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# Structural change in an open economy

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ABSTRACT

We study the importance of international trade in structural change. Our framework has both productivity and trade cost shocks, and allows for non-unitary income and substitution elasticities. We calibrate our model to investigate South Korea's structural change between 1971 and 2005. We find that the shock processes, propagated through the model's two main transmission mechanisms, non-homothetic preferences and the open economy, explain virtually all of the evolution of agriculture and services labor shares, and the rising part of the hump-shape in manufacturing. Counterfactual exercises show that the role of the open economy is quantitatively important for explaining South Korea's structural change.



## 1. Introduction

Two of the most important developments affecting the world's economies in the past half-century have been global integration, particularly in international trade, and the emergence of a hump-shaped pattern in manufacturing employment shares for many middle and upper-income countries. Employment shares in manufacturing were previously thought to be increasing monotonically as countries develop. However, recent research by Maddison (1991) and Buera and Kaboski (2012), among others, shows for many countries that structural change involves three distinct patterns: a decline in agriculture, a rise in services, and a hump-shaped pattern in manufacturing labor shares.

Global integration between developed and emerging market economies is often blamed for the decline in manufacturing in most developed countries. Indeed, Autor et al. (2011) find that one-third of the decline in US manufacturing employment is a result of trade with China. Moreover, some of the emerging market economies that recently joined the global trading system, such as South Korea and Taiwan, have themselves experienced a hump-shaped pattern in manufacturing employment. These findings plausibly suggest a linkage between globalization and structural change. Theoretically, such a linkage is natural: after all, the fundamental role of international trade is to facilitate specialization via an efficient reallocation of employment and other factors of production across sectors.

The main goals of our paper are to develop a multi-sector open economy model to study these linkages, and to conduct a quantitative analysis of the role of international trade in South Korea's structural change. Our model draws from three intellectual antecedents. First, there is the long literature, going back to Engel, that emphasizes the importance of non-unitary sectoral income elasticities—in particular an agriculture/food income elasticity of demand less than one. We embody this with the Stone–Geary non-homothetic preferences. Second, there is the literature, going back to Baumol (1967), that

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emphasizes the importance of non-unitary sectoral substitution elasticities in conjunction with asymmetric productivity growth across sectors. We allow for these forces in our model, as well. Finally, we introduce international trade via the Ricardian comparative advantage framework of Eaton and Kortum (2002). Patterns of specialization and international trade are determined by relative productivity differences across countries and goods. One additional feature of our model, incorporating intermediate goods, is useful for matching gross output concepts like trade and consumption expenditure, with value-added concepts like GDP and labor shares. Overall, our model shares features similar to other multi-sector Eaton–Kortum models such as Shikher (2012), di Giovanni et al. (2012), Levchenko and Zhang (2012), and Caliendo and Parro (2011).[1]

At the most basic level, international trade allows sectoral expenditure to deviate from sectoral production. Each country runs a net export surplus in its sector of comparative advantage. Hence, labor shares are directly affected by patterns of specialization induced by trade. In addition, trade affects relative prices, which affects sectoral expenditure shares, and hence sectoral labor shares.

In a simplified version of the model, we show how productivity shocks and trade cost shocks can qualitatively deliver the structural change patterns observed in South Korea. In particular, the hump-shape in manufacturing can be generated under one of two scenarios. First, if a country's productivity growth in manufacturing is sufficiently high, it will take market share from the other country, thus leading to increased labor devoted to manufacturing. This is the upward part of the hump. However, as manufacturing productivity continues to grow, the country will eventually be able to supply the world market with less labor. This leads to the downward part of the hump. Second, if a country has a comparative advantage in manufacturing and trade costs decline so that the comparative advantage is increasingly revealed, a similar result is obtained.

More broadly, international trade affects structural change along three dimensions. First, declines in trade costs affect patterns of specialization, which then affect labor allocations across sectors. Second, differential sectoral productivity growth also affects labor allocations, again operating through specialization patterns. Third, lower trade costs spur income growth and strengthen the role of non-homothetic preferences in structural change.

We calibrate our model to South Korea and the rest of the world in 1971–2005, focusing on explaining South Korea's structural change. We then simulate the effects of productivity shocks and trade cost shocks in our benchmark model. We find that it can explain virtually all of the evolution of Korea's agriculture and services sector labor shares. It can also explain the rise in Korea's manufacturing labor share. However, it cannot explain the decline in Korea's manufacturing labor share that occurred beginning around 1990. By contrast, a simulation under a closed economy cannot explain the time path of any sectoral labor share. The root mean square error between the implied and observed labor shares is 0.05 in the open economy model and 0.08 in the closed economy model; the closed economy fit is about 60% worse.

The open economy model does better because the asymmetric evolution of sectoral productivity gives Korea's manufacturing sector a comparative advantage over time, thus leading to greater labor in manufacturing, and less in agriculture. In addition, Korea's trade costs decline more rapidly in manufacturing than in agriculture, and this leads again to greater specialization in manufacturing and less in agriculture than otherwise. Finally, in the open economy setting, owing to specialization, Korea grows faster, which strengthens the impact of non-homothetic preferences on the labor share dynamics.

We then conduct a series of counterfactual simulations to assess the quantitative importance of trade cost shocks, TFP shocks, and non-homothetic preferences. We find that agriculture and manufacturing are significantly influenced by both changing trade costs and TFP, while the services sector is influenced primarily by TFP changes over time. In addition, we conduct simulations with homothetic preferences. Comparisons between open and closed economy results with both sets of preferences show that non-homothetic preferences matter for the evolution of agriculture and services, but not for manufacturing.

There is a large literature on structural change. One recent development is to shift the focus from two-sector closed economy frameworks to three-sector frameworks and open economy frameworks.[2] Recent studies of three-sector closed economy models include Echevarria (1997), Kongsamut et al. (2001), Ngai and Pissarides (2007), Rogerson (2008), Restuccia et al. (2008), Foellmi and Zweimuller (2008), Buera and Kaboski (2009, 2012), Duarte and Restuccia (2010), Verma (2012), and Herrendorf et al. (2012).[3] Earlier studies of open economy models of structural change include Matsuyama (1992, 2009) and Echevarria (1995). Echevarria (1995) studies the effect of trade on output composition and overall growth of OECD economies in a small open economy model. Matsuyama (2009) employs a simple Ricardian model to show that high manufacturing productivity growth need not lead to a decline in manufacturing employment.

The two papers most closely related to ours are Betts et al. (hereafter, BGV; 2011) and Sposi (2012). Both study Korea's structural change from a three-sector model. In the former, while several details of the model and calibration are different,

[1] Caliendo and Parro (2011) and Shikher (2012) study the effects of NAFTA on trade and welfare in the NAFTA countries. di Giovanni et al. (2012) examine the impact of different Chinese sectoral growth patterns on global welfare. Levchenko and Zhang (2012) study the welfare implications of the evolution of sectoral comparative advantages across countries over time.

[2] In terms of two-sector frameworks, the sectoral divisions have often been agriculture and non-agriculture, or capital-intensive and labor-intensive. For recent examples of these divisions, see Caselli and Coleman (2001), Laitner (2000), Acemoglu and Guerrieri (2008), and Desmet and Rossi-Hansberg (2009).

[3] Also, see Ju et al. (2009) for an $n$-sector model.

BGV also find that openness matters a great deal.[4] The latter employs a Ricardian model, and also finds that comparative advantage is important. However, owing to a time period that ends in 1995, the paper cannot assess the ability of the model to replicate the hump-shaped pattern in manufacturing.[5] A third paper, Teignier-Bacque (2012), also studies structural change in Korea (and two other countries), but focuses on the role of the agriculture sector in a two-sector small open economy model.[6]

The paper is organized as follows. Section 2 lays out the model and Section 3 uses a simplified version to illustrate the key impacts of an open economy on structural change. Section 4 presents the calibration and studies the importance of the two key sources of shocks and the two key transmission mechanisms (openness and non-homothetic preferences). Section 5 concludes.

## 2. Model

Our model has two countries and three sectors, and it includes non-unitary income and substitution elasticities of demand and sector-specific productivity growth to allow both Engel's law and the Baumol effect to operate. We introduce international trade based on the Ricardian motive, following Eaton and Kortum (2002). Agriculture and manufacturing goods are tradable and services are non-tradable. In each sector, production uses both labor and intermediate inputs. Productivity and trade costs change at different rates across sectors and countries; these forces drive structural change. Trade is balanced each period (We omit the time subscript unless needed.).

### 2.1. Technologies

There is a continuum of goods in the agriculture ($a$), manufacturing ($m$) and services ($s$) sectors. Each country possesses technologies for producing all the goods in all sectors. The production function for good $z\in[0,1]$ in sector $k\in\{a,m,s\}$ of country $i$ is

$$Y_{ik}(z)=A_{ik}(z)L_{ik}(z)^{\lambda_k}\left[\Pi_{n=a,m,s}M_{ikn}^{\gamma_{kn}}(z)\right]^{1-\lambda_k} \tag{1}$$

where $Y_{ik}(z)$ denotes output, $A_{ik}(z)$ denotes exogenous productivity, $L_{ik}(z)$ denotes labor, and $M_{ikn}(z)$ denotes sector-$n$ composite goods used as intermediates in the production of the sector $k$ good. The parameter $\lambda_k$ denotes the value-added share in production and $\gamma_{kn}$ denotes the share of intermediate inputs sourced from sector $n$.

