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 three transmission mechanisms: non-homothetic preferences, sector-biased productivity growth, and trade. We calibrate our model to investigate South Korea's structural change between 1971 and 2005. We find that the shock processes, amplified through the transmission mechanisms, explain virtually all of the evolution of agriculture and services labor shares, and the rising part of Korea's hump-shape in manufacturing. Counterfactual exercises show that all three forces — non-homothetic preferences, productivity growth, and trade openness — contribute significantly to Korea's structural change.

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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 (2008), among others, show 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, Dorn, and Hanson (2011) find that one-third of the decline in U.S. 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.

Surprisingly, there have been few quantitative analyses of the role of international trade in structural change. This paper first shows how international trade works as a transmission mechanism in a three-sector, two-country model, then conducts a quantitative analysis of the same for South Korea. International trade affects structural change along three dimensions. First, declines in trade costs affect patterns of specialization, which then affects labor allocations across sectors. Second, compared to a closed economy, trade openness alters the impact of changes in sectoral productivity on labor allocations. Third, increasing trade integration spurs income growth and strengthens the role of non-homothetic preferences in structural change.

Our model draws from three intellectual antecedents. First, there is the long literature, going back to Engel (1895), 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 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.

We demonstrate that a simplified version of the model can qualitatively deliver the structural change patterns observed in Korea. 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, and hence labor shares through expenditure shares. Generating a hump in manufacturing, in particular, rests on the intuition that if a country's productivity in manufacturing is rising rapidly, it will take market share from the other country, thus leading to increased labor devoted to manufacturing, but as the productivity continues to grow, eventually it will be able to supply the world market with less labor. The latter leads to the downward slope of the hump. A similar result occurs if a country has a comparative advantage in manufacturing and trade costs decline so that the comparative advantage is increasingly revealed.

We calibrate our model to South Korea and the rest of the world in 1971 to 2005, focusing on explaining South Korea's structural change. We then simulate our benchmark model that encompasses all the transmission mechanisms and both of our main shocks. 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 open economy fit is about 40 percent better. 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, in the open economy setting, owing to specialization, Korea grows faster, which strengthens the impact of non-homothetic preferences on the labor share dynamics. Finally, 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.

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. We conclude that all three transmission mechanisms contribute significantly to Korea's structural change.

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, open economy frameworks.[1] Recent studies of three-sector closed economy models include Echevarria

[1] 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).

(1997), Kongsamut, Rebelo, and Xie (2001), Ngai and Pissarides (2007), Rogerson (2008), Restuccia, Yang, and Zhu (2008), Foellmi and Zweimuller (2008), Buera and Kaboski (2009, 2012), Duarte and Restuccia (2010), Verma (2012), and Herrendorf, Rogerson and Valentinyi (2012).[2] 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.

In terms of methodology, our work relates to recent studies using the multi-sector Eaton-Kortum model. Contemporaneous work by Sposi (2012) studies Korea's structural change, focusing on output shares instead of labor shares. However, by ending in 1995, it cannot assess the ability of the model to explain the manufacturing hump-shaped pattern.[3] Caliendo and Parro (2011) and Shikher (forthcoming) focus on the effects of NAFTA on trade and welfare in the NAFTA countries, not on structural change *per se*. di Giovanni, Levchenko and Zhang (2012) examine the impact of different China's 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.

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 three transmission mechanisms and two key sources of shocks. Section 5 concludes.

[2]Also, see Ju, Lin and Wang (2009) for an n-sector model.

[3]Sposi (2012) examines the variation in trade costs stemming solely from lower tariffs; it abstracts from changes in other non-policy barriers. Other quantiative open economy models of structural change include Coleman (2007), Galor and Mountford (2008), Stefanski (2012), Teignier-Bacque (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. Stefanski (2012) study the effect of structural transformation of India and China on oil prices. Teignier-Bacque (2012) studies structural change in South Korea (and two other countries), but focuses on the role of the agriculture sector in a two-sector small open economy model. Ungor (2012) uses a two-sector model to study the effects of China's growth on de-industrialiization of the United States.

2 Model

Our model has two countries and three sectors, and it includes non-homothetic preferences 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. As noted above, the key features draw from Ngai and Pissarides (2007) and Eaton and Kortum (2002). Agriculture and manufacturing goods are tradable and the services good is 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 Preferences

There is a continuum of goods in the agriculture (a), manufacturing (m) and services (s) sectors. Period utility of the representative household in country i is given by:

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

where for each sector $k \in \{a, m, s\}$, C_{ik} denotes consumption of sector-k composite goods, and $\bar{C}_k$ denotes a subsistence requirement for sector-k composite goods. Specifically, a positive $\bar{C}_k$ generates an income elasticity of demand for the sector k goods less than one. The preference share parameters ω_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 goods are substitutes. If $\epsilon \leq 1$, the sectoral goods are complements.

The composite good in each sector is an aggregate of the individual goods as follows:

$$C_{ik} = \left(\int_0^1 c_{ik}(z)^{\frac{\eta-1}{\eta}} dz\right)^{\frac{\eta}{\eta-1}}, \quad (2)$$

where $c_{ik}(z)$ is the use of good z by country i to make the composite sectoral consumption good $k \in \{a, m, s\}$, and the elasticity of substitution across goods within a sector is $\eta > 0$.

The representative household maximizes his/her utility (1) and (2) subject to the following budget constraint in each period:

$$P_{ia}C_{ia} + P_{im}C_{im} + P_{is}C_{is} = w_i L_i, \tag{3}$$

$$P_{ik}C_{ik} = \int_0^1 p_{ik}(z)c_{ik}(z)dz, \quad \text{for } k \in \{a, m, s\}, \tag{4}$$

where $p_{ik}(z)$ denotes the price of good z in sector k, and w_i and P_{ik} denote the wage rate and the prices of the sector-k composite good, respectively. The household supplies L_i inelastically and spends all labor income on consumption. The budget constraints (3) and (4) ensure that balanced trade holds period-by-period.

2.2 Technologies

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

$$Y_{ik}(z) = A_{ik}(z)L_{ik}(z)^{\lambda_k} \left[\Pi_{n=a,m,s} M_{ikn}^{\gamma_{kn}}(z)\right]^{1-\lambda_k} \tag{5}$$

where $Y_{ik}(z)$ denotes output, $L_{ik}(z)$ denotes labor, and $M_{ikn}(z)$ denotes intermediates from sector n devoted to the production of the sector n good. $A_{ik}(z)$ denotes exogenous productivity, λ_k denotes the value-added share in production, and γ_{kn} denotes the share of intermediate inputs coming from sector n.

Productivity $A_{ik}(z)$ is the realization of a random variable Z_{ik} drawn from the cumulative distribution function $F_{ik}(A) = Pr[Z_{ik} \leq A]$. 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 parameter T_{ik} governs the mean of the distribution; a larger T_{ik} implies that a high efficiency draw for any good z is more likely. The larger is θ, the lower the heterogeneity or variance of Z_{ik}.[4] We assume that the productivity is drawn each period.[5]

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 $\frac{1}{\tau_{ijm}}$ units arrive in country i. We assume that trade costs within a country are zero, i.e., $\tau_{iia} = \tau_{iim} = 1$. Under free trade, trade costs across countries are also zero, i.e., $\tau_{12a} = \tau_{21a} = 1$ and $\tau_{12m} = \tau_{21m} = 1$.

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

Under the Fréchet distribution of productivities, Eaton and Kortum (2002) show that the price of composite good $k \in \{a, m\}$ in country i is simply $p_{ik} = \Gamma\left(\Phi_{ik}\right)^{-\frac{1}{\theta}}$, where the constant Γ is the Gamma function evaluated at $(1 - \frac{\eta-1}{\theta})^{\frac{1}{1-\eta}}$, and Φ_{ik} summarizes country i's access to global production technologies in sector k scaled by relevant unit costs of inputs and trade costs,[6] given by $\Phi_{ik} = T_{1k}\left(v_{1k}\tau_{1ik}\right)^{-\theta} + T_{2k}\left(v_{2k}\tau_{2ik}\right)^{-\theta}$.

The probability of importing sector-k goods from country i in country j, π_{jim}, equals the share of country j's expenditure on sector-k goods coming from country i, and is given by

$$\pi_{jik} = \frac{T_{ik}\left(v_{ik}\tau_{jik}\right)^{-\theta}}{\Phi_{jk}}. \tag{6}$$

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

[5] 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.

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

Equation (6) shows how a higher average productivity, a lower unit cost of input bundles, and a lower trade cost in country i translates into a greater import share by country j.

