effects are more important than between effects it suggests that using aggregated sectors in the model-based decomposition may not be unreasonable. This is, in fact, our finding, as we discuss below.

We conduct our accounting decomposition with 384 Korean Standard Industrial Classification (KSIC) industries covering the period 1990-2014. The decomposition reveals that the within effect accounts for both the high export growth period, as well as the recent slowdown. That is, the majority of the slowdown in aggregate export growth to China is accounted for by individual sectors exporting a smaller fraction of their output to China than before.

Our model-based decomposition framework has four "countries": South Korea, China, the G7, and the rest-of-the-world (ROW), and two sectors, non-manufacturing and manufacturing. The framework has five shocks that drive the model: an aggregate employment shock, shocks to the costs of international trade, total factor productivity (TFP) shocks, a saving shock that determines investment, and a sectoral preference shock. We back out these shocks from the model for each country covering the period 2005-2016. We find that all five shocks were quite large during the period we examine. However, only two, the investment shock, and the preference shock, can potentially explain the decline in Korea's exports to China. In particular, China experienced a sharp decline in its investment or saving rate, which implies a lower rate of capital accumulation, and consequently, a decline in imports of capital goods, and materials used to make capital goods, from countries like Korea. In addition, China experienced a shift in preferences away from manufacturing goods, which would also imply a decline in imports of such goods from countries like Korea.

In the next section, we provide a brief overview of South Korea's export patterns. This is followed by the accounting decomposition. In section 4, we set up the model and discuss briefly some of the intuition underlying it. Then, we present a formulation of the model in "changes", and we show how to back out the shocks. Section 6 presents our calibration, as well as the results, and Section 7 concludes.

Ⅱ. Overview of Korea's Export Patterns

Figure 1 shows the growth rate of Korea's exports to China (blue line) and the growth rate of Korea's exports to the world (red line). The exports are expressed in nominal values. From 1990 to the mid-2000s, Korea's exports to China grew much faster than its exports to the world. However, in recent years, the growth rates of exports to China, as well

Figure 1: Korea Export Growth Rate

Note: Growth rate of nominal value of goods exports
Source: Korea International Trade Association (KITA)

as to the world, have turned negative. In 2015 and 2016, the negative growth was largest. Although Korean export growth has been negative in the past, these periods were during times of economic recession. Thus, it is a puzzle that the negative growth in the recent period occurred during a period of Korean and global economic recovery.

The slowdown and decline in Korea's exports to China is more pronounced when the data is expressed as a share of GDP or gross output. The first column of Table 1 shows that Korean exports of goods and services as a share of GDP fell from 58 percent in 2012 to 44 percent in 2016. In the same period, Korean exports of goods as a share of GDP also fell from 49 percent to 36 percent. The third column shows that exports of goods to China as a share of GDP fell from 11 percent in 2013 to 9 percent in 2016. The table reveals that the shares of exports to the world and China peaked in 2012 and 2013, respectively. Table 2 focuses on manufacturing exports as a share of gross manufacturing output. It reveals a similar pattern to the previous table; manufacturing exports to China as a share of output peaked in 2013; manufacturing exports to the world as a share of output peaked in 2008.

Table 1: Korea Export Share of GDP

Year	World (Goods and Services)	World (Goods Only)	China (Goods Only)
1990	0.251	0.214	0.002
1995	0.262	0.215	0.016
1998	0.406	0.340	0.032
2000	0.362	0.302	0.033
2003	0.347	0.286	0.052
2005	0.384	0.318	0.069
2006	0.395	0.326	0.069
2007	0.417	0.341	0.073
2008	0.530	0.432	0.091
2009	0.495	0.403	0.096
2010	0.513	0.424	0.107
2011	0.574	0.488	0.112
2012	0.583	0.494	0.110
2013	0.558	0.474	0.112
2014	0.517	0.434	0.103
2015	0.474	0.393	0.099
2016	0.441	0.362	0.088
2017	0.457	0.377	0.093

Sources: BOK (GDP, Goods and Services Export), KITA(Goods Export)

Table 2: Korea Export Share of Gross Output (Manufacturing)

Year	World	China
1990	0.234	0.005
1995	0.250	0.018
1998	0.375	0.031
2000	0.320	0.034
2003	0.321	0.058
2005	0.319	0.069
2006	0.316	0.067
2007	0.314	0.069
2008	0.360	0.078
2009	0.354	0.084
2010	0.354	0.089
2011	0.352	0.085
2012	0.347	0.085
2013	0.348	0.090
2014	0.343	0.086
2015	0.351	0.090
2016	0.341	0.084

Sources: BOK (Output), UN Comtrade (Export)

Notes: Manufacturing export values are calculated by aggregating HS 6-digit export data mapped into the ISIC rev.3 3-digit code, where manufacturing sector is defined as ISIC code 15-36.

Figure 2: Korea Exports to China as Share of Total Exports

Source: KITA

Figure 2 shows that the share of Korea's exports to China relative to its exports to the world increased from virtually 0 percent in 1990 to more than 25 percent by the time of the Great Recession. However, since then, the export share has remained constant and/or declined.

Ⅲ. Accounting Decomposition

In this section, we decompose changes in Korea's exports to China as a fraction of Korea's gross output into "within-industry" and "between-industry" effects. To this end, we use 6-digit HS code product-level trade data and output data of approximately 380 industries classified by basic Korea Standard Industry Classification (KSIC) code.

1. Framework

The aggregate change of Korea's exports to China (X_{kc}) relative to Korea's gross output (Y_k) can be decomposed into two components as equation 1 shows below:

$$\triangle \frac{X_{kc}}{Y_k} = \sum_{i \in I} \left[\underbrace{0.5 \triangle \frac{X^i_{kc,t}}{Y^i_{kt}} (w^i_t + w^i_{t-1})}_{Within-industry\ Effect} + \underbrace{0.5 \triangle w^i_t \left(\frac{X^i_{kc,t}}{Y^i_{kt}} + \frac{X^i_{kc,t-1}}{Y^i_{kc,t-1}} \right)}_{Between-industry\ Effect} \right] \quad (1)$$

where $w^i_t \equiv \frac{Y^i_{kt}}{\Sigma_{i \in I} Y^i_{kt}}$.

$X^i_{kc,t}$ and $Y^i_{kc,t}$ are Korea's exports to China in industry i at time t and Korea's gross output in industry i at time t, respectively. The left-hand side variable in equation 1, the change of Korea's total exports to China over some time period, as a fraction of total output in Korea, can be decomposed into a sum across industries of two different terms on the right-hand side. The first term, the within-industry effect, is the change in industry-level export to output ratio weighted by average share of output of the industry. The second term, the between-industry effect, is the change in the output share of the industry weighted by the average of export-output ratio of the industry. For instance, if the aggregate export to output ratio declines, there are two sources of changes. One is that the individual industry's export to output ratio declines, the within-industry effect. The other is that output shifted as resources are reallocated to sectors that have low export to output ratio, the between-industry effect.

2. Data for Accounting Decomposition

To conduct the within-between accounting decomposition, we use product-level export data and industry-level output data. Export values at the 6-digit HS classification are obtained from customs data compiled by the Korea International Trade Association (KITA). Output values categorized into 384 basic KSIC codes ares sourced from Input-Output (I-O) tables provided by the Bank of Korea. We concord the HS classification of trade data with the KSIC classification of output data to that the 6-digit HS codes are mapped into 384 KSIC industries.

The time period of the final dataset covers from 1990 to 2014, including 1990, 1995, 1998, 2000, 2003, and every year from 2005 to

2014. There was limited availability of I-O tables before 2005.[3] This time period essentially covers most of the economic growth of China, as well as the global financial crisis.[4]

3. Accounting Decomposition Results

Table 3 shows the accounting decomposition of equation 1 for all sectors. For each row, the second column shows the aggregate change in the export to output ratio compared to the preceding period. The next two columns show the within-industry and between-industry effects, respectively. In 1995, for example, Korea's exports to China, as a share of Korea's gross output, increased by almost 2 percentage points compared to 1990. The within effect is almost two thirds of the total increase, indicating that Korea's industries exported a greater share of their output to China. On the other hand, the between effect accounts for almost one third of the change, indicating that the output share of Korea's industries shifted towards industries that have high export shares to China.

Looking at the broader pattern, the within and between effects fluctuate over time, but generally the within effects tend to be larger in magnitude than the between effects. The decomposition results for the manufacturing sector is presented in Table 4, and it also shows a similar pattern as the results for all sectors.

To better understand the pattern in Table 3 and Table 4, we present the sum of each effect over time in Table 5. As seen in the final row of the summary table, the within effect is dominant and in the right direction for the entire 1990-2014 period. Indeed, the within effect accounts for more than 100 percent of the growth in Korea's exports to

3) We also address the changes in industry categories of KSIC over time due to classification revision by rearranging old KSIC code based on 2010 standard.

4) The decline in Korea's exports to China and to the world was more pronounced in 2015 and 2016. However, our accounting decomposition is limited to years until 2014 due to data availability. Korean IO tables in 2015 and 2016 are not currently published. When these tables become available, we will update our accounting decomposition to include these years.

