

Structural Change in an Open Economy

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Abstract

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

JEL: F20, F40, O13, O41

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1 Introduction

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

9 Global integration between developed and emerging market economies is often blamed for
10 the decline in manufacturing in most developed countries. Indeed, Autor, Dorn, and Hanson
11 (2011) find that one-third of the decline in U.S. manufacturing employment is a result of
12 trade with China. Moreover, some of the emerging market economies that recently joined
13 the global trading system, such as South Korea and Taiwan, have themselves experienced
14 a hump-shaped pattern in manufacturing employment. These findings plausibly suggest a
15 linkage between globalization and structural change. Theoretically, such a linkage is natural:
16 after all, the fundamental role of international trade is to facilitate specialization via an
17 efficient reallocation of employment and other factors of production across sectors.

18 The main goals of our paper are to develop a multi-sector open economy model to study
19 these linkages, and to conduct a quantitative analysis of the role of international trade in
20 South Korea's structural change. Our model draws from three intellectual antecedents.
21 First, there is the long literature, going back to Engel, that emphasizes the importance of
22 non-unitary sectoral income elasticities—in particular an agriculture/food income elasticity
23 of demand less than one. We embody this with the Stone-Geary non-homothetic preferences.
24 Second, there is the literature, going back to Baumol (1967), that emphasizes the importance
25 of non-unitary sectoral substitution elasticities in conjunction with asymmetric productivity
26 growth across sectors. We allow for these forces in our model, as well. Finally, we introduce

1 international trade via the Ricardian comparative advantage framework of Eaton and Ko-
2 rtum (2002). Patterns of specialization and international trade are determined by relative
3 productivity differences across countries and goods. One additional feature of our model,
4 incorporating intermediate goods, is useful for matching gross output concepts like trade
5 and consumption expenditure, with value-added concepts like GDP and labor shares. Over-
6 all, our model shares features similar to other multi-sector Eaton-Kortum models such as
7 Shikher (2012), di Giovanni, Levchenko and Zhang (2012), Levchenko and Zhang (2012),
8 and Caliendo and Parro (2011).¹

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

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

24 More broadly, international trade affects structural change along three dimensions. First,
25 declines in trade costs affect patterns of specialization, which then affect labor allocations

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

1 across sectors. Second, differential sectoral productivity growth also affects labor allocations,
2 again operating through specialization patterns. Third, lower trade costs spur income growth
3 and strengthen the role of non-homothetic preferences in structural change.

4 We calibrate our model to South Korea and the rest of the world in 1971 to 2005,
5 focusing on explaining South Korea's structural change. We then simulate the effects of
6 productivity shocks and trade cost shocks in our benchmark model. We find that it can
7 explain virtually all of the evolution of Korea's agriculture and services sector labor shares.
8 It can also explain the rise in Korea's manufacturing labor share. However, it cannot explain
9 the decline in Korea's manufacturing labor share that occurred beginning around 1990. By
10 contrast, a simulation under a closed economy cannot explain the time path of any sectoral
11 labor share. The root mean square error between the implied and observed labor shares is
12 0.05 in the open economy model and 0.08 in the closed economy model; the closed economy
13 fit is about 60 percent worse.

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

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

1 There is a large literature on structural change. One recent development is to shift the
2 focus from two-sector closed economy frameworks to three-sector frameworks and open econ-
3 omy frameworks.² Recent studies of three-sector closed economy models include Echevarria
4 (1997), Kongsamut, Rebelo, and Xie (2001), Ngai and Pissarides (2007), Rogerson (2008),
5 Restuccia, Yang, and Zhu (2008), Foellmi and Zweimuller (2008), Buera and Kaboski (2009,
6 2012), Duarte and Restuccia (2010), Verma (2012), and Herrendorf, Rogerson and Valentinyi
7 (2012).³ Earlier studies of open economy models of structural change include Matsuyama
8 (1992, 2009) and Echevarria (1995). Echevarria (1995) studies the effect of trade on out-
9 put composition and overall growth of OECD economies in a small open economy model.
10 Matsuyama (2009) employs a simple Ricardian model to show that high manufacturing pro-
11 ductivity growth need not lead to a decline in manufacturing employment.

12 Sposi (2012) also studies Korea’s structural change in a three-sector model, and also
13 finds that comparative advantage is important. However, owing to a time period that ends
14 in 1995, the paper cannot assess the ability of the model to replicate the hump-shaped
15 pattern in manufacturing.⁴ Teignier-Bacque (2012) studies structural change in Korea (and
16 two other countries), but focuses on the role of the agriculture sector in a two-sector small
17 open economy model.⁵

18 The paper is organized as follows. Section 2 lays out the model, and Section 3 uses a
19 simplified version to illustrate the key impacts of an open economy on structural change.
20 Section 4 presents the calibration and studies the importance of the two key sources of

²In 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).

³Also, see Ju, Lin and Wang (2009) for an n -sector model.

⁴There are several other differences between Sposi’s work and ours. His paper does not examine the effects of changes in non-tariff trade costs, nor the importance of non-homothetic preferences. On the other hand, his model allows for non-zero trade deficits and includes more than two countries.

⁵Other quantitative open economy models of structural change include Coleman (2007), Galor and Mountford (2008), Stefanski (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. Ungor (2012) uses a two-sector model to study the effects of China’s growth on de-industrialization of the United States.

1 shocks and the two key transmission mechanisms (openness and non-homothetic preferences).
 2 Section 5 concludes.

3 2 Model

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

12 2.1 Technologies

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

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

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

20 $A_{ik}(z)$ is the realization of a random variable Z_{ik} drawn from the cumulative distribution
 21 function $F_{ik}(A) = Pr[Z_{ik} \leq A]$. Following Eaton and Kortum (2002), we assume that $F_{ik}(A)$
 22 is a Fréchet distribution: $F_{ik}(A) = e^{-T_{ik}A^{-\theta}}$, where $T_{ik} > 0$ and $\theta > 1$. The larger is T_{ik} , the

1 greater the mean efficiency for any good z . The larger is θ , the lower the heterogeneity or
 2 variance of Z_{ik} .⁶ We assume that the productivity is drawn each period.⁷

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

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

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

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

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

20 Under the Fréchet distribution of productivities, Eaton and Kortum (2002) show that
 21 the price of tradable composite good $k \in \{a, m\}$ in country i is $P_{ik} = \Gamma(\Phi_{ik})^{-\frac{1}{\theta}}$, where the
 22 constant Γ is the Gamma function evaluated at $(1 - \frac{\eta-1}{\theta})^{\frac{1}{1-\eta}}$, and $\Phi_{ik} = T_{1k}(v_{1k}\tau_{i1k})^{-\theta} +$

⁶ 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.

⁷Alternatively, 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.

1 $T_{2k} (v_{2k} \tau_{i2k})^{-\theta}$. Φ_{ik} summarizes country i 's access to global production technologies in sector
 2 k scaled by the relevant unit costs of inputs and trade costs.⁸ For the services composite
 3 good, the price is $P_{is} = \Gamma (\Phi_{is})^{-\frac{1}{\theta}}$, where $\Phi_{is} = T_{is} (v_{is})^{-\theta}$.

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

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

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

8 2.2 Preferences

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

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

10 where for each sector $k \in \{a, m, s\}$, C_{ik} is consumption of sector- k composite goods, and
 11 \bar{C}_k is the subsistence requirement for sector- k composite goods. A positive value of \bar{C}_k gen-
 12 erates an income elasticity of demand for the sector k goods less than one. The preference
 13 share parameters ω_k 's are positive and sum to one across sectors. The elasticity of substi-
 14 tution across sectoral composite goods is $\epsilon > 0$. If $\epsilon > 1$, the sectoral composite goods are
 15 substitutes, and if $\epsilon \leq 1$, the sectoral composite goods are complements.