$A_{ik}(z)$ is the realization of a random variable $Z_{ik}$ drawn from the cumulative distribution function $F_{ik}(A)=Pr[Z_{ik}\le A]$. Following Eaton and Kortum (2002), we assume that $F_{ik}(A)$ is a Fréchet distribution: $F_{ik}(A)=e^{-T_{ik}A^{-\theta}}$, where $T_{ik}>0$ and $\theta>1$. The larger is $T_{ik}$, the greater the mean efficiency for any good $z$. The larger is $\theta$, the lower the heterogeneity or variance of $Z_{ik}$.[7] We assume that the productivity is drawn each period.[8]

When agriculture or manufacturing goods are shipped abroad, they incur trade costs, which include tariffs, transportation costs, and other barriers to trade. We model these costs as iceberg costs. Specifically, if one unit of manufacturing good $z$ is shipped from country $j$, then $1/\tau_{ijm}$ units arrive in country $i$. We assume that trade costs within a country are zero, i.e., $\tau_{iia}=\tau_{iim}=1$.

Goods markets are perfectly competitive; goods prices are determined by marginal costs of production. The cost of an input bundle in sector $k$ is $v_{ik}=w_i^{\lambda_k}(\Pi_{n=a,m,s}(P_{in})^{\gamma_{kn}})^{1-\lambda_k}$, which is the same within a sector, but varies across sectors given different input shares across sectors. The price of the services good $z$ is $p_{is}(z)=v_{is}/A_{is}(z)$. For tradable goods, the price at which country $j$ can supply tradable good $z$ in sector $k$ to country $i$ equals $p_{ijk}(z)=\tau_{ijk}v_{jk}/A_{jk}(z)$. Since buyers will select to buy from the cheapest source, the actual price for this good in country $i$ is $p_{ik}(z)=\min\{p_{i1k}(z),p_{i2k}(z)\}$.

The composite good in each sector $Q_{ik}$ is an aggregate of the individual goods $Q_{ik}(z)$

$$Q_{ik}=\left(\int_0^1 Q_{ik}(z)^{(\eta-1)/\eta}\,dz\right)^{\eta/(\eta-1)},$$

[4] Three differences in modeling and calibration are: (a) BGV set several preference parameters from the literature, while we estimate the parameters. (b) BGV employ a value-added framework, which is not consistent with the measurement of international trade in the data. (c) We evaluate the role of non-homothetic preferences.

[5] There are several other differences. Sposi does not examine either the effects of changes in non-tariff trade costs or the importance of non-homothetic preferences. On the other hand, his model allows for non-zero trade deficits and includes more than two countries.

[6] Other quantitative open economy models of structural change include Coleman (2007), Galor and Mountford (2008), Reyes-Heroles (2012), Stefanski (2012), Swiecki (2012), and Ungor (2012). Coleman (2007) uses a multi-country Heckscher–Ohlin–Ricardo framework to study the effect of a large emerging market country on other countries' GDPs and welfare. Galor and Mountford (2008) study the effect of trade on fertility and population growth, and on human capital acquisition. Reyes-Heroles (2012) studies structural transformation in the United States. Stefanski (2012) studies the effect of structural transformation of India and China on oil prices. Swiecki (2012) employs a multi-sector model that includes intersectoral distortions and evaluates the welfare gains from trade. Ungor (2012) uses a two-sector model to study the effects of China's growth on de-industrialization of the United States.

[7] $Z_{ik}$ has geometric mean $e^{\frac{\gamma}{\theta}}T_{ik}^{1/\theta}$ and its log has a standard deviation $\pi/\theta\sqrt{6}$, where $\gamma$ is Euler's constant.

[8] Alternatively, we could assume that the productivity is drawn once in the initial period, and as the $T$'s change over time, the productivity relative to $T$ remains constant.

where the elasticity of substitution across goods within a sector is $\eta>0$. For the services sector, each good $z$ is produced locally, while for the tradable sectors, each good $z$ is either produced locally or imported from abroad. The composite sectoral goods are used in domestic final consumption, $C_{ik}$, and domestic production as intermediate inputs.

Under the Fréchet distribution of productivities, Eaton and Kortum (2002) show that the price of tradable composite good $k\in\{a,m\}$ in country $i$ is $P_{ik}=\Gamma(\Phi_{ik})^{-1/\theta}$, where the constant $\Gamma$ is the Gamma function evaluated at $(1-((\eta-1)/\theta))^{1/(1-\eta)}$, and $\Phi_{ik}=T_{1k}(v_{1k}\tau_{i1k})^{-\theta}+T_{2k}(v_{2k}\tau_{i2k})^{-\theta}$. $\Phi_{ik}$ summarizes country $i$'s access to global production technologies in sector $k$ scaled by the relevant unit costs of inputs and trade costs.[9] For the services composite good, the price is $P_{is}=\Gamma(\Phi_{is})^{-1/\theta}$, where $\Phi_{is}=T_{is}(v_{is})^{-\theta}$.

The share of country $j$'s expenditure on sector-$k$ goods from country $i$, $\pi_{jik}$, equals the probability of importing sector-$k$ goods from country $i$ in country $j$, and is given by

$$\pi_{jik}=\frac{T_{ik}(v_{ik}\tau_{jik})^{-\theta}}{\Phi_{jk}}. \tag{2}$$

Eq. (2) shows how a higher average productivity, a lower unit cost of input bundles, and a lower trade cost in country $i$ translate into a greater import share by country $j$.

### 2.2. Preferences

Period utility of the representative household in country $i$ is given by

$$U(C_{ia},C_{im},C_{is})=\left[\omega_a^{1/\epsilon}(C_{ia}-\overline{C}_a)^{(\epsilon-1)/\epsilon}+\omega_m^{1/\epsilon}(C_{im}-\overline{C}_m)^{(\epsilon-1)/\epsilon}+\omega_s^{1/\epsilon}(C_{is}-\overline{C}_s)^{(\epsilon-1)/\epsilon}\right]^{\epsilon/(\epsilon-1)}, \tag{3}$$

where for each sector $k\in\{a,m,s\}$, $C_{ik}$ is consumption of sector-$k$ composite goods, and $\overline{C}_k$ is the subsistence requirement for sector-$k$ composite goods. A positive value of $\overline{C}_k$ generates an income elasticity of demand for the sector $k$ goods less than one. The preference share parameters $\omega_k$'s are positive and sum to one across sectors. The elasticity of substitution across sectoral composite goods is $\epsilon>0$. If $\epsilon>1$, the sectoral composite goods are substitutes, and if $\epsilon\le 1$, the sectoral composite goods are complements.

The representative household maximizes his/her utility (3) subject to the following budget constraint in each period

$$P_{ia}C_{ia}+P_{im}C_{im}+P_{is}C_{is}=w_i, \tag{4}$$

where $w_i$ and $P_{ik}$ denote the wage rate and the price of the sector-$k$ composite good, respectively. The household supplies its unit labor endowment inelastically and spends all labor income. The budget constraints (4) ensure that balanced trade holds period-by-period.

### 2.3. Equilibrium

All factor and goods markets are characterized by perfect competition. Labor is perfectly mobile across sectors within a country, but immobile across countries. Let $L_i$ denote total labor endowment in country $i$ and $L_{ik}$ denote labor employed in sector $k$. The factor market clearing conditions in each period are given by

$$L_i=L_{is}+L_{im}+L_{ia}. \tag{5}$$

We next characterize the good market clearing condition. For each sector $k$, we have

$$Q_{ik}=C_{ik}+\sum_{n=a,m}(1-\lambda_n)\gamma_{nk}\sum_{j=1,2}\frac{\pi_{jin}P_{jn}Q_{jn}}{P_{ik}}+(1-\lambda_s)\gamma_{sk}\frac{P_{is}Q_{is}}{P_{ik}}. \tag{6}$$

That is, the quantity of sector-$k$ composite goods produced in country $i$, $Q_{ik}$, is the sum of the quantity demanded (i) for domestic final consumption $C_{ik}$; (ii) for use as intermediate inputs in the production of domestic tradable goods, $\sum_{n=a,m}(1-\lambda_n)\gamma_{nk}\sum_{j=1,2}\pi_{jin}P_{jn}Q_{jn}/P_{ik}$; and (iii) for use as intermediate inputs in the production of domestic services goods, $(1-\lambda_s)\gamma_{sk}(P_{is}Q_{is}/P_{ik})$. These good market clearing conditions demonstrate that our model captures two key features of the world economy. First, the model allows trade in intermediates, as much of world trade is in intermediates. Second, the model captures two-way input linkages across sectors.