Table 3: Accounting Decomposition Results for All Sectors

Year	$\triangle \frac{X_{kc}}{Y_k}$	Within Effect	Between Effect
1990			
1995	0.0177	0.0126	0.0051
1998	0.0168	0.0148	0.0020
2000	−0.0207	−0.0010	−0.0197
2003	0.0082	0.0114	−0.0031
2005	0.0082	0.0057	0.0025
2006	−0.0005	−0.0001	−0.0004
2007	0.0016	0.0022	−0.0006
2008	0.0064	0.0051	0.0013
2009	0.0031	0.0026	0.0004
2010	0.0025	−0.0031	0.0057
2011	−0.0002	−0.0031	0.0029
2012	−0.0005	0.0009	−0.0014
2013	0.0020	0.0031	−0.0011
2014	−0.0026	−0.0009	−0.0017

Table 4: Accounting Decomposition Results for Manufacturing Sectors

Year	$\triangle \frac{X_{kc}}{Y_k}$	Within Effect	Between Effect
1990			
1995	0.0187	0.0178	0.0010
1998	0.0178	0.0162	0.0016
2000	−0.0071	−0.0016	−0.0056
2003	0.0197	0.0246	−0.0049
2005	0.0148	0.0123	0.0024
2006	−0.0011	−0.0003	−0.0008
2007	0.0031	0.0047	−0.0015
2008	0.0097	0.0104	−0.0006
2009	0.0080	0.0054	0.0026
2010	0.0056	−0.0065	0.0121
2011	−0.0042	−0.0064	0.0022
2012	0.0003	0.0018	−0.0015
2013	0.0061	0.0064	−0.0002
2014	−0.0039	−0.0020	−0.0020

Table 5: Summary of Accounting Decomposition

	All Sectors		Manufacturing Sector	
Year	Within	Between	Within	Between
1990–2009	0.0532	–0.0125	0.0894	–0.0058
2010–2014	–0.0032	0.0044	–0.0066	0.0106
1990–2014	0.0500	–0.0081	0.0828	0.0048

China in all sectors, and more than 90 percent of the growth in Korea's exports to China in manufacturing. These results are particularly true in the 1990-2009 period. In the 2010-2014 period, in which overall exports to China grew slightly, the within effect is contributing negatively. This means that individual sectors are, on net, exporting a slightly smaller fraction of their output to China.[5)]

Given that the within effect dominates, we examine what industries account for the large within effect. Out of approximately 380 industry categories, we list the top 20 industries with the highest total within effect over the entire sample period. The sum of the within effect of these top 20 industries is 2.8 percent, where the total within effect is 5 percent, indicating that these industries account for almost three-fifths of the total within effect. Most of these industries comprise of intermediate goods related to electronics, chemicals, and steel, except for some industries such as automobiles and gasoline. During the sample period, a greater fraction of the output in these industries was exported to China.

To summarize, our within-between accounting decompositions suggest that the recent slowdown and decline in Korea's exports to China can be attributed to the within effect. Sectors that previously exported a greater and greater share of their output to China, year after year, are now sending a slightly smaller share of their output to China. The within effect appears to be larger in intermediate goods which tend to be more

5) One caveat is that the decomposition result numbers are specific to the particular disaggregation where we use 384 industries in our analysis. If the data is more aggregated, for example 2-digit industry level data, the result numbers could be different leading more emphasis on the within effect. If the data is more disaggregated such as firm-level data, the within effect could be smaller and between effect could be larger because the within effect in a sector masks a lot of activities and churning across firms within the sector.

involved in global value chain. Thus, the decline in the within effect after 2009 could imply that the global value chain between Korea and China has been weakened compared to pre-crisis period.

Table 6: Top 20 Industries with the Highest Within Effects

Rank	Product Categories	Within Effect
1	Integrated Circuits	0.0051
2	Other Electric Components	0.0036
3	Synthetic Resins	0.0024
4	Other Wireless Telecom and Broadcasting appr.	0.0018
5	Leather	0.0018
6	Aromatics	0.0015
7	Petrochemical Intermediate Products	0.0014
8	LCD at-panel Display Boards	0.0013
9	Cold Rolled Steel Plates and Sheets	0.0010
10	Chemical Fiber Fabrics	0.0010
11	Aliphatics	0.0010
12	Other Basic Organic Chemical Products	0.0009
13	Gasoline	0.0007
14	Computer Storage Units	0.0007
15	Mobile Phones	0.0007
16	Hot Rolled Steel Plates and Sheets	0.0007
17	Passenger Automobiles	0.0007
18	Other Textile Products	0.0006
19	Primary Plastic Products	0.0006
20	Footwear	0.0006
Total		0.0280

Notes: The rank is based on the total within effect for the entire sample period 1990-2014.
Sources: Author's calculation

Ⅳ. Model-Based Decomposition: Set up and Intuition

In this section, we lay out the dynamic, multi-country, multi-sector model. Time will be indexed by t. There are four “countries”: Korea, China, the G-7, and the rest-of-the-world, and they are indexed by n. There will be two sectors, manufacturing (m) and non-manufacturing (n); each will be indexed by j, and the two of them collectively will be denoted by the set $\Omega = \{m, n\}$. There is capital, but only one type, and it is accumulated via an exogenous saving rate — as in the Solow growth model. Aggregate labor adjusts exogenously. There is a representative household in each country.

1. Technologies

Each sector consists of a continuum of goods on the unit interval, indexed by z. Each good is made from labor, capital, and composite intermediate goods from both sectors via a Cobb-Douglas production function in period t with coefficients $\beta_n^{x,j}$ (where possible, we will use the same notation as in EKNR):

$$y_{n,t}^{j}(z) = a_{n,t}^{j}(z)\left(\frac{L_{n,t}^{j}(z)}{\beta_n^{L,j}}\right)^{\beta_n^{L,j}}\left(\frac{K_{n,t}^{j}(z)}{\beta_n^{K,j}}\right)^{\beta_n^{K,j}}\prod_{j'\in\Omega}\left(\frac{M_{n,t}^{jj'}(z)}{\beta_n^{M,jj'}}\right)^{\beta_n^{M,jj'}} \tag{2}$$

where $y_{n,t}^{j}(z)$ is output in country n, date t of good z in sector j. $L_{n,t}^{j}(z)$ is labor in country n, date t used to make good z in sector j, and similarly for $K_{n,t}^{j}(z)$. $M_{n,t}^{jj'}(z)$ is the amount of composite intermediate from sector j' used to make good z in sector j, country n, date t. Related, $\beta_n^{M,jj'}$ is the Cobb-Douglas intermediate input coefficient that gives the weight of the sector j' intermediate in sector j production (for good z, country n, date t). The sum of all the Cobb-Douglas coefficients equals one: $\beta_n^{L,j} + \beta_n^{K,j} + \sum_{j'\in\Omega}\beta_n^{M,jj'} = 1\,\forall\, j$.

Finally, $a_{n,t}^{j}(z)$ is the productivity term. The key assumption is that the productivity comes from Fréchet distribution.[6] The cumulative distribution function (CDF) of this distribution for country n, date t, and sector j is given by:

6) It has a special property that is useful, which is that the min or max of a sequence of Fréchet variables also has a Fréchet distribution.

$$F^j_{n,t}(a) = Pr[a^j_{n,t} \leq a] = e^{-\left(\frac{a}{\gamma A^j_{n,t}}\right)^{-\theta}} \tag{3}$$

There are two key parameters, $A^j_{n,t}$ and θ. $A^j_{n,t}$ governs the mean of the distribution and captures the overall productivity of country n, sector j, date t. θ relates to the variance of the distribution. A higher θ corresponds to less variance, i.e., a tighter distribution.

The individual goods can be traded — we will discuss this further below. Eventually, they are aggregated by a constant elasticity of substitution (CES) aggregator (with elasticity σ) to make a composite sectoral good, $x^j_{n,t}$.

$$x^j_{n,t} = \left(\int_0^1 x^j_{n,t}(z)^{\frac{\sigma-1}{\sigma}} dz\right)^{\frac{\sigma}{\sigma-1}} \tag{4}$$

where $x^j_{n,t}(z)$ is country n's absorption of good z in sector j. The sectoral good $x^j_{n,t}$ has three uses. It can be used for final consumption in country n: $C^j_{n,t}$. It can be used for investment: $I^j_{n,t}$. Finally, it can be used as an intermediate in the production of individual goods z in each sector j': $M^{j'j}_{n,t}(z)$.

2. Trade Costs

The trade costs will follow the usual "iceberg" form. For country n to receive one unit of a good in sector j date t from country i, $d^j_{ni,t} \geq 1$ goods need to be shipped. $d^j_{ni,t}$ is the iceberg cost. It is important to note that in quantitative applications of these types of models, the vast majority of trade costs are not barriers imposed by governments like tariff rates. Rather, they represent technological costs such as transportation costs, as well as unobservable barriers associated with culture, language, and related forces.