16 The representative household maximizes his/her utility (3) subject to the following bud-
 17 get constraint in each period:

$$P_{ia}C_{ia} + P_{im}C_{im} + P_{is}C_{is} = w_i, \quad (4)$$

⁸We 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 .

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

4 2.3 Equilibrium

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

$$L_i = L_{is} + L_{im} + L_{ia}. \quad (5)$$

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

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

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

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

20 **Definition 1.** A competitive equilibrium is a sequence of goods and factor prices $\{P_{ia},$

1 $P_{im}, P_{is}, w_i\}_{i=1,2}$, allocations $\{L_{ia}, L_{im}, L_{is}, Q_{ia}, Q_{im}, Q_{is}, C_{ia}, C_{im}, C_{is}\}_{i=1,2}$, and trade
 2 shares $\{\pi_{ija}, \pi_{ijm}\}_{i,j=1,2}$, such that, given prices, the allocations solve the firms' maximiza-
 3 tion problems associated with technologies (1) and the household's maximization problem
 4 characterized by (3)–(4), and satisfy the market clearing conditions (5)–(6).

5 **3 How Trade Impacts Structural Change**

6 This section illustrates the mechanisms through which trade impacts the patterns of struc-
 7 tural change — sectoral labor shares — in an open economy. To deliver the results trans-
 8 parently, we abstract from intermediate input usage by assuming $\lambda_k = 1$ for all k . We
 9 compare the patterns of structural change in an open economy with those in a closed econ-
 10 omy, and highlight two channels—the expenditure and net export channels—through which
 11 trade impacts structural change.

12 **3.1 Structural Change in a Closed Economy**

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

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

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

19 The feasibility conditions imply that the sectoral labor share equals the sectoral expen-

1 diture share.⁹ For each sector $k \in \{a, m, s\}$, we have:

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

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

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

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

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

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

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

⁹The 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.

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 $\frac{A_{im}}{A_{jm}/\tau_{ijm}} > \frac{A_{ia}}{A_{ja}/\tau_{ija}}$. Our definition is thus the traditional definition augmented by trade costs.¹⁰ The comparative advantage patterns determine intra-sector trade patterns. If country 1 has a comparative advantage in manufacturing, equation (2) implies that $\pi_{11m} > \pi_{11a}$. Intuitively, a greater share of spending is on domestic goods in the comparative advantage sector.

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

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

Comparing equation (10) to (7), one can see that $\frac{P_{ik}}{w_i} < \frac{P_{ik}^c}{w_i^c}$ because $\pi_{iik} < 1$. The lower is the sectoral expenditure share on domestic goods, the lower is the sectoral price. Trade essentially allows countries to enlarge their effective technologies in the tradable sectors, thus leading to lower prices, especially in the comparative disadvantage sector. The aggregate price level relative to the wage rate $\frac{P_i}{w_i}$ is also lower in the open economy than in autarky, which is consistent with the well known result from classical trade theory that there are gains from trade.¹¹

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

¹⁰Hence, it is possible for a country to have a relative disadvantage in manufacturing from the productivities alone, but, owing to sufficiently small manufacturing trade costs, an overall comparative advantage in manufacturing. See Deardorff (2004) for further discussion on the topic of comparative advantage in the presence of trade costs. In this section, we restrict our attention to cases in which one country has a comparative advantage in 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.

¹¹ $\frac{P_i}{w_i}$ is the reciprocal of the real wage or the real purchasing power of each country's income.

1 discussed above, and also its impact on income.

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

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

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

7 Three forces determine country 1's labor share in sector k . First, it depends on the expendi-
8 ture share of each country on sector k goods, X_{1k} and X_{2k} . It also depends on the extent of
9 specialization, π_{11k} and π_{21k} . Finally, it depends on the relative size of the two economies.

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

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

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

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

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

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

3 **3.2.1 The Net Export Channel**

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

14 Assume that country 1 (2) has a comparative advantage in manufacturing (agriculture).
15 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
16 expenditure share is ω_k in both countries. The pattern of comparative advantage implies
17 $\pi_{21m} > \pi_{21a}$ and $\pi_{12m} < \pi_{12a}$. If country 1 ran a trade deficit in the manufacturing sector, it
18 cannot run a trade deficit in the agriculture sector, otherwise it would violate the balanced
19 trade condition. Hence, it must be the case that $NX_{1m} > 0$ and $NX_{1a} < 0$.¹²

20 We describe two scenarios in which the presence of trade can generate a hump-shaped
21 pattern in the manufacturing employment share. In the first scenario, a country with a
22 comparative advantage in manufacturing experiences both relative and absolute productiv-
23 ity growth in manufacturing over time. Because of the relative productivity growth, the
24 country's manufacturing labor share rises initially as it supplies an increasing share of world
25 demand for manufacturing products. As time passes, the continuing increase in absolute pro-

¹²This result can also be established for CES preferences and free trade.

1 ductivity implies that, despite the increasing net export surplus, fewer workers are needed
2 to produce the manufactured goods. Eventually, the latter effect dominates, and the manu-
3 facturing labor share declines.¹³

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

13 **3.2.2 Adding The Expenditure Channel**

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

19 Equation (8) also shows that when the substitution elasticity differs from one, relative
20 prices impact the expenditure shares. Focusing on the Baumol case, $\epsilon < 1$, in both countries,
21 $\frac{P_{is}}{P_i}$ is higher in the open economy; hence, the services expenditure share and labor share
22 are higher in the open economy. For the sector in which country i has a comparative
23 disadvantage, its price relative to the aggregate price is lower, and its expenditure share is
24 lower in the open economy.¹⁴ Suppose manufacturing has the highest productivity growth;

¹³The conditions under which productivity growth is sufficiently high are available in the Appendix.

¹⁴In the comparative advantage sector, the sectoral relative price may or may not be lower in the open economy, hence, the effect of trade on the expenditure share cannot be signed.

1 then, the expenditure channel would imply a declining manufacturing labor share. For the
2 model to generate a rising manufacturing labor share, the net export channel needs to be
3 sufficiently strong initially to more than offset the expenditure channel. However, as in the
4 unitary elasticity case, over time, the net export channel diminishes, and the expenditure
5 channel begins to dominate, leading to declining manufacturing labor shares.

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

17 **4 Quantitative Analysis**

18 We now employ our model to quantitatively analyze the importance of openness in South
19 Korea's structural change between 1971 and 2005. As Figure 1 shows, Korean experienced
20 substantial structural change during this 35-year period. The agriculture labor share declined
21 sharply and essentially monotonically from 0.48 to 0.09, and the services labor share rose
22 sharply and essentially monotonically from 0.40 to 0.73. In addition, the manufacturing
23 labor share displayed the hump-shaped pattern: rising from 0.13 in 1971 to 0.27 by 1989
24 and then declining to 0.17 by 2005. Explaining these dynamics over time is the challenge
25 posed to our model. The first subsection discusses how we calibrate the model. The second

1 subsection presents simulation results of our model, including counterfactuals designed to
2 assess the relative importance of the two main shocks in our model, changes in trade costs
3 and in TFP, as well as the importance of two key transmission channels, the open economy
4 and non-homothetic preferences.

5 4.1 Calibration

6 We calibrate our two-country model with South Korea as one country and the rest of the
7 world (ROW) as the other country. The ROW consists of most of South Korea's (hereafter,
8 Korea) important trading partners in this period, and includes the G7 countries, other OECD
9 countries, and several oil-producing countries in the Middle East and Latin America. These
10 countries accounted for, on average, two-thirds of Korea's trade during this time period.
11 Some countries were excluded because of data availability issues or because they were not
12 important in Korea's trade.¹⁵ The list of countries is given in the Appendix.