We define a competitive equilibrium of our model economy with country-specific labor endowment processes $\{L_i\}$, trade cost processes $\{\tau_{ija},\tau_{ijm}\}$, productivity processes $\{T_{ia},T_{im},T_{is}\}$ and common structural parameters $\{\epsilon,\eta,\theta,\{\lambda_k,\gamma_{kn},\overline{C}_k,\omega_k\}_{n,k=a,m,s}\}$ as follows.

**Definition 1.** *A competitive equilibrium* is a sequence of goods and factor prices $\{P_{ia},\ P_{im},\ P_{is},\ w_i\}_{i=1,2}$, allocations $\{L_{ia},\ L_{im},\ L_{is},\ Q_{ia},\ Q_{im},\ Q_{is},\ C_{ia},\ C_{im},\ C_{is}\}_{i=1,2}$, and trade shares $\{\pi_{ija},\pi_{ijm}\}_{i,j=1,2}$, such that, given prices, the allocations solve the firms'

[9] We need to assume $\eta-1<\theta$ to have a well-defined price index. Under this assumption, the parameter $\eta$, which governs the elasticity of substitution across goods within a sector, can be ignored because it appears only in the constant term $\Gamma$.

maximization problems associated with technologies (1) and the household's maximization problem characterized by (3) and (4), and satisfy the market clearing conditions (5) and (6).

## 3. How trade impacts structural change

This section illustrates the mechanisms through which trade impacts the patterns of structural change — sectoral labor shares — in an open economy. To deliver the results transparently, we abstract from intermediate input usage by assuming $\lambda_k = 1$ for all $k$. We compare the patterns of structural change in an open economy with those in a closed economy, and highlight two channels — the expenditure and net export channels — through which trade impacts structural change.

### 3.1. Structural change in a closed economy

We begin our analysis of the model by developing the pattern of structural change in a closed economy, which is a special case of our model in which the trade costs are infinitely high. We use the superscript $c$ to denote the relevant variables in the closed economy. Under autarky, all goods are produced domestically. It is straightforward to show for country $i$ and each period, the sectoral composite good prices are given by

$$\frac{P_{ia}^c}{w_i^c} = \frac{1}{A_{ia}}, \quad \frac{P_{im}^c}{w_i^c} = \frac{1}{A_{im}}, \quad \frac{P_{is}^c}{w_i^c} = \frac{1}{A_{is}}, \tag{7}$$

where $A_{ik} = T_{ik}^{1/\theta}/\Gamma$.

The feasibility conditions imply that the sectoral labor share equals the sectoral expenditure share.[10] For each sector $k \in \{a, m, s\}$, we have

$$l_{ik}^c = \frac{L_{ik}^c}{L_i} = \frac{w_i^c L_{ik}^c}{w_i^c L_i} = \frac{P_{ik}^c C_{ik}^c}{w_i^c L_i} \equiv X_{ik}^c = \omega_k \left(\frac{P_{ik}^c}{P_i^c}\right)^{1-\epsilon} \left(1 - \sum_n \frac{P_{in}^c \overline{C}_n}{w_i^c}\right) + \frac{P_{ik}^c \overline{C}_k}{w_i^c}, \tag{8}$$

where the aggregate price $P_i^c$ equals $(\sum_k \omega_k (P_{ik}^c)^{1-\epsilon})^{1/(1-\epsilon)}$. Clearly, non-unitary income and non-unitary substitution elasticities allow changing relative prices (relative productivities) and changing income to impact structural change in autarky.

If $\overline{C}_k$ in all sectors is set to zero, preferences become homothetic, and the implications are similar to those in Ngai and Pissarides (2007)

$$l_{ik}^c \equiv X_{ik}^c = \omega_k \left(\frac{P_{ik}^c}{P_i^c}\right)^{1-\epsilon}.$$

Turning to dynamics, let $\hat{Z}$ denote the log growth rate of variable $Z$. Then, for any period $t$, we have

$$\hat{l}_{ikt}^c = \hat{X}_{ikt}^c = (1-\epsilon)(\hat{P}_{ikt}^c - \hat{P}_{it}^c) = (\epsilon - 1)(\hat{A}_{ikt} - \hat{A}_{it}^c), \tag{9}$$

where $\hat{A}_{it}^c = \sum_k X_{ikt}^c \hat{A}_{ikt}$. Thus, the elasticity of substitution links changes in sectoral labor shares to changes in sectoral relative prices and productivities. In the Cobb–Douglas case ($\epsilon = 1$), there is no structural change: sectoral expenditure and labor shares are constant over time. In an empirically relevant case with $\epsilon < 1$, a sector with rising relative productivities experiences declining relative prices, expenditure shares, and labor shares over time. Labor moves from high productivity growth sectors to low productivity growth sectors. If the manufacturing sector has the fastest productivity growth among the three sectors, its labor share declines over time. This implication is consistent with the post-war experience of many developed countries. However, in many developing countries, the manufacturing sector has both the fastest growth in productivity and a rising labor share: clearly at odds with the implications of the closed economy model.[11]

### 3.2. Structural change in an open economy

We now turn to an open economy and begin by defining comparative advantage. Country $i$ has a *comparative advantage in manufacturing* if and only if $A_{im}/(A_{jm}/\tau_{ijm}) > A_{ia}/(A_{ja}/\tau_{ija})$. Our definition is thus the traditional definition augmented by trade costs.[12] The comparative advantage patterns determine intra-sector trade patterns. If country 1 has a comparative

[10] The sectoral labor share equals the sectoral expenditure share even in a framework with capital and intermediate goods, as long as the factor intensity in the production function is identical across sectors.

[11] We examine the 19 countries in Asia and Latin America from the GGDC 10-sector data base, and compute sectoral employment shares and growth in sectoral real-value added per worker for each country. Of the 19, 10 had the highest productivity growth in manufacturing, and of these 10, 7 countries (Indonesia, Japan, Korea, Singapore, Thailand, Taiwan, and Venezuela) experience a higher manufacturing employment share over most of the sample period than in the initial year.

[12] Hence, it is possible for a country to have a relative disadvantage in manufacturing from the productivities alone, but, owing to sufficiently small manufacturing trade costs, an overall comparative advantage in manufacturing. See Deardorff (2004) for further discussion on the topic of comparative advantage in the presence of trade costs. In this section, we restrict our attention to cases in which one country has a comparative advantage in

advantage in manufacturing, Eq. (2) implies that $\pi_{11m} > \pi_{11a}$. Intuitively, a greater share of spending is on domestic goods in the comparative advantage sector.

First, consider the impact of an open economy on sectoral prices. The services good price in country $i$ relative to wage is $P_{is}/w_i = 1/A_{is}$, which is the same as under autarky. The price of tradable composite good $k$ relative to wage is

$$\frac{P_{ik}}{w_i} = \frac{1}{A_{ik}}\left[1 + \left(\frac{\tau_{ijk} w_j}{A_{jk}} \frac{A_{ik}}{w_i}\right)^{-\theta}\right]^{-1/\theta} = \frac{\pi_{iik}^{1/\theta}}{A_{ik}}. \tag{10}$$

Comparing Eqs. (10)–(7), one can see that $P_{ik}/w_i < P^c_{ik}/w^c_i$ because $\pi_{iik} < 1$. The lower is the sectoral expenditure share on domestic goods, the lower is the sectoral price. Trade essentially allows countries to enlarge their effective technologies in the tradable sectors, thus leading to lower prices, especially in the comparative disadvantage sector. The aggregate price level relative to the wage rate $P_i/w_i$ is also lower in the open economy than in autarky, which is consistent with the well known result from classical trade theory that there are gains from trade.[13]

Next consider the impact of trade on expenditure shares. The expression of the expenditure share is the same in the open economy as in the closed economy, and is given by Eq. (8). However, openness affects the expenditure shares through its impact on relative prices, discussed above, and also its impact on income.

Now we turn to the sectoral labor allocations. Because services sector goods are non-tradable, $l_{is} = X_{is}$, as in the closed economy. Nonetheless, trade impacts the services labor share by affecting the services expenditure share.

For the tradable sectors, country 1's income from sector $k$ equals expenditures of both countries on its sector-$k$ goods: $w_1 L_{1k} = \pi_{11k} P_{1k} C_{1k} + \pi_{21k} P_{2k} C_{2k}$, implying

$$l_{1k} = \frac{L_{1k}}{L_1} = \pi_{11k} X_{1k} + \pi_{21k} X_{2k} \frac{w_2 L_2}{w_1 L_1}. \tag{11}$$

Three forces determine country 1's labor share in sector $k$. First, it depends on the expenditure share of each country on sector $k$ goods, $X_{1k}$ and $X_{2k}$. It also depends on the extent of specialization, $\pi_{11k}$ and $\pi_{21k}$. Finally, it depends on the relative size of the two economies.

Alternatively, substituting $1-\pi_{12k}$ for $\pi_{11k}$ in Eq. (11) gives

$$l_{1k} = X_{1k} + \frac{\pi_{21k} X_{2k} w_2 L_2 - \pi_{12k} X_{1k} w_1 L_1}{w_1 L_1} = X_{1k} + N_{1k}, \tag{12}$$

where $N_{1k}$ denotes the sectoral net export share of total GDP in country 1. Thus, the tight link that binds sectoral demand and production in the closed economy does not hold in the open economy. The net export channel, $N_{1k}$, captures the direct contribution of international trade to structural change. In addition, trade contributes indirectly to structural change through the expenditure channel, $X_{1k}$.