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_{ik} denote total labor employed in sector k and country i. The factor market clearing conditions in each period are given by

$$L_i = L_{is} + L_{im} + L_{ia}. \tag{7}$$

We next characterize the good market clearing condition. Let Q_{ik} denote the total demand of composite sector-k goods in country i, which is used for both final consumption and intermediate inputs in domestic production. Specifically, for each sector k, we have

$$Q_{ik} = C_{ik} + \sum_{n=a,m} (1-\lambda_n)\gamma_{nk} \sum_{j=1,2} \frac{\pi_{jin} P_{jn} Q_{jn}}{P_{ik}} + (1-\lambda_s)\gamma_{sk} \frac{P_{is} Q_{is}}{P_{ik}}. \tag{8}$$

That is, the quantity of sector-k composite goods demanded in country i, Q_{ik}, is the sum of (i) the quantity demanded by domestic final consumption C_{ik}; (ii) the quantity demanded as intermediate inputs in the production of the tradable goods which are demanded globally, $\sum_{n=a,m}(1-\lambda_n)\gamma_{nk}\sum_{j=1,2}\frac{\pi_{jin}P_{jn}Q_{jn}}{P_{ik}}$; and (iii) the quantity demanded as intermediate inputs in the domestic services sector, $(1-\lambda_s)\gamma_{sk}\frac{P_{is}Q_{is}}{P_{ik}}$. These good market clearing conditions demonstrate that our model captures well 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 in the data.

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 $\{\epsilon, \eta, \theta, \{\lambda_k, \gamma_{kn}, \bar{C}_k, \omega_k\}_{n,k=a,m,s}\}$ 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' maximization problems associated with technologies (5) and the household's maximization problem characterized by (1)–(4), and satisfy the market clearing conditions (7)–(8).

3 Analytical Analysis of Trade Mechanisms

This section illustrates the mechanisms through which trade impacts the patterns of structural change in an open economy. To deliver the results transparently, the model is simplified by assuming that $\bar{C}_k = 0$ and $\lambda_k = 1$ for all k. Under these assumptions, the preferences are homothetic, and labor is the only input in production. We compare the patterns of structural change in an open economy with those in a closed economy, and highlight two channels—the expenditure channel and the net export channel—through which trade impacts structural change. The next section returns to the full model and quantifies the role of trade, sectoral biased productivity and nonhomothetic preferences in Korean 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. Autarky is a special case of our model in which the trade costs are infinitely high. The autarky implications are similar to those in Ngai and Pissarides (2007). We use the superscript c to denote the corresponding variables in the closed economy. Under autarky, all goods are produced domestically. It is straightforward to show for country i and each period,

$$\frac{P_{ia}^c}{w_i^c} = \frac{1}{A_{ia}}, \quad \frac{P_{im}^c}{w_i^c} = \frac{1}{A_{im}}, \quad \frac{P_{is}^c}{w_i^c} = \frac{1}{A_{is}}, \tag{9}$$

where $A_{ik} = \frac{T_{ik}^{\frac{1}{\theta}}}{\Gamma}$. A continuum of goods in a sector can be essentially reduced to one good.

The feasibility conditions imply that the sectoral labor share equals the sectoral expenditure share.[7] For each sector $k \in \{a, m, s\}$, we have

$$l_{ik}^c = \frac{L_{ik}^c}{L_i} = \frac{w_i^c L_{ik}^c}{w_i^c L_i} = \frac{P_{ik}^c C_{ik}^c}{w_i^c L_i} \equiv X_{ik}^c = \omega_k^\epsilon \left(\frac{P_{ik}^c}{P_i^c} \right)^{1-\epsilon},$$

where $(P_i^c)^{1-\epsilon} = \sum_k \omega_k^\epsilon (P_{ik}^c)^{1-\epsilon}$. Turning to dynamics, let $\hat{Z}$ denote the log growth rate of variable Z. Then, for any period t, we have

$$\hat{l}_{ikt}^c = \hat{X}_{ikt}^c = (1-\epsilon)(\hat{P}_{ikt}^c - \hat{P}_{it}^c) = (\epsilon - 1)(\hat{A}_{ikt} - \hat{A}_{it}^c), \tag{10}$$

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 in a closed economy: 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 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 overtime. This implication is consistent with the post-war experience of many developed countries. In many developing countries, however, the manufacturing sector has the fastest growth in productivity and a rising labor share.

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 $\frac{A_{im}}{\tau_{jim} A_{jm}} > \frac{A_{ia}}{\tau_{jia} A_{ja}}$. Our definition is thus the traditional definition augmented by trade costs.[8] The comparative advantage

[7]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.

[8]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

patterns determine intra-sector trade patterns. If country 1 has a comparative advantage in manufacturing, equation (6) 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 trade on sectoral prices. The services good price in country i relative to wage is $\frac{P_{is}}{w_i} = \frac{1}{A_{is}}$, which is the same as under autarky. The price of tradable composite good k relative to wage is

$$\frac{P_{ik}}{w_i} = \frac{1}{A_{ik}} \left[1 + \left(\frac{\tau_{ijk} w_j}{A_{jk}} \frac{A_{ik}}{w_i} \right)^{-\theta} \right]^{-\frac{1}{\theta}} = \frac{\pi_{iik}^{\frac{1}{\theta}}}{A_{ik}}. \tag{11}$$

Comparing equation (11) to (9), one can see that $\frac{P_{ik}}{w_i} < \frac{P^c_{ik}}{w^c_i}$ because $\pi_{iik} < 1$. The lower is the sectoral expenditure share on domestic goods, the lower is the sectoral price under trade. Given the pattern of intra-sector trade, the price gap between trade and autarky is larger in the comparative disadvantage sector. Trade essentially allows countries to enlarge effective states of technology in the tradable sectors, thus leading to lower prices, especially in the comparative disadvantage sector. The aggregate price level relative to the wage rate $\frac{P_i}{w_i}$ is also lower in the open economy than in autarky. $\frac{w_i}{P_i}$ measures the real purchasing power of each country's income; hence, we have the well-known result from classical trade theory that opening up to trade leads to a rise in welfare in both countries.

Next consider the impact of trade on expenditure shares. Assume the Baumol case where $\epsilon < 1$. In both countries, the services expenditure share is also higher in the open economy since $\frac{P_{is}}{P_i}$ is 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 also lower in the open economy. For the comparative advantage sector, since its sectoral price relative to the aggregate price may or may not be lower in the open economy than under autarky, we cannot sign the direction of trade affecting its expenditure share.

presence of trade costs. We restrict our attention to cases in which one country has a comparative advantage in 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.

Now consider the impact of trade on sectoral labor allocations. Because the services good is non-tradable, the market clearing condition requires that $C_{is} = A_{is}L_{is} = \frac{X_{is}w_iL_i}{P_{is}}$.[9] Thus, we have $l_{is} = \frac{L_{is}}{L_i} = X_{is}$. In an open economy, the non-tradable sector's labor share equals its expenditure share—just 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: $w_1L_{1k} = \pi_{11k}P_{1k}C_{1k} + \pi_{21k}P_{2k}C_{2k}$, implying

$$l_{1k} = \frac{L_{1k}}{L_1} = \pi_{11k}X_{1k} + \pi_{21k}X_{2k}\frac{w_2L_2}{w_1L_1}. \tag{12}$$

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, π_{11k} and π_{21k}. Finally, it depends on the relative size of the two economies.

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

$$l_{1k} = X_{1k} + \frac{\pi_{21k}X_{2k}w_2L_2 - \pi_{12k}X_{1k}w_1L_1}{w_1L_1} = X_{1k} + N_{1k},$$

where N_{1k} denotes the sectoral net export share of total GDP. 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}.

The cleanest way to see the direct contribution of trade to the sectoral labor shares is with the Cobb-Douglas case, i.e., $\epsilon = 1$. In this case, the services labor share is ω_s under both autarky and trade. The labor share of tradable sector $k \in \{a, m\}$ is ω_k under autarky and is $\omega_k + N_{ik}$ in the open economy. N_{ik} captures exactly the impact of international trade on structural change. We now derive a natural, but important, implication of the model:

[9] Our simple framework implies that each sector's value-added share equals its employment share.

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 ω_k in both countries. The pattern of comparative advantages implies $\pi_{21m} > \pi_{21a}$ and $\pi_{12m} < \pi_{12a}$. If country 1 ran a trade deficit in the manufacturing sector, it cannot run 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 $NX_{1a} < 0$. This result can also be established for CES preferences and free trade.