3. Capital Accumulation

Capital in country n is used as an input in each individual good's production. Capital is accumulated according to the standard equation:

$$K_{n,t+1} = (1-\delta)K_{n,t} + I_{n,t} \tag{5}$$

The aggregate investment good, $I_{n,t}$, is a Cobb-Douglas composite of the two sectoral investment goods:

$$I_{n,t} = \left(\frac{I^m_{n,t}}{\alpha_m}\right)^{\alpha_m}\left(\frac{I^n_{n,t}}{\alpha_n}\right)^{\alpha_n} \tag{6}$$

where $\alpha_m + \alpha_n = 1$. We can imagine a competitive investment "aggregator" firm that purchases the two sectoral investment goods and then combines them to make the composite investment good, which it sells at price $P^I_{n,t}$. The first order conditions from this problem imply:

$$P^m_{n,t} I^m_{n,t} = \alpha_m P^I_{n,t} I_{n,t} \tag{7}$$

and

$$P^n_{n,t} I^n_{n,t} = (1-\alpha_m) P^I_{n,t} I_{n,t} \tag{8}$$

Also,

$$P^I_{n,t} = (P^m_{n,t})^{\alpha_m} (P^n_{n,t})^{1-\alpha_m} \tag{9}$$

4. Preferences, Budget Constraint, and Household First Order Conditions

The representative household (consumer) in country n maximizes the following utility function:

$$U_n(.) = \sum_{t=0}^{\infty} \rho^t \left(\sum_{j \in \Omega} \psi_{n,t}^j \ln(C_{n,t}^j) \right) \tag{10}$$

where ρ is the discount factor. Also, $\psi_{n,t}^j$ is a time-varying Cobb-Douglas preference parameter — $\psi_{n,t}^j + \psi_{n,t}^n = 1$ — that governs the weight that the consumer puts on each sectoral good.

The consumer maximizes the above preferences subject to the following budget constraint:

$$P_{n,t}^m C_{n,t}^m + P_{n,t}^n C_{n,t}^n + P_{n,t}^I I_{n,t} = w_{n,t} L_{n,t} + R_{n,t} K_{n,t} \tag{11}$$

where $P_{n,t}^m$ is the price of the manufactured final good, $P_{n,t}^n$ is the price of the non-manufactured final good, $P_{n,t}^I$ is the price of the investment good, $w_{n,t}$ is the wage rate, and $R_{n,t}$ is the rental rate on capital, all expressed in a common unit.

At this point, we introduce the exogenous investment rate. We will assume that:

$$P_{n,t}^I I_{n,t} = s_{n,t}(w_{n,t} L_{n,t} + R_{n,t} N_{n,t}) \tag{12}$$

This has three implications. First, once we know current period output, we know current period investment, and as soon as we know current period investment, we can calculate the investment inputs from each sector. Second, we can rewrite the budget constraint as follows:

$$P_{n,t}^m C_{n,t}^m + P_{n,t}^n C_{n,t}^n = (1 - s_{n,t})(w_{n,t} L_{n,t} + R_{n,t} K_{n,t}) \tag{13}$$

The third and most important implication is that, because the investment decision is exogenous, we do not need the Euler equation to solve the model. Instead, the consumer problem is essentially just a static problem. Consumption of manufactured goods and non-manufactured goods are given by:

$$P^m_{n,t}C^m_{n,t} = \psi^m_{n,t}(1-s_{n,t})(w_{n,t}L_{n,t} + R_{n,t}K_{n,t}) \tag{14}$$

$$P^n_{n,t}C^n_{n,t} = (1-\psi^m_{n,t})(1-s_{n,t})(w_{n,t}L_{n,t} + R_{n,t}K_{n,t}) \tag{15}$$

5. Equilibrium Conditions

Labor and capital are freely mobile across sectors, and all factor and goods markets are characterized by perfect competition. The main sets of equilibrium conditions are those associated with the "static" problem of allocating resources in a given period. The factor market clearing conditions for each period t are:

$$\sum_{j\in\Omega}\int_0^1 L^j_{n,t}(z)dz = L_{n,t} \tag{16}$$

$$\sum_{j\in\Omega}\int_0^1 K^j_{n,t}(z)dz = K_{n,t} \tag{17}$$

The world's use of each good (inclusive of trade costs) (in each sector j, country n, date t) must equal the output of that good:

$$\sum_{m=1}^{4} d^j_{mn}x^j_{mn,t}(z) = y^j_{n,t}(z) \tag{18}$$

where $x^j_{mn,t}(z)$ is country m's use of good z, sector j, produced in country n at date t.

In addition, a country's use of a good z must equal its purchases of that good from all possible sources:

$$x_{n,t}^{j}(z) = \sum_{i=1}^{N} x_{ni,t}^{j}(z) \tag{19}$$

As shown above, the CES aggregator (4) converts the individual goods z into the composite good. The final equilibrium condition is that the use of the composite sector j good — as an intermediate, for consumption, or for investment — must equal the output of the composite sector good (in country n at date t):

$$\sum_{j' \in \Omega} \int_0^1 M_{n,t}^{j'j}(z) dz + C_{n,t}^{j} + I_{n,t}^{j} = x_{n,t}^{j} \tag{20}$$

There are some addition market clearing conditions in terms of spending; they are shown in the next section.

6. Costs, Prices, Spending, and Trade Shares

Because the production function is Cobb-Douglas, the cost of a bundle of labor, capital and intermediate inputs in country n, sector j, date t also has the following Cobb-Douglas form:

$$c_{n,t}^{j} = (w_{n,t})^{\beta_n^{L,j}} (r_{n,t})^{\beta_n^{K,j}} \prod_{j' \in \Omega} (p_{n,t}^{j'})^{\beta_n^{M,jj'}} \tag{21}$$

where $p_{n,t}^{j}$ is the sector j (country n, date t) price index.

Owing to the Fréchet distribution for the individual goods' productivities, the sector j price index can be written as:

$$p_{n,t}^{j} = \left[\sum_{i=1}^{n} \left(\frac{c_{i,t}^{j} d_{ni,t}^{j}}{A_{i,t}^{j}} \right)^{-\theta} \right]^{\frac{-1}{\theta}} \tag{22}$$

One of the key equations from this framework is the expression for the import shares. Analogous to the original Eaton-Kortum paper (2002), the shares are defined as the share of a country n's spending on goods from country i (in sector j, period t):

$$\pi^j_{ni,t} = \left(\frac{c^j_{i,t} d^j_{ni,t}}{A^j_{i,t} p^j_{n,t}} \right)^{-\theta} \tag{23}$$

(23) shows that the import share depends negatively on country i's costs, as well as the trade costs, and positively on the exporting country's productivity, as well as on the overall price level of the importing country. Why does the latter term matter? If the importing country's price level is high, this means there are more opportunities for the exporting country to take market share. Finally, the sensitivity of the import share to trade costs is largely determined by the parameter θ, which acts like an elasticity.

Now, let us turn to the equilibrium spending conditions. Define total spending by country n on sector j goods at date t as:

$$X^j_{n,t} = p^j_{n,t} x^j_{n,t} \tag{24}$$

Then, the value of country n's (gross) production of goods in sector j at date t is given by:

$$Y^j_{n,t} = \sum_{m=1}^{N} \pi^j_{mn,t} X^j_{m,t} \tag{25}$$

There is another way to characterize country m's spending on sector j goods. By definition, that spending includes spending on the goods for final use, and spending on goods for intermediate use:

$$X^j_{m,t} = X^{F,j}_{m,t} + \sum_{j' \in \Omega} \beta^{M,j'j} Y^{j'}_{m,t} \tag{26}$$

where $X^{F,j}_{m,t} = p^j_{m,t}(C^j_{m,t} + I^j_{m,t})$.

Equations (25) and (26) can be combined to yield a set of equations linking gross production across countries:

$$Y_{n,t}^{j}=\sum_{m=1}^{N}\pi_{mn,t}^{j}\left(p_{m,t}^{j}(C_{m,t}^{j}+I_{m,t}^{j})+\sum_{j'\in\Omega}\beta^{M,j'j}Y_{m,t}^{j'}\right) \tag{27}$$

In turn, because, $p_{m,t}^{j}(C_{m,t}^{j}+I_{m,t}^{j})=(\psi_{m,t}^{j}(1-s_{m,t})+\alpha_{m}^{j}s_{m,t})(w_{m,t}L_{m,t}+R_{m,t}K_{m,t})$, we have:

$$Y_{n,t}^{j}=\sum_{m=1}^{N}\pi_{mn,t}^{j}((\psi_{m,t}^{j}(1-s_{m,t})+\alpha_{m}^{j}s_{m,t})(w_{m,t}L_{m,t}+R_{m,t}K_{m,t})+\sum_{j'\in\Omega}\beta^{M,j'j}Y_{m,t}^{j'}) \tag{28}$$

This is a key equilibrium condition expressed in terms of factor prices and quantities, and also gross production.

We now present a slightly different version of the labor market clearing condition. Instead of labor supply equals labor demand, below we have labor income equals labor demand in nominal units:

$$w_{n,t}L_{n,t}=\sum_{j\in\Omega}\beta_{n}^{L,j}Y_{n,t}^{j} \tag{29}$$

The right-hand side of the above captures the share of a country's production that results in payments to labor. It comes from the firm's first order conditions of its profit maximization problem.

Finally, we present a slightly different version of the capital market clearing condition — rental income from capital equals capital demand in nominal units:

$$R_{n,t}K_{n,t}=\sum_{j\in\Omega}\beta_{n}^{K,j}Y_{n,t}^{j} \tag{30}$$

So, other than the prices and shares, the key equations are (28), (29), and (30).