Consider the dynamics of structural change in an open economy. For services, as in the closed economy, the growth rate of the labor share equals the growth rate of the expenditure share: $\hat{l}_{ist} = \hat{X}_{ist}$. However, because openness affects the growth rate of overall income and of the services relative price, trade will affect the growth rate of the services expenditure share and labor share. The growth rate of the labor share of tradable sector $k$ in country $i$ is given by

$$\hat{l}_{ikt} = \frac{X_{ikt}}{l_{ikt}} \hat{X}_{ikt} + \frac{N_{ikt}}{l_{ikt}} \hat{N}_{ikt},$$

which differs from (9) by the addition of the net export term. Changes in both expenditure and net export shares affect structural change.

### 3.2.1. The net export channel

The cleanest way to see the direct contribution of trade to the sectoral labor shares is with unit income and substitution elasticities of demand. In this case, the expenditure share of sector $k$ is simply $\omega_k$ and constant over time. In autarky, the labor share is thus also constant; asymmetric productivity growth and the evolution of income play no role in structure change. In an open economy, the services labor share is $\omega_s$, as in autarky. The labor share of tradable sector $k \in \{a, m\}$ is $\omega_k + N_{ik}$ in the open economy. $N_{ik}$ captures exactly the impact of trade on structural change. We now derive a natural, but important, implication of the model: a country will experience a net export surplus in its comparative advantage sector. Hence, when a country opens up to trade, labor moves from its comparative disadvantage sector to its comparative advantage sector.

Assume that country 1 (2) has a comparative advantage in manufacturing (agriculture). The trade balance of sector $k$ in country 1 is $NX_{1k} = \pi_{21k}\omega_k w_2 L_2 - \pi_{12k}\omega_k w_1 L_1$, where the expenditure share is $\omega_k$ in both countries. The pattern of comparative advantage implies $\pi_{21m} > \pi_{21a}$ and $\pi_{12m} < \pi_{12a}$. If country 1 ran a trade deficit in the manufacturing sector, it cannot run

(*footnote continued*)
manufacturing and the other country has a comparative advantage in agriculture, which is a restriction that trade costs cannot be too different across sectors and countries.

[13] $P_i/w_i$ is the reciprocal of the real wage or the real purchasing power of each country's income.

a trade deficit in the agriculture sector, otherwise it would violate the balanced trade condition. Hence, it must be the case that $NX_{1m} > 0$ and $NX_{1a} < 0$.[14]

We describe two scenarios in which the presence of trade can generate a hump-shaped pattern in the manufacturing employment share. In the first scenario, a country with a comparative advantage in manufacturing experiences both relative and absolute productivity growth in manufacturing over time. Because of the relative productivity growth, the country's manufacturing labor share rises initially as it supplies an increasing share of world demand for manufacturing products. As time passes, the continuing increase in absolute productivity implies that, despite the increasing net export surplus, fewer workers are needed to produce the manufactured goods. Eventually, the latter effect dominates, and the manufacturing labor share declines.[15]

In the second scenario, the primary driving force is declining trade costs over time. As trade costs decline, each country's comparative advantage is increasingly revealed, and there is increased specialization. A country with a comparative advantage in manufacturing experiences a rising manufacturing employment share initially. If the country is small, its relative wage increases over time, because the gains from trade are larger for smaller countries. Consequently, the relative purchasing power of its trading partner declines, which reduces the amount of its labor needed to satisfy foreign demand for manufactured goods. As long as its relative wage continues to increase, this relative purchasing power effect will eventually dominate, and the manufacturing labor share will peak and then decline.

*3.2.2. Adding the expenditure channel*

We now consider the impact of trade on expenditure shares by allowing either the income or substitution elasticities to be different from one. When the income elasticities are different from one across sectors, real income levels impact the expenditure share as shown in Eq. (8). In the open economy, trade increases real income in both countries, reinforcing income-induced labor reallocations.

Eq. (8) also shows that when the substitution elasticity differs from one, relative prices impact the expenditure shares. Focusing on the Baumol case, $\epsilon < 1$, in both countries, $P_{is}/P_i$ is higher in the open economy; hence, the services expenditure share and labor share are higher in the open economy. For the sector in which country $i$ has a comparative disadvantage, its price relative to the aggregate price is lower, and its expenditure share is lower in the open economy.[16] Suppose manufacturing has the highest productivity growth; then, the expenditure channel would imply a declining manufacturing labor share. For the model to generate a rising manufacturing labor share, the net export channel needs to be sufficiently strong initially to more than offset the expenditure channel. However, as in the unitary elasticity case, over time, the net export channel diminishes, and the expenditure channel begins to dominate, leading to declining manufacturing labor shares.

In this section, we have used our model to demonstrate the multiple channels through which an open economy can affect a country's structural change. All the channels start from comparative advantage and specialization. These starting forces affect relative prices, which then feed into expenditure shares and labor shares. In addition, specialization by itself leads to reallocation of labor across sectors. Finally, these forces lead to higher income, which, in a world with non-homothetic preferences, also affects labor shares. Over time, structural change is driven by productivity growth and by changes in trade costs. Because these shocks affect comparative advantage and specialization, their ultimate impact is different in an open economy from a closed economy. It remains to be seen whether an open economy framework is quantitatively relevant, and which channels and shocks are quantitatively important. The next section addresses these questions.

## 4. Quantitative analysis

We now employ our model to quantitatively analyze the importance of openness in South Korea's structural change between 1971 and 2005. As Fig. 1 shows, Korean experienced substantial structural change during this 35-year period. The agriculture labor share declined sharply and essentially monotonically from 0.48 to 0.09, and the services labor share rose sharply and essentially monotonically from 0.40 to 0.73. In addition, the manufacturing labor share displayed the hump-shaped pattern: rising from 0.13 in 1971 to 0.27 by 1989 and then declining to 0.17 by 2005. Explaining these dynamics over time is the challenge posed to our model. The first section discusses how we calibrate the model. The second section presents simulation results of our model, including counterfactuals designed to assess the relative importance of the two main shocks in our model, changes in trade costs and in TFP, as well as the importance of two key transmission channels, the open economy and non-homothetic preferences.

### 4.1. Calibration

We calibrate our two-country model with South Korea as one country and the rest of the world (ROW) as the other country. The ROW consists of most of South Korea's (hereafter, Korea) important trading partners in this period, and

[14] This result can also be established for CES preferences and free trade.
[15] The conditions under which productivity growth is sufficiently high are available in Appendix.
[16] In the comparative advantage sector, the sectoral relative price may or may not be lower in the open economy, hence, the effect of trade on the expenditure share cannot be signed.

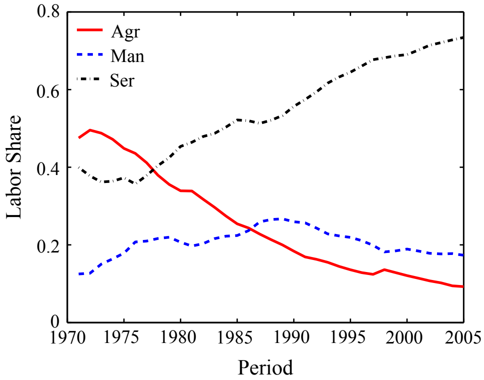


**Fig. 1.** Korean structural change.

includes the G7 countries, other OECD countries, and several oil-producing countries in the Middle East and Latin America. These countries accounted for, on average, two-thirds of Korea's trade during this time period. Some countries were excluded because of data availability issues or because they were not important in Korea's trade.[17] The list of countries is given in Appendix.

