# Trade, Reform, and Structural Transformation in South Korea

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A two country, three sector hybrid model of structural change with distortionary government policies is used to quantify the impact of international trade and trade reform for industrialization. The model features Armington motivated trade in agriculture and industry, and a novel representation of trade reform as a time sequence of import tariffs, export subsidies and lump sum government transfers of net tariff revenue. We calibrate our economy to data on South Korea and the OECD, inputting time series of country and sector specific labor productivity, tariffs and export subsidies which determine evolution of the effective pattern of comparative advantage. The model's predicted reallocations of Korean labor from agriculture into industry and services from 1963 through 2000 are quantitatively similar to those in the data. Incorporating trade and measured Korean trade reform are both important for the accuracy of this predicted structural change, although international real income differences under non-homothetic preferences primarily determine trade and specialization patterns rather than comparative advantage. Counterfactually eliminating a) international trade b) international labor productivity differentials c) post 1967 Korean tariff reform and d) post 1967 industrial export subsidy reform increase the model's SSE by 91 percent, 56 percent, 27 percent, and 62 percent respectively.

**JEL Codes**: F13, F14, F43, O14, O41

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# 1 Introduction

Increased international trade, export promotion and trade reform policies, have been coincident with massive changes in the structure as well as the size of the South Korean economy since 1963. Similar observations can be made about the modern industrialization experiences of several Asian economies, most recently that of China. Yet most quantitative models of structural change which evolved to account for the observed decline in the employment share of agriculture and rise in that of industry during a country's economic development assume that the economy in question is closed and are silent on the importance of international trade and trade reform for shifts in the composition of employment and production across sectors. In this paper, we develop a quantitative two-country, three sector model to a) characterize analytically the role of international trade and trade policies for changes in the composition of employment and production across sectors, and b) measure the importance of trade and trade policies for observed structural change in a series of experiments in which the model is calibrated to data from South Korea and the OECD.

In closed economy investigations of structural change reallocations of employment and production across sectors are driven by two key features.[1] Provided goods are complements resources are allocated out of sectors with the fastest productivity growth and into sectors with the slowest productivity growth.[2] One class of models emphasizes this role of differential productivity growth across sectors for structural transformation, and assumes that consumer preferences are homothetic (Baumol (1967), Ngai and Pissarides (2007), and Acemoglu and Guerrieri (2008) are examples). A second class of models emphasizes the role of non-homothetic consumer preferences in driving reallocations of resources across sectors. Non-homothetic preferences imply that the income elasticity of demand is unequal across goods (and non-unitary) and reallocations of resources across sectors result from income expansion, even when productivity growth is equal across sectors (see Caselli and Coleman II

[1] Herrendorf et al. (Forthcominga) provide a comprehensive survey of the literature.

[2] Verma (2012) is an example of structural transformation when final goods of different sectors are substitutes.

(2001) and Gollin et al. (2002)). Other investigations, for example Rogerson (2008), employ a hybrid approach; uneven productivity growth across sectors coupled with non-homothetic preferences generates resource reallocations.

Quantitative research employing these models suggests that non-homothetic preferences are required to produce a sufficiently large movement of resources out of agriculture, while uneven productivity growth contributes substantively to explaining observed reallocations from industry to services observed in the later stages of development. Nonetheless, Buera and Kaboski (2009) argue that not even a hybrid closed economy model can quantitatively account for US de-industrialization observed in the last two decades. Further, Matsuyama (2009) argues that international trade may help account for diverse structural transformation experiences in a broader cross section of countries. In mature economies such as Germany and Japan, and also in some smaller emerging countries such as Hong-Kong, and Taiwan, relatively rapid growth in measured manufacturing productivity has not produced a declining employment share of the sector. Matsuyama argues that relatively fast productivity growth in the manufacturing sector may shift comparative advantage in its favor, increasing its net exports, so that the net effect for its domestic employment share can be ambiguous or even positive.

In this paper, we qualitatively and quantitatively examine the role of international trade and trade policies for re-allocations of employment and production in a three-sector, two-country hybrid model of structural change with labor as the only factor of production. We characterize the three sectors as agriculture, industry and services. An infinitely lived representative household consumes a composite of the three sectors' final goods and supplies labor inelastically; labor is perfectly mobile across sectors, but internationally immobile.

Perfectly competitive final good producers in each sector aggregate in Armington fashion domestically produced and imported varieties of that sector's good. Perfectly competitive firms in each sector employ domestic labor in a linear production function to produce each country's variety of the sector's good, and exogenously determined labor productivity varies over time, sectors and countries. Armington weights on domestic and imported varieties in final good production, which are sector and country specific, are assumed to be "deep" parameters, originating from technological, geographical, and psychological real costs of trade not otherwise explicitly modeled. We assume that prohibitively high trade costs for service varieties preclude trade, and nor is there any trade in final goods.

We explicitly account for how the evolution of trade policies affects the relative prices of varieties confronted by final good producers and consumer income. Specifically, a government in each country offers proportional price subsidies to foreign final good producers importing domestic varieties, and imposes proportional tariffs on domestic final good producers importing foreign varieties. Tariff income net of subsidy payments of each government is rebated to consumers as a lump-sum transfer. Tariff and subsidy rates can vary over time, sectors and countries. The ratio of relative international labor productivities across sectors dictates the pattern of comparative advantage, which is distorted by tariff and subsidy rates. However, the pattern of inter-industry trade and specialization is also influenced by the static pattern of Armington weights across countries and sectors, and relative importance of subsistence consumption of agriculture across countries.

We compute the competitive equilibrium of our two-country world economy, which - because of the presence of distortionary tariffs and subsidies - is not Pareto efficient in general, and provide an analytical characterization of a sector's employment and GDP share. We calibrate the model to data from South Korea and the OECD over the period 1963 through 2000 when the bulk of Korean trade reform occurred and the OECD accounted for a substantial 68 percent of South Korean exports and 71 percent of South Korean imports annually on average. We carefully calibrate the crucial determinants of the international pattern of trade and specialization as follows: the Armington weights are matched to an observed sample average of expenditure on domestic and imported goods for each traded good sector and country; the subsistence level of agricultural consumption is calibrated to match the initial employment share of agriculture observed in Korea; and we construct and input Korean and OECD time-series of sector-specific labor productivity, export subsidy and tariff rates. The employment and GDP share of a sector are identical in our model, owing to Ricardian production of varieties. We quantify the fit of the model's predicted structural transformation by focusing on its ability to match the sectoral employment shares observed in South Korea.

The model's predicted shares of employment by sector are comparable to those observed in the data. The model closely matches the observed decline in the employment share of agriculture in Korea; the predicted decline from 0.63 to 0.08 is just 3 percentage points more than the observed decline from 0.63 to 0.11. The model also does a reasonable job of matching the observed growth in the employment share of Korean industry, predicting an increase from 0.21 to 0.32 which is 7 percentage points less than the observed increase from 0.11 to 0.29. And the model's predicted growth in services' employment share from 0.15 to 0.60 over-predicts by 11 percentage points the observed increase from 0.25 to 0.61. The correlations of actual and predicted employment shares are high and positive, ranging from 0.76 for industry to 0.96 for agriculture. The model fails to reproduce the downward portion of the "hump-shape" in industry's share of employment witnessed in South Korea, however. Empirically, the share reached a peak of 0.36 in 1991 and fell to 0.29 by 2000. In the model, only the rate of increase in industry's employment share declines after 1991. And, we find that the pattern of trade in our benchmark model involves Korean trade surpluses (deficits) in industry (agriculture) throughout the sample. This is determined by the interaction of international real income disparity with non-homothetic preferences rather than by the pattern of comparative advantage for most of the period.

We conduct counter-factual experiments to answer two, quantitative questions. 1. How important is international trade in the model's accounting for structural transformation in South Korea? 2. How important is trade reform, measured by the time series evolution of tariffs and subsidies, in the model's accounting for structural transformation in South Korea?

First, we compare the performance of our benchmark open economy model to a counterfactual variant in which the Korean economy is closed to international trade. The total sum of squared prediction errors (SSE) of the closed economy is 91 percent higher than that of the open economy. Second, we quantify the importance of evolution in the pattern of comparative cost advantage by counterfactually letting OECD labor productivity by sector be equal at every date to that in South Korea. Notably, this implies that there is little relative income per capita growth in Korea either so the differences in sectoral allocations between this and the closed economy primarily reflect the impact of trade policies. The SSE of this counterfactual model is 56 percent higher than that of the benchmark economy. In both experiments, abstraction from measured trade patterns and resulting specialization results in a counterfactually low rate of labor reallocation from agriculture into industry. However, the specialization induced by trade is also responsible for the benchmark model's failure to produce a downward portion of the hump-shape in industry's employment share; each counterfactual model predicts a small decline after 1996.

To quantify the importance of Korean trade reform for structural change we assume that a) tariffs and b) industrial export subsidies in South Korea were counterfactually held at their 1967 rates throughout the period 1968 to 2000. 1968 is the date which Sachs and Warner (1995) identify with the initiation of trade reform in Korea. Abstracting from tariff reform results in a quantitatively important deterioration of the model's performance; the SSE rises by 27 percent. From 1968 until 1983, labor fails to move from agriculture into industry at the rate observed in the data and benchmark economy, and subsequently labor is reallocated from industry into services at a counterfactually high rate. The muting of industrialization results from the inter-temporal pattern of tariff reform by sector. In 1967 tariffs on agricultural products are higher than on industrial products but in 1968 there is substantial tariff reform in agriculture. Hence in our counterfactual experiment, we artificially preserve a small, tariff derived edge in effective comparative advantage of Korean agriculture relative to industry, which is eradicated in the benchmark model in 1968. Abstracting from industrial tariff reform in 1983 in the counterfactual exacerbates the reallocation of labor from industry to services.

We also abstract from export subsidy reform in industry, counterfactually holding subsidies on Korean industrial exports constant at their 1967 rates and allowing subsidies to agriculture and tariffs in both sectors and countries to evolve as in the benchmark economy. Awarding a counterfactually high subsidy rate to Korean industry for much of the sample distorts the pattern of comparative advantage in its favor, and deteriorates Korea's terms of trade, relative to the benchmark economy. As a result, there is excessive re-allocation of labor into industry from agriculture after 1971, when measured industrial subsidies peak in the benchmark economy and data and especially after 1980, when subsidies awarded to agricultural exports are eliminated completely. The smaller increase in government transfers after 1980 relative to our benchmark model also produces a smaller reallocation of labor from industry to services. The performance of the model deteriorates markedly; the SSE increases by 62 percent relative to the benchmark economy. Accounting for export subsidy reform in the industrial sector is important for limiting the magnitude of industrialization that the model produces relative to the data. Improved measures of agricultural subsidies are needed for an evaluation of subsidy reform in that sector, however; in the absence of comprehensive data on agricultural subsidies, we are forced to input the Korean industrial subsidy series for both sectors in our benchmark economy.

Our framework precludes endogenous labor productivity responses to trade reform policies and we likely underestimate the quantitative impact of trade reform for structural transformation as a result. Nevertheless, the merit and novelty of our modeling of trade reform as a sequence of sector-specific tariffs, subsidies and associated government transfers, is that it permits independent analysis and quantification of how distortionary trade policies effect structural change. The closely related multi-sector open economy analyses of Sposi (2012), Teignier (2012), Ungor (2010), and Uy et al. (2011) all corroborate our finding that trade is quantitatively important for explaining sectorial resource reallocations. However, our work is unique in separately identifying the role of trade policies from that of non-distortionary trade costs and in emphasizing the role of non-homothetic preferences for trade, specialization, and structural transformation in South Korea.

Ungor (2010), for example, develops a very similar two-country, three sector open economy model and shows there is a substantial impact of trade with China and Chinese manufacturing productivity growth for de-industrialization in the United States. However, he neither models nor quantifies the role of trade costs or policies. Sposi (2012) focuses on explaining differences in export and output shares rather than on employment shares in his multi-country three sector model. His measurement of trade barriers includes tariffs as a policy-related component of trade costs, but Sposi abstracts from export subsidies, while tariff revenue melts in iceberg fashion and is non-distortionary. In his framework tariff changes are not quantitatively important in influencing structural change; by contrast we find that holding Korean tariffs at estimated pre-reform levels substantially diminishes the fit of our model.

Uy et al. (2011) emphasize the role of trade in generating the hump pattern seen in Korea's manufacturing sector employment and, like Sposi (2012), incorporate non-distortionary iceberg trade costs. However, they do not independently measure tariffs. "Turning off" their sector biased trade costs alters the pattern of comparative advantage and affects resource allocation, but is silent on the quantitative impact of trade reforms for structural transformation in Korea. Teignier (2012) argues that more rapid industrialization would have occurred in Korea had agricultural production subsidies from 1972, and agricultural tariffs, counter-factually been absent. However, his measurement of agricultural subsidies and tariffs is rather arbitrary and the experiments essentially numerical. His two sector model abstracts from all industrial trade policy reform.

We initiate our quantitative investigation of open economy structural change by reviewing the data on South Korea's trade reform and development experience.

## 2 Structural Change and Trade Reform in South Korea

Prior to 1963, South Korea was essentially a closed economy. From 1963, however, a variety of export incentive and promotion policies were enacted and rapid export growth ensued. Systematic reform, in the sense of reducing those incentives and the barriers to free trade at world prices they represent, occurred from roughly 1971 and the policies were completely phased out after 1980. In addition, extremely high barriers to imports in the 1950s and 1960s were systematically removed starting, in 1968, with selective quantitative barrier and tariff reductions for agricultural products. Substantial and comprehensive tariff reform for industrial and especially manufacturing products began only in 1979, with the largest manufacturing tariff declines occurring in 1983. Tariff reform continued through the last tariff rate reductions observed in our sample in 1994. [3]

Figures 1a and 1b show the evolution of Korean bilateral exports and imports by sector and in total with the OECD during the trade promotion and reform era that is our sample period, 1963 through 2000. The OECD accounted for 68 percent of South Korean exports and 71 percent of South Korean imports annually on average over this period. Unfortunately, accurate and complete service sector trade data is unavailable for Korea or the OECD for these years so the 'total' export and 'total' import trade measures in the figures comprise the sum of agricultural and industrial exports and imports. We believe that this is a minor omission, quantitatively.

The figures show that the export promotion and trade reform era in South Korea was associated with a dramatic increase in the size of, and shift in the composition of, its bilateral trade with the OECD. The size of total bilateral trade with the OECD increased by a factor of three over a 38 year period; from about 13 percent of Korean GDP in 1963 to roughly 40 percent in 2000, while the composition of this trade shifted heavily in favor of industrial exports and imports. Industrial sector exports, expressed as a share of GDP,

[3]We describe the composition and evolution of export promotion and tariff reform policies in detail in Appendix 1. In addition, all data sources for this section and elsewhere in the paper, and detail on construction of data series, are described in the Data Appendix (Appendix A).

rose from practically zero in 1963 to reach about 20 percent of GDP in 2000. Agricultural exports were trivial as a percentage of GDP throughout the sample period. Figure 1b shows a similar shift towards industrial relative to agricultural imports.

### 2.1 Growth

Figure 2a shows that Korean trade reform, and the three-fold increase in the size of South Korea's bilateral OECD trade, was accompanied by a dramatic rise in real living standards and labor productivity, measured by GDP per capita relative to the OECD. South Korea's real GDP per capita rose from about 12.5 percent of that in the OECD to roughly 43 percent, an increase of about 244 percent over the sample period. As shown in Figure 2b, this is driven by a more than 200 percent increase in relative value added per worker in the industrial sector, from about 23 percent to roughly 70 percent of that in the OECD. While Korean agriculture and service sectors also saw increases in relative value added per worker, these were dwarfed by that in the industrial sector. Notably, the data in Figure 2b show that there was a shift in the pattern of comparative advantage between South Korea and the OECD in favor of Korean industrial products after the mid-1970s, when relative industrial productivity in Korea begins to grow rapidly.

### 2.2 Structural Transformation

Figure 3 shows that South Korea's export promotion and trade reform era, trade growth and growth in relative income and labor productivity also coincided with substantial structural transformation of the economy as is typical for developing countries. Figure 3a shows the evolution of employment shares of the three major sectors of the economy, expressed as a percentage of total employment, and Figure 3b shows the evolution of GDP shares of the three sectors, expressed as a percentage of aggregate GDP.

A large decline in the employment and GDP share of agriculture and an increase in the employment and GDP share of the industrial and service sectors occurred between 1963 and 2000. Specifically, in 1963 agriculture accounted for 63 percent of South Korean employment, and 43 percent of GDP; by 2000, these shares had declined to 11 and 5 percent respectively.

By contrast, the employment and GDP shares of industry rose from 11 and 20 percent to 29 and 42 percent respectively, while those of the service sector rose from 25 and 36 percent to 61 and 53 percent. The industrial sector's employment share exhibits the "humped" shape that is highlighted in the literature on structural change, declining to 29 percent in 2000 after reaching a peak of 36 percent in 1991. GDP shares obviously evolve rather differently from employment shares, with services showing much less GDP than employment share growth, and industry greater growth. In the model that we develop employment and GDP shares of a sector are identical owing to Ricardian production, however. We focus on employment shares as our measure of structural change and calibrate the model accordingly.