13 We now describe our calibration of the preference parameters $\{\omega_j, \bar{C}_j, \epsilon\}$ and the produc-
14 tion parameters $\{\lambda_j, \gamma_{jk}, \theta\}$. These parameters are assumed to be identical across countries
15 and time invariant. Consistent with recent estimates by Simonovska and Waugh (2011), we
16 set $\theta = 4$. The other parameters are calibrated to Korean data. Much of the literature
17 (e.g. Duarte and Restuccia 2010 and Herrendorf, Rogerson, and Valeninyi 2012) focuses on
18 estimating \bar{C}_a and \bar{C}_s . Following this convention, we set $\bar{C}_m = 0$, which essentially implies
19 that manufacturing's income elasticity of demand is close to one. Consistent with this as-
20 sumption, we change the assignment of consumption of food, beverages, and tobacco from
21 the manufacturing sector to the agriculture sector.¹⁶

22 For the preference parameters, we appeal to restrictions imposed by the intratemporal
23 Euler equations governing sectoral consumption expenditure. Using the language of Herren-

¹⁵Notably, China is excluded owing to lack of data, especially in the 1970s and 1980s. We discuss the possible role of China in the conclusion.

¹⁶We 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.

1 dorf, Rogerson, and Valentinyi (HRY, 2012), we adopt the final consumption expenditure
 2 approach, which arises naturally from our model with intermediate inputs. We employ
 3 time-series data on Korean aggregate consumption expenditure $\{P_t C_t\}$, sectoral consump-
 4 tion 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
 5 minimizing the sum of squared deviations between the actual sectoral expenditure shares
 6 and the model-implied sectoral expenditure share given the observed sectoral prices and
 7 aggregate consumption expenditure:¹⁷

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

8 subject to the constraints $\sum_j \omega_j = 1$. This is also the estimating equation used in HRY. The
 9 estimated values (along with the other parameters) are reported in Table 1. The elasticity
 10 of substitution across sectors is 0.75, and the subsistence parameter of the agriculture goods
 11 is positive. The estimate for the services sector consumption parameter \bar{C}_s is nearly 0.¹⁸

12 Turning to the production parameters, we use all input-output tables for Korea available
 13 in our sample period.¹⁹ Specifically, the value added share λ_j and the matrix of intermediate
 14 input linkages γ_{jk} are computed directly from the input-output tables. We take a simple
 15 average across the tables, and report these values in Table 1.

16 We now describe the calibration of the time-varying exogenous variables and shocks. The
 17 primary exogenous variables are total labor in both Korea and the ROW. These variables
 18 are taken directly from the data; the appendix provides the data sources. The labor force
 19 grew at an average annual rate of 2.5 percent in Korea and 1.1 percent in the ROW over

¹⁷See 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.

¹⁸The 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.

¹⁹The list of years is given in the Appendix.

1 our sample period. The procedure for calibrating the productivity shocks and trade costs
 2 shocks for each sector, country, and year has three key parts. The first part involves the
 3 calibration of the initial year, 1971. As our main goal is to assess the importance of openness
 4 in explaining Korea’s structural change over time, we calibrate the initial productivity and
 5 trade cost levels — three sectoral productivities and two sectoral trade costs in each country
 6 — to match the ROW and Korea’s sectoral labor shares and sectoral trade shares in 1971.²⁰
 7 Because two sectoral labor shares automatically imply the third, we need two additional
 8 targets. We choose Korea’s per capita income relative to the ROW in 1971, and Korea’s
 9 agricultural subsistence expenditure as a share of total consumption expenditure. Table 1
 10 provides the values of our targets.

11 The second part involves the calibration of the productivity shocks after the initial period.
 12 These shocks are constructed using the initial period sectoral productivity levels computed
 13 above, and sectoral productivity growth rates, which are constructed in two main steps.²¹
 14 The first step arises from the fact that real sectoral gross output data do not exist for
 15 a number of the countries that comprise the ROW. Annual input-output tables are also
 16 lacking. Consequently, the usual approach of constructing (gross output) productivities
 17 directly from the gross output production function cannot be performed. Instead, we use
 18 the model to derive the sectoral value-added production function, and we compute sectoral
 19 value-added productivity. Owing to the Cobb-Douglas functional form, the sectoral value-
 20 added productivity is $A_{ik}^{\frac{1}{\lambda_k}}$, where A_{ik} is gross output productivity for country i and sector
 21 k . The second step arises from Waugh (2010) and Finicelli, Pagano and Sbracia (hereafter,
 22 FPS 2012), among others, who have shown that productivities computed in an open economy
 23 setting capture at least two forces, the fundamental productivity of firms within the country
 24 under autarky, and the additional productivity occurring from specialization in an open

²⁰The sectoral import shares are Korea’s sectoral imports from the ROW as a fraction of Korea’s sectoral absorption. The sectoral export shares are Korea’s sectoral exports to the ROW also expressed as a fraction of Korea’s sectoral absorption.

²¹Further details on the construction of the productivities and the data sources are provided in the Appendix.

1 economy (trade selection). We need to compute the fundamental productivity. FPS derive
2 a formula for adjusting the usual productivity measure for the specialization component to
3 yield the fundamental productivity. We apply that formula, which yields our final estimates
4 of sectoral gross output productivity or TFP. We calculate the growth rates of the sectoral
5 TFPs and apply them to the initial period to get the sectoral TFP levels for 1972 onwards.²²

6 The logged sectoral TFPs are shown in Figure 2. In the initial period, the ROW has
7 higher TFP levels in all three sectors. The average TFP growth rates are 1.8 percent in
8 agriculture, 2.2 percent in manufacturing, and 1.7 percent in services in Korea, and 1.2
9 percent in agriculture, 0.84 percent in manufacturing and 0.60 percent in services in the
10 ROW. The average TFP growth rates are higher in Korea than in the ROW for all three
11 sectors. Also, the manufacturing sector has the fastest TFP growth rate among the three
12 sectors in Korea.

13 The third part involves calibrating the trade costs over time after the initial period. It is
14 well known that the standard trade models can explain existing international trade flows only
15 if unobserved trade costs, i.e., costs other than tariff barriers and transportation costs, are a
16 multiple of observed trade costs. This is true under a wide range of elasticities of demand and
17 substitution. Consequently, as our focus is on whether the model can explain the dynamics
18 of Korea's labor shares, we calibrate the four sectoral trade costs to match the observed trade
19 flows between Korea and the ROW over time: Korea's export and import shares with the
20 ROW in manufacturing and agriculture. We solve for the trade costs jointly with solving the
21 model. We interpret the model-implied trade costs as capturing transportation costs, tariffs,
22 and any other costs that impede international trade.²³ The calibrated trade costs are shown
23 in Figure 3, together with Korean sectoral import and export shares. The figure shows that
24 trade costs from the ROW to Korea in both agriculture and manufacturing changed little
25 over time, while trade costs from Korea to the ROW declined substantially. Panels (b) and

²²Our 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.

²³To the extent there is model misspecification and measurement error, it will show up in the trade costs.

1 (c) of Figure 3 show that the model does a good job of recovering the actual time path of
2 the trade shares.²⁴

3 **4.1.1 Calibration of Closed Economy Version of Model**

4 As we showed in section 3, openness operates as a transmission channel in at least two ways.
5 First, openness via shocks to trade costs over time affect the evolution of structural change.
6 Second, TFP shocks affect the economy differently in an open setting compared to a closed
7 setting. To assess the quantitative effect of openness, we compare our results in an open
8 economy setting with those in a closed economy setting in which the economy is subject
9 to TFP shocks only. Our calibration of the closed economy is identical to that of the open
10 economy except for the TFP shocks. For the initial period, we use a closed economy version
11 of our model to calibrate, for Korea, three initial TFP levels to match two sectoral labor
12 shares and agriculture subsistence expenditure as a share of total consumption expenditure
13 in 1971. The TFP levels for subsequent years are computed in the same way as in the open
14 economy model, but without the adjustment for trade selection. Our computations imply
15 that Korea's average TFP growth rates for agriculture, manufacturing, and services are 2.2
16 percent, 2.2 percent, and 1.7 percent, respectively.²⁵

17 **4.2 Quantitative Results**

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

²⁴It is not a perfect fit, because the model assumes balanced trade.