We now describe our calibration of the preference parameters $\{\omega_j, \overline{C}_j, \epsilon\}$ and the production parameters $\{\lambda_j,\ \gamma_{jk},\ \theta\}$. These parameters are assumed to be identical across countries and time invariant. Consistent with recent estimates by Simonovska and Waugh (2011), we set $\theta = 4$. The other parameters are calibrated to Korean data. Much of the literature (e.g., Duarte and Restuccia, 2010; Herrendorf et al., 2012) focuses on estimating $\overline{C}_a$ and $\overline{C}_s$. Following this convention, we set $\overline{C}_m = 0$, which essentially implies that manufacturing's income elasticity of demand is close to one. Consistent with this assumption, we change the assignment of consumption of food, beverages, and tobacco from the manufacturing sector to the agriculture sector.[18]

For the preference parameters, we appeal to restrictions imposed by the intratemporal Euler equations governing sectoral consumption expenditure. Using the language of Herrendorf et al. (HRY, 2012), we adopt the final consumption expenditure approach, which arises naturally from our model with intermediate inputs. We employ time-series data on Korean aggregate consumption expenditure $\{P_t C_t\}$, sectoral consumption expenditure shares $\{s_{jt}\}$ and sectoral prices $\{P_{jt}\}$ to estimate $\{\epsilon, \omega_a, \omega_m, \omega_s, \overline{C}_a, \overline{C}_s\}$ by minimizing the sum of squared deviations between the actual sectoral expenditure shares and the model-implied sectoral expenditure share given the observed sectoral prices and aggregate consumption expenditure[19]

$$\sum_t \sum_{j=a,m,s} \left[ s_{jt} - \left( \frac{\omega_j P_{jt}^{1-\epsilon}}{P_t^{1-\epsilon}} \left( 1 - \sum_{k=a,m,s} \frac{P_{kt}\overline{C}_k}{P_t C_t} \right) + \frac{P_{jt}\overline{C}_j}{P_t C_t} \right) \right]^2$$

subject to the constraints $\sum_j \omega_j = 1$. This is also the estimating equation used in HRY. The estimated values (along with the other parameters) are reported in Table 1. The elasticity of substitution across sectors is 0.75, and the subsistence parameter of the agriculture goods is positive. The estimate for the services sector consumption parameter $\overline{C}_s$ is nearly 0.[20]

Turning to the production parameters, we use all input–output tables for Korea available in our sample period.[21] Specifically, the value added share $\lambda_j$ and the matrix of intermediate input linkages $\gamma_{jk}$ are computed directly from the input–output tables. We take a simple average across the tables, and report these values in Table 1.

We now describe the calibration of the time-varying exogenous variables and shocks. The primary exogenous variables are total labor in both Korea and the ROW. These variables are taken directly from the data; the Appendix provides the data sources. The labor force grew at an average annual rate of 2.5% in Korea and 1.1% in the ROW over our sample period. The procedure for calibrating the productivity shocks and trade costs shocks for each sector, country, and year has three key parts. The first part involves the calibration of the initial year, 1971. As our main goal is to assess the importance of openness in explaining Korea's structural change over time, we calibrate the initial productivity and trade cost levels — three sectoral

[17] Notably, China is excluded owing to lack of data, especially in the 1970s and 1980s. We discuss the possible role of China in the conclusion.

[18] We adjust our trade, consumption, employment and production data so that they are all consistent in terms of the sectors covered. The matching of detailed sectors into our three broad sectors is given in Appendix.

[19] See Appendix for the data sources for the sectoral consumption expenditure and price data, as well as the aggregate consumption data. We estimate these parameters over data from 1970 to 2010; we use a larger period than the period for our calibration to increase the number of observations. With three sectors, there are a total of 123 observations. The estimates over the period 1971–2005 are similar.

[20] The elasticity of substitution across goods within a sector $\eta$ is set to 4; this parameter plays virtually no role in our model, as is the case with virtually all versions of the Eaton–Kortum model.

[21] The list of years is given in the Appendix.

**Table 1**
Parameter values and calibration targets.

| Preference parameters | | | | | | | |
|---|---|---|---|---|---|---|---|
| $\epsilon$ | $\omega_a$ | $\omega_m$ | $\omega_s$ | $\overline{C}_a$ | $\overline{C}_m$ | $\overline{C}_s$ | $\eta$ |
| 0.751 | 0.131 | 0.214 | 0.655 | 696.0 | 0.0 | 0.0 | 4.0 |

| Production parameters | | | | | |
|---|---|---|---|---|---|
| $\lambda_j$ | $\gamma_{\text{row,column}}$ | | | | $\theta$ |
| | | Agr | Man | Ser | |
| 0.456 | Agr | 0.665 | 0.165 | 0.171 | 4.0 |
| 0.275 | Man | 0.118 | 0.699 | 0.183 | |
| 0.576 | Ser | 0.073 | 0.396 | 0.530 | |

| Initial period calibration targets | Data | Model |
|---|---|---|
| SK agricultural labor share | 0.48 | 0.48 |
| SK manufacturing labor share | 0.13 | 0.13 |
| SK agricultural subsistence share | 0.51 | 0.54 |
| ROW agricultural labor share | 0.16 | 0.16 |
| ROW manufacturing labor share | 0.23 | 0.23 |
| Income of ROW relative to SK | 5.90 | 7.00 |
| SK agricultural import share | 0.12 | 0.04 |
| SK manufacturing import share | 0.26 | 0.26 |
| SK agricultural export share | 0.02 | 0.09 |
| SK manufacturing export share | 0.16 | 0.16 |

productivities and two sectoral trade costs in each country — to match the ROW and Korea's sectoral labor shares and sectoral trade shares in 1971.[22] Because two sectoral labor shares automatically imply the third, we need two additional targets. We choose Korea's per capita income relative to the ROW in 1971, and Korea's agricultural subsistence expenditure as a share of total consumption expenditure. Table 1 provides the values of our targets.

The second part involves the calibration of the productivity shocks after the initial period. These shocks are constructed using the initial period sectoral productivity levels computed above, and sectoral productivity growth rates, which are constructed in two main steps.[23] The first step arises from the fact that real sectoral gross output data do not exist for a number of the countries that comprise the ROW. Annual input–output tables are also lacking. Consequently, the usual approach of constructing (gross output) productivities directly from the gross output production function cannot be performed. Instead, we use the model to derive the sectoral value-added production function, and we compute sectoral value-added productivity. Owing to the Cobb–Douglas functional form, the sectoral value-added productivity is $A_{ik}^{1/\lambda_k}$, where $A_{ik}$ is gross output productivity for country $i$ and sector $k$. The second step arises from Waugh (2010) and Finicelli et al. (hereafter, FPS 2013), among others, who have shown that productivities computed in an open economy setting capture at least two forces, the fundamental productivity of firms within the country under autarky, and the additional productivity occurring from specialization in an open economy (trade selection). We need to compute the fundamental productivity. FPS derive a formula for adjusting the usual productivity measure for the specialization component to yield the fundamental productivity. We apply that formula, which yields our final estimates of sectoral gross output productivity or TFP. We calculate the growth rates of the sectoral TFPs and apply them to the initial period to get the sectoral TFP levels for 1972 onwards.[24]

The logged sectoral TFPs are shown in Fig. 2. In the initial period, the ROW has higher TFP levels in all three sectors. The average TFP growth rates are 1.8% in agriculture, 2.2% in manufacturing, and 1.7% in services in Korea, and 1.2% in agriculture, 0.84% in manufacturing and 0.60% in services in the ROW. The average TFP growth rates are higher in Korea than in the ROW for all three sectors. Also, the manufacturing sector has the fastest TFP growth rate among the three sectors in Korea.

[22] The sectoral import shares are Korea's sectoral imports from the ROW as a fraction of Korea's sectoral absorption. The sectoral export shares are Korea's sectoral exports to the ROW also expressed as a fraction of Korea's sectoral absorption.

[23] Further details on the construction of the productivities and the data sources are provided in the Appendix.

[24] Our approach will yield an estimate for TFP levels in the initial year, 1971; as a diagnostic, these can be compared to the ones we choose to match the labor shares, etc. They are close in relative magnitudes.

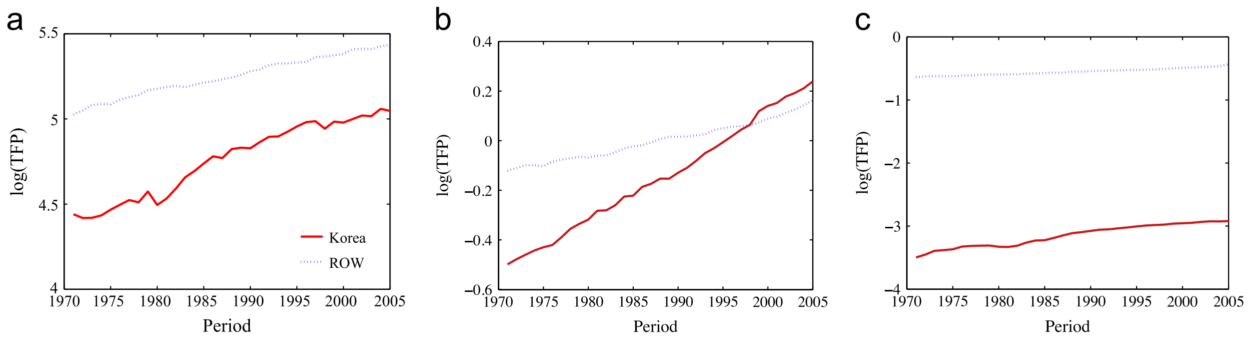


**Fig. 2.** Calibrated TFP series. (a) Agriculture. (b) Manufacturing. (c) Services.

The third part involves calibrating the trade costs over time after the initial period. It is well known that the standard trade models can explain existing international trade flows only if unobserved trade costs, i.e., costs other than tariff barriers and transportation costs, are a multiple of observed trade costs. This is true under a wide range of elasticities of demand and substitution. Consequently, as our focus is on whether the model can explain the dynamics of Korea's labor shares, we calibrate the four sectoral trade costs to match the observed trade flows between Korea and the ROW over time: Korea's export and import shares with the ROW in manufacturing and agriculture. We solve for the trade costs jointly with solving the model. We interpret the model-implied trade costs as capturing transportation costs, tariffs, and any other costs that impede international trade.[25] The calibrated trade costs are shown in Fig. 3, together with Korean sectoral import and export shares. The figure shows that trade costs from the ROW to Korea in both agriculture and manufacturing changed little over time, while trade costs from Korea to the ROW declined substantially. Panels (b) and (c) of Fig. 3 show that the model does a good job of recovering the actual time path of the trade shares.[26]