This structural transformation of the South Korean economy is the object of our analysis. Specifically we seek to answer the questions: 1) To what extent was the structural transformation in South Korea attributable to her openness to international trade over the sample period 1963 through 2000, and to relative international labor productivity improvements? 2) To what extent was the structural transformation attributable to the specific trade reform policies adopted there? We now develop a quantitative model that, when calibrated to Korean and OECD data and simulated, can potentially answer these questions.

# 3 Model

## 3.1 The Environment

We consider a three sector, two country world economy. Each country is inhabited by an infinitely lived representative household with perfect foresight. Households derive utility from a composite final consumption bundle and supply labor in-elastically to production. Agents and countries are indexed by $i$, and we call the countries 'home' and 'foreign', so that $i$=$h$,$f$. Time is discrete and indexed by $t$.

Three types of final good enter the composite consumed by the household called "Agriculture", "Industry" and "Services". We index these by $k$, with $k$ =$A$,$I$,$S$. Each type of good is exclusively produced by a single sector within each country, so that sectors are also indexed by $k$=$A$,$I$,$S$. The sector $k$ final good of country $i$ is produced by combining in a constant returns to scale technology inputs of two varieties of good $k$; variety $i$ produced in country $i$ and variety $j$ produced in country $j \neq i$. Varieties are therefore traded internationally; however, final consumption goods once produced are not traded. We assume, for simplicity, that trade is balanced at every date which is approximately true of the year 2000 trade balance for industry and agriculture shown in Figure 1. We also assume that Service varieties are not traded, so that final good producers in the service sector of country $i$ simply supply variety $i$ to consumers.

Variety $i$ of good $k$ is produced in country $i$ using a simple Ricardian technology in which labor is the sole input. Labor productivity can differ by sector, country, and date and the infinite sequence of labor productivities of each sector in both countries is exogenous. Labor effort in variety production is mobile across sectors within country $i$, but immobile across countries.

There is a government in each country which imposes proportional taxes on imported units of each traded good, and rewards exports with proportional subsidies. Any net revenue (expenditure) is rebated (financed) via a lump sum transfer (tax) to (on) the representative household in that government's country.

### 3.2 Households

Household $i$ maximizes the lifetime utility function

$$\max \quad U^i(C_i) = \sum_{t=0}^{\infty} \beta^t \frac{C_{i,t}^{\psi} - 1}{\psi} \quad , \tag{3.1}$$

where $0 < \beta < 1$ is a subjective time discount factor and $C_{i,t}$ comprises a composite of the three types of final good.

$$C_{i,t} = \left(\xi_A \left(C_{i,t}^A - \bar{A}\right)^{\omega} + \xi_I \left(C_{i,t}^I\right)^{\omega} + \xi_S \left(C_{i,t}^S\right)^{\omega}\right)^{\frac{1}{\omega}} \quad . \tag{3.2}$$

Here, $C_{i,t}^A, C_{i,t}^I$ and $C_{i,t}^S$ are household $i$'s consumption of Agriculture, Industry, and Services respectively at date $t$, and $\bar{A}$ denotes subsistence consumption of Agriculture. In addition, $\xi_k$ is the weight assigned to consumption of final good type $k$, $\omega$ governs the elasticity of substitution between the three types of final good, and $\psi$ governs the elasticity of inter-temporal substitution. Preference parameters are assumed to be identical across countries.

Household $i$ maximizes lifetime utility (3.1) by choice of consumption subject to (3.2) and the budget constraint

$$\sum_k P_{i,t}^k C_{i,t}^k = w_{i,t} N_{i,t} + T_{i,t} \quad \forall\ t \quad , \tag{3.3}$$

where $P_{i,t}^k$ is the consumer price of final good $k$ (defined below in (3.7)), $w_{i,t}$ is the wage rate, $N_{i,t}$ is the household's endowment of labor time, and $T_{i,t}$ is the lump sum transfer from the government of country $i$ which may be positive or negative, depending on the relative size of tariff revenue and the cost of export subsidies. Without loss of generality, we let the foreign produced variety of industrial goods be the numeraire at every date.

## 3.3 Firms and Production

### 3.3.1 Varieties

A representative perfectly competitive firm in country $i$ produces the $i$th variety of good $k$ at date $t$ using a simple linear Ricardian technology:

$$y_{i,t}^k = \theta_{i,t}^k N_{i,t}^k \quad ,$$

where $\theta_{i,t}^k$ is the productivity of labor, $N_{i,t}^k$ the number of labor units employed, and $y_{i,t}^k$ the level of output. The representative variety $i$ producer in sector $k$ takes the prices of output and labor as given, and chooses employment to solve the profit maximization problem.

$$\begin{aligned} &\max \quad p_{i,t}^k y_{i,t}^k - w_{i,t} N_{i,t}^k \\ &\text{s.t.} \quad y_{i,t}^k = \theta_{i,t}^k N_{i,t}^k \text{ ,and } N_{i,t}^k \geq 0. \quad \text{for} i = h, f, \ k{=}A,I,S \text{ and } \forall\ t \end{aligned} \tag{3.4}$$

Here, $p_{i,t}^k$ is the producer price of variety $i$ of good type $k$ at date $t$.

### 3.3.2 Government

There is a government in each country which can choose taxes and subsidies subject to a balanced budget at every date. Government $i$, $i$=$h$,$f$, imposes a per unit tax - $\tau_{i,j,t}^k$ -

on units of variety $j \neq i$ for sector $k$=$A,I$, imported from abroad by domestic final good producers at date $t$. Government $i$ may also award subsidies for units of variety $i$ exported. It does so by reducing the unit price paid by producer $k$=$A,I$ in country $j \neq i$ for imports of variety $i$ by a proportionate factor $\frac{s^k_{i,j,t}}{1+s^k_{i,j,t}}$ which it pays directly to the exporting variety producer. The unit price paid by country $j \neq i$ importers for variety $i$ of good $k$ is therefore $\frac{p^k_{i,t}}{1+s^k_{i,j,t}}$. Country $j$ tariffs are levied on this value as goods cross the border.

While tariffs raise the price of imported varieties confronted by domestic final good producers, subsidies stimulate foreign demand for domestic varieties. We assume that the tariff revenue net of the cost of subsidies is rebated to the consumer in the form of a lump sum transfer so that the budget constraint of government $i$, $i \neq j$ is

$$T_{it} = \sum_k \tau^k_{i,j,t} \frac{p^k_{j,t}}{(1+s^k_{j,i,t})} y^k_{j,i,t} - \sum_k \frac{s^k_{i,j,t}}{(1+s^k_{i,j,t})} p^k_{i,t} y^k_{i,j,t} \text{ for } k = A, I, \ \forall\, t \quad . \tag{3.5}$$

Here $y^k_{j,i,t}$ is country $i$ imports of variety $j$ of good type $k$ and $y^k_{i,j,t}$ is country $i$ exports of variety $i$ to country $j$ of good $k$, $i \neq j$. The presence of distortionary taxes and subsidies means that the equilibria we analyze are not, in general, Pareto efficient.

### 3.3.3 Final Goods

A representative perfectly competitive firm in each sector $k$ of country $i \neq j$ produces final good $k$ by using the following production functions:

$$Y^k_{i,t} = \begin{cases} \left(\mu^k_i \left(y^k_{i,i,t}\right)^\rho + (1-\mu^k_i)\left(y^k_{j,i,t}\right)^\rho\right)^{1/\rho} & \textit{for } k\textit{=}A,I \quad , \\ y^k_{i,i,t} = y^k_{i,t} & \textit{for } k\textit{=}S \quad . \end{cases}$$

Here, $Y^k_{i,t}$ is total final output of good $k$, and $y^k_{i,i,t}$ and $y^k_{j,i,t}$ are domestic variety $i$ and imported variety $j$ inputs respectively. In addition, $\mu^k_i$ is the weight assigned to variety $i$ of good $k$, $(1-\mu^k_i)$ is the weight assigned to imported variety $j \neq i$ of good type $k$, and $\rho$ reflects the elasticity of substitution between locally produced and imported varieties. Following convention in the international trade literature, we assume that the domestic and foreign varieties are substitutes, or $0 < \rho < 1$. Since Service varieties are not traded and sold only domestically, $\mu_i^S = 1$ for $i$=$h$,$f$.

The values of $\mu_i^k$ and $\rho$ are exogenous determinants of final good producers' allocation of spending on local and imported varieties of inputs. We think of $\mu_i^k$ as a reduced form "home bias" parameter; it captures primitive technological and preference factors which encourage use of locally produced relative to imported varieties. These factors include all real costs of trade that are not explicitly modeled as domestic country tariffs or foreign country subsidies which discourage (encourage) imported variety use.

Final good producers of sector $k$ take prices as given, as well as the government policies that they confront, and solve the following profit maximization problem:

$$\max \quad P_{i,t}^k Y_{i,t}^k - p_{i,t}^k y_{i,i,t}^k - \frac{(1+\tau_{i,j,t}^k)}{(1+s_{j,i,t}^k)} p_{j,t}^k y_{j,i,t}$$
$$\text{s.t.} \quad Y_{i,t}^k = \left(\mu_i^k \left(y_{i,i,t}^k\right)^\rho + (1-\mu_i^k)\left(y_{j,i,t}^k\right)^\rho\right)^{1/\rho} \quad . \tag{3.6}$$

$P_{i,t}^k$ is the consumer price index for good $k$ and is given by

$$P_{i,t}^k = \left(\left(\mu_i^k\right)^{1/(1-\rho)}\left(p_{i,t}^k\right)^{\rho/(\rho-1)} + (1-\mu_i^k)^{1/(1-\rho)}\left(\frac{(1+\tau_{i,j,t}^k)}{(1+s_{j,i,t}^k)} p_{j,t}^k\right)^{\rho/(\rho-1)}\right)^{\frac{(\rho-1)}{\rho}} \tag{3.7}$$

Since $\mu_i^S = 1$, $P_{i,t}^S = p_{i,t}^S$ .

### 3.4 Equilibrium

A competitive equilibrium is an allocation $\{N_{i,t}, C_{i,t}, C_{i,t}^A, C_{i,t}^I, C_{i,t}^S\}_{t=0}^\infty$ for household $i$; an allocation $\{N_{i,t}^k, y_{i,t}^k\}_{t=0}^\infty$ for variety producer $i$ of sector $k$; an allocation $\{y_{i,i,t}^k, y_{j,i,t}^k, Y_{i,t}^k\}_{t=0}^\infty$ for final good producer $k$ in country $i$, $i \neq j$; prices $\{w_{i,t}, p_{i,t}^k, P_{i,t}^k\}_{t=0}^\infty$ for country $i$ and sector $k$; and exogenous government policies $\{\tau_{i,j,t}^k, s_{i,j,t}^k, T_{i,t}\}_{t=0}^\infty$ for $i = h, f$,$i \neq j$, and $k = A, I, S$; such that for $i = h, f$ and $k = A, I, S$,

(1) Given prices, household $i$'s allocation solves the maximization problem ((3.1)-(3.3));

(2) Given prices, variety $i$ producer's allocation solves the maximization problem (3.4) $\forall$ $t$;

(3) Given prices, final good $k$ producer's allocation solves the maximization problem (3.6) $\forall$ $t$;

(4) Prices are such that labor markets clear

$$\sum_k N_{i,t}^k = N_{i,t} \ \forall\ t \quad ,$$

variety markets clear

$$y_{i,t}^k = y_{i,i,t}^k + y_{i,j,t}^k \ , \text{ for } k = A, I \text{ and } \forall\ t \quad ,$$

$$y_{i,t}^k = y_{i,i,t}^k \ , \text{ for } k = S \text{ and } \forall\ t \quad ,$$

and final goods markets clear

$$Y_{i,t}^k = C_{i,t}^k \ \forall\ t \quad ;$$

(5) Government *i's* budget constraint is satisfied:

$$T_{it} = \sum_k \tau_{i,j,t}^k \frac{p_{j,t}^k}{(1 + s_{j,i,t}^k)} y_{j,i,t}^k - \sum_k \frac{s_{i,j,t}^k}{(1 + s_{i,j,t}^k)} p_{i,t}^k y_{i,j,t}^k \ \forall\ t \quad .$$

## 3.5 Analysis

### 3.5.1 Varieties

The first order conditions for the variety producer's profit maximization problem imply that labor is paid its marginal product if a variety is produced. In that event, the price of variety $i$ of the $k$th good at $t$ is just

$$p_{i,t}^k = \frac{w_{i,t}}{\theta_{i,t}^k} \tag{3.8}$$

and when all goods are produced in country $i$ their relative internal prices are simply the inverse of relative labor productivities:

$$\frac{p_{i,t}^A}{p_{i,t}^I} = \frac{\theta_{i,t}^I}{\theta_{i,t}^A} \text{ and } \frac{p_{i,t}^S}{p_{i,t}^I} = \frac{\theta_{i,t}^I}{\theta_{i,t}^S} \quad .$$

We focus on equilibria in which all three types of good are produced in each country, as we observe in the Korean and OECD data.

### 3.5.2 Final Goods

The first order conditions for profit maximization of final goods producer $k$ in country $i \neq j$ imply that the shares of expenditure on final good type $k$ in country $i$ accounted for by varieties $i$ and $j$ respectively are given by

$$Z^k_{i,i,t} = \frac{p^k_{i,t} y_{i,i,t}}{P^k_{i,t} Y^k_{i,t}} = \left(\mu^k_i\right)^{\frac{1}{1-\rho}} \left(\frac{p^k_{i,t}}{P^k_{i,t}}\right)^{\frac{\rho}{\rho-1}} \quad , \tag{3.9}$$

$$Z^k_{j,i,t} = \frac{\frac{(1+\tau^k_{i,j,t})}{(1+s^k_{j,i,t})} p^k_{j,t} y^k_{j,i,t}}{P^k_{i,t} Y^k_{i,t}} = \left(1-\mu^k_i\right)^{\frac{1}{1-\rho}} \left(\frac{\frac{(1+\tau^k_{i,j,t})}{(1+s^k_{j,i,t})} p^k_{j,t}}{P^k_{i,t}}\right)^{\frac{\rho}{\rho-1}} \quad . \tag{3.10}$$

For Services $Z^S_{j,i,t} = 0$. Finally, market clearing for final good $k$ implies that $P^k_{i,t} Y^k_{i,t} = P^k_{i,t} C^k_{i,t}$ for $i = h, f$ and $k = A, I, S \; \forall \; t$.

### 3.5.3 Households

The first order conditions for the household's intra-temporal problem combined with the budget constraint yield the size of expenditure on each type of good relative to the total final consumption expenditure.

$$E^k_{i,t} \equiv \frac{P^k_{i,t} C^k_{i,t}}{\Xi_{i,t}} = \begin{cases} \dfrac{\xi_k^{\frac{1}{1-\omega}} \left(P^k_{i,t}\right)^{\frac{\omega}{\omega-1}}}{\sum\limits_{m=\{A,I,S\}} \xi_m^{\frac{1}{1-\omega}} \left(P^m_{i,t}\right)^{\frac{\omega}{\omega-1}}} \left(1 - \frac{P^A_{i,t}\bar{A}}{\Xi_{i,t}}\right) + \frac{P^A_{i,t}\bar{A}}{\Xi_{i,t}} \; , & \text{if } k = A \\ \dfrac{\xi_k^{\frac{1}{1-\omega}} \left(P^k_{i,t}\right)^{\frac{\omega}{\omega-1}}}{\sum\limits_{m=\{A,I,S\}} \xi_m^{\frac{1}{1-\omega}} \left(P^m_{i,t}\right)^{\frac{\omega}{\omega-1}}} \left(1 - \frac{P^A_{i,t}\bar{A}}{\Xi_{i,t}}\right) \; , & \text{if } k = I, S \quad , \end{cases} \tag{3.11}$$

where $\Xi_{i,t} = \sum\limits_k P^k_{i,t} C^k_{i,t}$ is total final consumption expenditure.

### 3.5.4 World Equilibrium

The balanced trade or world payments equilibrium condition for our economy is derived from the consumer's budget constraint, and is, for country *i=h,f*, $i \neq j$

$$\sum_{k=A,I} \frac{1}{1+s^k_{i,j,t}} p^k_{i,t} y^k_{i,j,t} = \sum_{k=A,I} \frac{1}{1+s^k_{j,i,t}} p^k_{j,t} y^k_{j,i,t} \quad . \tag{3.12}$$

That is, once international government subsidy payments are accounted for, the effective world prices at which trade occurs between importing final good producers and exporting variety producers are producer prices adjusted for export subsidies.