²⁵The difference between the open and closed economy TFP growth rates stems from the evolution of π_{ii} over time. In particular, as discussed in the Appendix, if π_{ii} is increasing over time, as it is in agriculture, then the growth rate of the (fundamental) open economy TFP will be lower than the growth rate of the closed economy TFP.

1 costs over time.

2 **4.2.1 Main Results**

3 We first simulate the effects of the TFP shocks and trade cost shocks in our benchmark
4 model. The implied sectoral labor shares are given in the blue dashed line in each panel
5 of Figure 4. The red solid line shows the actual sectoral labor share. The model is able to
6 capture the evolution of the agriculture and services labor shares over almost the entire time
7 period. The model generates a decline in the agriculture labor share of slightly more than the
8 actual decline, and an increase in the services labor share of about 85 percent of the actual
9 rise in the services labor share. Turning to manufacturing, the model is able to generate an
10 increase in the manufacturing labor share of 0.13 to 0.24 — close to the actual peak share of
11 0.27 — in the first half of the time period. However, subsequently the implied manufacturing
12 labor share stays relatively flat, instead of declining as it does in the data. Hence, the model
13 is able to replicate only the rising part of the hump-shaped pattern. Overall, the fit of our
14 benchmark model is quite good, although it is not able to capture the declining part of
15 Korea’s manufacturing hump pattern.

16 To assess the importance of openness, we also simulate the model under a closed economy
17 in which there are only TFP shocks. The model’s implications for Korea’s sectoral labor
18 shares are shown as the gray dotted lines in Figure 4. Panels (a) and (c) show that the
19 closed economy model also generates a substantial decline in the agricultural labor share
20 and a substantial increase in the services labor share. However, the magnitudes of the
21 changes are smaller than in the benchmark model. The closed economy model explains only
22 62 percent of the actual decline in the agriculture labor share and about 67 percent of the
23 actual increase in the services labor share. In terms of manufacturing, as panel (b) of Figure
24 4 shows, the model does not come close to generating either side of the hump. Rather, it
25 generates only a slight increase over time.²⁶

²⁶Duarte 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

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

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

19 In an open economy, three additional forces lead to a larger response in the two tradable
20 sectors, agriculture and manufacturing. First, the patterns of initial TFP and trade costs
21 suggest that Korea had a comparative advantage in manufacturing; moreover, Korea’s man-
22 ufacturing TFP grew at a faster rate than agriculture’s TFP. Second, the trade costs facing
23 Korea’s exporters declined over time, and more rapidly in manufacturing than in agriculture.
24 Korea’s comparative advantage in manufacturing becomes more “revealed”, thus leading to
25 more specialization and labor in manufacturing, and less in agriculture. The first force, in

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.

1 conjunction with a sectoral elasticity of substitution less than one, and the second force are
2 evidently sufficient to generate a rise in the manufacturing labor share. Essentially, Korea
3 is able to employ more workers in manufacturing, because expanding export markets more
4 than offset the declining need for labor to satisfy domestic demand. The opposite is true
5 for agriculture, leading to a decline in its share. The third force is that trade leads to faster
6 economic growth in Korea. Real income rises by a factor of eight in the open economy; it
7 rises by a factor of seven in the closed economy. The faster growth of real income strengthens
8 the non-homothetic preferences channel and leads to a larger decline in the agriculture labor
9 share and a larger rise in the services labor share.

10 The combination of all three forces leads to a significantly larger increase in the manu-
11 facturing labor share (more than 10 percentage points), a significantly larger decrease in the
12 agriculture labor share (about 15 percentage points), and a larger increase in the services la-
13 bor share (about 6 percentage points), than in the closed economy model. All three changes
14 lead to a closer fit of the open economy model to the data.

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

1 4.2.2 The Role of TFP Shocks versus Trade Cost Shocks

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

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

23 The green dashed line in Figure 7 illustrates the results of the second experiment. The
24 benchmark model results and the closed economy results are shown with the blue dashed
25 line and the gray line, respectively. All three panels show that TFP shocks contribute sig-
26 nificantly to structural change. Note that the closed economy results indicate that TFP
27 shocks exert a large effect on agriculture and services, but a small effect on manufacturing.

1 The figure also shows that for manufacturing and agriculture, TFP shocks exert quanti-
2 tatively significant effects in an open economy, as captured by the gap between the green
3 and gray lines.²⁷ In particular, agriculture’s labor share falls by more, and manufacturing’s
4 labor share rises by more than in the closed economy. The services labor share is about
5 the same.²⁸ Thus, variation in each set of shocks is quantitatively significant in explaining
6 Korea’s structural change over time. TFP shocks matter more than trade cost shocks for ser-
7 vices and agriculture, while both shocks are quantitatively important for manufacturing and
8 agriculture. Moreover, for both shocks, trade serves as an effective transmission mechanism
9 that enables the open economy to outperform the closed economy.

10 **4.2.3 The Role of Non-homothetic Preferences**

11 The above simulations and experiments were all conducted under non-homothetic prefer-
12 ences. These preferences are widely thought to be the most important transmission mecha-
13 nism for structural change; however, underlying much of this thinking is an assumption of a
14 closed economy setting. We now examine the importance of non-homothetic preferences in
15 our open economy setting. To do so, we set \bar{C}_a to zero, which makes preferences homoth-
16 etic. The sectoral trade costs and TFPs are recalibrated in the same way as the benchmark
17 calibration for both the open and closed economy models.²⁹

18 The blue dashed line in figure 8 plots the model-implied sectoral labor shares under
19 homothetic preferences. The panels show that even under these preferences, openness plays
20 a key role: the agriculture labor share falls by more than 20 percentage points, while the

²⁷Part of the gap is because the TFP shocks themselves are different, as described above, and part is because they operate differently in an open economy.

²⁸Our assumption that services goods are non-traded implies that trade matters for this sector to the extent that relative prices and incomes change owing to the changing patterns of specialization. These forces do affect services, although to a lesser extent than the change in income arising from TFP growth.

²⁹Homothetic 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.

1 manufacturing labor share rises by almost 20 percentage points. On the other hand, services
2 changes by little. However, compared to the benchmark results in Figure 4, we can see that
3 for each sector the fit is worse under homothetic preferences, especially for services and also
4 for agriculture. Manufacturing is little affected by the nature of the preferences. The RMSEs
5 are 0.147, 0.049, and 0.170 for agriculture, manufacturing and services, respectively. The
6 overall RMSE is 0.122, as shown in Table 2. This exercise shows that leaving out the income
7 effects induced by non-homothetic preferences significantly reduces the explanatory power
8 of the model in explaining Korea's structural change.³⁰

9 Table 2 provides a crude assessment of the relative importance of non-homothetic pref-
10 erences and the open economy. The closed economy model with homothetic preferences has
11 a RMSE of 0.176, as stated above. The open economy with non-homothetic preferences has
12 an RMSE of 0.053. Inspection of the table suggests that about 1/3 of the improvement in
13 RMSE is because of the open economy and 2/3 is because of non-homothetic preferences.