Finally consider the dynamics of structural change in an open economy. The growth rate of the services labor share in country i equals the growth rate of the services expenditure share: $\hat{l}_{ist} = \hat{X}_{ist}$. While this is the same expression as in the closed economy, trade affects the growth rate of the services labor share through its effect on the growth rates of the services relative price and the services expenditure 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 is clearly different from (10). Structural change dynamics involve changes in both the expenditure and net export channels. Proposition 1 summarizes these results.[10]

Proposition 1 *(i)* $l_{ik} = X_{ik} + N_{ik}$ *for* $k \in \{a, m\}$*, and* $l_{is} = X_{is}$*. Under* $\epsilon = 1$ *or free trade,* $N_{ik} > 0$ *if country* i *has a comparative advantage in sector* k*. (ii)* $\hat{l}_{ikt} = \frac{X_{ikt}}{l_{ikt}}\hat{X}_{ikt} + \frac{N_{ikt}}{l_{ikt}}\hat{N}_{ikt}$ *for* $k \in \{a, m\}$*, and* $\hat{l}_{ist} = \hat{X}_{ist}$*.*

We describe two scenarios in which the presence of trade can generate a hump-shaped pattern in the manufacturing employment share. To isolate the net export channel, consider

[10] Proofs are omitted, and available upon request from the authors.

the Cobb-Douglas case in which there is no structural change in the absence of trade. 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.

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.

In the Baumol case ($\epsilon < 1$), the expenditure channel interplays with the net export channel, affecting structural change dynamics. Since the manufacturing sector has the fastest growth among all three sectors, the expenditure channel implies a declining manufacturing labor share. To generate a rising manufacturing labor share, the net export channel needs to be sufficiently strong initially to more than offset the expenditure channel. Over time the net export channel diminishes, and the expenditure channel begins to dominate, leading to declining manufacturing labor shares. Owing to the expenditure channel, the peak of the hump will occur earlier in time compared to the Cobb-Douglas case.

Trade therefore has the potential to rationalize the post-war structural change patterns observed in both developing and developed countries. In both groups of countries, the manufacturing sector tends to have the fastest productivity growth among the three sectors. However, developed countries often experience a declining manufacturing labor share, while the developing countries experience either a rising or a hump-shaped manufacturing labor share. A closed economy model with sectoral biased productivity cannot rationalize the different manufacturing labor share dynamics of both groups. An open economy model however can be consistent with both dynamics as long as developing countries have a comparative advantage in manufacturing.

4 Quantitative Analysis

We now employ our model to quantitatively analyze the importance of trade openness in South Korea's structural change between 1971 and 2005. As Figure 1 shows, the Korean economy has undergone substantial structural change. During the 35 years covered by our analysis, 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 subsection discusses how we calibrate the model. The second subsection 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 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 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.[11] The list of countries is given in the Appendix.

We now describe our calibration of the preference parameters $\{\omega_j, \bar{C}_j, \epsilon\}$ 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 (2012), we set $\theta = 4$. The other parameters are calibrated to Korean data. Much of the literature (e.g. Duarte and Restuccia 2010 and Herrendorf, Rogerson, and Valeninyi 2012) focuses on estimating $\bar{C}_a$ and $\bar{C}_s$. Following this convention we set $\bar{C}_m = 0$, 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.[12]

For the preference parameters, we appeal to restrictions imposed by the intratemporal Euler equations governing sectoral consumption expenditure. Using the language of Herrendorf, Rogerson, and Valentinyi (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 $\{C_t\}$, sectoral consumption expenditure shares $\{s_{jt}\}$ and sectoral prices $\{p_{jt}\}$ to estimate $\{\epsilon, \omega_a, \omega_m, \omega_s, \bar{C}_a, \bar{C}_s\}$ 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

[11] 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.

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

consumption expenditure:[13]

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

subject to the constraints $\sum_j \omega_j = 1$, $\bar{C}_s \leq 0$, and $\bar{C}_a \geq 0$. This is the same as equation (4) in Herrendorf, Rogerson, and Valentinyi (2012). 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 $\bar{C}_s$ is 0.[14]

Turning to the production parameters, we use all input-output tables for Korea available in our sample period.[15] Specifically, the value added share λ_j and the matrix of intermediate input linkages γ_{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 variable is total labor in each of Korea and the ROW. These variables are taken directly from the data; the appendix provides the data sources. The labor force grew an average of 2.5 percent in Korea and 1.1 percent 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 trade openness in explaining Korea's structural change over time, we calibrate the initial productivity and trade cost levels — three sectoral 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.[16] Because two

[13]See the 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 1970-2010; 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.

[14]The elasticity of substitution across goods within a sector η is set to 4; this parameter plays virtually no roles in our model, as is the case with virtually all versions of the Eaton-Kortum model.

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

[16]The sectoral import shares are Korea's sectoral imports from the ROW as a fraction of Korea's sectoral

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, as well as the resulting values of the productivities and trade costs.

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. (Further details on the construction of the productivities and the data sources are provided in the Appendix.) 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. Owing to the Cobb-Douglas nature of production, the sectoral value-added productivity is $A_{ik}^{\frac{1}{\lambda_k}}$, where A_{ik} is gross output productivity for country i and sector k. Hence, we compute the sectoral value-added productivity and transform it into the gross output productivity. The second step arises from Waugh (2010) and Finicelli, Pagana and Sbracia (hereafter, FPS 2012), among others, who have noted that productivities computed in an open economy setting capture at least two forces, the fundamental productivity of firms within the country, 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.[17]

absorption. The sectoral export shares are Korea's sectoral exports to the ROW also expressed as a fraction of Korea's sectoral absorption.

[17]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.

The logged sectoral TFPs are shown in Figure 2. In the initial period, the ROW has higher TFP levels in all three sectors. The average TFP growth rates are 1.8 percent in agriculture, 2.2 percent in manufacturing, and 1.7 percent in services in Korea, and 1.2 percent in agriculture, 0.84 percent in manufacturing and 0.60 percent 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. By 1998, Korean manufacturing TFP surpasses that in the ROW.

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.[18] The calibrated trade costs are shown in Figure 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, by several hundred percent. Panels (b) and (c) of Figure 3 show that the model does a good job of recovering the actual time path of the trade shares.[19]

Calibration of Closed Economy Version of Model

The primary goal of this paper is to assess the importance of trade openness in Korea's structural change. As we showed in section 3, openness operates as a transmission channel in

[18] To the extent there is model misspecification and measurement error, it will show up in the trade costs.
[19] It is not a perfect fit, because the model assumes balanced trade.

two ways. First, if openness, i.e., trade costs, changes over time, this will affect the evolution of structural change. Second, TFP shocks affect the economy differently in an open setting compared to a closed setting. To see most clearly 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 percent, 2.2 percent, and 1.7 percent, respectively.

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 Figure 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 slighly more than the actual decline, and an increase in the services labor share of almost 90 percent 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 to 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. 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 Figure 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 percent of the actual decline in the agriculture labor share and only 67 percent of the actual increase in the services labor share. In terms of manufacturing, as panel (b) of Figure 4 shows, the model does not come close to generating either side of the hump. Rather, it generates only a slight increase over time.[20]

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 over-

[20]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.

all RMSE across all sectors is 0.053 in the open economy model and 0.083 in the closed economy model; hence, the open economy fit is about 40 percent better.

What explains the substantially better performance of the benchmark model? It helps to begin with 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.

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. These forces, combined with a sectoral elasticity of substitution less than one, were evidently sufficient to generate a rise in the manufacturing labor share. Essentially, Korea was able to employ more workers in manufacturing, because the expanding markets overseas more than offset the declining need for labor at home. The opposite is true for agriculture, leading to a decline in its share.

Second, the trade costs facing Korea's exporters declined over time, and more rapidly in manufacturing than in agriculture. On both counts, Korea's comparative advantage in manufacturing becomes more "revealed", thus leading to more specialization and labor in manufacturing, and less in agriculture. Of these two forces, we infer that the second force was more important, because if the first was, then Korea's manufacturing labor share would have been more likely to show the hump pattern.

The third force is that trade leads to faster economic growth in Korea as shown in Figure

5. Real income rises by a factor of seven in the closed economy, but by about a factor of eight in the open economy. The faster growth of real income in the open economy model 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.