### 3.5.5 Employment and GDP Structure

Value added (GDP) in country $i$ at any date $t$ is just the sum of the value of outputs of each sector's variety, $Y_{i,t} = \sum_k p^k_{i,t} y^k_{i,t}$. Profits are zero in equilibrium, and labor is the only production factor, so GDP is also measured by labor income at $t$, $Y_{i,t} = w_{i,t} \sum_k N^k_{i,t} = w_{i,t} N_{i,t}$ . Therefore, the GDP and employment share of sector are identical:

$$\frac{p^k_{i,t} y^k_{i,t}}{Y_{i,t}} = \frac{N^k_{i,t}}{N_{i,t}} \quad .\forall t \tag{3.13}$$

We now characterize the determinants of the economy's structure in terms of the employment and GDP shares of each sector $k$.

From the variety market clearing condition, the value added of variety $i$ output in sector $k$ equals the sum of the value of domestic consumption and exports, or

$$p^k_{i,t} y^k_{i,t} = p^k_{i,t} \left( y^k_{i,i,t} + y^k_{i,j,t} \right) \ \forall \ t \quad ,$$

where exports are zero for services. Dividing this by $w_{i,t} N_{i,t}$ and using (3.13) yields

$$\frac{p^k_{i,t} y^k_{i,t}}{Y_{i,t}} = \frac{N^k_{i,t}}{N_{i,t}} = \frac{p^k_{i,t} \left( y^k_{i,i,t} + y^k_{i,j,t} \right)}{w_{i,t} N_{i,t}} = \left( \frac{p^k_{i,t} y^k_{i,i,t}}{P^k_{i,t} Y^k_{i,t}} \right) \left( \frac{P^k_{i,t} Y^k_{i,t}}{w_{i,t} N_{i,t}} \right) + \left( \frac{p^k_{i,t} y^k_{i,j,t}}{P^k_{j,t} Y^k_{j,t}} \right) \left( \frac{P^k_{j,t} Y^k_{j,t}}{w_{i,t} N_{i,t}} \right)$$

Using (3.9), (3.10), (3.11), the final goods market clearing conditions, and the budget constraints of the households, we find the share of employment and GDP accounted for by sector $k$ at date $t$ as:

$$\frac{p^k_{i,t} y^k_{i,t}}{Y_{i,t}} = \frac{N^k_{i,t}}{N_{i,t}} = Z^k_{i,i,t} E^k_{i,t} \left( 1 + \frac{T_{it}}{w_{i,t} N_{i,t}} \right) + \left( \frac{1 + s^k_{i,j,t}}{1 + \tau^k_{j,i,t}} \right) Z^k_{i,j,t} E^k_{j,t} \left( 1 + \frac{T_{jt}}{w_{j,t} N_{j,t}} \right) \frac{w_{j,t} N_{j,t}}{w_{i,t} N_{i,t}}$$

Finally, substituting from (3.9) and (3.10) for the expenditure shares of final good producers in each country on variety $i$, and from (3.11) for consumption expenditure shares, we obtain the following expressions for the employment and GDP share of Agriculture,

$$V_{i,t}^{A} = \mu_i^{A\,\frac{1}{1-\rho}} \left(\frac{p_{i,t}^{A}}{P_{i,t}^{A}}\right)^{\frac{\rho}{\rho-1}} \left[\frac{\xi_A^{\frac{1}{1-\omega}} \left(P_{i,t}^{A}\right)^{\frac{\omega}{\omega-1}}}{\sum\limits_{m=\{A,I,S\}} \xi_m^{\frac{1}{1-\omega}} \left(P_{i,t}^{m}\right)^{\frac{\omega}{\omega-1}}} \left(1-\frac{P_{i,t}^{A}\bar{A}}{\Xi_{i,t}}\right) + \frac{P_{i,t}^{A}\bar{A}}{\Xi_{i,t}}\right] \left(1+\frac{T_{i,t}}{w_{i,t}N_{i,t}}\right)$$

$$+ (1-\mu_j^{A})^{\frac{1}{1-\rho}} \left(\frac{1+s_{i,j,t}^{A}}{1+\tau_{j,i,t}^{A}}\right)^{\frac{1}{1-\rho}} \left(\frac{p_{i,t}^{A}}{P_{j,t}^{A}}\right)^{\frac{\rho}{\rho-1}} \left[\frac{\xi_A^{\frac{1}{1-\omega}} \left(P_{j,t}^{A}\right)^{\frac{\omega}{\omega-1}}}{\sum\limits_{m=\{A,I,S\}} \xi_m^{\frac{1}{1-\omega}} \left(P_{j,t}^{m}\right)^{\frac{\omega}{\omega-1}}} \left(1-\frac{P_{j,t}^{A}\bar{A}}{\Xi_{j,t}}\right)\right.$$

$$\left. + \frac{P_{j,t}^{A}\bar{A}}{\Xi_{j,t}}\right] \left(1+\frac{T_{j,t}}{w_{j,t}N_{j,t}}\right) \frac{w_{j,t}N_{j,t}}{w_{i,t}N_{i,t}} \quad , \tag{3.14}$$

Industry,

$$V_{i,t}^{I} = \mu_i^{I\,\frac{1}{1-\rho}} \left(\frac{p_{i,t}^{I}}{P_{i,t}^{I}}\right)^{\frac{\rho}{\rho-1}} \frac{\xi_I^{\frac{1}{1-\omega}} \left(P_{i,t}^{I}\right)^{\frac{\omega}{\omega-1}}}{\sum\limits_{m=\{A,I,S\}} \xi_m^{\frac{1}{1-\omega}} \left(P_{i,t}^{m}\right)^{\frac{\omega}{\omega-1}}} \left(1-\frac{P_{i,t}^{A}\bar{A}}{\Xi_{i,t}}\right) \left(1+\frac{T_{i,t}}{w_{i,t}N_{i,t}}\right)$$

$$+ (1-\mu_j^{I})^{\frac{1}{1-\rho}} \left(\frac{1+s_{i,j,t}^{I}}{1+\tau_{j,i,t}^{I}}\right)^{\frac{1}{1-\rho}} \left(\frac{p_{i,t}^{I}}{P_{j,t}^{I}}\right)^{\frac{\rho}{\rho-1}} \frac{\xi_I^{\frac{1}{1-\omega}} \left(P_{j,t}^{I}\right)^{\frac{\omega}{\omega-1}}}{\sum\limits_{m=\{A,I,S\}} \xi_m^{\frac{1}{1-\omega}} \left(P_{j,t}^{m}\right)^{\frac{\omega}{\omega-1}}} \left(1-\frac{P_{j,t}^{A}\bar{A}}{\Xi_{j,t}}\right) \left(1\right.$$

$$\left. + \frac{T_{j,t}}{w_{j,t}N_{j,t}}\right) \frac{w_{j,t}N_{j,t}}{w_{i,t}N_{i,t}} \quad , \tag{3.15}$$

and Services

$$V_{i,t}^{S} = \frac{\xi_S^{\frac{1}{1-\omega}} \left(P_{i,t}^{S}\right)^{\frac{\omega}{\omega-1}}}{\sum\limits_{m=\{A,I,S\}} \xi_m^{\frac{1}{1-\omega}} \left(P_{i,t}^{m}\right)^{\frac{\omega}{\omega-1}}} \left(1-\frac{P_{i,t}^{A}\bar{A}}{\Xi_{i,t}}\right) \left(1+\frac{T_{i,t}}{w_{i,t}N_{i,t}}\right) \quad , \tag{3.16}$$

The first term on the right-hand side of equations (3.14) - (3.16) is what we call the "domestic effect" for a sector's GDP share; this is the share in GDP of domestic expenditure on the domestic variety of sector $k$=$A,I,S$. For Agriculture and Industry, the domestic effect is the product of the domestic variety's share of domestic final output in the sector

${\mu_i^k}^{\frac{1}{1-\rho}} \left(\frac{p_{i,t}^k}{P_{i,t}^k}\right)^{\frac{\rho}{\rho-1}}$ , and the domestic consumption expenditure share of the sector in GDP. For the Service sector, the domestic effect is simply the domestic consumption expenditure share of the sector in GDP which wholly constitutes its employment and GDP share. Although Services are not traded, their GDP share is influenced by international trade through the prices indices of traded goods relative to that of Services, and government transfers.

Analogously, the second term on the right-hand side of (3.14) and (3.15) captures the "foreign effect" for a sector's GDP share in country $i$. It is the domestic GDP share of exports of the sector, or the domestic GDP share of foreign country expenditure on the domestic variety of sector $k$. This is the product of the domestic variety's share of foreign final output in sector $k$, $(1-\mu_j^k)^{\frac{1}{1-\rho}} \left(\frac{1+s_{i,j,t}^k}{1+\tau_{j,i,t}^k}\right)^{\frac{1}{1-\rho}} \left(\frac{p_{i,t}^k}{P_{j,t}^k}\right)^{\frac{\rho}{\rho-1}}$ , and the foreign consumption expenditure share in domestic GDP of the sector.

### 3.5.6 Structural Change in the Open Economy

By structural change, we refer to (secular) change over time in the employment and GDP shares of sectors. Time variation in domestic and foreign variety $i$ expenditure shares results from relative price changes for Agriculture and Industry, and time variation in consumption expenditure shares results from relative price and income changes.

Using the definition of final good price indexes in (3.7) and the first order conditions of variety producers in (3.8) we re-write the domestic variety expenditure shares in country $i$ GDP of domestic and foreign final good producers, for $k$=$A$,$I$, and $i$=$h$,$f$ $i \neq j$, as

$$(\mu_i^k)^{\frac{1}{1-\rho}} \left(\frac{p_{i,t}^k}{P_{i,t}^k}\right)^{\frac{\rho}{\rho-1}} = \left[1 + \left(\frac{1-\mu_i^k}{\mu_i^k}\right)^{\frac{1}{1-\rho}} \left(\frac{(1+\tau_{i,j,t}^k)}{(1+s_{j,i,t}^k)} \frac{w_{j,t}}{w_{i,t}} \frac{\theta_{i,t}^k}{\theta_{j,t}^k}\right)^{\frac{\rho}{\rho-1}}\right]^{-1} , \tag{3.17}$$

$$(1-\mu_j^k)^{\frac{1}{1-\rho}} \left(\frac{1+s_{i,j,t}^k}{1+\tau_{j,i,t}^k}\right)^{\frac{1}{1-\rho}} \left(\frac{p_{i,t}^k}{P_{j,t}^k}\right)^{\frac{\rho}{\rho-1}} = \left(\frac{1+s_{i,j,t}^k}{1+\tau_{j,i,t}^k}\right) \left[1 + \left(\frac{\mu_j^k}{1-\mu_j^k}\right)^{\frac{1}{1-\rho}} \left(\frac{(1+s_{i,j,t}^k)}{(1+\tau_{j,i,t}^k)} \frac{w_{j,t}}{w_{i,t}} \frac{\theta_{i,t}^k}{\theta_{j,t}^k}\right)^{\frac{\rho}{\rho-1}}\right]^{-1} . \tag{3.18}$$

(3.17) and (3.18) are 1 and 0 for Services, respectively.

In (3.17), since we assume that foreign and domestic varieties are substitutes, $0 < \rho < 1$, if $\frac{(1+\tau^k_{i,j,t})}{(1+s^k_{j,i,t})}\frac{w_{j,t}}{w_{i,t}}\frac{\theta^k_{i,t}}{\theta^k_{j,t}}$ increases over time, the relative price of variety $i$ confronted by domestic final good $k$ producers falls relative to that of the foreign variety, and the share of sector $k$ in domestic GDP rises due to more intensive use of the domestic variety. This occurs when sector $k$ domestic tariff rates increase relative to foreign subsidy rates, when sector $k$ relative domestic labor productivity increases, and when the relative foreign wage rises. Similarly, in (3.18), increases in domestic subsidies relative to foreign tariffs, in relative domestic labor productivity and the relative foreign wage promote a lower relative price and more intensive use of the domestic variety abroad, and the share of sector $k$ in country $i$ rises as a result.

Finally, the higher is $\rho$ and hence the elasticity of substitution between domestic and imported varieties, the larger is the impact of changes in relative variety prices for sector $k$'s variety use and share of employment and GDP.

Relative prices of final goods are key determinants of domestic and foreign consumption expenditure shares of sector $k$ in country $i$ GDP. As (3.11) shows, an increase in the relative price of sector $k$'s final good $\frac{\xi_k^{\frac{1}{1-\omega}}\left(P^k_{i,t}\right)^{\frac{\omega}{\omega-1}}}{\sum_{m=\{A,I,S\}}\xi_m^{\frac{1}{1-\omega}}\left(P^m_{i,t}\right)^{\frac{\omega}{\omega-1}}}$ causes consumer $i$ to increase (decrease) the share of consumption expenditure on that good if final goods are complements (substitutes) or $\omega < (>) 0$ . Since the final price indexes of Agriculture and Industry are functions of the prices of varieties $i$ and $j$ confronted by final good producers, time variation in country and sector-specific productivity and trade policies are sources of expenditure switching by the domestic consumer, and (3.14) - (3.16) show how this changes the size of a sector's domestic effect. The same statements apply to expenditure switching by the foreign consumer, and the size of the foreign effect for Agriculture and Industry. Further, with non-homothetic consumer preferences, growth in income causes expenditure on Agriculture to fall relative to that of Industry and Services, as (3.11) shows. This can cause potentially large reallocations of employment and GDP from agriculture into Industry and Services and, as (3.14) - (3.16) show, in the open economy this mechanism affects both the domestic and export shares of sectors.

### 3.5.7 The Pattern of Trade and Comparative Advantage

In the model, intra-sector trade is exogenously motivated by Armington aggregation of varieties[4] and occurs irrespective of comparative advantage. Nevertheless, the pattern of comparative cost advantage affects the relative producer prices of varieties across sectors and countries, shares of expenditure on varieties by final good producers vary accordingly, and inter-industry trade can result.

However, heterogeneity of Armington weights and of tariffs and subsidies across sectors and countries, can distort variety expenditure shares and the pattern of trade from those induced by comparative advantage. Further, international relative subsistence consumption expenditure and relative international consumption expenditures on final goods in general, can powerfully influence inter-industry trade.

To see that comparative cost advantage need not dictate the pattern of trade, we use (3.14) - (3.15) to write the export (evaluated at world prices) to GDP ratio of sector $k$ as

$$X_{i,t}^k = \left(\frac{1}{1+\tau_{j,i,t}^k}\right)\left[1+\left(\frac{\mu_j^k}{1-\mu_j^k}\right)^{\frac{1}{1-\rho}}\left(\frac{\left(1+s_{i,j,t}^k\right)}{\left(1+\tau_{j,i,t}^k\right)}\frac{w_{j,t}}{w_{i,t}}\frac{\theta_{i,t}^k}{\theta_{j,t}^k}\right)^{\frac{\rho}{\rho-1}}\right]^{-1} E_{j,t}^k\left(1+\frac{T_{jt}}{w_{j,t}N_{j,t}}\right)\frac{w_{j,t}N_{j,t}}{w_{i,t}N_{i,t}} \quad . \tag{3.19}$$

and its import to GDP ratio as

$$M_{i,t}^k = \left(\frac{1}{1+\tau_{i,j,t}^k}\right)\left[1+\left(\frac{\mu_i^k}{1-\mu_i^k}\right)^{\frac{1}{1-\rho}}\left(\frac{\left(1+s_{j,i,t}^k\right)}{\left(1+\tau_{i,j,t}^k\right)}\frac{w_{i,t}}{w_{j,t}}\frac{\theta_{j,t}^k}{\theta_{i,t}^k}\right)^{\frac{\rho}{\rho-1}}\right]^{-1} E_{i,t}^k\left(1+\frac{T_{it}}{w_{i,t}N_{i,t}}\right) \quad . \tag{3.20}$$

From (3.19) and (3.20), the trade to GDP ratio for sector $k$ in country $i$ is $T_{i,t}^k = X_{i,t}^k + M_{i,t}^k$ , the trade to GDP ratio of country $i$ is $T_{i,t} = \sum_{k=A,I} T_{i,t}^k$ , and the trade balance of sector $k$ valued at world prices, is

$$TB_{i,t}^k = \left(X_{i,t}^k - M_{i,t}^k\right) w_{i,t}N_{i,t} \quad . \tag{3.21}$$

[4]This is the simplest and most parsimonious specification of openness that can accommodate the large intra-sector bilateral trade flows over the period 1963 to 2000 between South Korea and the OECD that we observe at the high level of aggregation we are studying.