14 5 Conclusion

15 Our main contribution is a quantitative assessment of the role of international trade in
16 structural change. We employ a three-sector, two-country model with non-unitary income
17 and substitution elasticities, and intermediate goods, and with sector-biased, time-varying
18 productivity and trade cost shocks. We calibrate our framework to investigate South Korea's
19 structural change between 1971 and 2005. The benchmark model accounts for virtually the
20 entire evolution of labor shares in agriculture and services, as well as the rising part of the
21 hump-shape in manufacturing. The root mean square error of the closed economy version of
22 the model is 60 percent higher than that of the benchmark model. Clearly, openness plays

³⁰In the closed economy, illustrated by the gray dashed line, there is almost no structural change. This result can be understood using Equation (9). 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 explaining Korea's structural change.

1 an indispensable role in Korea’s structural change.

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

8 While our calibrated model can quantitatively explain the rising portion of Korea’s hump-
9 shape in manufacturing, it does not explain the declining portion of the hump. In our
10 view, the key missing country from the calibrated model is China. Over the past twenty
11 years, China has opened up to international trade and trade volumes have surged. In 1991,
12 Korea’s and China’s exports to the world were about the same, about 72 billion dollars.
13 Over the next 14 years, China’s exports grew by more than an order of magnitude to about
14 750 billion dollars, while Korea’s grew only four-fold. China experienced manufacturing
15 productivity growth and lower trade costs that enabled it to essentially take market share
16 in manufacturing from Korea. Thus, including China as a third country would help explain
17 the declining portion of Korea’s hump.³¹ However, as discussed earlier, for China, good data
18 do not exist before 1980, and in some cases, prior to 1990. Finding a way to include China
19 is an exercise that we leave for future work.

³¹Our 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 and Calibration Targets

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			
Initial Period Calibration Targets							
					Data	Model	
					0.48	0.48	
					0.13	0.13	
					0.51	0.54	
					0.16	0.16	
					0.23	0.23	
					5.90	7.00	
					0.12	0.04	
					0.26	0.26	
					0.02	0.09	
					0.16	0.16	

Table 2: Model Performance: RMSE

	Non-homothetic Preferences	Homothetic Preferences
Open economy	0.053	0.122
Closed economy	0.083	0.176