#### 4.1.1. Calibration of closed economy version of model

As we showed in Section 3, openness operates as a transmission channel in at least two ways. First, openness via shocks to trade costs over time affect the evolution of structural change. Second, TFP shocks affect the economy differently in an open setting compared to a closed setting. To assess the quantitative effect of openness, we compare our results in an open economy setting with those in a closed economy setting in which the economy is subject to TFP shocks only. Our calibration of the closed economy is identical to that of the open economy except for the TFP shocks. For the initial period, we use a closed economy version of our model to calibrate, for Korea, three initial TFP levels to match two sectoral labor shares and agriculture subsistence expenditure as a share of total consumption expenditure in 1971. The TFP levels for subsequent years are computed in the same way as in the open economy model, but without the adjustment for trade selection. Our computations imply that Korea's average TFP growth rates for agriculture, manufacturing, and services are 2.2%, 2.2%, and 1.7%, respectively.[27]

### 4.2. Quantitative results

We now assess the quantitative importance of openness in structural change, and the roles of TFP shocks and trade cost shocks, in particular. We also assess the importance of non-homothetic preferences as a transmission mechanism. To review the key features of our benchmark model, it has non-homothetic preferences, an elasticity of substitution across sectors less than one, asymmetric and growing TFP shocks over time, and changing trade costs over time.

#### 4.2.1. Main results

We first simulate the effects of the TFP shocks and trade cost shocks in our benchmark model. The implied sectoral labor shares are given in the blue dashed line in each panel of Fig. 4. The red solid line shows the actual sectoral labor share. The model is able to capture the evolution of the agriculture and services labor shares over almost the entire time period. The model generates a decline in the agriculture labor share of slightly more than the actual decline, and an increase in the services labor share of about 85% of the actual rise in the services labor share. Turning to manufacturing, the model is able to generate an increase in the manufacturing labor share of 0.13–0.24 — close to the actual peak share of 0.27 — in the first half of the time period. However, subsequently the implied manufacturing labor share stays relatively flat, instead of declining as it does in the data. Hence, the model is able to replicate only the rising part of the hump-shaped pattern.

[25] To the extent there is model misspecification and measurement error, it will show up in the trade costs.

[26] It is not a perfect fit, because the model assumes balanced trade.

[27] The difference between the open and closed economy TFP growth rates stems from the evolution of $\pi_{ii}$ over time. In particular, as discussed in Appendix, if $\pi_{ii}$ is increasing over time, as it is in agriculture, then the growth rate of the (fundamental) open economy TFP will be lower than the growth rate of the closed economy TFP.

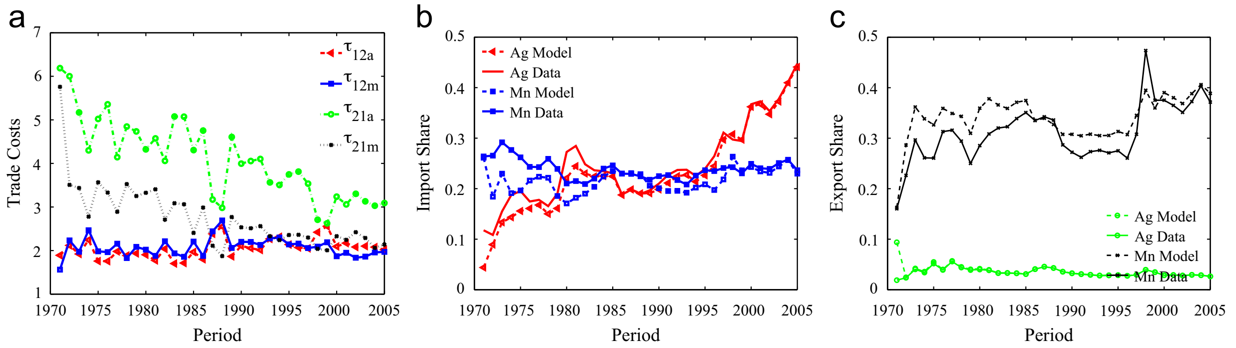

**Fig. 3.** Calibrated trade costs and Korean trade shares. (a) Trade costs. (b) Korean import shares. (c) Korean export shares.

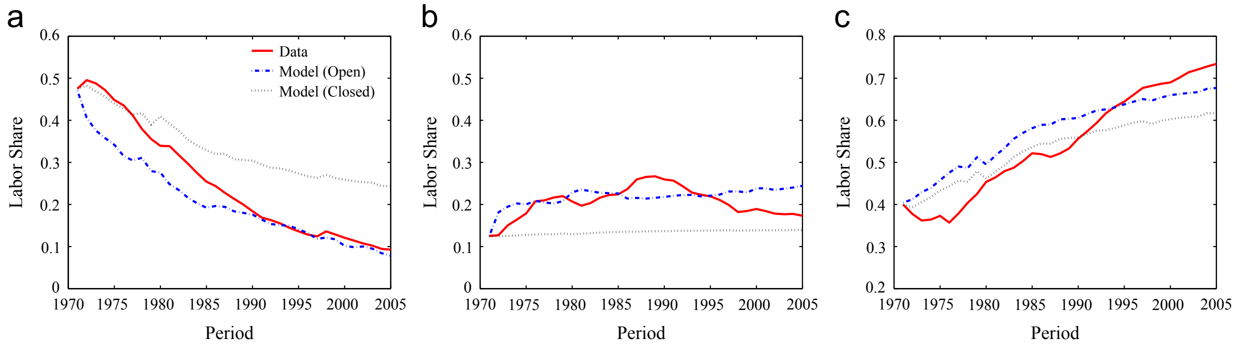

**Fig. 4.** Korean structural change: benchmark. (a) Agriculture. (b) Manufacturing. (c) Services. (For interpretation of the references to color in this figure caption, the reader is referred to the web version of this article.)

Overall, the fit of our benchmark model is quite good, although it is not able to capture the declining part of Korea's manufacturing hump pattern.

To assess the importance of openness, we also simulate the model under a closed economy in which there are only TFP shocks. The model's implications for Korea's sectoral labor shares are shown as the gray dotted lines in Fig. 4. Panels (a) and (c) show that the closed economy model also generates a substantial decline in the agricultural labor share and a substantial increase in the services labor share. However, the magnitudes of the changes are smaller than in the benchmark model. The closed economy model explains only 62% of the actual decline in the agriculture labor share and about 67% of the actual increase in the services labor share. In terms of manufacturing, as panel (b) of Fig. 4 shows, the model does not come close to generating either side of the hump. Rather, it generates only a slight increase over time.[28]

We summarize the overall performance of the benchmark model and the closed economy model in explaining Korea's structural change by computing the root mean square error (RMSE) between the implied and observed labor shares. The RMSEs for agriculture, manufacturing and services in the open economy are: 0.059, 0.037, and 0.060. With the closed economy model, the RMSEs are 0.10, 0.079, and 0.062. Thus, introducing trade significantly improves the model fit to the data, particularly in agriculture and manufacturing. The overall RMSE across all sectors is 0.053 in the open economy model and 0.083 in the closed economy model; hence, the closed economy fit is about 60% worse.

What explains the substantially better performance of the benchmark model? Consider first the closed economy model results. The decline in the model-implied agriculture share stems largely from the interaction of growing per capita income (resulting from growing TFP in all three sectors), and the non-homothetic preferences. Korea's services labor share grows partly because of the interaction of a low productivity growth rate and the low sectoral elasticity of substitution — as Ngai and Pissarides (2007) show, this combination leads to an increasing sectoral labor share — but primarily because it needs to absorb the labor leaving the agricultural sector. Finally, manufacturing is subject to two forces that largely cancel. The first force is that it absorbs labor leaving the agriculture sector. The second force is the tendency to shrink because it has the highest productivity growth rate.

[28] Duarte and Restuccia (2010) use a somewhat different closed economy model to examine the structural change of a number of countries, including Korea. We thank them for kindly providing their results for Korea. Our closed economy results are similar to theirs. Their model also implies a small change in the manufacturing labor share, and substantial changes in the agriculture and services labor shares. Compared to our closed economy model, their model generates a closer fit to agriculture and worse fit for services.