World equilibrium requires that $\sum_{k=A,I} TB_{i,t}^{k} = 0$ for $i = h, f$ . A necessary and sufficient condition for sector $k$ to run a trade surplus (deficit) and sector $m \neq k$ to run a deficit (surplus) in equilibrium is that $X_{i,t}^{k}/M_{i,t}^{k} > (<) X_{i,t}^{m}/M_{i,t}^{m}$ or if, $x_{i,t}^{k} \equiv \left(\frac{X_{i,t}^{k}/M_{i,t}^{k}}{X_{i,t}^{m}/M_{i,t}^{m}}\right)$, $x_{i,t}^{k} > (<) 1$ . Specifically, let $k = A$ and $m = I$. Then

$$x_{i,t}^{A} = \Lambda_{i,t}^{A} \Gamma_{i,t}^{A} \Theta_{i,t}^{A} \quad , \tag{3.22}$$

where

$$\Lambda_{i,t}^{A} = \frac{\left(\frac{1+\tau_{i,j,t}^{A}}{1+\tau_{j,i,t}^{A}}\right)}{\left(\frac{1+\tau_{i,j,t}^{I}}{1+\tau_{j,i,t}^{I}}\right)} \quad , \quad \Gamma_{i,t}^{A} = \frac{\left(\frac{1+\left(\frac{\mu_i^A}{1-\mu_i^A}\right)^{\frac{1}{1-\rho}} \left(\frac{(1+s_{j,i,t}^{A})}{(1+\tau_{i,j,t}^{A})} \frac{w_{i,t}}{w_{j,t}} \frac{\theta_{j,t}^{A}}{\theta_{i,t}^{A}}\right)^{\frac{\rho}{\rho-1}}}{1+\left(\frac{\mu_j^A}{1-\mu_j^A}\right)^{\frac{1}{1-\rho}} \left(\frac{(1+s_{i,j,t}^{A})}{(1+\tau_{j,i,t}^{A})} \frac{w_{j,t}}{w_{i,t}} \frac{\theta_{i,t}^{A}}{\theta_{j,t}^{A}}\right)^{\frac{\rho}{\rho-1}}}\right)}{\left(\frac{1+\left(\frac{\mu_i^I}{1-\mu_i^I}\right)^{\frac{1}{1-\rho}} \left(\frac{(1+s_{j,i,t}^{I})}{(1+\tau_{i,j,t}^{I})} \frac{w_{i,t}}{w_{j,t}} \frac{\theta_{j,t}^{I}}{\theta_{i,t}^{I}}\right)^{\frac{\rho}{\rho-1}}}{1+\left(\frac{\mu_j^I}{1-\mu_j^I}\right)^{\frac{1}{1-\rho}} \left(\frac{(1+s_{i,j,t}^{I})}{(1+\tau_{j,i,t}^{I})} \frac{w_{j,t}}{w_{i,t}} \frac{\theta_{i,t}^{I}}{\theta_{j,t}^{I}}\right)^{\frac{\rho}{\rho-1}}}\right)} \quad ,$$

$$\text{and} \quad \Theta_{i,t}^{A} = \frac{\left(\frac{\frac{\xi_A^{\frac{1}{1-\omega}} \left(P_{j,t}^{A}\right)^{\frac{\omega}{\omega-1}}}{\sum_{m=\{A,I,S\}} \xi_m^{\frac{1}{1-\omega}} \left(P_{j,t}^{m}\right)^{\frac{\omega}{\omega-1}}} \left(1-\frac{P_{j,t}^{A}\bar{A}}{\Xi_{j,t}}\right)+\frac{P_{j,t}^{A}\bar{A}}{\Xi_{j,t}}}{\frac{\xi_A^{\frac{1}{1-\omega}} \left(P_{i,t}^{A}\right)^{\frac{\omega}{\omega-1}}}{\sum_{m=\{A,I,S\}} \xi_m^{\frac{1}{1-\omega}} \left(P_{i,t}^{m}\right)^{\frac{\omega}{\omega-1}}} \left(1-\frac{P_{i,t}^{A}\bar{A}}{\Xi_{i,t}}\right)+\frac{P_{i,t}^{A}\bar{A}}{\Xi_{i,t}}}\right)}{\left(\frac{\frac{\xi_I^{\frac{1}{1-\omega}} \left(P_{j,t}^{I}\right)^{\frac{\omega}{\omega-1}}}{\sum_{m=\{A,I,S\}} \xi_m^{\frac{1}{1-\omega}} \left(P_{j,t}^{m}\right)^{\frac{\omega}{\omega-1}}} \left(1-\frac{P_{j,t}^{A}\bar{A}}{\Xi_{j,t}}\right)}{\frac{\xi_I^{\frac{1}{1-\omega}} \left(P_{i,t}^{I}\right)^{\frac{\omega}{\omega-1}}}{\sum_{m=\{A,I,S\}} \xi_m^{\frac{1}{1-\omega}} \left(P_{i,t}^{m}\right)^{\frac{\omega}{\omega-1}}} \left(1-\frac{P_{i,t}^{A}\bar{A}}{\Xi_{i,t}}\right)}\right)} \quad .$$

$\Lambda_{i,t}^{A}$ measures the relative size of country $i$ policy-related trade barriers in Agriculture compared to Industry. $\Gamma_{i,t}^{A}$ measures the relative size of country $j$ to country $i$ final good producer's expenditure share on the imported variety of Agriculture compared to Industry. And, $\Theta_{i,t}^{A}$ measures the relative size of the country $j$ to country $i$ consumer expenditure share of Agriculture compared to Industry, including expenditure on subsistence consumption of Agriculture. If country $i$ is relatively poor, its subsistence spending on agriculture is relatively high and this reduces the trade balance of Agriculture. The higher is each of these terms, the larger are country $i$ net exports of Agriculture relative to Industry.

To illustrate conditions under which trade patterns are solely dictated by comparative cost advantage, abstract from home bias and trade policies, $\mu_i^k = \mu_j^k = 0.5$, $\tau_{i,j,t}^k = \tau_{j,i,t}^k = s_{i,i,t}^k = s_{j,i,t}^k = 0$, for $k = A, I$ and $i \neq j$, and income effects for consumer expenditure $\bar{A} = 0$ . Assume arbitrarily that country $i$ has a comparative cost advantage in Agriculture at date $t$, for $i \neq j$,

$$\frac{p_{i,t}^A}{p_{i,t}^I} = \frac{\theta_{i,t}^I}{\theta_{i,t}^A} < \frac{\theta_{j,t}^I}{\theta_{j,t}^A} = \frac{p_{j,t}^A}{p_{j,t}^I},$$

and let $\frac{p_{j,t}^A}{p_{i,t}^A} = (1+\epsilon_t)\frac{p_{j,t}^I}{p_{i,t}^I}$, $\epsilon_t > 0$ . Now, $x_{i,t}^A \equiv \Gamma_{i,t}^A \Theta_{i,t}^A$ is

$$x_{i,t}^A = \left[\frac{1+\left((1+\epsilon_t)\frac{p_{j,t}^I}{p_{i,t}^I}\right)^{\frac{\rho}{1-\rho}}}{1+\left((1+\epsilon_t)\frac{p_{j,t}^I}{p_{i,t}^I}\right)^{\frac{\rho}{\rho-1}}}\right]\left[\frac{1+\left(\frac{p_{j,t}^I}{p_{i,t}^I}\right)^{\frac{\rho}{\rho-1}}}{1+\left(\frac{p_{j,t}^I}{p_{i,t}^I}\right)^{\frac{\rho}{1-\rho}}}\right]\left[\frac{P_{j,t}^A P_{i,t}^I}{P_{i,t}^A P_{j,t}^I}\right]^{\frac{\omega}{\omega-1}} \equiv \Gamma_{i,t}^A\left[\frac{P_{j,t}^A P_{i,t}^I}{P_{i,t}^A P_{j,t}^I}\right]^{\frac{\omega}{\omega-1}} \tag{3.23}$$

and it is easy to show that $x_{i,t}^A > 1$ - Agriculture runs a trade surplus.

When a relatively low producer price of country $i$'s variety of Agriculture reflects a comparative cost advantage, final good producers' expenditure share on variety $i$ in Agriculture rises relative to that in Industry in both countries. Country $i$'s export share of Agriculture relative to Industry rises, its import share of Agriculture relative to Industry falls, and $\Gamma_{i,t}^A > 1$. Relative consumption expenditure $\Theta_{i,t}^A = 1$ . In general, a relatively low country $i$ producer price of Agriculture reduces its price index relative to that of Industry in both countries since in country $i$ ($j$) the relative home (imported) variety price of Agriculture falls. When goods are complements (substitutes), consumers in both countries reduce (increase) their expenditure on Agriculture relative to Industry, reducing (increasing) both exports and imports of country $i$ Agriculture relative to Industry. With no home bias, consumer prices of Agriculture and Industry are identical across countries and the export and import expenditure effects cancel exactly.

# 4 Calibration

We now calibrate the model of Section 3 to data from South Korea and the OECD. We treat Korea as the home country and an OECD aggregate as the foreign country wherever availability of the data required to match objects in the model makes this possible, and the

United States as the foreign country when OECD data is unavailable - the instances of which we note explicitly below.

The OECD aggregate includes Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Italy, Japan, Netherlands, Norway, Portugal, Spain, Sweden, the United Kingdom and United States. This aggregate accounted for an average of a substantial 68 percent of South Korean exports and 71 percent of South Korean imports annually over the period 1963-2000 and is, as a result, our preferred measure of the second country in this two country world economy model. Since China's external liberalization would inevitably play an important role in Korean trade patterns and domestic performance, we end the sample in 2000 to isolate the impact of opening to trade and trade reform policies of Korea.

## 4.1 Data Inputs

### 4.1.1 Tariff and Subsidy Rates

We construct time-series of estimated average tariff and subsidy rates for the two traded good sectors in both countries for the period 1963 through 2000. Complete annual average tariff rate estimates by sector are unavailable for this sample period for South Korea, so we draw on multiple sources for estimates of average tariff rates by sub-period and splice them. We construct two alternative time-series estimates: "Tariff Estimate I" and "Tariff Estimate II". The data appendix explains in detail how we construct the two series and Table 1 presents them. We find that the results from simulations using Tariff Estimate I and Tariff Estimate II are qualitatively and quantitatively very similar. Hence, we elect to report results for only one of the series, average Tariff Estimate I in Section 5.

Average tariff rates by sector imposed by the OECD on South Korean imports we proxy with World Integrated Trade Solution (WITS) - Trade Analysis and Information System (TRAINS) -data of the World Bank and use the AHS (effectively applied tariffs) rates. For the period 1988 through 2010, simple average effective import tariff rates imposed by the US on Korean imports are available. We use the rates for 1988 through 2000 as inputs to our model. Using a constant annual growth rate calculated for the 1989-2010 period, we construct tariffs on agriculture (defined as food-SITC 0+1+22+4- and agricultural raw materials -SITC 2-22-27-28) and manufacturing imports for the period 1963-1987. The entire constructed time series for 1963 through 2000 is shown in Table 2.

For our estimated time series of average subsidy rates by sector in South Korea, we use the industrial gross subsidy rate series calculated through 1980 by Collins and Park (1989). It is widely believed that quantitatively significant subsidies ended in South Korea during the 1980s, and the Collins and Park estimates are zero after 1980. Unfortunately, we are unaware of any estimates of average agricultural subsidy rates although they were reputedly large as Teignier (2012) reports, and so we assume in our benchmark calibration that agricultural subsidies are awarded at the same rate as in industry. The subsidy rate time series that we input is shown in Table 3.

In the absence of evidence to the contrary, we assume that OECD subsidies offered for exports to Korea are zero in both sectors throughout the sample period. It is worth noting that, since subsidies awarded to agriculture and industry are the same in Korea, and both zero in the OECD, in our benchmark calibration subsidy rates do not distort the pattern of comparative advantage.

### 4.1.2 Labor Productivities

Country and sector specific labor productivity, the $\theta^k_{i,t}$, is constructed by dividing value added by the level of employment in each sector at each date from 1963 through 2000. Value added data come from the World Development Indicators (WDI) database of the World Bank and employment by sector for Korea and OECD are constructed using the GGDC data base and the OECD Annual Labor Force Statistics database respectively as we describe in the data appendix. Notably, value added by sector is not final output of a sector in the data, as it is in our model absent intermediate goods; gross output by sector is. Given the incompleteness of gross output by sector data for our sample period, we chose to use value added data.

## 4.2 Preference Parameters

The curvature parameter in household preferences, ,$\psi$, determines the representative household's elasticity of inter-temporal substitution. We follow Backus et al. (1992) and set, $\psi$=-1; hence, the elasticity of inter-temporal substitution is $\frac{1}{1-\psi} = 0.5$. The weight on the consumption of the sector $k$ good in the consumption aggregate, $\xi_k$, and the elasticity of substitution between the three type of goods, $\omega$, are taken from Herrendorf et al. (Forthcomingb). Specifically, we take proximate averages of each of the parameters across different specifications of their model where the authors use data on final consumption expenditures for the United States to calibrate each specification. The values we use are $\xi_A = 0.02, \xi_I = 0.20, \xi_S = 0.78$. In addition, we let $\omega = -0.5$ implying that the three types of final good are complements in preferences. Since most countries in the OECD have similar income levels, we assume that the OECD aggregate has the same consumption expenditure pattern as the United States.

The subsistence level of consumption of agricultural goods, $\bar{A}$, is assumed to be the same for South Korea and the OECD. It is chosen to match the 1963 employment share of agriculture in South Korea, which is 0.63, and in our benchmark calibration $\bar{A}$ equals 863.20. This implies that in 1963 the subsistence level of consumption of agricultural goods accounted for 70 percent of total final consumption expenditure and 96 percent of consumption expenditure on agricultural goods in Korea.

## 4.3 Trade Parameters

In our model, the Armington weight on the domestic variety in country $i$'s final goods aggregator for each traded goods sector $k = A, I, \mu_i^k$ is assumed to capture all real costs of trade which would affect expenditure by final goods producers on domestic varieties of goods relative to imported varieties, after controlling for the marginal costs of production in the two countries, and for tariffs and subsidies. To calibrate the values of $\mu_i^A$ and $\mu_i^I$ for each country, we use the first order conditions for profit maximization of each sector $k$'s final good producer given by (3.9) and (3.10) to deliver the following expressions for the home bias parameter and the weight assigned to imported varieties:

$$\mu_i^k = \left[\frac{p_{i,t}^k y_{i,i,t}^k}{P_{i,t}^k Y_{i,t}^k}\right]^{1-\rho} \left[\frac{p_{i,t}^k}{P_{i,t}^k}\right]^{\rho} \tag{4.1}$$

$$1 - \mu_i^k = \left[\frac{\frac{(1+\tau_{i,j,t}^k)}{(1+s_{j,i,t}^k)} p_{j,t}^k y_{i,j,t}^k}{P_{i,t}^k Y_{i,t}^k}\right]^{1-\rho} \left[\frac{\frac{(1+\tau_{i,j,t}^k)}{(1+s_{j,i,t}^k)} p_{j,t}^k}{P_{i,t}^k}\right]^{\rho} \tag{4.2}$$

We calibrate the expressions on the right hand sides of (4.1) and (4.2) for each sector $k = \{A, I\}$ and country to annual data on Korean and -since there is no comparable OECD data- US data on expenditures, prices and trade policies. We obtain independent estimates for the value of $\mu_i^k$ and $1 - \mu_i^k$ period by period which we denote by $\mu_{i,t}^k$ and $1 - \mu_{i,t}^k$, apply the following normalizations in each period to ensure that the values of the weights sum to unity,

$$\widetilde{\mu_{i,t}^k} = \left[\frac{\mu_{i,t}^k}{\mu_{i,t}^k + (1 - \mu_{i,t}^k)}\right] \quad \text{and} \quad 1 - \widetilde{\mu_{i,t}^k} = \left[\frac{1 - \mu_{i,t}^k}{\mu_{i,t}^k + (1 - \mu_{i,t}^k)}\right]$$

and compute the sample average of the normalized estimates for each sector $k$=$A$,$I$ and country $i$=$h$,$f$. Although expenditure and price data by sector for South Korea are available for the sample period 1971 through 2000, the relevant price data for the United States is available only from 1983. Our time series estimates of $\mu_{i,t}^k$ and $1 - \mu_{i,t}^k$ therefore use data for 1983 through 2000 for both countries. This means that the South Korean subsidy rates shown in Table 3 are irrelevant for the calibrated value of (4.2) since estimated export subsidy rates are zero after 1980.

Specifically, to compute the share of spending on the domestic variety in the numerator of the first term of (4.1), we subtract from nominal value added of a sector the nominal value of the sector's exports to estimate nominal spending on the domestic variety by domestic final good producers. For both Korea and the US, nominal value added data by sector is taken from the World Development Indicators (2003). For Korea, we use the value of exports by sector to the rest of the world obtained from a data set provided by Robert Feenstra (SITC Revision 2), and for the United States we use the value of exports by sector to the rest of the world from the WITS database of the World Bank. Total spending on both varieties by sector in the denominator of the first term on the right hand side of (4.1) is constructed as the sum of value added less exports of the sector and spending on imports from the rest of the world by sector, drawn from Feenstra's data (Korea) and the WITS database (United States). The second term in equation (4.1) is the producer price of the domestic variety used in sector $k$'s final good relative to the consumer price index of sector $k$ in country $i$. To compute it, we use Korean producer price indexes by sector obtained from the Bank of Korea, data on US producer price indexes from the Bureau of Labor Statistics, and consumer price indexes by sector for both Korea and the US are constructed using data from the Bank of Korea and the Bureau of Economic Analysis, following the methodology in Herrendorf et al. (Forthcomingb) and described in the data appendix.