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

Figure 1: Korean Structural Change

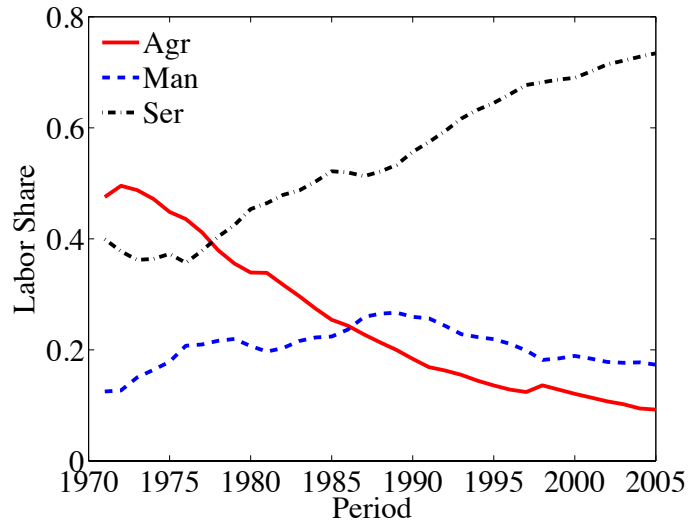


Figure 2: Calibrated TFP Series

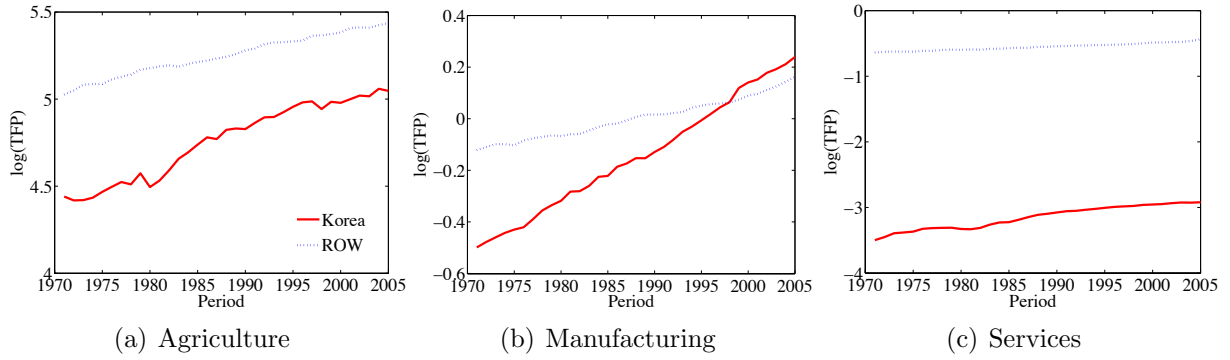


Figure 3: Calibrated Trade Costs and Korean Trade Shares

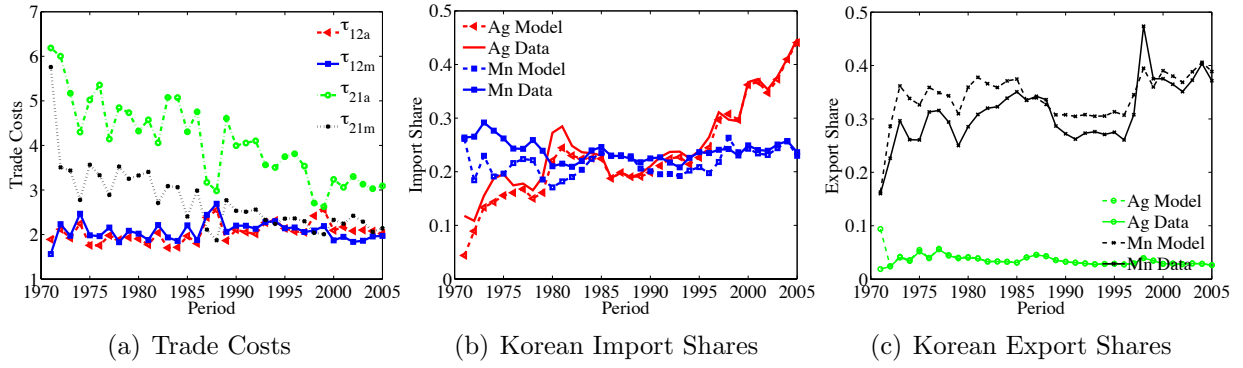


Figure 4: Korean Structural Change: Benchmark

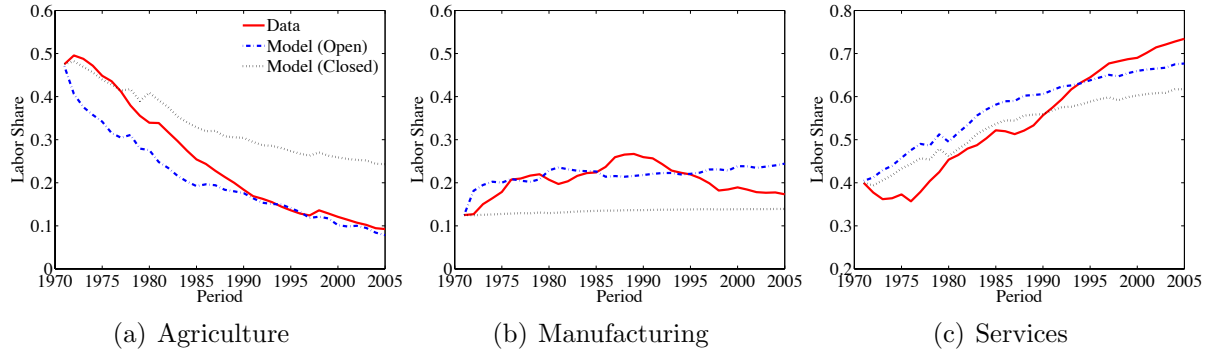


Figure 5: Korean Output Shares: Benchmark

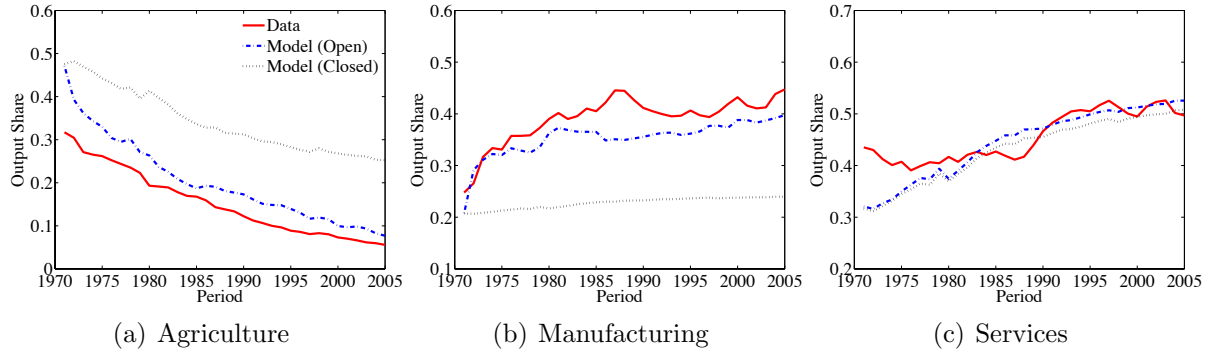
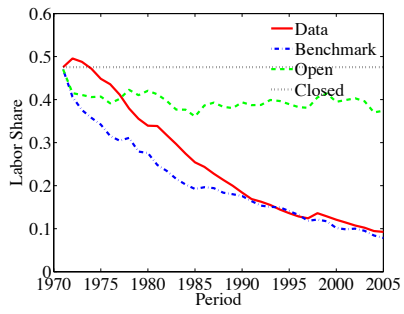
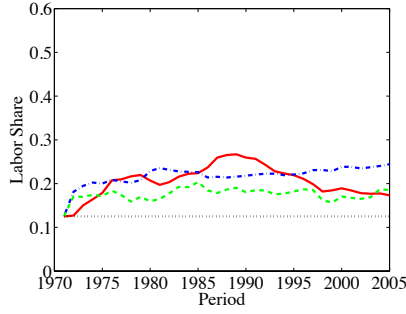


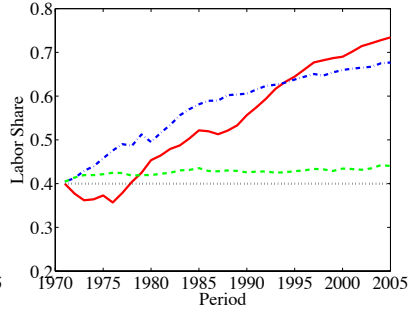
Figure 6: Korean Structural Change: Constant TFPs



(a) Agriculture



(b) Manufacturing



(c) Services

Figure 7: Korean Structural Change: Constant Trade Costs

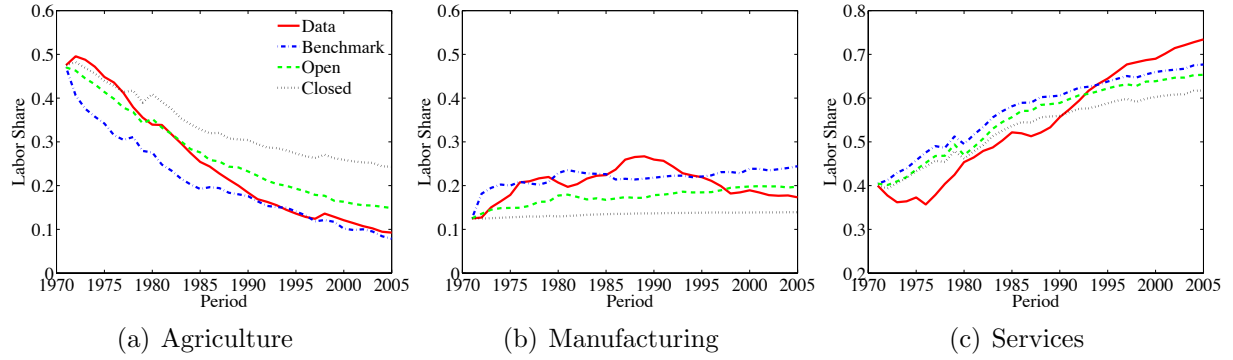
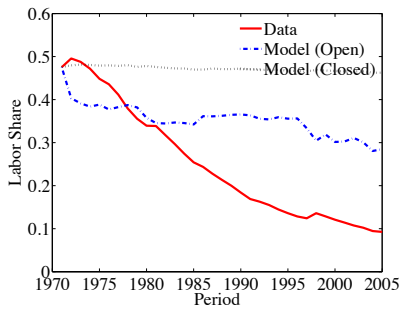
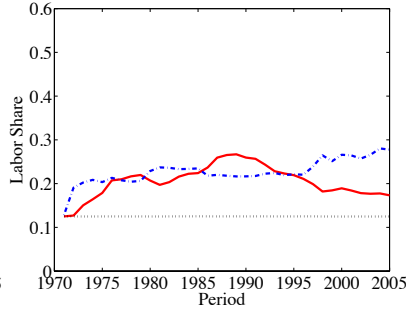


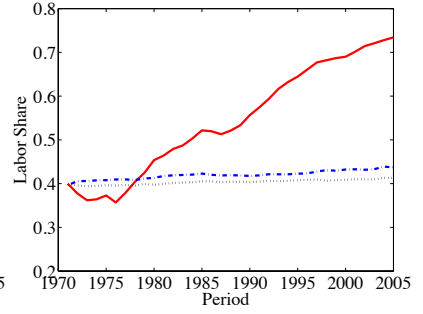
Figure 8: Korean Structural Change: Homothetic Preferences



(a) Agriculture



(b) Manufacturing



(c) Services

Appendix

Countries, Sample Period, and Sectors

The 26 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. All the countries but South Korea make up the rest of the world (ROW). Our data covers the period 1971–2005.³²

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, transport, government, financial, professional, and personal services such as education, health care, and real estate services).³³

Sectoral Employment Share

Our sectoral employment data comes from two data sources, the EU KLEMS database, and the GGDC 10-sector database (Timmer and de Vries, 2008).³⁴ 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 employed, 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 the 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),³⁵ 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 $L_i \times l_{\text{VEN},k}$.

For each sector, the sectoral employment share l_{ik} for country i is defined as the ratio of sectoral employment L_{ik} to total employment L_i . Total employment in a country is the sum across sectors of sectoral employment. We normalize total employment in each country by dividing by the U.S. population in 1971. ROW sectoral and total employment is

³²For a few series, not all countries are included in the data due to limited availability.

³³In 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.

³⁴See <http://www.euklems.net/> and <http://www.rug.nl/feb/onderzoek/onderzoekscentra/ggdc/data/10sector>.

³⁵http://pwt.econ.upenn.edu/php_site/pwt_index.php

the sum across all countries of each country’s sectoral employment and total employment, respectively.

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. In particular, we put FBT into the agriculture sector.

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.³⁶ The nominal exchange rate used to convert Korea’s output in local currency to dollars is the variable “xrat” 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 summarizes 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 . The 3×3 matrix $\{\gamma_{kn}\}$ is the use intensity of sector n goods in producing sector k goods, with $\sum_{n=a,m,s} \gamma_{kn} = 1$. We calculate these parameters for every available input-output table and then take the sample mean. The values of the parameters are reported in Table 1.