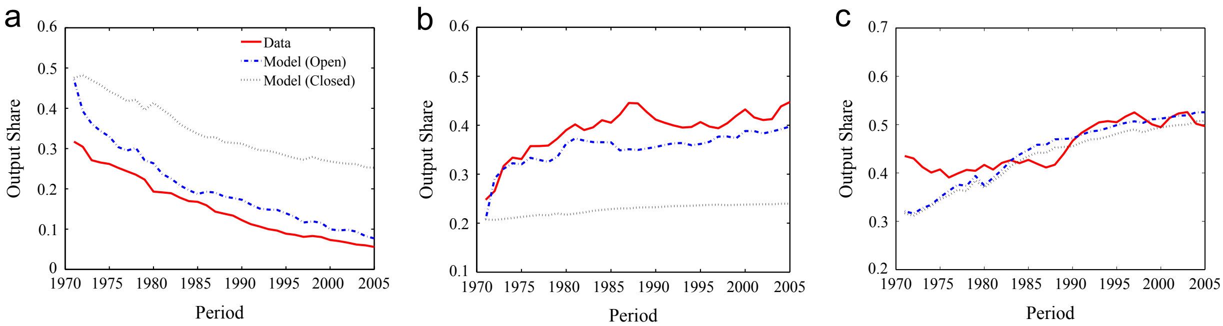


**Fig. 5.** Korean output shares: benchmark. (a) Agriculture. (b) Manufacturing. (c) Services.

In an open economy, three additional forces lead to a larger response in the two tradable sectors, agriculture and manufacturing. First, the patterns of initial TFP and trade costs suggest that Korea had a comparative advantage in manufacturing; moreover, Korea's manufacturing TFP grew at a faster rate than agriculture's TFP. Second, the trade costs facing Korea's exporters declined over time, and more rapidly in manufacturing than in agriculture. Korea's comparative advantage in manufacturing becomes more "revealed", thus leading to more specialization and labor in manufacturing, and less in agriculture. The first force, in conjunction with a sectoral elasticity of substitution less than one, and the second force are evidently sufficient to generate a rise in the manufacturing labor share. Essentially, Korea is able to employ more workers in manufacturing, because expanding export markets more than offset the declining need for labor to satisfy domestic demand. The opposite is true for agriculture, leading to a decline in its share. The third force is that trade leads to faster economic growth in Korea. Real income rises by a factor of eight in the open economy; it rises by a factor of seven in the closed economy. The faster growth of real income strengthens the non-homothetic preferences channel and leads to a larger decline in the agriculture labor share and a larger rise in the services labor share.

The combination of all three forces leads to a significantly larger increase in the manufacturing labor share (more than 10 percentage points), a significantly larger decrease in the agriculture labor share (about 15 percentage points), and a larger increase in the services labor share (about 6 percentage points), than in the closed economy model. All three changes lead to a closer fit of the open economy model to the data.[29]

To understand better the results for manufacturing, we employ a decomposition of the manufacturing labor share into an expenditure channel and a net export channel, analogous to that in Eq. (12).[30] Full details of the decomposition, which includes for intermediate goods and non-homothetic preferences, are given in the Appendix. Our decomposition shows that, over our entire sample period, the expenditure channel accounts for about 80% of the model-implied manufacturing labor share, with the net export channel accounting for the remainder.[31] However, if we trace the contribution of the net export channel over time, we see that this channel's contribution to the manufacturing labor share rose fairly steadily from −2.5 percentage points in 1971 to 6 percentage points in 2005. Thus, the net export channel accounts for about two-thirds of the increase in the model-implied manufacturing labor share during our sample period. The expenditure channel also increases steadily over the sample period by about three percentage points; this suggests that income effects from non-homothetic preferences that lead to more employment in manufacturing are stronger than relative price and substitution effects that lead to less employment in manufacturing. Because both channels increase over the entire sample period, they are both "responsible" for the model's inability to generate the downward portion of the manufacturing hump in the data.

Our analysis focuses on labor shares as a measure of structural change. It is also common to examine output shares. Because we did not use output shares to calibrate our model, one diagnostic of the model is to assess how it performs in terms of initial year output shares, as well as the dynamics of output shares over time. Fig. 5 shows that for agriculture, the benchmark model over-predicts the initial output share quite substantially, but the dynamics over time are quite strong, so that by 2005, the model-implied labor share is quite close to the actual share. For manufacturing, the model and data fit very closely in both the initial output share and the evolution over time; indeed, they fit more closely than do the labor shares. Finally, the model under-predicts the initial services output share, but like with agriculture it catches up over time, so that by 2005, the model and data line up closely. The figure also shows the closed economy implications. Other than for services, the fit is quite poor. Overall, we find that our benchmark model does a good job in matching the dynamics of the sectoral output shares.

[29] Do our results suggest that Buera and Kaboski (2009), who find that a closed economy framework with non-homothetic preferences and asymmetric productivity growth cannot explain the movement of US value-added shares in services and manufacturing after 1960, should have employed an open economy model? On the one hand we would say, yes; on the other hand, clearly trade has not been as important for the US as it has been for Korea.

[30] We thank the referee for this suggestion.

[31] As we have discussed, the net export channel is only one way for openness to affect structural change, because part of the effect of increased openness is to change relative prices, which then affects expenditures.

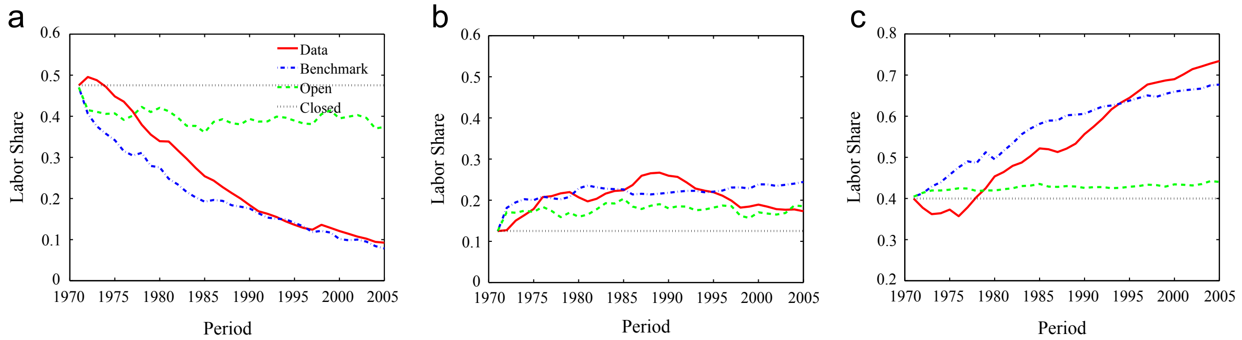


**Fig. 6.** Korean structural change: constant TFPs. (a) Agriculture. (b) Manufacturing. (c) Services. (For interpretation of the references to color in this figure caption, the reader is referred to the web version of this article.)

### *4.2.2. The role of TFP shocks versus trade cost shocks*

In the benchmark analysis, both the TFP and trade cost series vary over time. In this section we quantify the contribution of each set of shocks to Korea's structural change. To do so, we conduct two counterfactual experiments. In the first experiment, we set all sectoral TFP series constant at their initial levels, and examine the effects of varying trade costs alone. In the second experiment, we set the sectoral trade costs constant at the initial levels, and examine the effects of varying TFPs alone. All other exogenous variables and parameter values are the same as in the benchmark model.

The green dashed line in Fig. 6 illustrates the results of the first experiment. For comparison, the benchmark model results are illustrated with the blue dashed line. In addition, results from the closed economy version of this experiment — they are trivially zero, because TFP is constant, and in a closed economy, trade costs do not change — are illustrated by the gray line. Beginning with the left panel, the figure shows that the agriculture labor share declines by a little more than 10 percentage points or about one-fourth of the actual decline. This is not insignificant, but the figure illustrates indirectly the importance of TFP in driving income growth and the consequent re-allocation of labor away from agriculture. The middle panel shows that manufacturing rises by about 10 percentage points; this represents more than half of the increase generated by the benchmark model. Comparing this experiment to the benchmark model, then, suggests that changes in trade costs are more important for manufacturing than agriculture. The right panel shows that the services sector labor share increases by little, less than 5 percentage points. This is the flip side of the small decline in the agriculture labor share.

The green dashed line in Fig. 7 illustrates the results of the second experiment. The benchmark model results and the closed economy results are shown with the blue dashed line and the gray line, respectively. All three panels show that TFP shocks contribute significantly to structural change. Note that the closed economy results indicate that TFP shocks exert a large effect on agriculture and services, but a small effect on manufacturing. The figure also shows that for manufacturing and agriculture, TFP shocks exert quantitatively significant effects in an open economy, as captured by the gap between the green and gray lines.[32] In particular, agriculture's labor share falls by more, and manufacturing's labor share rises by more than in the closed economy. The services labor share is about the same.[33] Thus, variation in each set of shocks is quantitatively significant in explaining Korea's structural change over time. TFP shocks matter more than trade cost shocks for services and agriculture, while both shocks are quantitatively important for manufacturing and agriculture. Moreover, for both shocks, trade serves as an effective transmission mechanism that enables the open economy to outperform the closed economy.