To compute the share of spending on the foreign variety in the first term of (4.2), we use data on the value of imports from the rest of the world by sector from Robert Feenstra (Korea) and WITS (United States), and the same measure of total spending on both varieties for the denominator as we constructed for (4.1). The second term of (4.2) reflects the price paid by a final good producer in sector $k$ of country $i$ for the imported variety relative to the consumer price index of sector $k$ in country $i$. To calibrate import prices in the second term of (4.2) we use import price index data by sector from the Bank of Korea and the Bureau of Economic Analysis for Korea and the US respectively, and our estimates of tariff rates from 1983 onwards in Tables 1 and 2. Feenstra's import value data include the value of any tariffs and so yield a good estimate of the numerator in the first component of (4.2) at each date. The import price data that we use to calibrate the second term, by contrast, are measured inclusive of "cost, insurance and freight" (CIF) but do not reflect the value of tariffs. We therefore include our estimated tariff series in calibrating the numerator in the second component of (4.2). Specifically, for Korea we compute $\mu_{i,t}^k$ and $1-\mu_{i,t}^k$ using Tariff Estimate I and Estimate II separately, and compare our final (normalized, sample average) results.

The resulting values of the Armington weights by sector, and for each constructed tariff rate series, are shown in Table 4. Since the calibrated values are not very different across the two alternative tariff measures, we use those computed using Tariff Estimates I.

A key parameter of the model is $\rho$ which controls the elasticity of substitution between home and foreign goods, $\frac{1}{1-\rho}$. International real business cycle (IRBC) models need small values of this elasticity to generate the volatility of the terms-of-trade and the negative correlation between the terms-of-trade and the trade balance that are found in the data. For example, Backus et al. (1994) and Zimmermann (1997) use an elasticity of 1.50. By contrast, general equilibrium models need large values of the elasticity to explain the growth in trade volumes that results from tariff reductions. Yi (2003) shows that these models need an elasticity of 12 or more to match the magnitude of trade growth observed in post-liberalization data. Anderson and Wincoop (2004) survey the literature and establish a range of values between 5 and 10. Eaton and Kortum (2002) establish a range for the elasticity estimate between 3.6 and 12.8, with their preferred strategy yielding a value in the middle of this range. However, Simonovska and Waugh (2011) show that the small sample size of the price data used in this strategy results in a small sample bias. Correcting for this bias, they find a lower and narrower range of 2.47 to 5.51, with a preferred estimate of 4.4. Giri (2012) also shows that, within the Eaton and Kortum framework, the elasticity estimate needed to match the cross-country dispersion in prices of individual goods ranges from 1.72 to 5.5. In line with these latest estimates, we choose a value of 4 for the elasticity which implies $\rho$=0.75. However, we also conduct sensitivity analysis in which we allow the elasticity to be as low as 2, and as high as 8.

# 5 Results

## 5.1 Benchmark Open Economy Model Performance

In our benchmark open economy model, the preference parameters, Armington technology, and subsistence consumption level in agriculture are calibrated as we have described in Section 4. Tariff Estimate I for agriculture and industry and industrial subsidy rates for

South Korea, tariff rates for agriculture and industry for the OECD, and measured labor productivity by sector for both countries are time series inputs.

In Figure 4 we plot the benchmark model's predicted shares of employment by sector for South Korea against those observed in the data for the period 1963 through 2000. Quantitatively, the model matches reasonably well the magnitude of decline in the employment share of agriculture and the magnitude of increase in the employment shares of industry and services over the sample period. The employment share of agriculture fell from 0.63 in 1963 to 0.11 in 2000 in Korea, while the model predicts a decline from 0.63 in 1963 to 0.08 in 2000, a 3 percentage point over-prediction of the magnitude of decline. The employment share of industry increased from 0.11 in 1963 to 0.29 in 2000 in the Korean data, while the model predicts an increase from 0.21 to 0.32, an under-prediction error of 7 percentage points. The employment share of services increased from 0.25 to 0.61 in the data, and from 0.15 to 0.60 in the model, an over prediction error of 9 percentage points.

While the Korean data show a mild hump shape in the industrial sector employment share - which declines from a peak of 0.36 in 1991 to 0.29 in 2000 - the model predicts a flattening of the employment share from 0.29 in 1991 to 0.31 in 2000, but no decline. In addition, the model over-predicts industry's 1963 share of employment and under-predicts that of services, and produces an initial decline in the employment share of industry from 1963 through 1967 from 0.21 to 0.14 before it begins to rise while the employment share in the data shows no such decline.

Table 5 records the values of some goodness of fit summary statistics.[5] The statistics in the first two rows of the table quantify the distance between the predicted and actual time series of the employment share of each sector, according to two standard criteria; the sum of squared prediction errors (SSE) and the root mean squared prediction error statistic

[5] The sum of squared errors statistic, for outcome variable $X$, is defined as $SSE = \sum_{t=1}^{T}(X_t - \hat{X}_t)^2$ where $T$ is the number of years, $X$ is the data value, and $\hat{X}$ is the model's predicted value. This is computed by sector, and the "total" statistic is just the sum of these across sectors. The root mean squared error statistic is $RMSE = \sqrt{\frac{SSE}{T}}$. The correlation statistic is defined as $CORR = \sum_{t=1}^{T}(X_t - \mu_x)(\hat{X}_t - \mu_{\hat{X}})/(T-1)/\sqrt{(var(X_t)var(\hat{X}_t))}$ where $\mu_j$ denotes the sample mean of variable $j$, and $var(j)$ denotes the sample variance.

(RMSE) respectively. We also present the summation of SSE's over sectors, the "total" SSE, and the associated "total" RMSE for the model. The statistics presented in the third row of the table are the sample correlation coefficients between the model's predicted time series for the share of a sector and that in the data, and measure the similarity of annual fluctuations in the two. The sample correlations between predicted and actual employment shares of each sector are positive and high; they are 0.963, 0.757, and 0.937 for agriculture, industry, and services respectively while the SSE is 0.1 or lower in each sector, and the total SSE is 0.291.[6]

Figures 6a and 6b show the benchmark model's performance in matching the export, import, and trade shares in GDP of sectors. The model vastly over predicts the total size of trade in South Korea especially early in the sample period. This is almost entirely attributable to a large over-prediction of the export and import to GDP ratios of agriculture early in the sample period. By the year 2000, agricultural exports in GDP predicted by the model fall to less than one-third of their 1963 value, and imports fall by one half. By contrast, Korea's trade in industrial products is quite well matched by the model. The size of industrial imports in GDP predicted by the model is approximately correct, as is the magnitude of its growth over time. Although industry's export to GDP ratio is slightly over-predicted, the increase over time in industry's GDP share of exports is of roughly the right magnitude. Nonetheless, because total trade in agriculture is about twelve times that observed in the data in 1963, the model counterfactually predicts that total trade in GDP slightly declines over the sample period.

The trade balances of agriculture and industry for our benchmark model, evaluated at world prices, are shown in Figure 8. At world prices, trade must be balanced. Agriculture

[6]A full set of results for the models match to GDP shares is available from the authors upon request. The model is less successful in matching quantitatively the GDP shares of sectors. That its performance in matching shares of GDP shares and employment shares is different is perfectly predictable since GDP shares evolve rather differently from employment shares in the data,while a Ricardian model implies that GDP and employment shares are identical. We found in a sensitivity experiment that for agriculture and services, the poorer match of the model to GDP than employment shares is attributable to our calibration of subsistence consumption of agriculture to the 1963 employment rather than GDP share of agriculture (primarily a "level" effect). The models better performance in matching industry's employment than GDP share, however, appears independent of this calibration choice.

runs a deficit from 1963 throughout the sample and industry an exactly offsetting surplus. However, in 1963 measured labor productivities are such that Korea has a comparative advantage in agriculture in our model, and the 1963 values of tariffs and subsidies distort relative international prices of varieties across sectors further in favor of a Korean agricultural trade surplus. We find that the model's prediction for the pattern of trade, as well as its over-prediction of agricultural trade in GDP, are attributable to the interaction of non-homothetic preferences with relative incomes as we now document. [7]

### 5.2 The Role of Non-Homothetic Preferences for Trade

The presence of subsistence consumption raises the relative share of agriculture in consumer expenditure when income is low and disproportionately reduces it as income rises (see equation 3.14). In a sensitivity experiment, we assume that preferences in both countries are homothetic so that $\bar{A}$ equals zero. As Figures 7a and 7b show, Korean agriculture's export to GDP ratio in 1963 falls from 30 percent in the benchmark model to 10 percent, although is still much higher than in the data, and its 1963 import to GDP ratio falls from 37 percent to about 5 percent or about equal to that in the data. The decline in agriculture's consumption share in the two countries reduces predicted total trade in 1963 from 80 percent of GDP in the benchmark model to about 46 percent.

Moreover, in 1963 when Korea is relatively poor, there is a much larger expenditure share of subsistence consumption of agriculture in South Korea than in the OECD. The larger agricultural imports than exports which result dominate the pattern of trade rather than the pattern of comparative advantage. When $\bar{A}$ equals zero, the pattern of comparative advantage - distorted by tariffs and subsidies - dictates trade patterns and the model predicts that Korea runs a trade surplus in agriculture in 1963 as we show in Figure 9. Only in 1980 does comparative advantage shift sufficiently in favor of Korean industry that it runs a trade surplus, and only after 1995 does it do so consistently.

[7] In Appendix D, we present a sensitivity analysis of the trade and structural transformation predicted by our benchmark model when we calibrate it for alternative values of the elasticity of substitution between home and foreign varieties, $\rho$. In summary, $\rho = 0.75$, which implies a mid-range elasticity of four, generates a closer match of the model to employment data overall than does either a high elasticity of eight or a low elasticity of two.

Not surprisingly in light of extant results in the literature, while abstracting from agricultural subsistence consumption improves the model's performance in matching trade volumes it deteriorates substantially its match to structural transformation, which we document in Table 6. The model's total SSE for employment shares rises 1550 percent and the SSE and RMSE for employment shares increase for each sector. The large deterioration for employment shares is partly a result of losing the free parameter to match agriculture's initial share of employment in Korea, and partly because the influence of the level and growth of relative income for resource allocation in agriculture relative to services is eliminated, as can be seen in Figure 5. As is also noted by Uy et al. (2011), industry's expenditure share is relatively undisturbed by the specification of preferences.

Figures 10a and 10b show the level and rate of increase of Korean relative income per capita predicted by the benchmark model. Although relative real GDP per worker -which equals the relative real wage in our model over-predicts the level of relative GDP per capita in the data, Korea's predicted income per worker is only twenty percent that of the OECD in 1963, and the resulting large subsistence consumption share in Korea is why we observe trade deficits in agriculture early in the sample. Figure 10b shows the model predicts slower relative growth of Korean GDP per worker over much of the sample compared to the data, however. This exacerbates the powerful role of income differences compared to comparative advantage for the pattern of trade in our model.

## 5.3 Counterfactuals

### 5.3.1 Closed Economy Model

Closing the economy and comparing its quantitative performance in matching the data to that of our benchmark open economy is a measure of how important openness to trade and measured trade policies are in our model's ability to account for South Korean structural transformation. To close the economy, we set $\mu^k_{KOR} = \mu^k_{OECD} = 1$ for all $k$. All other parameters maintain their benchmark values, except the subsistence level of agriculture. This is re-calibrated so that the prediction of the closed economy model for agriculture's initial employment share in Korea matches the observed 1963 employment share of agriculture in the data.[8]

Figure 11 shows that the closed economy model can capture some of the decline in the employment share of agriculture in Korea. However, it does a poorer job of matching the magnitude of decline than does the benchmark open economy model. As we noted above, the employment share of agriculture fell from 0.63 in 1963 to 0.11 in 2000 in the Korean data; the closed economy model forecasts a fall from 0.63 in 1963 to 0.17 in 2000, an under-prediction error of 6 percentage points. This contrasts to the open economy's 3 percentage point over-prediction of the magnitude of agriculture's employment share decline.

There are several reasons for the muting of decline in agriculture's share in the closed economy. A much larger calibrated value of subsistence in agriculture is required to match its initial employment share in the absence of agricultural exports which marginally slows the consumer's reallocation of expenditure from agriculture into services. Growth in the service sector employment share is also smaller as a result, but actually a little closer to that observed in the data. The employment share of services increased from 0.25 to 0.61 in the data, and from 0.24 to 0.63 in the closed economy model, an over prediction of only 4 percentage points compared to an over prediction of 9 percentage points in the benchmark model.

More importantly, a source of decline in agriculture's export to GDP ratio and employment share in the benchmark economy is a shift of comparative advantage in favor of industry over the sample period which is exacerbated by a sharp decline in Korean tariffs on agricultural relative to industrial imports from 1968 through 1979. As a result, the closed economy model produces less industrialization than the benchmark economy, measured by the employment share of industry. This share increased from 0.11 in 1963 to 0.29 in 2000 in the Korean data, while the closed economy model predicts an increase from 0.12 to only 0.20. This prediction error of 10 percentage points compares unfavorably to an under-prediction

[8]Obviously, since there are no distortionary trade policies in the closed economy, the competitive equilibrium is Pareto efficient.

error of 7 percentage points in the benchmark economy.

The closed economy model matches better the 1963 employment shares of industry and services, reducing the former and raising the latter. This is because the benchmark model generates too much trade early in the sample, when trade was factually a small percentage of GDP. The absence of industrial exports, and the larger subsistence parameter required to match agriculture's initial employment share in the absence of agricultural exports,reduces the predicted 1963 consumption and employment share of industry. The 1963 domestic consumer expenditure share of services must rise and does so - when final goods are complements - because the relative consumer price of services is higher in the closed economy.

In Table 5, according to most (although not all) of our summary statistics, the benchmark open economy model outperforms the closed economy model in matching Korea's employment share data. Closing the economy raises the total SSE by 92 percent. The correlation coefficients for employment shares by sector generally are a little higher for the closed than the open economy model however, ranging from 0.907 to 0.991, but substantially higher for industry. The correlation between the predicted and actual employment share of industry is 0.95 in the closed economy and 0.757 in the benchmark economy. The interaction of trade policies with the pattern of comparative cost advantage in the open economy is responsible for the relatively low correlation of industry's share of employment predicted by the benchmark model with that in the data. Specifically, these two features of the benchmark together produce a) the counterfactual decline of industry's share of employment from 1963 through 1967, which is coincident with a large drop in measured subsidies, and b) the absence of any downward portion of the "hump" shape observed in industry's share of employment. A very small downward movement can be observed in the employment share of industry after 1996 in the closed economy model. Nonetheless, the benchmark open economy model with international labor productivity differentials, tariffs and subsidies does a better job of minimizing the distance between the predicted and actual data overall relative to the closed economy, and substantially better for industry's employment share.

### 5.3.2 Controlling for International Productivity Differentials

The data on relative labor productivity by sector in Figure 2b suggest that Korea experienced an industrial sector labor productivity "take-off" from the early 1970s relative to that in the OECD, and compared to the growth in her agricultural productivity relative to the OECD, so that the pattern of comparative advantage shifted towards the industrial sector of Korea and agricultural sector of the OECD. As we have described, in our benchmark model the pattern of comparative advantage does not always dictate the pattern of trade or specialization, however. To isolate the impact of comparative cost advantage for structural transformation we set labor productivity in the OECD for each sector equal to measured Korean productivity at every date. The absence of relative productivity growth in Korea also eliminates most of the benchmark model's predicted relative growth in Korean GDP per worker after roughly 1972. Consequently, not only is there no role for comparative cost advantage in determining trade patterns and specialization in this experiment, but there is only a very minor role for change in the relative sizes of subsistence expenditure. This counterfactual primarily isolates the role for structural change of tariff and subsidy rates, and the (constant) configuration of home bias parameters, in the open relative to the closed economy.

Figure 12 shows that the predictions of the counterfactual and the closed economy for the levels of and fluctuations in employment shares deviate a little. Agriculture's predicted share of employment behaves much like that of the closed economy until 1968 but is a little lower between 1969 and 1982 and a little higher from 1983. The counterfactual economy predicts a slightly higher employment share for industry relative to the closed economy throughout the sample, and their predictions are very similar from 1983. The counterfactual predicts a lower employment share for services throughout the sample than does the closed economy, but early in the sample the two models' predictions are very similar. The lower employment share in agriculture relative to the closed economy, and the larger gap between the counter-factual and closed economy employment share of industry from 1969 until 1982, are primarily the result of lower Korean tariff barriers in agriculture relative to industry from 1968 until 1982 and the 1983 reduction in industrial tariffs.

Table 6 shows that the model's predictive performance relative to the data deteriorates much as the closed economy's does by comparison to that of the benchmark economy. The SSE of the counterfactual model for employment shares of agriculture and industry, and overall, increase relative to the benchmark while that of services decreases; the total SSE of the model with respect to employment shares rises by over 56 percent relative to the benchmark economy. Like the closed economy, this counterfactual model fails to re-allocate resources from agriculture into industry at the rate observed in the data and in the benchmark economy.

#### 5.3.3 Controlling For Trade Reform

We attempt to quantify how specific trade reform policies enacted in Korea are responsible for the goodness of fit to the data of our benchmark open economy model. By trade reform, we mean the reduction and elimination of tariffs and subsidies which represent barriers to free trade. 1968 is typically referred to in the literature as the first year of trade liberalization in Korean, and specifically by Sachs and Warner (1995), and this date coincides in our data with the first set of tariff reductions in agriculture.