³⁶Table 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 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 limitations, 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 the 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:

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

Abstracting from the continuum of goods and working with sectoral aggregates gives:

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

The first order condition gives the demand for intermediate goods:

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

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

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

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

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

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 would exist under autarky. To recover the fundamental TFP from the measured TFP, we follow 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 $F_{ik}(T_{ik}, \theta)$. Fundamental TFP is the unconditional

mean of Z_{ik} , given by:

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

We denote the measured TFP for tradable sector k in an open economy setting by \tilde{A}_{ik} , the average productivity conditional on the good being produced by country i . Proposition 5 of FPS shows that trade shares serve as a link between fundamental TFP and measured TFP in an open economy setting. Specifically,

$$A_{ik} = \pi_{iik}^{1/\theta} \tilde{A}_{ik}.$$

π_{iik} is the sectoral domestic absorption ratio. Autarky, where $\pi_{iik} = 1$, is a special case in which the fundamental TFP and measured TFP coincide.

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:

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

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 sectoral employment series has been discussed above. We now focus on sectoral real value-added in 2000 U.S. dollars, which is constructed in three major steps. 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 Tornqvist indexes. We also use an appropriate PPP exchange rate to convert real value added in the national 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.³⁷ 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. 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_{xkt}^{2005} and VA_{xkt}^{2000} denote real value added of the same subsector at chained 2005 and 2000 prices, respectively. Because we choose 2000 to be the base year, the following holds:

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

³⁷The data is available for download from the Bank of Korea [ecos.bok.or.kr/10.NationalAccounts/10.4SupportingTables/10.4.1.3GDPandGNIbyKindofEconomicActivity\(atcurrentprices,quarterly&annual\)and10.4.1.4GDPandGNIbyKindofEconomicActivity\(atchained2005yearprices,quarterly&annual\)](http://ecos.bok.or.kr/10.NationalAccounts/10.4SupportingTables/10.4.1.3GDPandGNIbyKindofEconomicActivity(atcurrentprices,quarterly&annual)and10.4.1.4GDPandGNIbyKindofEconomicActivity(atchained2005yearprices,quarterly&annual)).

where X_k is the set of subsectors within sector k .³⁸ Using Laspeyres indices, the growth rate of sectoral value added at chained 2000 prices is given by:

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

For years prior to 2000, we iterate backwards, and for years after 2000, we iterate forwards.

We then convert sectoral real value added from Korean 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.³⁹ The PPP for sector k at year 2000 is given by

$$PPP_{k2000} = PPP_{k2005} \left(\frac{VA_{SKk2005}^{2000}}{VA_{SKk2005}} \right) \left(\frac{VA_{USk2005}}{VA_{USk2005}^{2000}} \right).$$

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

$$RVA_{SKkt}^{2000 \text{ USD}} = \frac{VA_{SKkt}^{2000} / PPP_{k2000}}{L_{SKkt}}.$$

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.⁴⁰ First, we compute relative price $IPD_{xkt} = \frac{VA_{xkt}}{VA_{xkt}^{2005}}$, for all subsectors $x \in X_k$ within sector $k \in \{a, m, s\}$. Next, we calculate Fischer Indexes (FI) for each sector k at year t , which is given by:

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

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

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

³⁸The aggregation here is standard, following the ISIC rev. 3 definition of sectors, and FBT is included in agriculture.

³⁹This 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. The corresponding PWT v7.0 PPP number is virtually identical.

⁴⁰We 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 Price Indexes (2005=100, 1947-2009).

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

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

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.⁴¹ 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:

$$\frac{VA_{\text{FBT } 2000} * QI_{\text{FBT } 1977} / QI_{\text{FBT } 2000}}{VA_{m2000} * QI_{m1977} / QI_{m2000}}.$$

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 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. Aggregating employment is straight-forward. For sectoral real value added, the EU KLEMS database is the primary source for 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 in 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 indexes (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:

1. The subsector weight is $\alpha_{xkt} = \frac{VA_{xkt} + VA_{xkt+1}}{\sum_{x \in X_k} VA_{xkt} + VA_{xkt+1}}$ for each subsector $x \in X_k$.
2. The subsector quantity index (QI) growth rate is $\log \left(\frac{QI_{xt+1}}{QI_{xt}} \right)$ for each subsector x .
3. The sector QI growth rate is $\Delta QI_{kt} = \sum_{x \in X_k} \alpha_{xkt} \log \left(\frac{QI_{xt+1}}{QI_{xt}} \right)$ for each sector k .
4. For each sector k , $QI_{k1995} = 100$, and QI_{kt} can be solved successively using $\log QI_{kt} = \log QI_{kt-1} + \Delta QI_{kt-1}$.
5. Real sectoral value added at constant 2000 USD: set $VA_{kt}^{2000 \text{ USD}} = VA_{k2000}$. Using the growth rate of sectoral value added implied by the quantity indexes, we can iterate forward and backward to solve for sectoral value added in 2000 U.S. dollars for every year. In particular,

$$\frac{VA_{kt}^{2000 \text{ USD}}}{VA_{kt+1}^{2000 \text{ USD}}} = \frac{QI_{kt}}{QI_{kt+1}}.$$

⁴¹We obtain these two series from table "1947-97 GDPbyInd.VA.NAICS.xls" at http://www.bea.gov/industry/gdpbyind_data.htm

The UN National Accounts Main Aggregates Database is the primary source for the oil countries, including Iran, Iraq, Kuwait, Mexico, Saudi Arabia, and Venezuela.⁴² 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 $VA_{kt}^{2000} = VA_{kt}^{2005} \frac{VA_{k2000}}{VA_{k2005}}$.⁴³

The final step is to sum up sectoral real value added in 2000 U.S. dollars and sectoral employment across countries in the ROW. 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 π_{ikk} . We now discuss how we construct π_{ikk} for South Korea and the rest of the world. For South Korea, we compute the ratio using the same trade flows and gross output data series discussed in above. 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 as for South Korea's trade shares. 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 1971-1976.⁴⁴ The EU KLEMS database is the primary source for Australia, Austria, Belgium, Canada, Denmark, Spain, Finland, France, Germany, Greece, Ireland, Italy, Japan, Luxembourg, the Netherlands, Portugal, Sweden, and the United Kingdom.⁴⁵ For the oil countries, OECD STAN is the primary source for Mexico.⁴⁶ The Venezuela national accounts is the primary source for Venezuela.⁴⁷ The UN National Accounts database is the source for Kuwait.⁴⁸ 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 are in the national currency, we convert it into U.S. dollars using nominal exchange rates from PWT 7.0. 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.⁴⁹ 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.

⁴²The data is available for download at <http://unstats.un.org/unsd/snaama/selbasicFast.asp>. We use both "Value Added by Economic Activity, at current prices - US dollars" and "Value Added by Economic Activity, at constant 2005 prices - US dollars".

⁴³Since 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.

⁴⁴http://www.bea.gov/industry/gdpbyind_data.htm and <http://www.worldklems.net/data/index.htm>.

⁴⁵<http://www.euklems.net/>.

⁴⁶<http://stats.oecd.org/Index.aspx?DatasetCode=STAN08BIS>.

⁴⁷<http://www.bcv.org.ve/cuadros/series/series.asp>.

⁴⁸<http://unstats.un.org/unsd/snaama/selbasicFast.asp>.

⁴⁹Gross output for FBT is not available 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.

Preference Parameters

We now discuss the construction of time-series data for Korean aggregate consumption expenditure $\{P_t C_t\}$, sectoral consumption expenditure shares $\{s_{kt}\}$ and sectoral prices $\{P_{kt}\}$ that are used to estimate the preference parameters $\{\epsilon, \omega_a, \omega_m, \omega_s, \bar{C}_a, \bar{C}_s\}$.

The OECD national accounts database is the primary source for final consumption expenditures data.⁵⁰ The data are available in both current prices and 2000 prices, denominated in national currencies. We first aggregate both these series into our three broad sectors. The definition of the three broad sectors for final consumption expenditure follows the Classification of Individual Consumption According to Purpose (COICOP). Agriculture corresponds to P31CP010 (Food and non-alcoholic beverages) and P31CP020 (Alcoholic beverages, 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).