7. Discussion of Model

To think about how the model laid out above works, it helps to divide the model into a static part and a dynamic part. In the static part, capital is given, and contributes to the output capacity of the economy. Capital and labor are allocated to the manufacturing and non-manufacturing sectors according to the relative prices of the composite sectoral goods, as well as the relative factor prices of labor and capital. The relative prices of these goods, in turn, are determined by the global economy. Comparative advantage, which shows up as the "ability" to export a good at a lower price than other countries (through a combination of relatively high productivity and relatively low factor costs), drives which sector has positive net exports, and which has negative net exports. In particular, if a country has a comparative advantage in manufacturing, for example, it will produce more manufactured goods than it spends on manufactured goods (for final consumption or intermediate use), and hence, have a net export surplus in that sector.

On the dynamic side, capital accumulation is endogenous, but is determined by the exogenous investment rate.[7] The investment rate helps determine the next period's capital stock, which is taken as given by firms and households. Households then make within-period decisions on how to allocate their non-saved income between the manufacturing and non-manufacturing sector, as mentioned above.

Overall, the model has five shocks: $\left\{d_{ni,t}^{j}, A_{n,t}^{j}, s_{n,t}, \psi_{n,t}^{j}, L_{n,t}\right\}$. If there is a trade cost shock, e.g., trade costs increase, then, international trade will decline, which will lead to a reallocation of resources to those sectors in which the economy formerly imported its goods. Increases in sectoral productivity will do the opposite, shift resources to the sectors with higher productivity — mainly owing to changes in comparative advantage. An increase in $s_{n,t}$ puts more weight on future consumption, and hence,

7) By contrast, in the usual intertemporal approach, there is a consumption Euler equation that determines the dynamics of the capital stock. We leave this for future research.

causes consumption to switch to the future. A shock to $\psi^j_{n,t}$ puts more weight on consumption of the sector j good, and shifts consumption spending in that period towards that good. Increases in aggregate labor supply will lower the real wage, shift production to the sector that uses labor more intensively, and increase overall production, as well.

V. Solving the Model in 'Changes'

It turns out it is convenient to solve the model in changes (see Dekle, Eaton, and Kortum (DEK), 2008), which is analogous to doing comparative statics. The main advantage of solving it this way is that it eliminates the need to calibrate a number of parameters and variables in levels in the initial period. For example, the initial productivities associated with the Fréchet distribution, as well as the initial trade costs, are not needed. A key assumption is that the initial period values represent an equilibrium outcome.

We now re-write the key equations from the above in "changes" form. In particular, we define a variable $\hat{x}_{t+1} = \frac{x_{t+1}}{x_t}$.[8] So the ^ variables represent gross rates of change.

Below, we start by converting the equations for sectoral costs, sectoral prices, and sectoral trade shares (21, 22, and 23) into "changes":

$$\hat{c}^j_{n,t+1} = (\hat{w}_{n,t+1})^{\beta^{L,j}_n} (\hat{r}_{n,t+1})^{\beta^{K,j}_n} \prod_{j' \in \Omega} (\hat{p}^{j'}_{n,t+1})^{\beta^{M,jj'}_n} \tag{31}$$

$$\hat{p}^j_{n,t+1} = \left[\sum_{i=1}^{n} \pi^j_{ni,t} \left(\frac{\hat{c}^j_{i,t+1} \hat{d}^j_{ni,t+1}}{\hat{A}^j_{i,t+1}} \right)^{-\theta} \right]^{\frac{-1}{\theta}} \tag{32}$$

8) Equation terms that are multiplicative are easy to convert to changes form. Terms that are additive need to be multiplied by share weights.

$$\hat{\pi}^j_{ni,t+1} = \left(\frac{\hat{c}^j_{i,t+1} \hat{d}^j_{ni,t+1}}{\hat{A}^j_{i,t+1} \hat{p}^j_{n,t+1}} \right)^{-\theta} \tag{33}$$

Now, let us go to the spending relations. The key equations are (7), (8), (12), (14), (15), (25), and (26). Start by converting (25), which links gross production by country n, sector j, time t to spending by the rest of the world on those goods, into "changes":

$$\hat{Y}^j_{n,t+1} = \sum_{m=1}^{N} \frac{\pi^j_{mn,t} X^j_{m,t} \hat{\pi}^j_{mn,t+1} \hat{X}^j_{m,t+1}}{\Sigma^N_{m'=1} \pi^j_{m'n,t} X^j_{m',t}} \tag{34}$$

Now, let us convert (26), which decomposes total spending into spending for final use and spending for intermediate use, into changes:

$$\hat{X}^j_{m,t+1} = \frac{X^{F,j}_{m,t}}{X^j_{m,t}} \hat{X}^{F,j}_{m,t+1} + \sum_{j' \in \Omega} \left(\frac{\beta^{M,j'j} Y^{j'}_{m,t}}{X^j_{m,t}} \right) \hat{Y}^{j'}_{m,t+1} \tag{35}$$

In addition, we can use the definition of final goods spending to decompose $\hat{X}^{F,j}_{m,t+1}$:

$$\hat{X}^{F,j}_{m,t+1} = \hat{P}^j_{m,t+1} \left(\frac{C^j_{m,t}}{C^j_{m,t} + I^j_{m,t}} \hat{C}^j_{m,t+1} + \frac{I^j_{m,t}}{C^j_{m,t} + I^j_{m,t}} \hat{I}^j_{m,t+1} \right) \tag{36}$$

Finally, we can link changes in final goods spending in country m to changes in income via the budget constraint:

$$\hat{P}^j_{m,t+1} \hat{C}^j_{m,t+1} = \hat{\psi}^j_{m,t+1} (1 - \hat{s}_{m,t+1}) \left[\left(\frac{w_{m,t} L_{m,t}}{w_{m,t} L_{m,t} + R_{m,t} K_{m,t}} \right) \hat{w}_{m,t+1} \hat{L}_{m,t+1} + \left(\frac{R_{m,t} K_{m,t}}{w_{m,t} L_{m,t} + R_{m,t} K_{m,t}} \right) \hat{R}_{m,t+1} \hat{K}_{m,t+1} \right] \tag{37}$$

$$\hat{P}^{j}_{m,t+1}\hat{I}^{j}_{m,t+1}=\hat{s}_{m,t+1}\left[\left(\frac{w_{m,t}L_{m,t}}{w_{m,t}L_{m,t}+R_{m,t}K_{m,t}}\right)\hat{w}_{m,t+1}\hat{L}_{m,t+1}+\left(\frac{R_{m,t}K_{m,t}}{w_{m,t}L_{m,t}+R_{m,t}K_{m,t}}\right)\hat{R}_{m,t+1}\hat{K}_{m,t+1}\right] \tag{38}$$

We also have:

$$\hat{K}_{m,t+1}=(1-\delta)+\frac{I_{m,t}}{K_{m,t}} \tag{39}$$

The above, combined with the same equation one period earlier, and then dividing the $t+1$ equation by the t equation, we get:

$$\frac{I_{m,t}/K_{m,t}}{I_{m,t-1}/K_{m,t-1}}=\frac{\hat{K}_{m,t+1}-(1-\delta)}{\hat{K}_{m,t}-(1-\delta)} \tag{40}$$

Multiply both sides by $K_{m,t}/K_{m,t-1}$ and we get:

$$\hat{I}_{m,t}=\hat{K}_{m,t}\left(\frac{\hat{K}_{m,t+1}-(1-\delta)}{\hat{K}_{m,t}-(1-\delta)}\right) \tag{41}$$

Finally, we have:

$$\hat{I}_{m,t+1}=\left(\hat{I}^{m}_{m,t+1}\right)^{\alpha_m}\left(\hat{I}^{n}_{m,t+1}\right)^{1-\alpha_m} \tag{42}$$

with

$$\hat{P}^{m}_{m,t+1}\hat{I}^{m}_{m,t+1}=\hat{P}^{n}_{m,t+1}\hat{I}^{n}_{m,t+1}=\hat{P}^{I}_{m,t+1}\hat{I}_{m,t+1} \tag{43}$$

Next, let's look at the factor market equilibrium conditions:

$$\hat{w}_{n,t+1}\hat{L}_{n,t+1}w_{n,t}L_{n,t}=\sum_{j\in\Omega}\beta^{L,j}_{n}Y^{j}_{n,t+1} \tag{44}$$

$$\hat{R}_{n,t+1}\hat{K}_{n,t+1}R_{n,t}K_{n,t} = \sum_{j\in\Omega}\beta_n^{K,j}\,Y_{n,t+1}^j \tag{45}$$

For a given set of shocks, $\hat{d}^j_{ni,t+1}$, $\hat{A}^j_{n,t+1}$, $\hat{s}_{n,t+1}$, $\hat{\psi}^j_{n,t+1}$, and $\hat{L}_{n,t+1}$, for all countries n, country-pairs n, i, sectors j, and time periods t, as well as for the initial values of the relevant variables, the equations above will enable us to solve for $\hat{P}^j_{n,t+1}$, $\hat{P}^I_{n,t+1}$, $\hat{c}^j_{n,t+1}$, $\hat{\pi}^j_{ni,t+1}$, $\hat{Y}^j_{n,t+1}$, $\hat{X}^j_{n,t+1}$, $\hat{X}^{F,j}_{n,t+1}$, $\hat{K}_{n,t+1}$, $\hat{I}_{n,t+1}$, $\hat{I}^j_{n,t+1}$, and of course $\hat{w}_{n,t+1}$ and $\hat{R}_{n,t+1}$.