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. Hence, we examine the effects of varying trade costs alone. In the second experiment, we set the sectoral trade costs constant at the initial levels; we 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 Figure 6 illustrates the results of the first experiment. For comparison, the benchmark model results are illustrated with the blue dashed line. In addition, the closed economy results are given by the gray line. The figure shows that both agriculture and manufacturing experience significant changes over time, although not as large as in the benchmark model. The trade costs faced by Korea's manufacturing exporters fall more rapidly than the costs for agriculture. Consequently, Korea's comparative advantage in manufacturing is more revealed, and the labor share rises in that sector, and falls in agriculture. By contrast, the services sector labor share changes by little. Thus, the expenditure channel, in which higher relative prices of services goods lead to higher expenditure shares (because the sectoral elasticity of substitution is less than one), is quite weak. The figure also shows, not surprisingly, that the evolution of the sectoral labor shares in all three sectors is less than in the benchmark case, indicating that the lack of TFP variation plays a substantial role. Finally, in the closed economy context with constant TFPs, there is no change in the labor shares. The gap between the closed economy case and the results of this experiment can be interpreted as the effect of trade costs on Korea's structural change.

The green dashed line in Figure 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. A useful comparison is the closed economy results to the open economy results. The figure shows that 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. The difference in results between the closed economy and the open economy reflects partly the effect of different TFP series that are fed into the two models, and partly the effect of an open economy. In an open economy, TFP shocks work differently, because they affect comparative advantage over time, as discussed above. In particular, owing the manufacturing TFP's higher growth rate, the comparative advantage in that sector strengthens, thus leading to a higher manufacturing employment share. Summarizing our results, we find that variation in each set of shocks is quantitatively significant in explaining Korea's structural change over time. We also find that trade as a transmission channel operates in a significant way.

4.2.3 The Role of Non-homothetic Prefereces

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 $\bar{c}_a$ to zero, i.e., preferences are now homothetic. The sectoral trade costs and TFPs are recalibrated in the same way as the benchmark calibration for both the open and closed economy models.[21]

The blue dashed line in Figure 8 plots the model-implied sectoral labor share under homothetic preferences. Compared to the benchmark model, manufacturing rises by more, while agriculture and services change by considerably less. In particular, the services labor share changes very little. These results suggest that the absence of income effects makes a large difference for agriculture and services. The figure also shows the implications of the closed economy model, plotted as the gray dotted line. There is almost no structural change in this case; the sectoral labor shares are roughly constant over time. This result can be understood using Equation (10). The TFP growth differentials across sectors are small; the largest difference is about 0.5 percent per year between the manufacturing sector and the services sector. Moreover, the calibrated elasticity of substitution across sectors is 0.75, close to 1. As a result, sector-biased productivity growth alone (without trade and non-homothetic preferences) plays an insignificant role in Korea's structural change.

When trade is introduced, regardless of homethetic or nonhomothetic preferences, labor is reallocated from the comparative disadvantage sector, agriculture, to the comparative advantage sector, manufacturing. Thus, the agriculture labor share declines and the manufacturing labor share rises over time. Trade improves the fit of the model to the data substantially under homothetic preferences; the RMSEs for agriculture, manufacturing and services in the open economy are: 0.147, 0.049, and 0.170. while the closed economy RMSEs are 0.255, 0.088, and 0.184. The overall RMSE across all sectors is 0.122 in the open economy model and 0.176 in the closed economy model under homothetic preferences; hence, the open economy fit is about 30 percent better. Recall however, that the RMSE for the benchmark model with both trade and nonhomothetic preferences are 0.059, 0.037, and 0.060 for

[21] 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 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.

agriculture, manufacturing, and services, and 0.053 overall, all of which dominate the case with trade but homothetic preferences. Thus, nonhomothetic preferences are important in matching the labor share dynamics, particularly for the agriculture and services sectors.

5 Conclusion

Over the past half century, the world has experienced rapid trade integration and enormous changes in manufacturing labor shares across countries — rising in some countries, falling in others, and following a hump-pattern in still others. As most international trade consists of manufactured goods, and a large and increasing share of manufactured output is traded, it is natural to investigate the role of trade in explaining the behavior of manufacturing, and more broadly, structural change. Our paper addresses this question both theoretically and quantitatively in a three-sector, two-country model with three key ingredients: nonhomothetic preferences, sector-biased productivity growth, and Ricardian trade.

We first use a simplified version of the model to demonstrate two ways in which the hump-pattern in manufacturing can occur. In the first scenario, if manufacturing's productivity growth is sufficiently high, the gains to employment from an increasingly large surplus in manufacturing net exports are larger than the losses to employment owing to declining manufacturing expenditure shares. The gains to employment will diminish over time, however, owing to the country's increasing size, as well as smaller increases in specialization. Eventually, manufacturing employment will decline. In the second scenario, if manufacturing trade barriers decline sufficiently rapidly, manufacturing employment will rise. However, once free trade is reached or once trade costs stop declining, the dynamics of the expenditure channel will dominate the net export channel.

Our main contribution is a quantitative assessment of the role of international trade in structural change. We calibrate our framework to investigate South Korea's structural change between 1971 and 2005. The model with the three key ingredients account for virtually the entire evolution of labor shares in agriculture and services, as well as the rising part of the hump-shape in manufacturing. Furthermore, counterfactual exercises that turn off any of the three ingredients lead to significant deterioration in the model performance, highlighting the importance of all three mechanisms.

While our calibrated model can quantitatively explain the rising portion of the hump-shape in manufacturing, it does not explain the declining portion of the hump. In our view, the key missing country 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.[22] 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.

[22]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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Table 1: Parameter Values

Preference Parameters							
ϵ	ω_a	ω_m	ω_s	$\bar{C}_a$	$\bar{C}_m$	$\bar{C}_s$	η
0.751	0.131	0.214	0.655	696.0	0.0	0.0	4.0

Production Parameters					
λ_j		$\gamma_{\text{row, column}}$			θ
		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	

Table 2: Calibration Targets of the Initial Period, 1971

Parameter	Value	Target Moments	Data	Model
z_{1a}	84.82	Share of SK Labor in Agriculture	0.48	0.48
z_{1m}	0.61	Share of SK Labor in Manufacturing	0.13	0.13
z_{1s}	0.03	SK Agricultural Subsistence Share	0.51	0.54
z_{2a}	152.36	Share of ROW Labor in Agriculture	0.16	0.16
z_{2m}	0.89	Share of ROW Labor in Manufacturing	0.23	0.23
z_{2s}	0.53	Income of ROW Relative to SK	5.9	7.0
d_{12a}	1.89	SK Agricultural Import Share	0.12	0.04
d_{12m}	1.56	SK Manufacturing Import Share	0.26	0.26
d_{21a}	6.19	SK Agricultural Export Share	0.02	0.09
d_{21m}	5.76	SK Manufacturing Export Share	0.16	0.16

Figure 1: Korean Structural Change

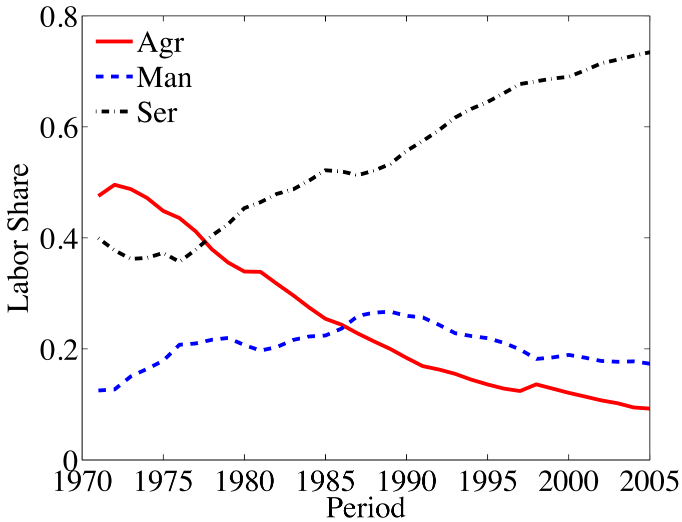
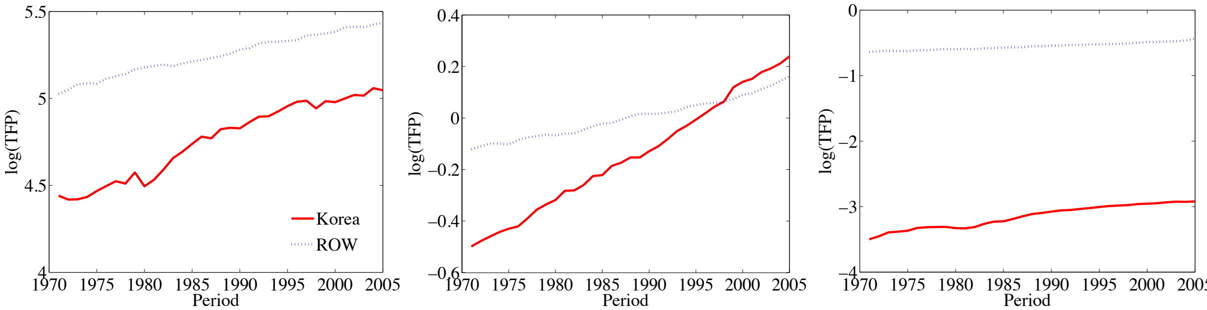
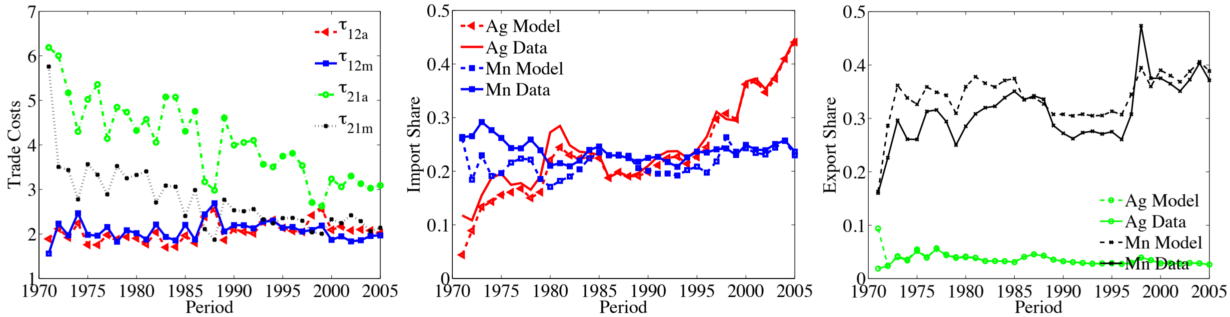