The above aggregation procedure yields time-series for sectoral consumption expenditure in both current and 2000 prices (local currency units), denoted by $\{\hat{C}_{kt}, \hat{c}_{kt}\}_{k=a,m,s}$. Then, we compute the sectoral consumption share s_{kt} as

$$s_{kt} = \frac{\hat{C}_{kt}}{\sum_{k=a,m,s} \hat{C}_{kt}}.$$

We then compute aggregate consumption expenditure per capita in current U.S. dollars $\{C_t\}$ by dividing nominal total consumption expenditure by population and the PPP for private consumption.⁵¹

$$P_t C_t = \frac{\sum_{k=a,m,s} \hat{C}_{kt}}{\text{POP}_t \text{PPP}_t}.$$

Finally, to compute sectoral relative prices P_{kt} in U.S. dollars, we make the appropriate PPP adjustment to relative prices in terms of national currency,

$$P_{kt} = \frac{\hat{C}_{kt}}{\text{PPP}_t} / \frac{\hat{c}_{kt}}{\text{PPP}_{2000}}.$$

Armed with these time series, we proceed to minimize the squared distance between the model-implied consumption expenditure shares and their counterparts in the data, as described in the text. To this end, we first perform a grid search before using the estimates obtained with this method as the initial guess for a minimization routine that employs a quasi-newton method. The grid is constructed so as to ensure that model-implied sectoral consumption is positive. The final estimates obtained with the quasi-newton method do not differ greatly from the estimates using the grid search, though there is a slight improvement

⁵⁰Table 5.Final consumption expenditure of households under Annual National Accounts/ Detailed Tables and Simplified Accounts. <http://stats.oecd.org/Index.aspx?QueryId=9189>.

⁵¹Table Population under “Demography and Population”, <http://stats.oecd.org/Index.aspx?QueryId=9189> Transaction “PPP/PRC: Purchasing Power Parities for private consumption” in Table 4. PPPs and Exchange Rates, under “Prices and Purchasing Power Parities”, <http://stats.oecd.org/Index.aspx?QueryId=9189>.

in the overall loss. These are the estimates used to calibrate the preference parameters.

Subsistence Share

The subsistence share is used to calibrate the initial period parameters and exogenous variables in 1971. Recall that we calibrated the minimum per-capita consumption requirements in agriculture and services, \bar{C}_a and \bar{C}_s , to be $\bar{C}_a = 696.03$ and $\bar{C}_s = 0$, (measured in 2000 U.S. dollars). We define the agriculture subsistence share as

$$\frac{\text{Agr. relative price} \times \bar{C}_a}{\text{Total final consumption expenditure per capita}} = \frac{P_{a1}\bar{C}_a}{P_1C_1}$$

where P_{a1} and C_1 are the aforementioned relative price of agriculture and total consumption expenditure in the first period.

Relative Income

We compute the income per capita of the ROW relative to South Korea in 1971 as a calibration target for the initial period estimation in the open economy. Relative income is constructed using historical real GDP data from the International Macroeconomic Data Set.⁵² Both GDP and GDP per capita are reported in 2005 U.S. dollars for every country in our sample. For the 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 the ROW. Our calculation yields a ratio of 5.9 between real GDP per capita of the ROW and South Korea in 1971.

Conditions under which Manufacturing Productivity Growth Leads to a Hump Pattern

Recall that in this scenario there are unit income and substitution elasticities of demand. (Preferences are homothetic and Cobb-Douglas across sectoral composite goods). Assume that labor supply is constant in both countries. From the balanced-trade condition, the equilibrium wage ratio $w_t = \frac{w_{1t}}{w_{2t}}$ solves:

$$[\omega_m\pi_{21mt} + \omega_a\pi_{21at}] \frac{w_t L_1 + L_2}{w_t L_1} = \omega_a + \omega_m. \quad (12)$$

Totally differentiating equation (12), we have

$$\frac{\omega_m\pi_{21mt}\hat{\pi}_{21mt} + \omega_a\pi_{21at}\hat{\pi}_{21at}}{\omega_m\pi_{21mt} + \omega_a\pi_{21at}} - \frac{L_2}{w_t L_1 + L_2} \hat{w}_t = 0,$$

⁵²<http://www.ers.usda.gov/data-products/international-macroeconomic-data-set.aspx>

where $\hat{\pi}_{21mt} = \theta\pi_{12mt}(\hat{A}_m - \hat{w}_t)$ and $\hat{\pi}_{21at} = \theta\pi_{12at}(\hat{A}_a - \hat{w}_t)$. Solving for \hat{w}_t yields:

$$\hat{w}_t = \frac{\psi_{mt}\hat{A}_m + \psi_{at}\hat{A}_a}{\psi_{lt} + \psi_{mt} + \psi_{at}},$$

where $\psi_{lt} = \frac{L_2}{w_t L_1 + L_2}$, $\psi_{mt} = \frac{\theta\omega_m\pi_{12mt}\pi_{21mt}}{\omega_m\pi_{21mt} + \omega_a\pi_{21at}}$, and $\psi_{at} = \frac{\theta\omega_a\pi_{12at}\pi_{21at}}{\omega_m\pi_{21mt} + \omega_a\pi_{21at}}$. Since \hat{A}_a and \hat{A}_m are both positive, we have \hat{w}_t is positive, which implies that the relative size of country 1 in the world economy keeps rising.

The manufacturing labor share in country 1 is given by $l_{1mt} = \omega_m\pi_{21mt} \left[\frac{w_t L_1 + L_2}{w_t L_1} \right]$. Again totally differentiating, we have:

$$\hat{l}_{1mt} = -\frac{L_2}{w_t L_1 + L_2}\hat{w}_t + \hat{\pi}_{21mt} = -\left[\frac{L_2}{w_t L_1 + L_2} + \theta\pi_{12mt} \right] \hat{w}_t + \theta\pi_{12mt}\hat{A}_m.$$

We then plug in the equation for \hat{w}_t and simplify. The necessary and sufficient condition for $\hat{l}_{1mt} > 0$ is:

$$\hat{A}_m > \hat{A}_a \frac{L_2\pi_{12at} + \theta(w_t L_1 + L_2)\pi_{12at}\pi_{12mt}}{L_2\pi_{12mt} + \theta(w_t L_1 + L_2)\pi_{12at}\pi_{12mt}} \equiv \hat{A}_a \xi_t, \quad (13)$$

where $\xi_t > 1$, because $\pi_{12at} > \pi_{12mt}$ under the pattern of comparative advantage.

Under the assumption that initially \hat{A}_m and \hat{A}_a satisfy equation (13), $\hat{l}_{1mt} > 0$, i.e., the manufacturing labor share in country 1 initially rises over time. It also implies that $\hat{A}_m > \hat{A}_a$ given that $\xi_t > 1$. Moreover, $\hat{\pi}_{12mt} = \theta\pi_{21mt}(\hat{w}_t - \hat{A}_m) = -\frac{\theta\pi_{21mt}(\hat{A}_m\phi_{lt} + \phi_{at}(\hat{A}_m - \hat{A}_a))}{\psi_{lt} + \psi_{mt} + \psi_{at}} < 0$. Thus, π_{12mt} declines over time to zero, or π_{21mt} rises over time to one.

When π_{21mt} approaches one over time, l_{1mt} starts to decline because $l_{1mt} = \omega_m\pi_{21mt} \left[\frac{w_t L_1 + L_2}{w_t L_1} \right]$ and $\frac{w_t L_1 + L_2}{w_t L_1}$ always declines over time. This completes the characterization of the hump pattern of l_{1mt} . *Q.E.D.*