To simplify the process of finding a solution, we are going to take the actual path of (changes in the) capital stocks, $\hat{K}_{n,t+1}$ as given, and from the actual data, and we will solve for the exogenous (changes in the) saving rates $\hat{s}_{n,t+1}$ that will yield that path of capital as an endogenous outcome. Below is an algorithm for finding the solution:

1. Begin with a guess for the time path of wage and rental rate changes, $\hat{w}_{n,t+1}$ and $\hat{R}_{n,t+1}$ for every country n and for the full-time period.

2. Use (31), (32), and (33) to solve for $\hat{P}^j_{n,t+1}$, $\hat{P}^I_{n,t+1}$, $\hat{c}^j_{n,t+1}$, and $\hat{\pi}^j_{ni,t+1}$.

3. Use (41) to back out the path of $\hat{I}_{n,t}$.

4. Use (38) to solve for $\hat{s}_{n,t+1}$.

5. Use (37) to solve for $\hat{P}^j_{n,t+1}\hat{C}^j_{n,t+1}$.

6. Use (36) to solve for $\hat{X}^{F,j}_{m,t+1}$.

7. Plug in expression for $\hat{X}^{F,j}_{m,t+1}$ into (35) and plug that into (34) and solve for $\hat{Y}^{j}_{n,t+1}$.

8. Solve for $\hat{Y}^{j}_{n,t+1}$.

9. Plug into right-hand side (44) and (45) to see if the equation holds. If it doesn't, adjust $\hat{w}_{n,t+1}$ and $\hat{R}_{n,t+1}$ and repeat the above steps. Keep repeating until the factor market equilibrium conditions hold.

Ⅵ. Results

We first discuss how we calibrate the model, and the data we use. We then present the shocks, and our interpretation of them.

1. Calibration and Calculation of "Shocks"

Above, we showed how to solve the model in changes. Now, we show how to use the model and actual data on trade shares, prices, capital, consumption and investment expenditure, and gross production to back out the shocks of the model.

First, use (33) to solve for the trade cost shocks for each country-pair ni and each sector j:[9]

$$\hat{d}^{j}_{ni,t+1} = \left(\frac{\hat{\pi}^{j}_{ni,t+1}}{\hat{\pi}^{j}_{ii,t+1}}\right)^{\frac{-1}{\theta}} \left(\frac{\hat{p}^{j}_{n,t+1}}{\hat{p}^{j}_{i,t+1}}\right) \tag{46}$$

Second, use (33) for country $i = n$ to solve for the sectoral TFP shocks:

9) As a reminder, the vast majority of model-implied trade costs represents non-political barriers. So they are unlikely to be tariffs or non-tariff barriers that are imposed by governments.

$$\hat{A}_{n,t+1} = \left(\frac{\hat{c}^{j}_{n,t+1}}{\hat{p}^{j}_{n,t+1}}\right)\left(\hat{\pi}^{j}_{nn,t+1}\right)^{\frac{1}{\theta}} \tag{47}$$

Third, use (38) to solve for $\hat{s}_{n,t+1}$.

Fourth, we can use (37) to solve for the preference shocks $\hat{\psi}^{j}_{n,t+1}$.

Finally, the $\hat{L}_{n,t+1}$ shocks come directly from the data.

2. Parameters and Data

As discussed above, implementing the DEK changes approach implies that the initial sectoral productivities, $\hat{A}^{j}_{n,t0}$, and the initial trade costs, $\hat{d}^{j}_{ni,t0}$, where $t0$ is the initial period in our sample, do not need to be calibrated. However, some other key parameters need to be calibrated, including the parameter governing the dispersion of productivities, θ. We set $\theta = 4$, following Simonovska and Waugh (2014). In addition, we need to calibrate the parameters governing value-added and intermediate use in the production function, $\beta^{L,j}_{n}$, $\beta^{K,j}_{n}$, $\beta^{M,jj'}_{n}$.

Correspondingly, we need data from input-output tables to calibrate the above parameters. In addition, we need data counterparts to the model's relative price, expenditure and import share, employment, and capital stock variables. The appendix describes these data in detail.

Table 7: Employment Growth (percent)

Country	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
China	0.52	0.44	0.46	0.32	0.35	0.37	0.41	0.37	0.36	0.36	0.26	0.20
S.Korea	1.33	1.29	1.22	0.62	−0.30	1.37	1.74	1.80	1.56	2.13	1.32	1.15
G7	1.43	1.46	1.15	0.18	−2.32	−0.40	0.73	0.98	0.73	1.36	1.15	1.52
ROW	2.67	2.18	2.09	1.35	1.29	1.51	1.73	1.48	1.74	1.63	1.50	1.47

Sources: ILO, OECD

3. Calculated Shocks

Before we present our main results, we want to highlight a factual pattern that emerges from our calculation of the $\pi^j_{ni,t}$ matrices. In 2004, 2.5 percent of China's spending on manufactured goods was on goods imported from Korea. By 2016, that share had fallen to 1.0 percent. This share fell fairly uniformly and continuously over this period. There is a similar pattern for China's spending on manufactured goods from the G7. That share fell from 7.2 percent in 2004 to 2.6 percent in 2016. These numbers suggest there is a broad trend of China's greater reliance on its own goods over time and across trading partners.

Below, we present each of the shocks along with our interpretation. In the interest of brevity, we do not present the ROW shocks other than for employment.

3.1 Employment Growth

Table (7) shows that China's employment growth has been relatively low compared to Korea (and to the G7 and the ROW). All else equal, lower employment growth implies higher wages than otherwise, which would be a force for greater reliance on imports. Hence, we conclude that the employment growth shocks are unlikely to be a key reason for the slowdown in Korea's exports to China.

3.2 Shocks to Trade Costs

Tables (8) and (9) give the average annual percent change in China's trade costs on imports from Korea and the G7 for manufacturing and non-manufacturing. The table shows two periods, 2004-2013, as well as 2014-2016. Table (8) shows that China's trade costs on manufactured goods imports from Korea grew at a faster annual rate, 3.33 percent in the later period than in the earlier period, 1.57 percent. However, the

Table 8: Average Annual Change in China's Trade Costs on Imports from Korea and G7 (Manufacturing, percent)

	Korea	G7
2004–2013	1.57	2.48
2014–2016	3.33	−0.01

Table 9: Average Annual Change in China's Trade Costs on Imports from Korea and G7 (Non-Manufacturing, percent)

	Korea	G7
2004–2013	1.68	3.16
2014–2015	1.88	3.28

opposite holds for the G7. Hence, while the implicit trade barriers imposed on Korea are consistent with the broad facts mentioned at the beginning of this sub-section, the implicit trade barriers imposed on the G7's exports to China remained constant in the past few years. This pattern is not consistent with the fact that China imports fewer goods from the G7. Hence, we tentatively conclude that trade costs alone cannot explain the downturn in Korea's exports to China.

Table (9) shows that in recent years, China's trade costs on non-manufacturing goods imported from Korea grew at a slightly faster rate than in earlier years. However, China's imports of non-manufactured goods from Korea are considerably smaller than its imports of manufactured goods. Overall, it does not appear that the trade cost shocks backed out from our model can account for the recent decline in Korea's exports to China.

3.3 Sectoral TFP Shocks

Figure (3) shows that China has had considerably greater manufacturing TFP growth than Korea or G7 throughout the 11 year period we look at. All else equal, higher TFP growth in manufacturing should lead to fewer manufactured imports from Korea. But, the figure also shows that the TFP growth gap was considerably narrower in recent years. Hence, it does not seem likely that the evolving pattern of TFP shocks in manufacturing can account for the recent reduction in Korea's exports to China.

Figure (4) shows that China's TFP growth in non-manufacturing is not much of an outlier compared to the other countries, especially in recent years. We do not view this pattern as contributing to our understanding of how and why Korea's exports to China have fallen.

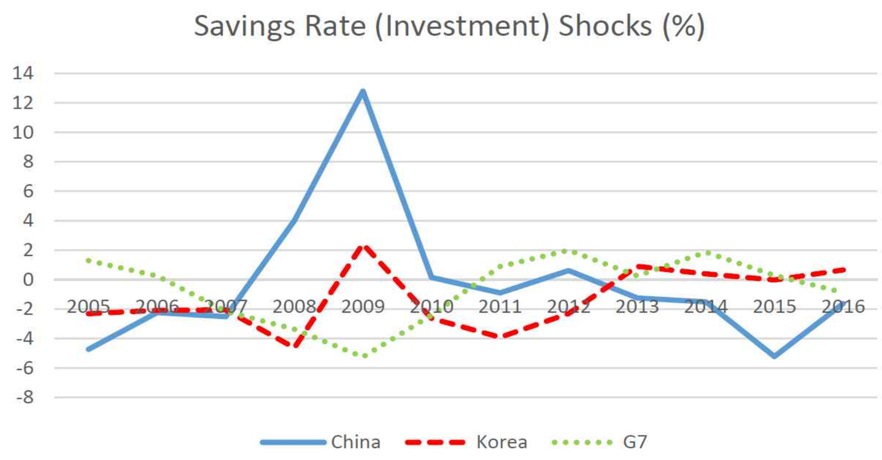
Figure 3: TFP Shocks (Manufacturing) (%)

Figure 4: TFP Shocks (Non-manufacturing) (%)

3.4 Investment Shocks

Figure (5) shows that China had a sequence of negative investment shocks in 2013-2016; these were considerably more negative than in Korea and the G7. All else equal, this would suggest lower imports of capital goods, as well as intermediate goods used to make capital goods, from its trading partners, including Korea.