We first counterfactually assume that Korean tariffs were held at their 1967 levels throughout the sample, while inputting subsidies and OECD tariffs as in the benchmark economy. 1968 is the first year of tariff liberalization for the agricultural sector, although tariff reductions of comparable size for industrial products did not begin until 1979 with the largest reductions from 1983. We do not re-calibrate the Armington weights in this experiment, although a reasonable argument could be made for doing so since average post 1983 tariff rates are reflected in this calibration. Nonetheless, we treat the home bias parameter as deep, and it is the effect for allocations of changes in trade policies over time that are of central interest.

Figure 13 shows that had tariffs not been lowered from 1967, a) agriculture's employment share would have been higher until 1989, and especially from 1968 through 1983, than in the benchmark economy, b) industry's employment share would have been systematically lower than in the benchmark economy from 1968 onwards, and c) services' employment share would have been systematically higher, especially after 1983. These results are driven by the inter-temporal pattern of tariff reform. The sharp decline in Korean tariffs on agricultural imports in 1968 in the data and benchmark economy shifts the effective pattern of comparative advantage against Korean agriculture, and the largest 1983 decline in industrial tariffs shifts the effective pattern of comparative advantage against industry. In the counterfactual, we artificially preserve a competitive "edge" in Korean agriculture relative to industry by maintaining 1967 tariff levels in both sectors. As a result, fewer labor resources leave agriculture and move into industry early in the sample, and more resources leave industry for services due to productivity growth after 1983.

Table 6 shows that the total SSE of the counterfactual economy is 0.368, higher by 26.5 percent than that of 0.291 for the benchmark economy. With respect to employment shares for individual sectors, the prediction error statistics increase substantially relative to the benchmark economy for industry and services but decline for agriculture. The correlation coefficients between the counterfactual model's predicted employment shares by sector and the data are extremely similar to those for the benchmark model, however they decline for industry; accounting for tariff reform after 1967 is quantitatively important for better matching annual fluctuations in industry's share of employment.

In a second experiment, we counterfactually abstract from measured subsidy reform for Korean industrial products, while inputting all tariffs and subsidies to agriculture as in the benchmark economy. Specifically, we allow subsidies in agriculture to decline as in the benchmark economy, while maintaining subsidies in industry at their 1967 levels. Table 2 shows that the average industrial subsidy rate fluctuates a little in the late 1960s, but declines more or less systematically after 1971 and is zero after 1980.

Awarding a counterfactually high subsidy rate to Korean industry for much of the sample distorts the pattern of comparative advantage in its favor, and deteriorates Koreas terms of trade, relative to the benchmark economy. Figure 14 shows that as a result, a) there is excessive re-allocation of labor into industry from agriculture after 1971, when industrial subsidies begin to decline in the benchmark economy and data, and especially after 1980 when they are eliminated completely, and b) the smaller increase in government transfer income after 1980 relative to our benchmark model, in which subsidies to both sectors are eliminated, produces a smaller reallocation of labor from industry to services and services lower share in the counterfactual is therefore closer to that in the data.

Accounting for industrial subsidy reform in our benchmark model is quantitatively important for limiting the magnitude of predicted industrialization relative to the data. There is a significant deterioration in the match of the counterfactual model to the data relative to the benchmark economy as Table 6 shows; the total SSE of the model increases by 62 percent. Improved measures of agricultural subsidies, however, are needed for evaluating the impact of agricultural export subsidy reform. Since we are forced by the lack of agricultural subsidy data to input the same, industrial subsidy rate in both sectors, abstracting from subsidy reform in both sectors simultaneously has little impact for our results as subsidies do not affect the pattern of comparative advantage. Our measured industrial subsidy series legitimately reflects industrial sector reform over the sample period but not agricultural subsidy reform.

## 6 Conclusion

We have identified three quantitatively important mechanisms through which international trade affects structural transformation in our two-country model. First, we find that changes in relative international per capita income, when preferences are non-homothetic and the income elasticity of demand in agriculture is less than one, dominate international trade and specialization patterns in Korea over much of the sample period and are a significant source of structural change. Second, changes in relative international labor productivities across sectors, which determine the pattern of comparative cost advantage, are quantitatively important determinants of structural transformation, although are inextricably linked to relative international income growth. Third, changes in relative international tariff and subsidy rates across sectors, which distort the pattern of comparative advantage, cause quantitatively important deviations of sectoral allocations of employment from those observed in a closed economy even when we abstract from the evolution of comparative advantage and the real income growth that relative productivity improvements generate. And specifically, measured trade reform after 1967 in Korea improves the model's accuracy in predicting structural change.

Two anomalies produced by our open economy model of structural transformation call for additional investigation. International specialization a) improves the model's fit to structural change but in doing so generates counterfactually high volumes of trade, and b) improves the model's match to the magnitude of industrialization, but is equally responsible for its inability to reproduce any de-industrialization. Finally, since our stylized model abstracts from endogenous labor productivity improvements resulting from tariff and subsidy reforms, we may under-estimate the scope of trade reform in effecting structural change. Beyond the scope of the current paper, this is a topic we leave for future work.

**Acknowledgements:** We are grateful to participants at the Midwest Macroeconomics Meetings and the Midwest Theory, Midwest International Trade Meetings, and the seminar participants at ITAM Business School for helpful comments and suggestions. We also thank Murat Ungor for numerous discussions. All remaining errors are ours.

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# A Appendix 1

Until 1962, South Korea was an "inward oriented" economy, with macroeconomic performance characterized by high unemployment and inflation, and large budget and balance of payments deficits. To combat inflation, the nominal exchange rate of the won against the US dollar was fixed, and to bring the balance of payments under control policy makers relied heavily on import barriers including multiple exchange rates, import licensing, quantitative restrictions, and high tariffs on selected items. Although some export incentives were introduced in the 1950s import substitution policies overtly encouraged production for domestic rather than for export markets and international trade between South Korea and the rest of the world was small. Figure 1shows that Korean exports were trivial in 1963 and imports were roughly 12 percent of GDP.

Korea's openness to trade began after Chung He Park took control of the government in 1961. The exchange rate system was unified in that year, and the Korean won was devalued from 130 won to 255 won per U.S. dollar in 1964. Trade policy initially consisted of export promotion policies beginning with the first five year plan implemented from 1962 which focused on the development of key export industries. Export sector specific incentives introduced during the 1960s included a preferential tax system, a preferential loan system, and various administrative support systems. While some export sector incentives freed Korean exporters to buy imported inputs and sell their outputs at prevailing world prices, many were distortionary subsidies that enhanced the profitability of export sales relative to domestic sales.

The preferential tax system, for example, included tariff exemptions on raw materials, intermediate goods and capital goods devoted specifically to export production; exemptions from indirect taxes on intermediate inputs and export sales; lower direct taxes on profits earned specifically through export activities; the introduction of reserve funds to develop new foreign markets and to defray export losses; and an accelerated depreciation allowance for fixed capital used directly in export production.

While the system of export incentives continued in the 1970s, the scope of subsidies was reduced and trade "reform" began. For example, a 50 percent reduction in taxes on profits from export earnings was abolished and in 1975 the system of tariff exemptions on imported inputs used in export production was changed to a "drawback" system. However, preferential loans for export activities were significantly expanded throughout this decade, increasing from 5.1 percent of total domestic credit in 1966 to 20.5 percent in 1978, although this expansion was accompanied by a gradual reduction of the interest rate differential between preferential and ordinary loans. In 1988, export related preferential loans were limited to small firms only.

Import controls were not relaxed until the late 1960's, and agricultural tariff reform began in 1968. Substantial industrial tariff reductions did not take place until 1979 and 1983. In the early 1960's, import controls were actually tightened in order to bring the trade deficit under control. The simple average of legal tariff rates reached a peak of nearly 40 percent in 1962 and remained at that level throughout the 1960s. Quantity restrictions were also used extensively to control imports although these were reduced significantly after 1967; while 88 percent of all import items were subject to quantity restrictions in the first half of 1967, in the second half of 1967 more than 60 percent of basic import items became automatically approved for import. However, the approval rate then fell steadily until 1975 when it reached 49.1 percent. There was also price based protection of the agricultural sector through a "high-rice-price" policy introduced in the late 1960s. Finally, in 1983 the government announced the first time-phased import liberalization plan for the period 1983-88. The range of tariff rates was to be reduced, and the average tariff rate lowered from 23.7 percent in 1983 to 18.1 percent in 1988. A second tariff reform phase for 1989-93 reduced the average tariff rate from 18.1 percent in 1988 to 7.9 percent in 1995.

Korea's export promotion and subsequent export and import liberalization policies are represented in our quantitative analysis by time-series of estimated average export subsidy and average effective import tax rates, the construction of which we describe in the Data Appendix (Appendix D).

# B Appendix 2 - Tables

**Table 1:** Tariff Measures for South Korea by Sector

| | Average Tariff Rate (%)-Estimate I | | Average Tariff Rate (%)-Estimate II | |
|---|---|---|---|---|
| Year | Industry | Agriculture | Industry | Agriculture |
| 1962 | 60.72 | 66.55 | 60.72 | 66.55 |
| 1963 | 60.72 | 66.55 | 60.72 | 66.55 |
| 1964 | 60.72 | 66.55 | 60.72 | 66.55 |
| 1965 | 60.72 | 66.55 | 60.72 | 66.55 |
| 1966 | 60.72 | 66.55 | 60.72 | 66.55 |
| 1967 | 60.72 | 66.55 | 60.72 | 66.55 |
| 1968 | 70.6 | 36.5 | 70.6 | 36.5 |
| 1969 | 70.6 | 36.5 | 70.6 | 36.5 |
| 1970 | 70.6 | 36.5 | 70.6 | 36.5 |
| 1971 | 70.6 | 36.5 | 70.6 | 36.5 |
| 1972 | 70.6 | 36.5 | 70.6 | 36.5 |
| 1973 | 67.78 | 32.44 | 67.78 | 32.44 |
| 1974 | 67.78 | 32.44 | 67.78 | 32.44 |
| 1975 | 67.78 | 32.44 | 67.78 | 32.44 |
| 1976 | 67.78 | 32.44 | 67.78 | 32.44 |
| 1977 | 67.78 | 32.44 | 67.78 | 32.44 |
| 1978 | 67.78 | 32.44 | 67.78 | 32.44 |
| 1979 | 49.42 | 29.48 | 49.42 | 29.48 |
| 1980 | 49.42 | 29.48 | 49.42 | 29.48 |
| 1981 | 49.42 | 29.48 | 49.42 | 29.48 |
| 1982 | 49.42 | 29.48 | 49.42 | 29.48 |
| 1983 | 22.6 | 31.4 | 31.91 | 43.49 |
| 1984 | 20.6 | 29.6 | 29.09 | 41 |
| 1985 | 20.3 | 28.8 | 28.66 | 39.89 |
| 1986 | 18.7 | 27.1 | 26.4 | 37.54 |
| 1987 | 18.2 | 26.4 | 25.7 | 36.57 |
| 1988 | 16.9 | 25.2 | 23.86 | 34.9 |
| 1989 | 11.2 | 20.6 | 15.81 | 28.53 |
| 1990 | 9.7 | 19.9 | 13.7 | 27.56 |
| 1991 | 9.7 | 19.9 | 13.7 | 27.56 |
| 1992 | 8.4 | 18.5 | 11.86 | 25.62 |
| 1993 | 7.1 | 17.8 | 10.03 | 24.65 |
| 1994 | 6.2 | 16.6 | 8.75 | 22.99 |
| 1995 | 6.2 | 16.6 | 8.75 | 22.99 |
| 1996 | 6.2 | 16.6 | 8.75 | 22.99 |
| 1997 | 6.2 | 16.6 | 8.75 | 22.99 |
| 1998 | 6.2 | 16.6 | 8.75 | 22.99 |
| 1999 | 6.2 | 16.6 | 8.75 | 22.99 |
| 2000 | 6.2 | 16.6 | 8.75 | 22.99 |

**Table 2:** Tariff Measures for OECD by Sector

| | Average Tariff Rate (%) | |
|---|---|---|
| Year | Manufacturing | Agriculture |
| 1963 | 12.8 | 4.2 |
| 1964 | 12.5 | 4.1 |
| 1965 | 12.1 | 4.1 |
| 1966 | 11.8 | 4.1 |
| 1967 | 11.5 | 4.0 |
| 1968 | 11.3 | 4.0 |
| 1969 | 11.0 | 4.0 |
| 1970 | 10.7 | 3.9 |
| 1971 | 10.4 | 3.9 |
| 1972 | 10.2 | 3.9 |
| 1973 | 9.9 | 3.9 |
| 1974 | 9.7 | 3.8 |
| 1975 | 9.4 | 3.8 |
| 1976 | 9.2 | 3.8 |
| 1977 | 8.9 | 3.7 |
| 1978 | 8.7 | 3.7 |
| 1979 | 8.5 | 3.7 |
| 1980 | 8.3 | 3.7 |
| 1981 | 8.1 | 3.6 |
| 1982 | 7.9 | 3.6 |
| 1983 | 7.7 | 3.6 |
| 1984 | 7.5 | 3.5 |
| 1985 | 7.3 | 3.5 |
| 1986 | 7.1 | 3.5 |
| 1987 | 6.9 | 3.5 |
| 1988 | 6.8 | 3.4 |
| 1989 | 6.6 | 3.4 |
| 1990 | 6.6 | 3.4 |
| 1991 | 6.7 | 3.0 |
| 1992 | 6.6 | 3.4 |
| 1993 | 6.7 | 3.2 |
| 1994 | 6.7 | 3.2 |
| 1995 | 5.9 | 3.2 |
| 1996 | 5.6 | 3.0 |
| 1997 | 5.3 | 3.0 |
| 1998 | 4.7 | 3.1 |
| 1999 | 4.3 | 3.8 |
| 2000 | 4.2 | 3.6 |

**Table 3:** Export Subsidies in South Korea

| Year | Subsidy Rate (%) |
|---|---|
| 1958 | 130.4 |
| 1959 | 172.0 |
| 1960 | 136.2 |
| 1961 | 18.1 |
| 1962 | 16.6 |
| 1963 | 45.8 |
| 1964 | 31.3 |
| 1965 | 14.8 |
| 1966 | 19.1 |
| 1967 | 23.0 |
| 1968 | 28.1 |
| 1969 | 27.8 |
| 1970 | 28.4 |
| 1971 | 29.7 |
| 1972 | 26.8 |
| 1973 | 23.7 |
| 1974 | 21.2 |
| 1975 | 16.7 |
| 1976 | 16.9 |
| 1977 | 19.2 |
| 1978 | 19.5 |
| 1979 | 20.2 |
| 1980 | 21.3 |

Note: Export subsidies include direct cash subsidies, export dollar premium, direct tax reduction, interest rate preference, indirect tax exemptions, and tariff exemptions

**Table 4:** Calibrated Values of Armington Weights

| Tariff Estimate I | Tariff Estimate II |
|---|---|
| $\mu^A_{KOR} = 0.37$ | $\mu^A_{KOR} = 0.36$ |
| $\mu^I_{KOR} = 0.34$ | $\mu^I_{KOR} = 0.33$ |
| $\mu^A_{OECD} = 0.53$ | $\mu^A_{OECD} = 0.53$ |
| $\mu^I_{OECD} = 0.55$ | $\mu^I_{OECD} = 0.55$ |

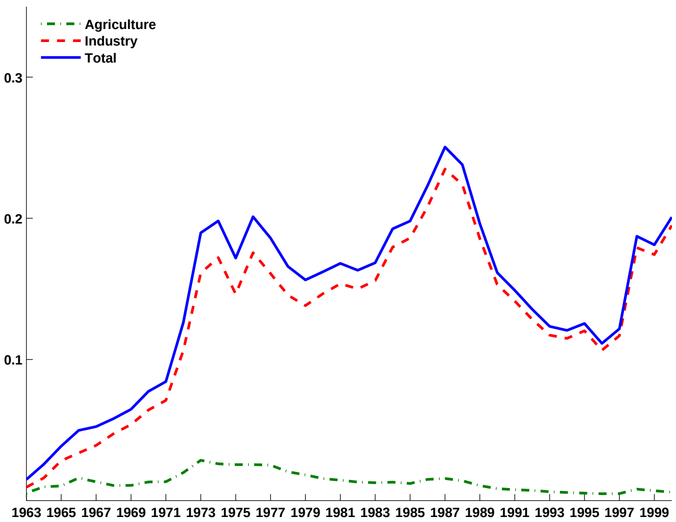
**Table 5:** Model Performance Measures for South Korea

| Open Economy | | | | |
|---|---|---|---|---|
| $\mu^A_{KOREA} = 0.37, \mu^I_{KOREA} = 0.34, \mu^A_{OECD} = 0.53, \mu^I_{OECD} = 0.55, \overline{A} = 863.20$ | | | | |
| | Employment Shares | | | |
| Performance Measure | Agriculture | Industry | Services | Total |
| Sum of Squared Errors | 0.105 | 0.093 | 0.093 | 0.291 |
| Root Mean Squared Error | 0.053 | 0.049 | 0.05 | 0.088 |
| Correlation Coefficient | 0.963 | 0.757 | 0.937 | |
| Closed Economy | | | | |
| $\mu^k_i = 1 \ \forall\ k, i, \quad \overline{A} = 1523.42$ | | | | |
| | Employment Shares | | | |
| Performance Measure | Agriculture | Industry | Services | Total |
| Sum of Squared Errors | 0.081 | 0.333 | 0.141 | 0.555 |
| Root Mean Squared Error | 0.046 | 0.094 | 0.061 | 0.121 |
| Correlation Coefficient | 0.991 | 0.95 | 0.968 | |