Figure 2: Calibrated TFP Series



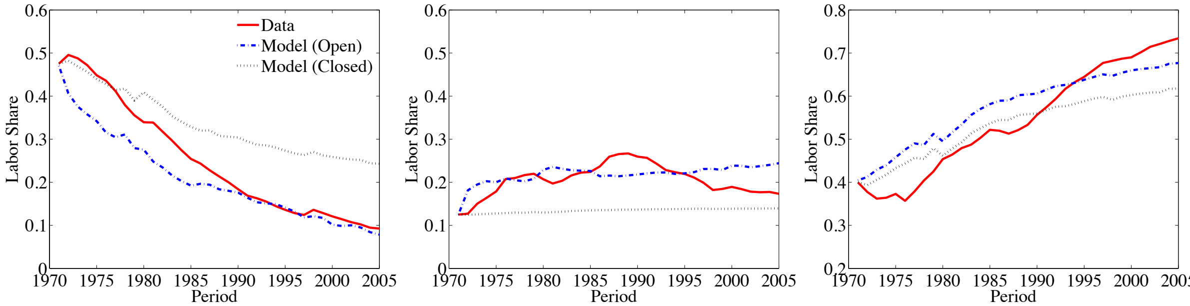
(a) Agriculture (b) Manufacturing (c) Services

Figure 3: Calibrated Trade Costs and Korean Trade Shares



(a) Trade Costs (b) Korean Import Shares (c) Korean Export Shares

Figure 4: Korean Structural Change: Benchmark



(a) Agriculture (b) Manufacturing (c) Services

Figure 5: Real Income (Welfare)

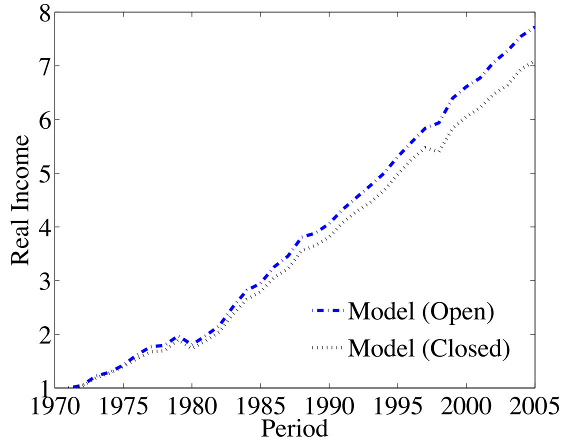
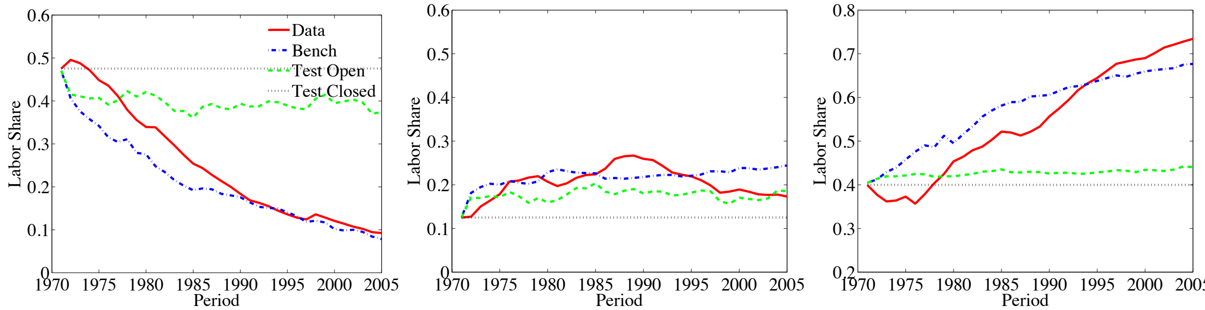
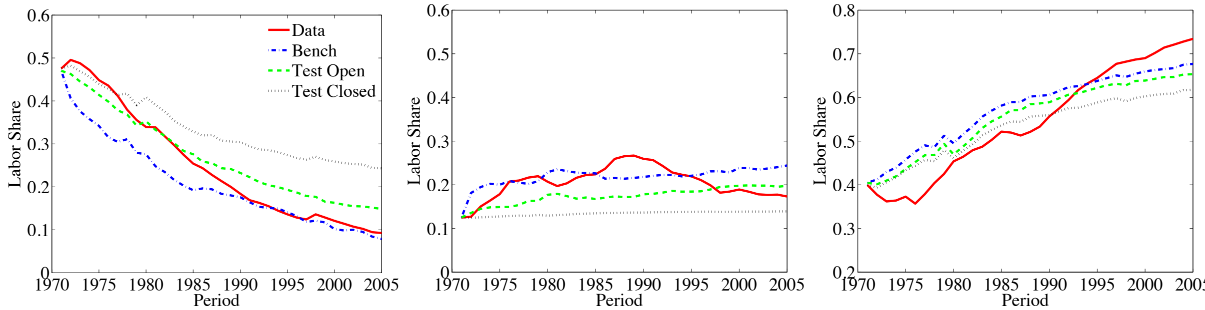


Figure 6: Korean Structural Change: Constant TFPs



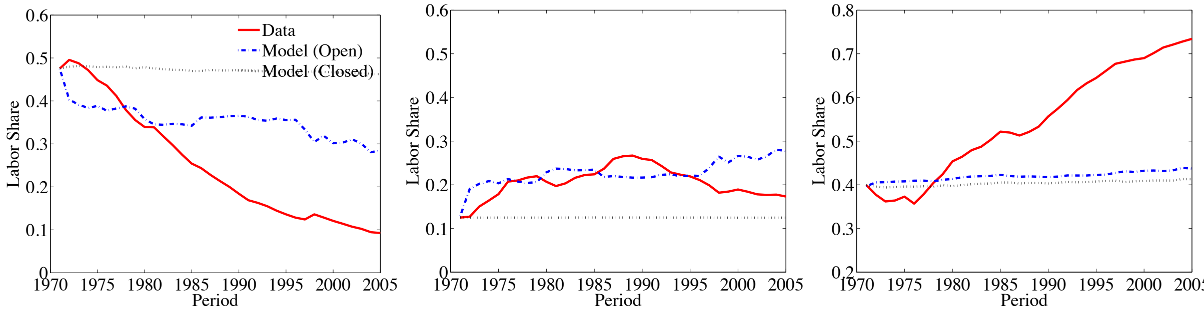
(a) Agriculture (b) Manufacturing (c) Services

Figure 7: Korean Structural Change: Constant Trade Costs



(a) Agriculture (b) Manufacturing (c) Services

Figure 8: Korean Structural Change: Homothetic Preferences



(a) Agriculture (b) Manufacturing (c) Services

Data Appendix

Countries, Sample Period, and Sectors

The countries covered in our data set are Australia, Austria, Belgium, Canada, Denmark, Spain, Finland, France, Germany, Greece, Iran, Iraq, Ireland, Italy, Japan, South Korea, Kuwait, Luxembourg, Mexico, the Netherlands, Portugal, Saudi Arabia, Sweden, the United Kingdom, the United States, and Venezuela. Our data covers the period 1971–2005.[23]