Figure 5: Saving Rate (Investment) Shocks (%)

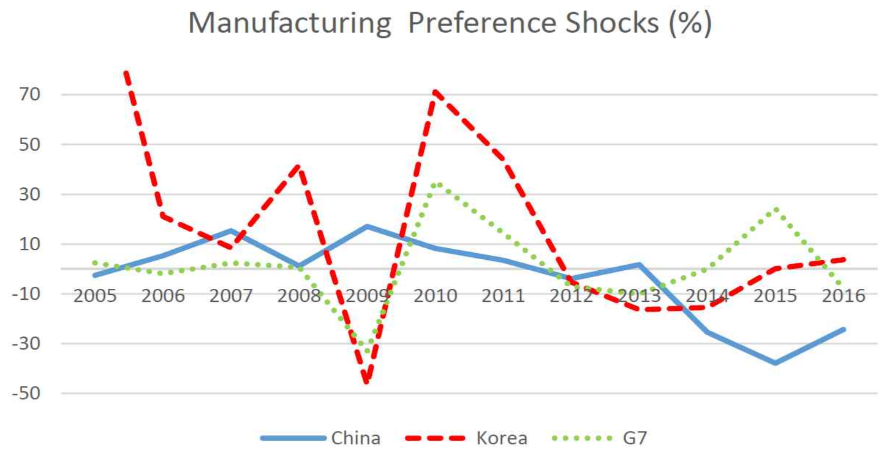


3.5 Preference Shocks

Figure (6) shows that China had a steep shift away from consuming manufactured goods in 2014-2016 — this was much larger than comparable changes in Korea and the G7. Like the investment shocks, these preference shocks could be a reason for lower imports of manufactured goods from Korea.

To summarize, of the five shocks, we view shocks to China's desire to invest (save), and to China's preference for manufacturing consumption goods, as the leading candidates for explaining why Korea's exports to China have fallen in recent years. That said, a complete story must also account for the decade long decline in China's reliance on imports from Korea, as well as the G7.

Figure 6: Manufacturing Preference Shocks (%)



Ⅶ. Conclusion and Further Research

In this paper, we have employed two methodologies to better understand the recent decline in Korea's exports to China. The first methodology is a standard "within-between" accounting decomposition, which we apply to KSIC sectoral data, covering 384 industries, for the period 1990-2014. Our results show that during the high trade growth period of 1990-2009, the within effect dominated. More than 100 percent of the growth of Korea's exports to China was accounted for by individual 5-digit sectors exporting a greater fraction of their output to China. A slightly offsetting force was a shift in Korea's output mix to sectors that export a small share of their output to China. Our results are true for all sectors and for manufacturing sectors only. We also find that in the export slowdown period of 2010-2014, the within effect contributed to the slowdown in that individual sectors, on net, exported a smaller fraction of their output to China. By contrast, the between effect had, on net, a slightly positive contribution to Korea's exports to China. Overall, the within effect has played an important role in both the export growth period, and the export slowdown period.

Our second methodology was the model-based decomposition of EKNR. EKNR specify a dynamic multi-sector, general equilibrium model of international trade, and with the model they solve for the shocks that enable the model fit the data. They then study the properties of these shocks. We follow this approach for a simplified version of their model in which there are four "countries", two sectors and five shocks. The shocks include employment shocks, TFP shocks, shocks to the costs of trade, investment (saving) shocks, and preference shocks. When we examine the period 2005-2016, we find that the two shocks that have the potential to account for the recent slowdown in Korea's exports are the saving shock and the preference shock. China experienced a sharp reduction in its desire to accumulate capital and in its desire to consume manufactured goods, in 2013-2016. All else equal, these two forces would imply fewer imports by China from Korea of manufactured goods. Given that Korea's exports to China are highly concentrated in intermediate and capital goods, these shocks could, in principle, explain most of the decline in Korea's exports to China during this period. In addition, to the extent these shocks are persistent, it suggests that the decline in exports could persist unless other Korean fundamentals (such as productivity in non-manufacturing) change.

One limitation of the EKNR methodology is that it does not take "risk" into account. For example, the possibility that some export markets may be subjected to unexpected tariff shocks is not included. All else equal, this would be a motive for more diversification than would be implied by the model. We leave this, as well as the broader implications of a "trade war", as an avenue for future research.

We believe there are three additional channels for future research. The first is to reconcile the findings above with the broader data trends discussed above in which the decline in Korea's exports to China mirror an overall decline in Korea's exports, and, from China's perspective, it has been importing fewer goods as a share of its spending, from Korea and the G7 since 2004. The second is to conduct counterfactual exercises by taking the shocks that we compute and plugging them back into the model to assess the relative importance of each in driving Korea's recent decline in exports. Third, as the U.S. is Korea's second largest trading partner, it will be useful to separate the G7 into the U.S. and the non-U.S. G7.

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Appendix. Data Sources and Calculations for Model-Based Decomposition

We describe the data needed to back out each of our main shocks from the model-based decomposition. Our description includes the raw data, as well as the calculations needed to map the raw data to the key variables like the $\pi^j_{ni,t}$ matrices. From these key variables, the shocks can be backed out from equations (31) to (45) in the main text. Our time period is 2004-2015, and we use annual data.

1. Employment

Employment data is obtained from International Labor Organization (ILO). The employment for China, S. Korea, G7, and the world is directly obtained from ILO. Employment in China for 2016 is obtained from www.statista.com. The employment for the rest of the world is calculated by subtracting the sum of China, S. Korea, and G7 employment from world employment.

2. Trade

Our trade data are at several levels of aggregation and come from several sources.

1. Aggregate nominal exports and imports of goods and services are from the national accounts variables in the World Bank's World Development Indicators (WDI) database. These data are expressed in current U.S. dollars.

2. Sectoral trade of merchandise (goods) is obtained from UN Comtrade at the 6-digit HS level for China, S. Korea, Canada, France, Germany, Italy, Japan, UK, US. Specifically, we collect each country's

total export and import with the world as well as bilateral trade with each other and the world. For the G7 countries, we subtract within-G7 exports (imports) from the sum of their total exports (imports) to create G7 exports (imports) vis-a-vis non-G7 countries. To compute each country's exports (imports) with the rest of the world, we subtract the country's bilateral exports to (imports from) China, S. Korea, and G7 from its exports to (imports from) the world. For example, exports by the rest of the world (ROW) to China is calculated as China's imports from the world less China's imports from Korea and the G7. A similar calculation is made for exports by ROW to Korea and to the G7, and a similar calculation is made for imports by the ROW from each of China, Korea, and the G7. Finally, to separate the exports (imports) data into manufacturing and non-manufacturing sectors, the HS6 data is concorded into ISIC rev.3. The manufacturing sector is defined as ISIC 15-36, and the non-manufacturing sector is defined as the total exports (imports) minus exports (imports) by all manufacturing sectors.

3. In addition, we include services trade in the non-manufacturing trade data. Services trade data are not available in Comtrade.

   (a) To calculate aggregate and bilateral services trade for 2004-2014, we use the World Input-Output Database (WIOD), which includes services transactions. We use rows D-U.

   (b) To calculate services trade in 2015 and 2016, we assume the growth of bilateral services exports between 2014 and 2015 (and between 2015 and 2016) equals the growth of aggregate services exports between the two years. Our measure of aggregate services exports for 2015 and 2016 is obtained by subtracting merchandise trade obtained from the WDI from aggregate exports of goods and services, also obtained from the WDI.

3. Gross Production

Our main data source is the national input-output tables from WIOD. Data is available for 43 countries between 2004 and 2014. From the national input-output tables (NIOT) total gross production and gross manufacturing production can be computed for each year and country. Gross non-manufacturing production is calculated as the difference between total gross production and gross manufacturing production. Two challenges are computing gross production for the ROW and for 2015 and 2016:

3.1 Gross Production for the ROW

1. Gross manufacturing production is calculated by first computing the China+S.Korea+G7 share of world value-added in manufacturing by using manufacturing, value-added (current US$) from the World Bank's WDI database. The share is close to 0.65 between 2007 and 2013. We assume that the China+S.Korea+G7 share of world gross output in manufacturing is also 0.65. We then compute the ROW's gross output in manufacturing as follows:

$$Y^{M}_{ROW,t} = 0.35 \times \frac{Y^{M}_{C,t} + Y^{M}_{K,t} + Y^{M}_{G7,t}}{0.65} \tag{48}$$

2. Gross non-manufacturing production is calculated first by computing non-manufacturing value-added as the difference between GDP and manufacturing value-added. GDP data comes from the IMF WEO database, and manufacturing value-added is from the World Bank WDI database. We again assume that the China+S.Korea+G7 share of value-added in non-manufacturing equals its share in gross output. That share was about 0.6 between 2007 and 2013. Then, we compute the ROW's gross output in non-manufacturing as follows:

$$Y^N_{ROW,t} = 0.4 \times \frac{Y^N_{C,t} + Y^N_{K,t} + Y^N_{G7,t}}{0.60} \quad (49)$$

3.2 Gross Production in 2015 and 2016

Total gross production in 2015 is computed by assuming the growth rate of total gross production between 2014 and 2015 equals the growth rate of total value-added, i.e., GDP, between 2014 and 2015. The GDP data are from the IMF WEO database.