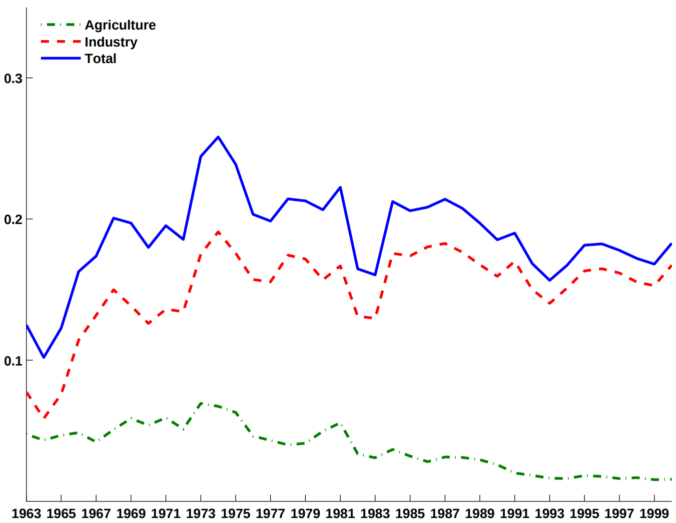
**Table 6:** Model Performance Measures for South Korea: Benchmark versus Counterfactuals

| Benchmark Open Economy | | | | |
|---|---|---|---|---|
| | Employment Shares | | | |
| Performance Measure | Agriculture | Industry | Services | Total |
| Sum of Squared Errors | 0.105 | 0.093 | 0.093 | 0.291 |
| Root Mean Squared Error | 0.053 | 0.049 | 0.049 | 0.088 |
| Correlation Coefficient | 0.963 | 0.757 | 0.937 | |
| Open Economy with $\bar{A} = 0$ | | | | |
| | Employment Shares | | | |
| Performance Measure | Agriculture | Industry | Services | Total |
| Sum of Squared Errors | 2.449 | 0.112 | 2.248 | 4.810 |
| Root Mean Squared Error | 0.254 | 0.054 | 0.243 | 0.356 |
| Correlation Coefficient | 0.917 | 0.778 | 0.791 | |
| Open Economy - OECD Productivities Equal to South Korea | | | | |
| | Employment Shares | | | |
| Performance Measure | Agriculture | Industry | Services | Total |
| Sum of Squared Errors | 0.154 | 0.240 | 0.059 | 0.453 |
| Root Mean Squared Error | 0.064 | 0.080 | 0.039 | 0.109 |
| Correlation Coefficient | 0.985 | 0.692 | 0.950 | |
| Open Economy - Tariffs at 1967 Values | | | | |
| | Employment Shares | | | |
| Performance Measure | Agriculture | Industry | Services | Total |
| Sum of Squared Errors | 0.064 | 0.141 | 0.163 | 0.368 |
| Root Mean Squared Error | 0.041 | 0.061 | 0.066 | 0.098 |
| Correlation Coefficient | 0.975 | 0.708 | 0.948 | |
| Open Economy - Subsidies in Industry at 1967 Values | | | | |
| | Employment Shares | | | |
| Performance Measure | Agriculture | Industry | Services | Total |
| Sum of Squared Errors | 0.244 | 0.162 | 0.065 | 0.471 |
| Root Mean Squared Error | 0.080 | 0.065 | 0.041 | 0.111 |
| Correlation Coefficient | 0.960 | 0.890 | 0.927 | |

# C Appendix 3 - Figures

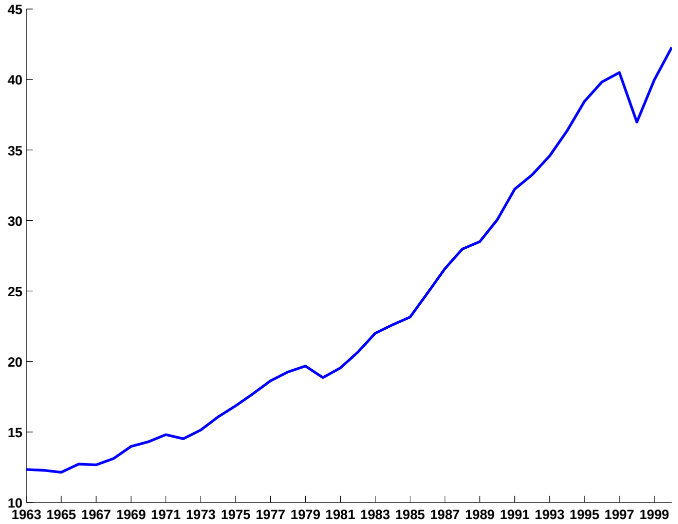



(a) Exports-to-GDP Ratio

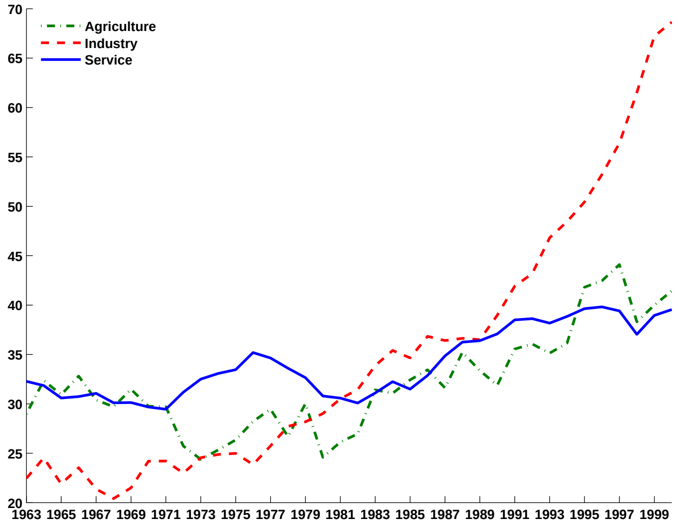



(b) Imports-to-GDP Ratio

**Figure 1:** Evolution of Trade in South Korea (with OECD), 1963-2000

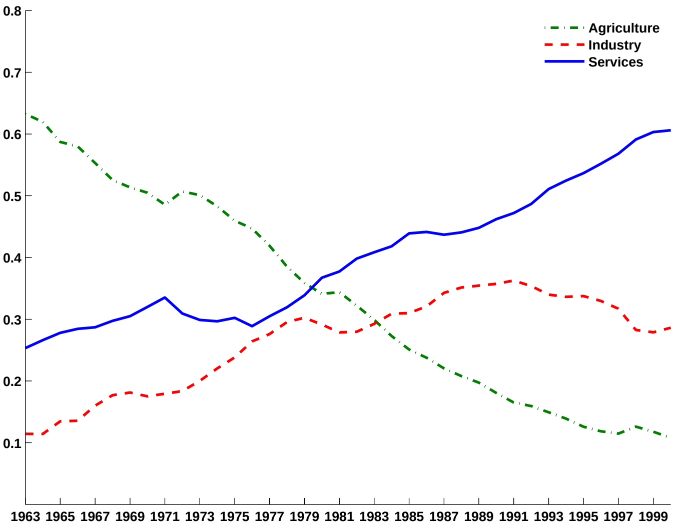



(a) Relative Real GDP Per Capita (in 1995 US$), OECD=100

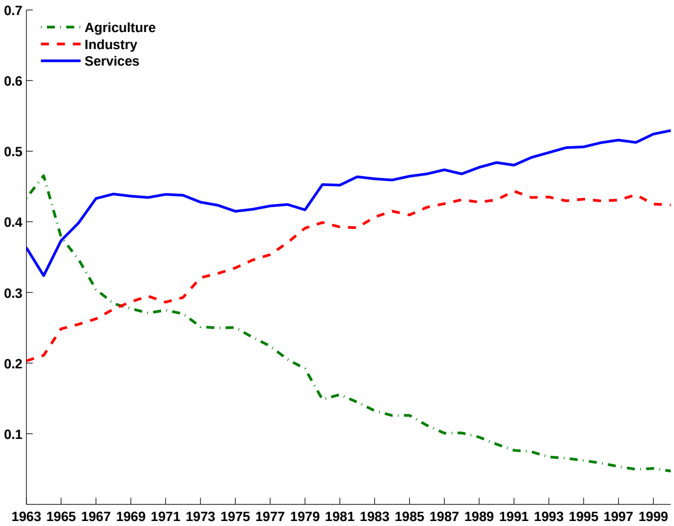



(b) Relative Real Value Added Per Worker by Sector (in 1995 US$), OECD=100

**Figure 2:** GDP Per Capita and Labor Productivity in South Korea (relative to OECD), 1963-2000




(a) Employment Shares by Sector




(b) GDP Shares by Sector

**Figure 3:** Structural Change in South Korea, 1963-2000

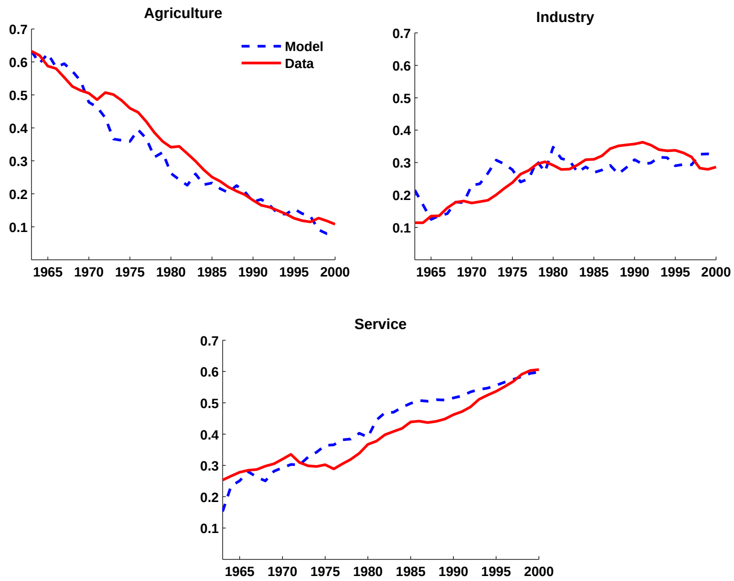



**Figure 4:** Employment Shares by Sector: Open Economy Model versus Data

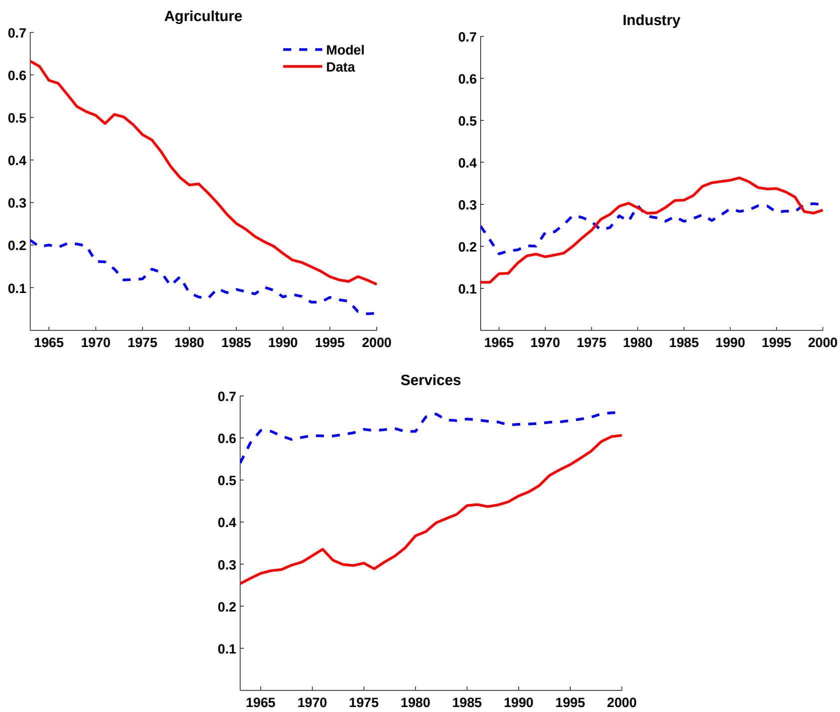
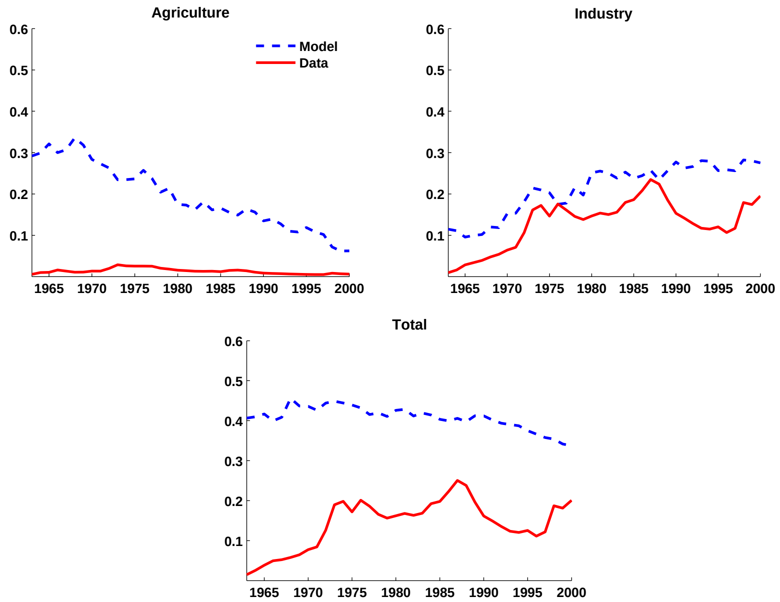
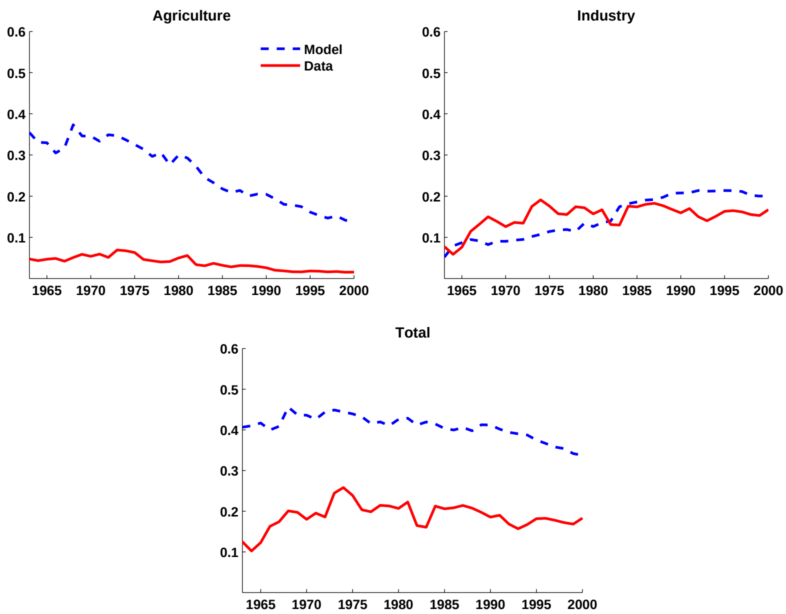