Unless otherwise noted, the sectors are defined by the International Standard Industrial Classification, revision 3 (ISIC III) definitions: Agriculture corresponds to ISIC divisions 1–5 (agriculture, forestry, hunting, and fishing), 10–14 (mining and quarry), 15–16 (food, beverages and tobacco (FBT)); Manufacturing corresponds to divisions 17–37 (total manufacturing less FBT); Services corresponds to divisions 40–99 (utilities, construction, wholesale and retail trade - including hotels and restaurants, transport, and government, financial, professional, and personal services such as education, health care, and real estate services).[24]

Sectoral Employment Share

For each sector, the sectoral employment share l_{ik} for country i is defined as the ratio between sectoral employment L_{ik} and total employment L_i. Our sectoral employment data comes from two data sources, the EU KLEMS database, and the GGDC 10-sector database (Timmers and de Vries, 2008).[25] The EU KLEMS database is the primary source for South Korea, the United States, Australia, Austria, Belgium, Canada, Denmark, Spain, Finland, France, Germany, Greece, Ireland, Italy, Japan, Luxembourg, the Netherlands, Portugal, Sweden, and the United Kingdom. We use the variable EMP, which measures the number of persons engaged, and aggregate the data into three broader sectors.

The primary source for Mexico and Venezuela is the GGDC 10-sector database. For both countries, we use Table 3 (Number of Persons Employed) and aggregate the data into our three broad sectors. Since employment data for food, beverages and tobacco is not available in the 10-sector data, it remains part of manufacturing sector for these two countries. For Iran, Iraq, Kuwait, and Saudi Arabia, we impute their sectoral employment under the assumption that their employment-population ratio and sectoral employment share are the same as in Venezuela (VEN). Using population data (POP) from Penn World Tables Version 7.0 (PWT),[26] we compute total employment in each country i as $L_i = \text{POP}_i \times L_{\text{VEN}}/\text{POP}_{\text{VEN}}$. Country i's employment in sector k is given by $L_i \times l_{\text{VEN},k}$.

[23]For a few series, not all countries are included in the data due to limited availability.

[24]In a few cases, food, beverages and tobacco remains part of manufacturing due to limited data availability. Also, the data series on final consumption expenditure and the production parameters are not compatible with the ISIC III classification. See below for a detailed definition of sectors for these two variables.

[25]See http://www.euklems.net/ and http://www.rug.nl/feb/onderzoek/onderzoekscentra/ggdc/data/10sector.

[26]http://pwt.econ.upenn.edu/php_site/pwt_index.php

South Korea's Trade Shares

South Korea's sectoral import (export) shares are defined as sectoral imports (exports) divided by the difference between sectoral gross output and sectoral net export. Our primary source for trade flows is COMTRADE, which reports bilateral trade flows by commodity in U.S. dollars. When downloading from COMTRADE, we select South Korea (country code: 410) as the reporter and the world (country code: 0) as the partner. We define sectors based on the SITC Rev.1 classification as follows.

Agriculture	FBT	Manufacturing
00, 011, 023, 024, 025, 031, 041, 042, 043, 044, 045, 051, 052, 054, 07, 2, 32, 331, 34, 35	012, 013, 022, 032, 046, 047, 048, 053, 055, 06, 081, 091, 099, 1	251, 26, 332, 4, 5, 6, 7, 8

We obtain the nominal sectoral gross output series for South Korea using national accounts data from the Bank of Korea.[27] The exchange rate series come from the Penn World Tables version 7.0.

Production Parameters

We calibrate the production parameters $\{\lambda_k, \gamma_{kn}\}_{k,n=a,m,s}$ using South Korea's input-output tables provided by the Bank of Korea.The following table summerizes the available years and the aggregation of detailed sectors in the raw data into our three broad sectors.

Year	Sector Codes		
	Agriculture	Manufacturing	Services
1970	1–15	16–41	42–56
1975	1–16	17–44	45–60
1980	1–18	19–45	46–64
1985–1988	1–3	4–11	12–20
1990, 1993	1–3	4–15	16–26
1995, 1998, 2000, 2003	1–3	4–16	17–28
2005	1–3	4–17	18–28

The parameter λ_k is given by the share of value added in gross output in sector k:

$$\lambda_k = \frac{\text{Total value added}_k}{\text{Total intermediate input}_k + \text{Total value added}_k}.$$

The 3×3 matrix $\{\gamma_{kn}\}$ is the use intensity of sector n goods in producing sector k goods:

$$\gamma_{kn} = \frac{\text{Use of sector } n\text{'s goods to produce goods in sector } k}{\text{Total intermediate input in sector } k},$$

with $\sum_{n=a,m,s} \gamma_{kn} = 1$. We calculate these parameters for every available input-output table and take the sample mean.

[27]Table 10.4.5 Gross Value Added and Factor Income by Kind of Economic Activity (at current prices, annual). Available for download at `http://ecos.bok.or.kr/`.

Sectoral Productivity (TFP) Growth

We construct annual TFP growth for South Korea and the rest of the world for both the closed and open economy cases. The TFP concept in our model is a gross output concept. Owing to data lmitations, however, we are unable to compute TFP directly from the gross output production function. Instead, we derive the value-added production function, which provides a mapping from value-added TFP to gross output TFP. We then show how to map from measured TFP, which includes the effects of being in an open economy, to the fundamental TFP in each country and sector. Finally, we discuss how we implement computing value-added TFP and the open economy adjustment.

Deriving valued-added TFP from gross output TFP

Recall that goods are produced with labor and sectoral composite goods:

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

In a closed economy, abstracting from the continuum of goods and working with sectoral aggregates, the sector-level firm solves

$$\max_{L_{ik},M_{ikn}} P_{ik}Y_{ik} - w_i L_{ik} - \sum_{n=a,m,s} P_{in}M_{ikn}.$$

The demand for intermediate goods is given by the first order condition

$$M_{ikn} = \frac{(1-\lambda_k)\gamma_{kn}P_{ik}Y_{ik}}{P_{in}}.$$

Substituting for M_{ikn} in the production function and rearranging the terms give

$$Y_{ik} = A_{ik}^{\frac{1}{\lambda_k}} L_{ik} \left[(1-\lambda_k)P_{ik}\Pi_{n=a,m,s}\left(\frac{\gamma_{kn}}{P_{in}}\right)^{\gamma_{kn}}\right]^{\frac{1-\lambda_k}{\lambda_k}}.$$

Thus, we can rewrite the maximization problem only in terms of choosing labor,

$$\max_{L_{ik}} \quad \lambda_k P_{ik}^{\frac{1}{\lambda_k}} \left[(1-\lambda_k)\Pi_{n=a,m,s}\left(\frac{\gamma_{kn}}{P_{in}}\right)^{\gamma_{kn}}\right]^{\frac{1-\lambda_k}{\lambda_k}} A_{ik}^{\frac{1}{\lambda_k}} L_{ik} - w_i L_{ik}.$$

The value added production function has the form $A_{ik}^{\frac{1}{\lambda_k}} L_{ik}$ with its corresponding price being $\lambda_k P_{ik}^{\frac{1}{\lambda_k}} \left[(1-\lambda_k)\Pi_{n=a,m,s}\left(\frac{\gamma_{kn}}{P_{in}}\right)^{\gamma_{kn}}\right]^{\frac{1-\lambda_k}{\lambda_k}}$.