Gross manufacturing production for S. Korea, Germany, France, and Italy is computed by assuming the growth rate of manufacturing production between 2014 and 2015 (and between 2015 and 2016) equals the growth rate of manufacturing value-added between the two years (2014 and 2015; 2015 and 2016). Manufacturing value-added in current U.S. dollars is available for these countries in the World Bank WDI database. For the United States and Canada, the methodology is the same, but the data sources for manufacturing value-added are the BEA for the U.S. and Statistics Canada (CANSIM) for Canada. For China, manufacturing value-added is available only up to 2015. We estimate Chinese manufacturing value-added in 2016 by using industry value-added data from the World Bank WDI database. For 2014 and 2015, the ratio of manufacturing value-added to industry value-added is 0.711. Assume that the average ratio for these two years holds in 2016. Then manufacturing value-added in 2016 can be computed by multiplying this ratio with the industry value-added in that year. Based on the estimates for manufacturing value-added in 2014 and 2015, we calculate the growth rate of manufacturing value-added between the two years. We assume that gross manufacturing output has the same growth rate as manufacturing value-added. Then, with China's gross manufacturing output in 2014, we can compute China's gross manufacturing output in 2015 and 2016.

4. Relative Prices

We want to calculate the growth rates of manufacturing prices and non-manufacturing prices. We start with the GDP deflator, which is computed as nominal GDP divided by real GDP. These data are from the IMF WEO database. The overall inflation rate is the rate of change of the GDP deflator.

1. Our proxy for manufacturing prices is the manufacturing producer price index (PPI). For Canada, Germany, France, Italy, and the United States, the manufacturing PPI data are available from OECD STAT. For the U.K., Japan, and S. Korea, the PPI index is available from the UK Office for National Statistics, Bank of Japan, and Bank of Korea, respectively. Note that for Korea, manufacturing PPI is not available for 2003, so for that year, the total PPI is used.

   China's PPI is from the National Bureau of Statistics of China (NBS). Note that starting from January 2011, the NBS implemented a new system of industrial producer survey methods, and "Industrial price statistics" changed to "Industrial producer price statistics". The PPI for manufacturing goods changed to the PPI for industrial products. Note that Chinese PPI is computed based on the assumption that the preceding year's index is 100. We convert the series so that the PPI in 2010 equals 100.

   Using these indices we compute the (net) PPI inflation rate for each year. The G7 PPI inflation rate is an un-weighed average of each country's PPI inflation rate, and the ROW's inflation rate is an un-weighted average of China, S. Korea's, and the G7 PPI inflation rate.

2. We construct the growth rate of non-manufacturing prices as the difference between the overall inflation rate and the average manufacturing value-added share multiplied by the manufacturing

PPI inflation rate. We obtained the value-added share of manufacturing in total GDP from the World Bank WDI database.

5. Investment and Capital

5.1 Investment

Data on aggregate gross fixed capital formation is from the World Bank's WDI database. These data are measured in current U.S. dollars.

5.2 Capital Stocks

For 2004-2014, our capital stock data comes from the Penn World Tables 9.0. The variable 'rkna' (national income accounts measure of capital, constant U.S. dollars) is used as our measure of capital stock. The ROW's capital stock is computed by substracting three countries' capital stock (China, S.Korea and G7) from the world's capital stock, which is the sum of 'rkna' across all countries available.

The capital stock data from the Penn World tables goes only to 2014. A measure of the capital stock in 2015 and 2016 can be constructed as follows:

1. We use the above investment series and convert the 2015 and 2016 value into real terms (2011 US$) using the U.S. GDP deflator.

2. For each of China, Korea, G7 and ROW, look at the years 2011-2012, 2012-2013, and 2013-2014. Based on the data on real investment and capital stock, back out the depreciation rate that makes the perpetual inventory method hold. Compute the average depreciation rate for each country. Note that we replace Chinese capital depreciation rate with zero since it is negative.

3. Then, use the capital accumulation equation to calculate the 2015 capital stock from the 2014 capital stock and 2015 real investment. 2016 capital stock is computed in a similar way. In so doing, we use a country-specific depreciation rate on capital.

6. Labor and Capital Shares of Value-Added

To compute the fraction of value-added (VA) that is labor and the fraction that is capital by sector, we use the OECD input-output tables for all the sample countries for 2009. These tables divide total value-added into three parts: labor compensation, taxes and gross operating surplus and missed income. We construct a value-added measure that equals the sum of the labor compensation and the returns to capital only (and ignore the taxes part). We do this for each of the disaggregated sectors in the tables.

We then aggregate up to a manufacturing aggregate and a non-manufacturing aggregate. Note that the sector codes between C15T16 and C36T37 corresponds to manufacturing sector, while all the other sectors (C01T05-C10T14, C40T41-C95) are considered as non-manufacturing. This yields the labor and capital value-added share for each of the two sectors. We did this calculation for S. Korea, China, and the G7, but not for the ROW.

7. Input-Output Coefficients

We use the WIOD database, which has a set of bilateral input-output tables for 43 countries. We focus on the table for 2009, which is the middle year of our sample period.

We reduce the input-output tables into a 3×2 matrix for each of our four countries (China, S. Korea, G7 and the ROW), and then convert it into coefficient form. The first and second column represents manufacturing and non-manufacturing sector, respectively, and the rows are manufacturing, non-manufacturing and value-added.

For each country and for manufacturing we use the rows and columns labeled "C"; non-manufacturing consists of all other industries. We then aggregate across the G7 countries to form the G7 aggregate. For the ROW, we collapse the tables to generate a single input-output table for the world. We then subtract the table for China S. Korea, and the G7 from the world table, which yields the ROW table, and, finally, convert it to coefficient form.

8. Expenditure and $\pi^j_{ni,t}$ Matrices

To compute the $\pi^j_{ni,t}$ matrices, we need gross production and net export data, as well as bilateral export and import data by sector. These data are described above. Total spending in sector j by country n in year t, $X^j_{n,t}$, equals sectoral gross production minus sectoral net exports. Then, each element of $\pi^j_{ni,t}$ is computed as follows:

$$\pi^j_{ni,t} = \frac{X^j_{ni,t}}{X^j_{n,t}} \tag{50}$$

where $X^j_{ni,t}$ is country n's imports from country i in sector j goods in year t. When $n = i$, we compute $\pi^j_{nn,t} = 1 - \Sigma_{n \neq i} \pi^j_{ni,t}$.

<Abstract in Korean>

우리나라 대중국 수출 감소의 원인 분석

최문정*, Kei-Mu Yi**

우리나라의 대중국 수출은 1990~2000년대 후반까지 빠르게 증가해왔으나 2013년 이후 감소하기 시작하였다. 이에 본 연구는 대중국 수출 감소의 원인을 회계분해(accounting decomposition) 및 모형에 기반한 분해(model-based decomposition) 두 가지 분석방법을 이용하여 살펴보았다. 첫째, 회계분해 분석에서는 세부 산업별 데이터를 이용하여 우리나라 총산출 대비 대중국 수출 변화를 각 산업내 대중국 수출비중 변화에 의한 '산업내 효과'(within-industry effect)와 산업간 생산비중 이동에 의한 '산업간 효과'(between-industry effect)로 분해하였다. 그 결과, 산업내 효과는 1990-2009년 기간중 대중국 수출 증가를 견인하였으나 2010-2014년 기간중에는 대중국 수출비중 감소를 초래한 것으로 분석되었다. 둘째, 다국가 · 다부문 동태 일반균형모형을 기반으로 하여 대중국 수출 변화를 일으킨 주요 충격요인을 분석한 결과, 2013-2016년 기간중 중국내 저축률(자본축적률) 및 제조업 제품에 대한 소비선호 감소 충격이 두드러진 것으로 나타났다. 이러한 두 요인의 감소충격은 우리의 대중국 수출품이 제조업 중간재 및 자본재 중심인 점을 감안할 때 대중국 수출 감소를 초래한 주요 원인으로 판단된다.