### *4.2.3. The role of non-homothetic preferences*

The above simulations and experiments were all conducted under non-homothetic preferences. These preferences are widely thought to be the most important transmission mechanism for structural change; however, underlying much of this thinking is an assumption of a closed economy setting. We now examine the importance of non-homothetic preferences in our open economy setting. To do so, we set $\overline{C}_a$ to zero, which makes preferences homothetic, and we re-calibrate the elasticity of substitution, $\epsilon$, and the share parameters $\omega_a, \omega_m$, and $\omega_s$ following the HRY approach, as before. The elasticity of substitution is calibrated to be 0.001, which is close to Leontieff. This will lead to a greater role for relative prices.[34] In addition, the sectoral trade costs and TFPs are recalibrated in the same way as the benchmark calibration for both the open and closed economy models.[35]

[32] Part of the gap is because the TFP shocks themselves are different, as described above, and part is because they operate differently in an open economy.

[33] Our assumption that services goods are non-traded implies that trade matters for this sector to the extent that relative prices and incomes change owing to the changing patterns of specialization. These forces do affect services, although to a lesser extent than the change in income arising from TFP growth.

[34] The new share parameters are: $\omega_a = 0.317$; $\omega_m = 0.106$; $\omega_s = 0.577$.

[35] Homothetic preferences allow us to normalize Korea's agriculture TFP level in the initial period to one. For the open economy model, the remaining five initial sectoral TFP levels and the four trade costs are calibrated to match the two labor shares in each country, four trade shares, and Korea's per capita

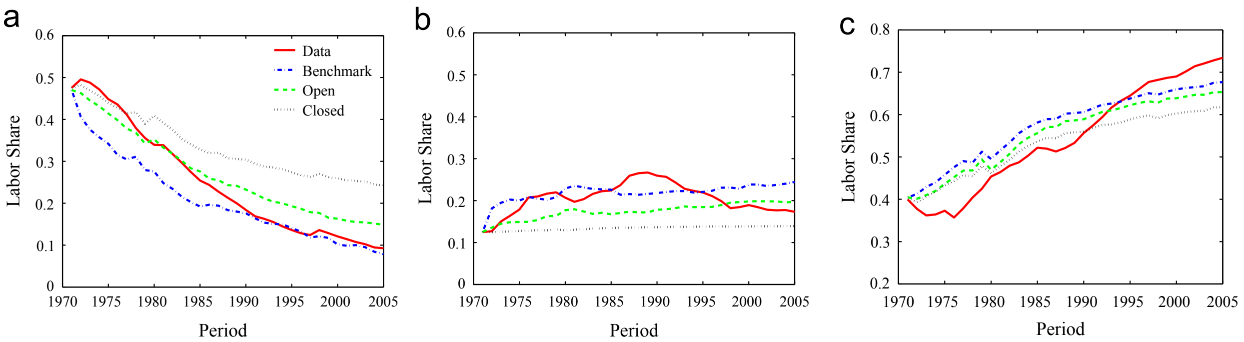


**Fig. 7.** Korean structural change: constant trade costs. (a) Agriculture. (b) Manufacturing. (c) Services. (For interpretation of the references to color in this figure caption, the reader is referred to the web version of this article.)

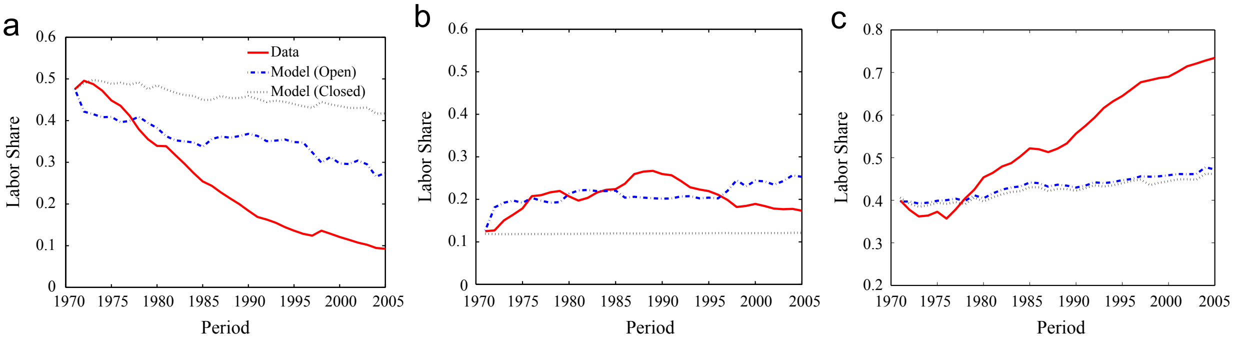


**Fig. 8.** Korean structural change: homothetic preferences. (a) Agriculture. (b) Manufacturing. (c) Services. (For interpretation of the references to color in this figure caption, the reader is referred to the web version of this article.)

The blue dashed line in Fig. 8 plots the model-implied sectoral labor shares under homothetic preferences. The panels show that even under these preferences, openness plays a key role: the agriculture labor share falls by about 20 percentage points, while the manufacturing labor share rises by almost 15 percentage points. On the other hand, services changes by little. However, compared to the benchmark results in Fig. 4, we can see that for each sector the fit is worse under homothetic preferences, especially for services and also for agriculture. Manufacturing is little affected by the nature of the preferences. The RMSEs are 0.142, 0.042, and 0.151 for agriculture, manufacturing and services, respectively. The overall RMSE is 0.122, as shown in Table 2. This exercise shows that leaving out the income effects induced by non-homothetic preferences significantly reduces the explanatory power of the model in explaining Korea's structural change.[36]

Table 2 provides a crude assessment of the relative importance of non-homothetic preferences and the open economy. The closed economy model with homothetic preferences has a RMSE of 0.175. The open economy with non-homothetic preferences has an RMSE of 0.053. Inspection of the table suggests that about one-third of the improvement in RMSE is because of the open economy and two-thirds is because of non-homothetic preferences.

## 5. Conclusion

Our main contribution is a quantitative assessment of the role of international trade in structural change. We employ a three-sector, two-country model with non-unitary income and substitution elasticities, and intermediate goods, and with sector-biased, time-varying productivity and trade cost shocks. We calibrate our framework to investigate South Korea's structural change between 1971 and 2005. The benchmark model accounts for virtually the entire evolution of labor shares in agriculture and services, as well as the rising part of the hump-shape in manufacturing. The root mean square error of

(*footnote continued*)
income relative to the ROW in 1971. For the closed economy, the remaining two initial sectoral TFP levels in Korea are calibrated to match the two labor shares in 1971. For both the open and closed models, the subsequent TFP levels and trade costs are constructed the same way as in the benchmark calibration.

[36] In the closed economy, illustrated by the gray dashed line, there is almost no structural change. This result can be understood via Eq. (9). The TFP growth differentials across sectors are small; the largest difference is about 0.5% per year between manufacturing and services. As a result, despite the Leontieff preferences, sector-biased productivity growth alone (without trade and non-homothetic preferences) plays a small role in explaining Korea's structural change.

**Table 2**
Model performance: RMSE.

| Model specification | Non-homothetic preferences | Homothetic preferences |
|---|---|---|
| Open economy | 0.053 | 0.122 |
| Closed economy | 0.083 | 0.175 |

*Note*: This table reports, for each model specification — e.g., non-homothetic preferences, open economy — the root mean squared error (RMSE) between the observed labor shares and the model-implied labor shares across all three sectors and the entire sample period.

the closed economy version of the model is 60% higher than that of the benchmark model. Clearly, openness plays an indispensable role in Korea's structural change.

Moreover, counterfactual exercises that turn off either shock lead to a significant deterioration in the model performance. Trade cost shocks are important for agriculture and manufacturing, while productivity shocks are important for all three sectors—with these shocks exerting a stronger effect in the open economy, partly by changing patterns of specialization and partly by changing income. We also find that non-homothetic preferences are important for the evolution of services and agriculture.

While our calibrated model can quantitatively explain the rising portion of Korea's hump-shape in manufacturing, it does not explain the declining portion of the hump. In this context, three useful extensions worth investigating include allowing for tradable services, endogenous trade imbalances, and a more general specification of preferences.[37] However, in our view, the key missing ingredient from the calibrated model is China. Over the past twenty years, China has opened up to international trade and trade volumes have surged. In 1991, Korea's and China's exports to the world were about the same, about 72 billion dollars. Over the next 14 years, China's exports grew by more than an order of magnitude to about 750 billion dollars, while Korea's grew only four-fold. China experienced manufacturing productivity growth and lower trade costs that enabled it to essentially take market share in manufacturing from Korea. Thus, including China as a third country would help explain the declining portion of Korea's hump.[38] However, as discussed earlier, for China, good data do not exist before 1980, and in some cases, prior to 1990. Finding a way to include China is an exercise that we leave for future work.

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## Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.jmoneco.2013.06.002.

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[37] Kim and Kim (2003) show that even by 1998, services trade was about 20% of Korea's merchandise trade. Swiecki (2012) and Reyes-Heroles (2012) allow for trade imbalances, and Swiecki (2012) employs a more general preference structure than what we employ.

[38] Our calibration also does not include Southeast Asian countries like Singapore, Taiwan, Malaysia, Thailand, and Indonesia. Adding these countries would also help explain the declining share of the hump.

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