Adjusting TFP for an Open Economy Setting

As a reminder, the measured TFP in an open economy setting captures the effects of both specialization and the fundamental TFP, i.e., the TFP that woud exist under autarky. To recover the fundamental TFP from the measured TFP, we follow Propositions 1 and 2 in

Finicelli, Pagana, and Sbracia (FPS, 2012). Recall that in our model, each country i possesses the technology to produce all goods in each sector. The productivity $A_{ik}(z)$ is the realization of random variable Z_{ik}, drawn from Fréchet distribution $F_{ik}(T_{ik}, \theta)$. Under autarky, sectoral TFP is the unconditional mean of Z_{ik}, given by

$$A_{ik} = E[Z_{ik}] = T_{ik}\Gamma\left(\frac{\theta - 1}{\theta}\right).$$

We denote the measured TFP for a tradeable sector k in an open economy setting by $A_{ik,o} = E[Z_{ik,o}]$, where the random variable $Z_{ik,o}$ has the same distribution as the probability distribution of Z_{ik} conditional on the good being produced by country i. Proposition 1 of FPS shows that $Z_{ik,o}$ is also Fréchet distributed with $F_{ik}(\Lambda_{ik}, \theta)$, where $\Lambda_{ik} = T_{ik} + \sum_{j\neq i} T_{jk}\left(\frac{v_{jk}\tau_{ijk}}{v_{ik}}\right)^{-\theta}$, and that

$$A_{ik,o} = E[Z_{ik,o}] = \Lambda_{ik}^{1/\theta}\Gamma\left(\frac{\theta - 1}{\theta}\right).$$

As noted in Proposition 2 of FPS 2012, trade shares serve as a link between TFP in a closed economy setting (fundamental TFP) and measured TFP in an open economy setting. Specifically,

$$\frac{A_{ik}}{A_{ik,o}} = \pi_{iik}^{1/\theta} = \left(\frac{X_{iik}}{X_{ik}}\right)^{1/\theta}.$$

The last term is the sectoral domestic absorption ratio, given by $\frac{\text{Gross Ouput - Export}}{\text{Gross Ouput - Net Export}}$. Therefore, the fundamental TFP A_{ik} can be computed as $A_{ik,o}\pi_{iik}^{1/\theta}$.

Computing Sectoral Value Added

The relation between value added labor productivity and gross output TFP allows us to measure gross output TFP using real value added (RVA) and employment data:

$$A_{ikt} = \left(\frac{\text{RVA}_{ikt}}{L_{ikt}}\right)^{\lambda_k}.$$

In a closed economy model, the fundamental TFP coincides with the measured TFP.

The two main ingredients for constructing TFP growth are sectoral employment and sectoral real value added for both South Korea and the ROW. The construction of employment series has been discussed above. We now focus on real value-added. There are three major steps in computing sectoral value added in 2000 U.S. dollars. We combine the disaggregated real value added data into our three broad sectors. As we will discuss in detail next, this procedure differs across countries, because different countries and databases adopt different measures of real value added. In particular, South Korea uses Laspeyres indexes, the U.S. uses the Fischer method, whereas EU KLEMS uses Torqvist indexes. We also use an appropriate PPP exchange rate to convert real value added from the nationall currency to U.S. dollars. Finally, we aggregate sectoral real value added across countries for the ROW.

South Korea Our primary source is GDP by kind of economic activity at current prices and at chained 2005 prices from the Bank of Korea.[28] Both series are measured in Billions of Won. The real series is aggregated using Laspeyres price indices, with a base year of 2005. First, we aggregate the real value added from the detailed industries into our three broad sectors; we choose 2000 as the base year. In particular, suppressing indices for countries, we use VA_{xkt} to denote nominal value added of a subsector x within one of the three broad sectors $k \in \{a, m, s\}$ at time t, VA^{2005}_{xkt} and VA^{2000}_{xkt} denote real value added of the same subsector at chained 2005 and 2000 prices, respectively. Because we choose 2000 to be the base year, it holds that:

$$\text{VA}^{2000}_{k2000} = \sum_{x \in X_k} \text{VA}_{xk2000},$$

where X_k is the set of subsectors within sector k.[29] Using Laspeyres indices, the growth rate of sectoral value added at chained 2000 prices is given by:

$$\frac{\text{VA}^{2000}_{kt}}{\text{VA}^{2000}_{kt+1}} = \frac{\sum_{x \in X_k} \text{VA}_{xkt}}{\sum_{x \in X_k} \text{VA}^{2005}_{xkt+1} \left(\frac{\text{VA}_{xkt}}{\text{VA}^{2005}_{xkt}} \right)}.$$

For years prior to 2000, we iterate backwards from 2000, and for years after 2000, we iterate forwards. We then convert sectoral real value added from Korea won to 2000 U.S. dollars. To do that, we need to impute the PPP for value added for each sector. We begin by assuming that the PPP for each sector is 788.92 in 2005, which is from the OECD PPP 2005 Benchmark results.[30] The PPP for sector k at year 2000 is given by

$$\text{PPP}_{k2000} = \text{PPP}_{k2005} \left(\frac{\text{VA}^{2000}_{\text{SK}k2005}}{\text{VA}_{\text{SK}k2005}} \right) \left(\frac{\text{VA}_{\text{US}k2005}}{\text{VA}^{2000}_{\text{US}k2005}} \right).$$

Finally, sectoral real value added for South Korea per worker is calculated as

$$\text{RVA}^{2000\ \text{USD}}_{\text{SK}kt} = \frac{\text{VA}^{2000}_{\text{SK}kt} / \text{PPP}_{k2000}}{L_{\text{SK}kt}}.$$

United States The procedure for constructing sectoral real value added for the U.S. is similar to that of South Korea. Because national accounts data from the BEA are our primary sources for the U.S., we need to aggregate sectoral real value added using Fischer indexes.[31] First, we compute relative price $IPD_{xkt} = \frac{VA_{xkt}}{VA^{2005}_{xkt}}$, for all subsectors $x \in X_k$ within

[28]The data is available for download from the Bank of Korea ecos.bok.or.kr/10.National Accounts/10.4 Supporting Tables/10.4.1.3 GDP and GNI by Kind of Economic Activity (at current prices, quarterly & annual) and 10.4.1.4 GDP and GNI by Kind of Economic Activity (at chained 2005 year prices, quarterly & annual).

[29]The aggregation here is standard, following the ISIC rev. 3 definition of sectors, and FBT is included in agriculture.

[30]This number is obtained from OECD Purchasing Power Parities (PPP) 2005 Benchmark results. The dataset can be accessed at http://stats.oecd.org/Index.aspx?DatasetCode=STAN08BIS#, Table 1.12: Purchasing Power Parities in national currencies per US dollar.

[31]We obtained a comprehensive table on nominal and real value added by industry from the BEA. We use the following two variables from the table, nominal value-added by industry (1947-2009), and Chained

sector $k \in \{a, m, s\}$. Next, we calculate Fischer Indexes (FI) for each sector k at year t, which is given by:

$$FI_{kt} = \sqrt{\frac{VA_{kt}}{\sum_{x \in X_k} IPD_{xkt} VA^{2005}_{xkt-1}} \times \frac{VA_{kt-1}}{\sum_{x \in X_k} IPD_{xkt-1} VA^{2005}_{xkt}}}.$$

By setting sectoral chaining indexes to be 100 for the year 2000, we can solve for sectoral chaining indices (CI) for each year using the equation:

$$\frac{CI_{kt}}{CI_{kt+1}} = \frac{1}{FI_{kt+1}}.$$

In the end, we compute sectoral value added at chained 2000 prices using:

$$VA^{2000}_{kt} = VA_{k2000} CI_{k2000}/100.$$

Because of data limitations, we need to impute real FBT value-added for the U.S. prior to 1977. Specifically, we make use of nominal FBT value added and the corresponding chained quantity indexes (QI) to compute a real FBT share.[32] We then assume that the real FBT share stays constant at the 1977 level from 1971-1977. The real FBT share in 1977 is given by:

$$\frac{VA_{FBT2000} * QI_{FBT1977}/QI_{FBT2000}}{VA_{m2000} * QI_{m1977}/QI_{m2000}}.$$

We calculate real FBT value added by multiplying the share by real value added in manufacturing, and we use the result to make the appropriate adjustment to real value added in agriculture and in manufacturing for the relevant years.

The Rest of the World and United States We need the sum of sectoral real value added and employment across all countries including the U.S. to calculate real value added per worker for the ROW. The second part can be done by using sectoral employment data discussed earlier. We now proceed to discuss the construction of sectoral real value added for all other countries.

For sectoral real value added, the EU KLEMS database is the primary source for the following countries: Australia, Austria, Belgium, Canada, Denmark, Spain, Finland, France, Germany, Greece, Ireland, Italy, Japan, Luxembourg, the Netherlands, Portugal, Sweden, and the United Kingdom. For each country, we first convert nominal series from the national currency to current U.S. dollars using the PPPs from PWT 7.0. The underlying assumption is that within each country, PPPs for all industries are the same as the national PPP for every year. Second, we aggregate sectoral quantity indices (QI), (from EU KLEMS and with a base year of 1995), following the Tornqvist formula. The final step is to iteratively compute the annual series of real sectoral value added from nominal values in year 2000, using the implied growth rate from sectoral QI. The last two steps are described in detail below. For each individual country, we calculate the following:

Price Indexes (2005=100, 1947-2009).