핵심 주제어: 대중국 수출, 산업내 효과, 산업간 효과, 일반균형모형, 충격 요인 분해

JEL Classification: F1, F4, O53

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BOK 경제연구 발간목록

한국은행 경제연구원에서는 Working Paper인 『BOK 경제연구』를 수시로 발간하고 있습니다. 『BOK 경제연구』는 주요 경제 현상 및 정책 효과에 대한 직관적 설명 뿐 아니라 깊이 있는 이론 또는 실증 분석을 제공함으로써 엄밀한 논증에 초점을 두는 학술논문 형태의 연구이며 한국은행 직원 및 한국은행 연구용역사업의 연구 결과물이 수록되고 있습니다.
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제2015 -1	글로벌 금융위기 이후 주요국 통화정책 운영체계의 변화	김병기 · 김인수
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
9	규제가 노동생산성에 미치는 영향: 한국의 산업패널 자료를 이용한 실증분석	이동렬 · 최종일 · 이종한
10	인구 고령화와 정년연장 연구 (세대 간 중첩모형(OLG)을 이용한 정량 분석)	홍재화 · 강태수
11	예측조합 및 밀도함수에 의한 소비자물가 상승률 전망	김현학
12	인플레이션 동학과 통화정책	우준명
13	Failure Risk and the Cross-Section of Hedge Fund Returns	Jung-Min Kim
14	Global Liquidity and Commodity Prices	Hyunju Kang · Bok-Keun Yu · Jongmin Yu

제2015-15	Foreign Ownership, Legal System and Stock Market Liquidity	Jieun Lee· Kee H. Chung
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
19	Entry of Non-financial Firms and Competition in the Retail Payments Market	Jooyong Jun
20	Monetary Policy Regime Change and Regional Inflation Dynamics: Looking through the Lens of Sector-Level Data for Korea	Chi-Young Choi· Joo Yong Lee· Roisin O'Sullivan
21	Costs of Foreign Capital Flows in Emerging Market Economies: Unexpected Economic Growth and Increased Financial Market Volatility	Kyoungsoo Yoon· Jayoung Kim
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
24	실물경기를 고려한 내재 유동성 측정	우준명·이지은
25	Deflation and Monetary Policy	Barry Eichengreen
26	Macroeconomic Shocks and Dynamics of Labor Markets in Korea	Tae Bong Kim· Hangyu Lee
27	Reference Rates and Monetary Policy Effectiveness in Korea	Heung Soon Jung· Dong Jin Lee· Tae Hyo Gwon· Se Jin Yun
28	Energy Efficiency and Firm Growth	Bongseok Choi· Wooyoung Park· Bok-Keun Yu
29	An Analysis of Trade Patterns in East Asia and the Effects of the Real Exchange Rate Movements	Moon Jung Choi· Geun-Young Kim· Joo Yong Lee
30	Forecasting Financial Stress Indices in Korea: A Factor Model Approach	Hyeongwoo Kim· Hyun Hak Kim· Wen Shi

제2016 -1	The Spillover Effects of U.S. Monetary Policy on Emerging Market Economies: Breaks, Asymmetries and Fundamentals	Geun-Young Kim · Hail Park · Peter Tillmann
2	Pass-Through of Imported Input Prices to Domestic Producer Prices: Evidence from Sector-Level Data	JaeBin Ahn · Chang-Gui Park · Chanho Park
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
8	The Relation Between Monetary and Macroprudential Policy	Jong Ku Kang
9	조세피난처 투자자가 투자 기업 및 주식시장에 미치는 영향	정호성 · 김순호
10	주택실거래 자료를 이용한 주택부문 거시건전성 정책 효과 분석	정호성 · 이지은
11	Does Intra-Regional Trade Matter in Regional Stock Markets?: New Evidence from Asia-Pacific Region	Sei-Wan Kim · Moon Jung Choi
12	Liability, Information, and Anti-fraud Investment in a Layered Retail Payment Structure	Kyoung-Soo Yoon · Jooyong Jun
13	Testing the Labor Market Dualism in Korea	Sungyup Chung · Sunyoung Jung
14	북한 이중경제 사회계정행렬 추정을 통한 비공식부문 분석	최지영

제2016 –15	Divergent EME Responses to Global and Domestic Monetary Policy Shocks	Woon Gyu Choi · Byongju Lee · Taesu Kang · Geun-Young Kim
16	Loan Rate Differences across Financial Sectors: A Mechanism Design Approach	Byoung-Ki Kim · Jun Gyu Min
17	근로자의 고용형태가 임금 및 소득 분포에 미치는 영향	최충 · 정성엽
18	Endogeneity of Inflation Target	Soyoung Kim · Geunhyung Yim
19	Who Are the First Users of a Newly-Emerging International Currency? A Demand-Side Study of Chinese Renminbi Internationalization	Hyoung-kyu Chey · Geun-Young Kim · Dong Hyun Lee
20	기업 취약성 지수 개발 및 기업 부실화에 대한 영향 분석	최영준
21	US Interest Rate Policy Spillover and International Capital Flow: Evidence from Korea	Jieun Lee · Jung-Min Kim · Jong Kook Shin
제**2017** –1	가계부채가 소비와 경제성장에 미치는 영향 – 유량효과와 저량효과 분석 –	강종구
2	Which Monetary Shocks Matter in Small Open Economies? Evidence from SVARs	Jongrim Ha · Inhwan So
3	FTA의 물가 안정화 효과 분석	곽노선 · 임호성
4	The Effect of Labor Market Polarization on the College Students' Employment	Sungyup Chung
5	국내 자영업의 폐업률 결정요인 분석	남윤미
6	차주별 패널자료를 이용한 주택담보대출의 연체요인에 대한 연구	정호성
7	국면전환 확산과정모형을 이용한 콜금리 행태 분석	최승문 · 김병국

제2017-8	Behavioral Aspects of Household Portfolio Choice: Effects of Loss Aversion on Life Insurance Uptake and Savings	In Do Hwang
9	신용공급 충격이 재화별 소비에 미치는 영향	김광환 · 최석기
10	유가가 손익분기인플레이션에 미치는 영향	김진용 · 김준철 · 임형준
11	인구구조변화가 인플레이션의 장기 추세에 미치는 영향	강환구
12	종합적 상환여건을 반영한 과다부채 가계의 리스크 요인 분석	이동진 · 한진현
13	Crowding out in a Dual Currency Regime? Digital versus Fiat Currency	KiHoon Hong · Kyounghoon Park · Jongmin Yu
14	Improving Forecast Accuracy of Financial Vulnerability: Partial Least Squares Factor Model Approach	Hyeongwoo Kim · Kyunghwan Ko
15	Which Type of Trust Matters?: Interpersonal vs. Institutional vs. Political Trust	In Do Hwang
16	기업특성에 따른 연령별 고용행태 분석	이상욱 · 권철우 · 남윤미
17	Equity Market Globalization and Portfolio Rebalancing	Kyungkeun Kim · Dongwon Lee
18	The Effect of Market Volatility on Liquidity and Stock Returns in the Korean Stock Market	Jieun Lee · KeeH.Chung
19	Using Cheap Talk to Polarize or Unify a Group of Decision Makers	Daeyoung Jeong
20	패스트트랙 기업회생절차가 법정관리 기업의 이자보상비율에 미친 영향	최영준
21	인구고령화가 경제성장에 미치는 영향	안병권 · 김기호 · 육승환
22	고령화에 대응한 인구대책: OECD사례를 중심으로	김진일 · 박경훈

제2017 –23	인구구조변화와 경상수지	김경근・김소영
24	통일과 고령화	최지영
25	인구고령화가 주택시장에 미치는 영향	오강현・김솔・윤재준・안상기・권동휘
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
33	Bank Globalization and Monetary Policy Transmission in Small Open Economies	Inhwan So
34	기존 경영자 관리인(DIP) 제도의 회생기업 경영성과에 대한 영향	최영준
35	Transmission of Monetary Policy in Times of High Household Debt	Youngju Kim・Hyunjoon Lim
제**2018** –1	4차 산업혁명과 한국의 혁신역량: 특허자료를 이용한 국가·기술별 비교 분석, 1976–2015	이지홍・임현경・정대영
2	What Drives the Stock Market Comovements between Korea and China, Japan and the US?	Jinsoo Lee・Bok-Keun Yu
3	Who Improves or Worsens Liquidity in the Korean Treasury Bond Market?	Jieun Lee

제2018-4	Establishment Size and Wage Inequality: The Roles of Performance Pay and Rent Sharing	Sang-yoon Song
5	가계대출 부도요인 및 금융업권별 금융취약성: 자영업 차주를 중심으로	정호성
6	직업훈련이 청년취업률 제고에 미치는 영향	최충 · 김남주 · 최광성
7	재고투자와 경기변동에 대한 동학적 분석	서병선 · 장근호
8	Rare Disasters and Exchange Rates: An Empirical Investigation of South Korean Exchange Rates under Tension between the Two Koreas	Cheolbeom Park · Suyeon Park
9	통화정책과 기업 설비투자 - 자산가격경로와 대차대조표경로 분석 -	박상준 · 육승환
10	Upgrading Product Quality: The Impact of Tariffs and Standards	Jihyun Eum
11	북한이탈주민의 신용행태에 관한 연구	정승호 · 민병기 · 김주원
12	Uncertainty Shocks and Asymmetric Dynamics in Korea: A Nonlinear Approach	Kevin Larcher · Jaebeom Kim · Youngju Kim
13	북한경제의 대외개방에 따른 경제적 후생 변화 분석	정혁 · 최창용 · 최지영
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15	Reserve Accumulation and Bank Lending: Evidence from Korea	Youngjin Yun
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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
21	Leverage, Hand-to-Mouth Households, and MPC Heterogeneity	Sang-yoon Song
22	선진국 수입수요가 우리나라 수출에 미치는 영향	최문정 · 김경근
23	Cross-Border Bank Flows through Foreign Branches: Evidence from Korea	Youngjin Yun
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