[32] We obtain these two series from table "1947-97 GDPbyInd_VA_NAICS.xls" at http://www.bea.gov/industry/gdpbyind_data.htm

1. Subsector weights: for each subsector $x \in X_k$ within sector k, the weight $\alpha_{xkt} = \frac{VA_{xkt}+VA_{xkt+1}}{\sum_{x \in X_k} VA_{xkt}+VA_{xkt+1}}$.

2. Subsector quantity index (QI) growth rate: for each subsector x, the growth rate is given by $\log\left(\frac{QI_{xt+1}}{QI_{xt}}\right)$.

3. Sector QI growth rate: for each sector k, the QI growth rate is given by $\Delta QI_{kt} = \sum_{x \in X_k} \alpha_{xkt} \log\left(\frac{QI_{xt+1}}{QI_{xt}}\right)$.

4. Sector QI: for each sector k, $QI_{k1995} = 100$. Since $\log QI_{kt} = \log QI_{kt-1} + \Delta QI_{kt-1}$, we can successively solve for QI_{kt}.[33]

5. Real sectoral value added at constant 2000 USD: set $VA_{kt}^{2000USD} = VA_{k2000}$. Using the growth rate of sectoral value added implied by the quantity indices, we can iterate forward and backward to solve for sectoral value added in 2000 U.S. dollars for every year. In particular,
$$\frac{VA_{kt}^{2000USD}}{VA_{kt+1}^{2000USD}} = \frac{QI_{kt}}{QI_{kt+1}}.$$

The UN National Accounts Main Aggregates Database is the primary source for the oil countries, including Iran, Iraq, Kuwait, Mexico, Saudi Arabia, and Venezuela.[34] Sectoral value added is reported in both current and constant 2005 U.S. dollars. Hence, we only need to renormalize the real series to constant 2000 U.S. dollars, given by $VA_{kt}^{2000} = VA_{kt}^{2005} \frac{VA_{k2000}}{VA_{k2000}^{2005}}$.[35]

The final step is to calculate the sum of sectoral real value added in 2000 U.S. dollars and sectoral employment across countries, including the countries from EU KLEMS, oil countries, and the U.S. Sectoral real value added per worker for the ROW is the ratio of these two terms.

Computing TFP in an Open Economy

Recall from above that the fundamental TFP in an open economy setting can be computed from observed TFPs by using the domestic absorption ratio. This ratio Ω is defined as $1 + \frac{\text{Import}}{\text{Gross Output-Export}}$. We now discuss how to construct Ω for South Korea and rest of the world. For South Korea, we compute the ratio using the same trade flows and gross output data series discussed in section 2.

For the ROW, we obtain the combined trade flows between South Korea and the countries in our ROW aggregate from COMTRADE, following the same classification of sectors

[33]For $t < 1995$, $QI_{kt} = \exp(\log(100) - \sum_{n=t}^{1994} \Delta QI_{kn})$. For $t > 1995$, $QI_{kt} = \exp(\log(100) + \sum_{n=1995}^{t-1} \Delta QI_{kn})$.

[34]The data is available for download at `http://unstats.un.org/unsd/snaama/selbasicFast.asp`. We use both "Value Added by Economic Acitivty, at current prices - US dollars" and "Value Added by Economic Acitivty, at constant 2005 prices - US dollars.

[35]Since we do not have nominal or real FBT value added for oil countries, no FBT adjustment is made and it remains part of manufacturing for these countries.

discussed section 2. In particular, we choose our subset of countries as reporters and South Korea as the partner country.

For gross output, the BEA industry accounts are the source for the U.S., supplemented by World Klems for 1971-1976.[36] The EU KLEMS database is the primary source for the following countries: Australia, Austria, Belgium, Canada, Denmark, Spain, Finland, France, Germany, Greece, Ireland, Italy, Japan, Luxembourg, the Netherlands, Portugal, Sweden, and the United Kingdom.[37] For the oil countries, OECD STAN is the primary source for Mexico.[38] The Venezuela national accounts is the primary source for Venezuela.[39] The UN National Accounts database is the source for Kuwait.[40] For Iran, Iraq, Saudi Arabia, we impute their sectoral gross output by multiplying sectoral gross output in Venezuela with the population ratio between these countries and Venezuela.

If the above data is in the national currency, we convert it into U.S. dollars using nominal exchange rates from PWT 7.0.[41] We then aggregate nominal gross output of the detailed industries into our three broad sectors according to the ISIC III definition of sectors discussed above.[42] Finally, we compute the sectoral absorption ratio for the ROW from the combined import flows, export flows, and gross output of all countries in our sample.

Subsistence Share:

The subsistence share is used to calibrate the initial parameters and exogenous variables in 1971. Recall that in the model the minimum per-capita consumption requirement in agriculture and services is given by $\bar{C}_a = 696.03$ and $\bar{C}_s = 0$, which are measured in 2000 U.S. dollars. From here, we define the agriculture subsistence share as

$$\frac{\text{Agr. relative price} \times \bar{C}_a}{\text{Total final consumption expenditure per capita}}.$$

For the numerator, we compute the sectoral relative price series from real and nominal sectoral final consumption expenditure data, as well as the PPP for private consumption (PPPs for sectoral consumption were not available). We need PPPs to get the prices in a common set of units. Specifically, the price of SK's agriculture in 1971 relative to 2000 is given by

$$p_{SK,ag,1971} = \left(\frac{\text{Nominal final consumption}_{SK,ag,1971}}{\text{PPP}_{SK,1971}} \right) / \left(\frac{\text{Real final consumption}_{SK,ag,1971}}{\text{PPP}_{SK,2000}} \right).$$

[36] http://www.bea.gov/industry/gdpbyind_data.htm and http://www.worldklems.net/data/index.htm.

[37] http://www.euklems.net/.

[38] http://stats.oecd.org/Index.aspx?DatasetCode=STAN08BIS.

[39] http://www.bcv.org.ve/cuadros/series/series.asp.

[40] http://unstats.un.org/unsd/snaama/selbasicFast.asp.

[41] We use variable "xrat" from PWT 7.0

[42] Gross output for FBT is not avaiable for Kuwait and Venezuela and therefore it remains part of manufacturing. The sectoral aggregation for Venezuela is broadly consistent with the ISIC III definition, with the exception that manufacturing corresponds to "Industry" on the National Accounts table, which also includes refinement of petroleum.

The OECD national accounts database is the primary source for final consumption expenditure.[43] This data is available in both current prices and 2000 prices, denominated in national currencies. We use the Purchasing Power Parity (PPP) for private consumption from OECD to convert consumption expenditure from national currencies to U.S. dollars.[44]

The definition of the three broad sectors for final consumption expenditure are according to the Classification of Individual Consumption According to Purpose (COICOP). Agriculture corresponds to P31CP010 (Food and non-alcoholic beverages) and P31CP020 (Alcoholic bevereages, tobacco and narcotics). Manufacturing is the sum of P311B (Durable goods), P312B (Semi-durable goods), and P313B (Non-Durable goods), less agriculture. Services is given by P314B (Services).

To compute Souh Korea's subsistence share in agriculture in 1971, we first aggregate sectoral final consumption expenditure in both nominal and real terms into three sectors according the COICOP definitions given above. After the PPP adjustment, we obtain the sectoral relative price in the numerator. For the denominator, we use annual population data from the OECD to convert nominal total final consumption into per capita terms.[45]

Total Employment:

We normalize total employment in each country by dividing by the U.S. population in 1971. Total employment is the sum of sectoral employment discussed above.

Relative Income:

We compute the income of ROW relative to South Korea as a calibration target for the initial productivity level for the open economy. Relative income is defined as the ratio of real GDP per capita between the rest of the world (ROW) and South Korea in 1971 using historical real GDP data from the International Macroeconomic Data Set.[46] Both GDP and GDP per capita are reported in 2005 U.S. dollars for every country in our sample. For ROW, we first compute population by dividing real GDP by real GDP per capita for each country. Using population as weights, we take a weighted average of real GDP per capita for ROW. Our calculation yields a real GDP per capita of ROW relative to South Korea in 1971 of 5.90.

[43] Table 5.Final consumption expenditure of households under Annual National Accounts/ Detailed Tables and Simplified Accounts. `http://stats.oecd.org/Index.aspx?QueryId=9189`.

[44] Transaction "PPPPRC: Purchasing Power Parities for private consumption" in Table 4. PPPs and exchange rate, under "Prices and Purchasing Power Parities", `http://stats.oecd.org/Index.aspx?QueryId=9189`.

[45] Table. Population under "Demography and Population", `http://stats.oecd.org/Index.aspx?QueryId=9189`.

[46] `http://www.ers.usda.gov/data-products/international-macroeconomic-data-set.aspx`