**Figure 5:** Employment Shares by Sector: Open Economy Model with $\bar{A} = 0$ versus Data

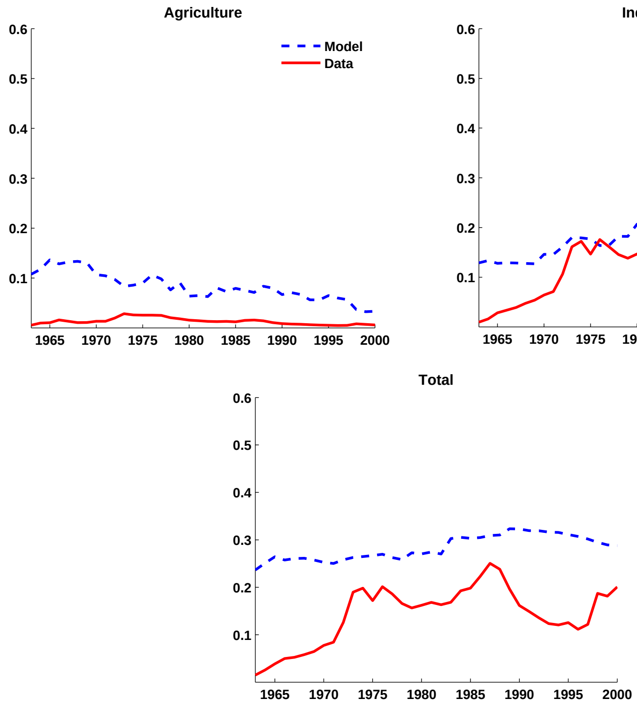



(a) Export to GDP Ratio by Sector

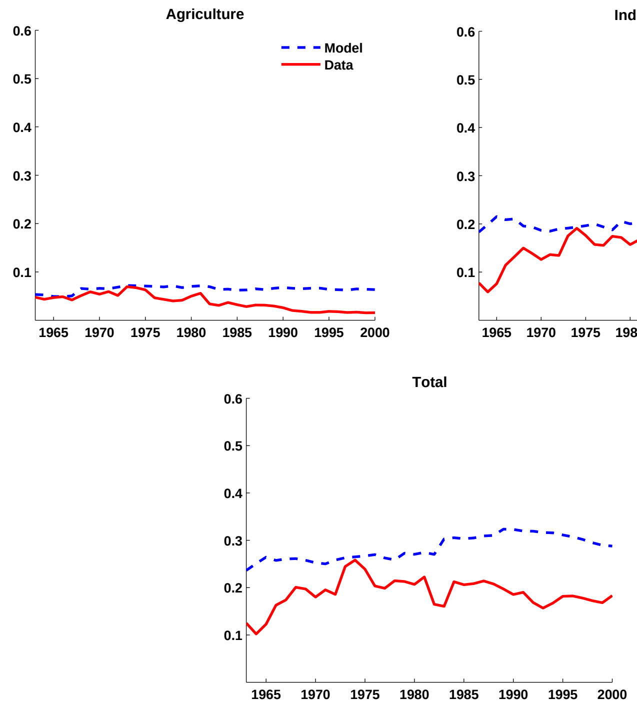



(b) Import to GDP Ratio by Sector

**Figure 6:** Evolution of Trade in South Korea - Open Economy Model versus Data




(a) Export to GDP Ratio by Sector




(b) Import to GDP Ratio by Sector

**Figure 7:** Evolution of Trade in South Korea - Open Economy Model with $\bar{A} = 0$ versus Data

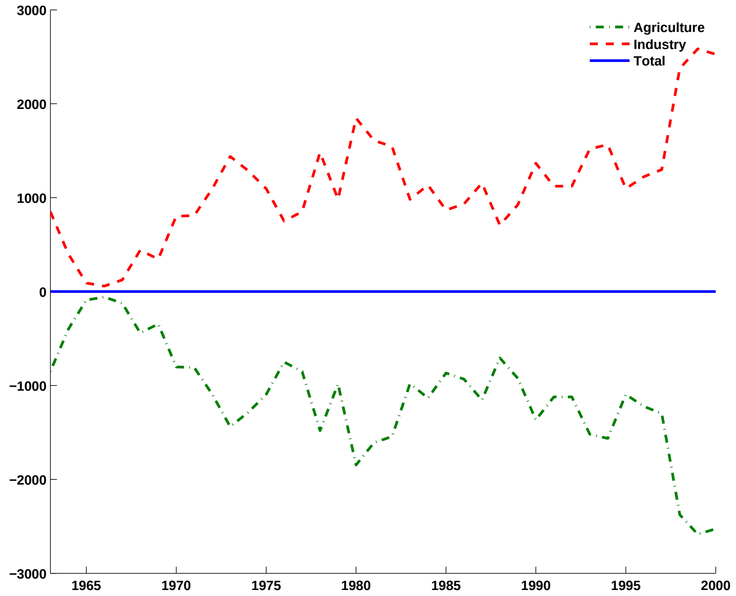



**Figure 8:** Trade Balance at World Prices

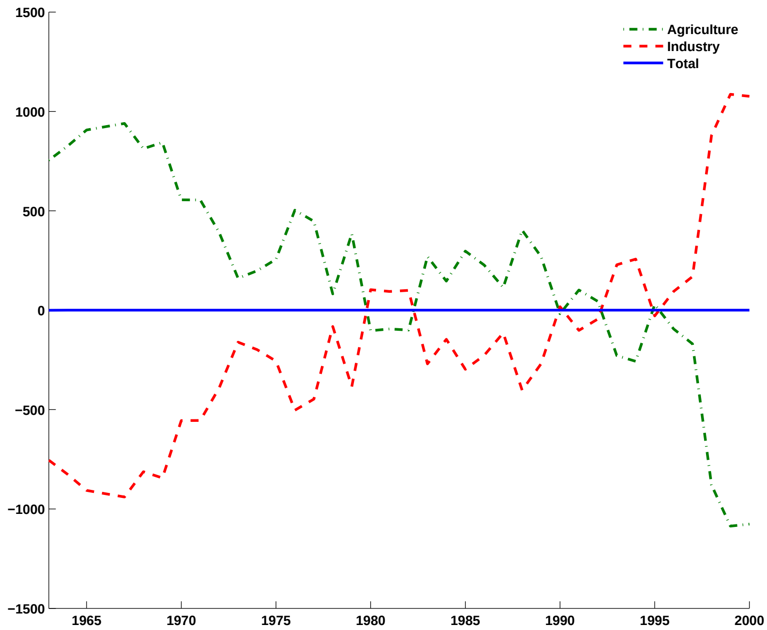
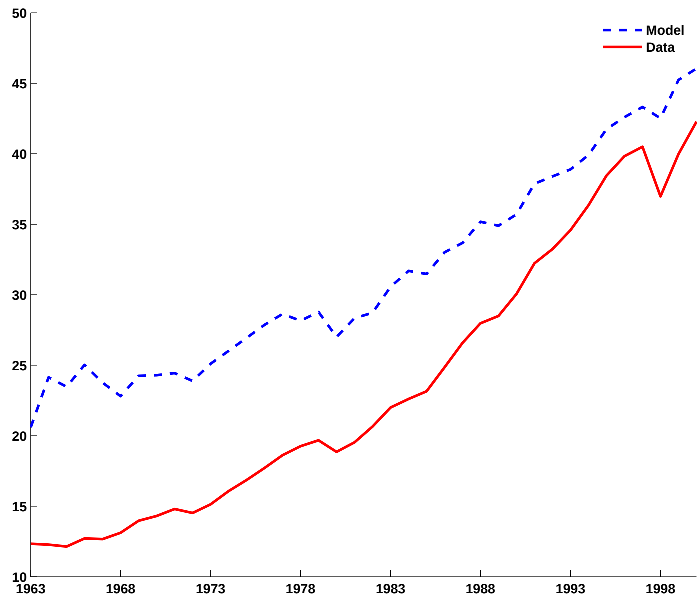
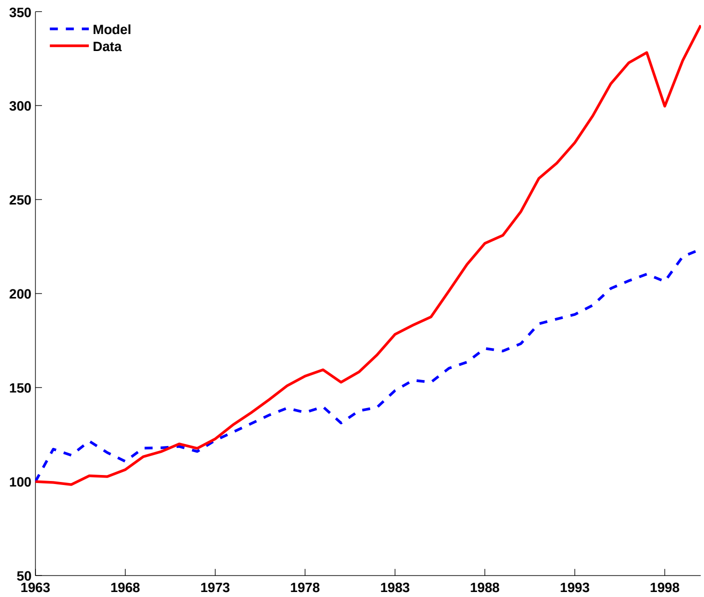



**Figure 9:** Trade Balance at World Prices with $\bar{A} = 0$




(a) Level




(b) Growth (1963=100)

**Figure 10:** Real GDP per Worker of Korea Relative to OECD (fixed base (1995)) - Open Economy Model versus Data

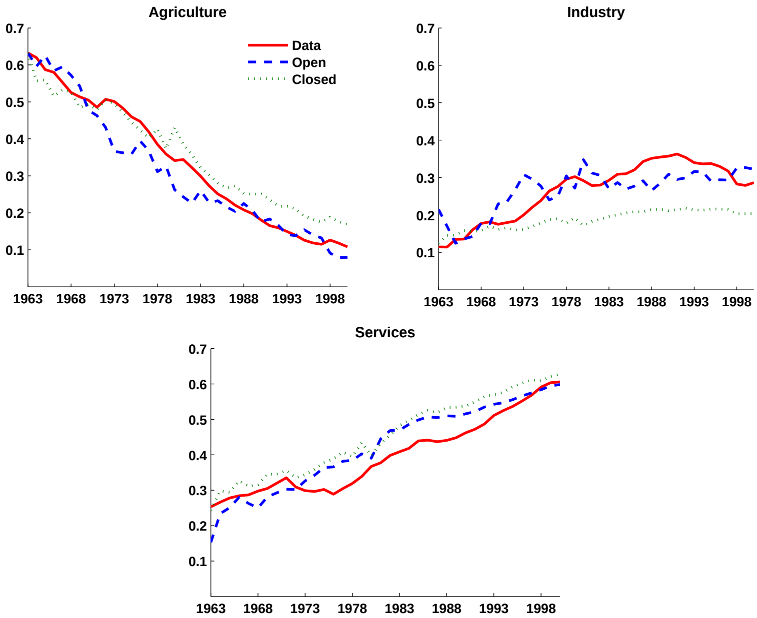



**Figure 11:** Employment Shares by Sector: Closed vs Open vs Data

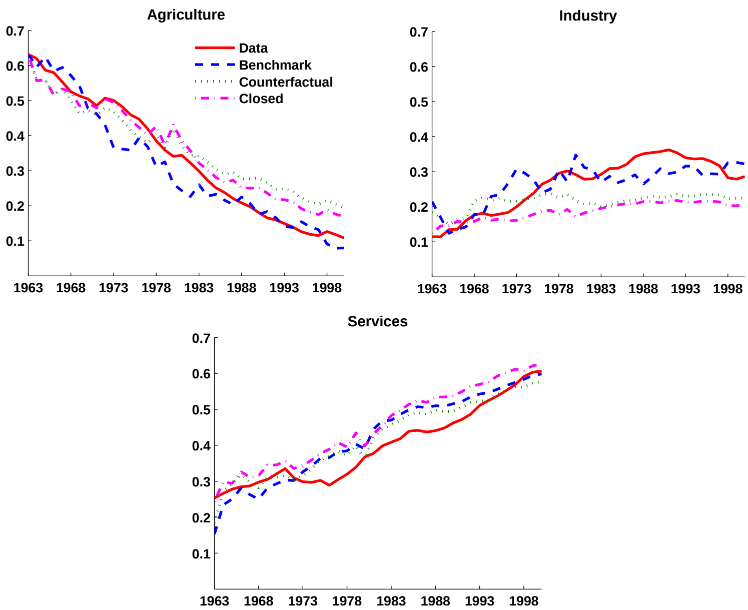



**Figure 12:** Employment Shares by Sector, OECD productivity = South Korea vs. Benchmark vs Closed vs Data

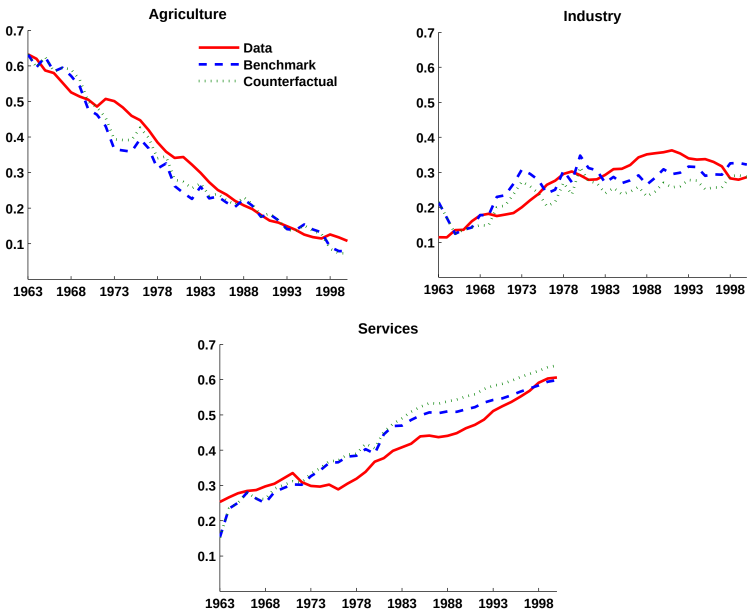



**Figure 13:** Employment Shares by Sector, Tariffs = 1967 vs. Benchmark vs Data

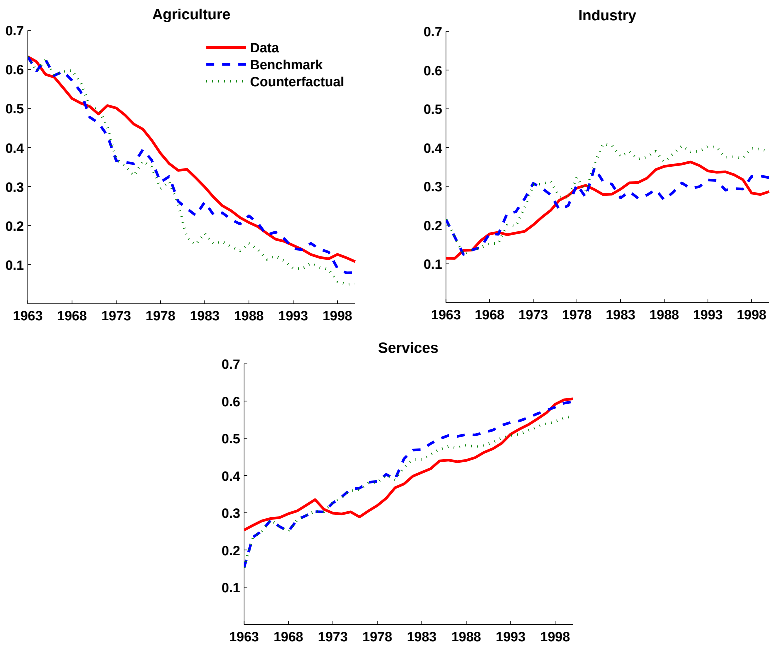



**Figure 14:** Employment Shares by Sector, Subsidies in Industry = 1967 vs. Benchmark vs Data

# D Appendix 4 - Sensitivity Analysis for Armington Elasticity

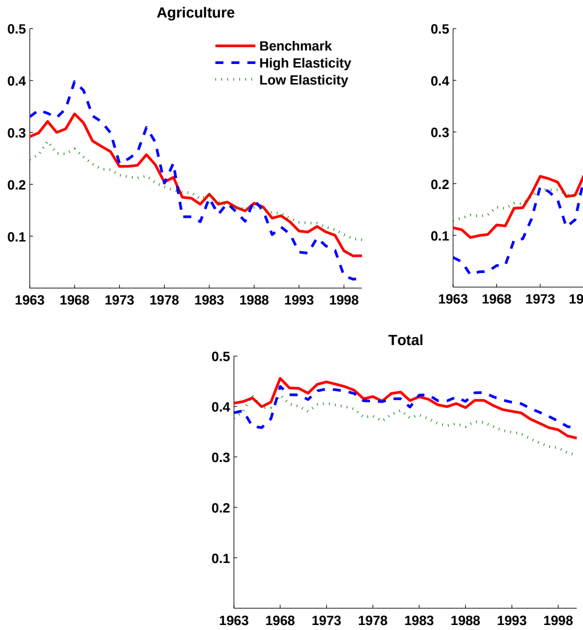
In Table 7 and Figures 15a and 15b, we show the results of sensitivity analysis for our benchmark open economy model when we calibrate it for alternative values of the elasticity of substitution between home and foreign varieties, $\rho$. Table 7 replicates the benchmark open economy performance statistics with respect to its predictions for employment shares for $\rho = 0.75$ (an elasticity of substitution of 4), and also shows the values of the statistics we obtain when $\rho = 0.875$ (a high elasticity of substitution of 8) and for $\rho = 0.5$(a low elasticity of substitution of 2). Figures 15a and 15b show the evolution of export andimport shares in GDP for South Korea predicted by the model for alternative values of theelasticity (including the benchmark value of 4).

Table 7 shows that a high value of $\rho$ deteriorates substantially the performance of the model in matching employment shares both by sector and overall relative to the benchmark calibration according to the SSE and RMSE criteria. A lower value of $\rho$ unambiguously deteriorates the fit of the model measured by the SSE and RMSE statistics relative to the benchmark calibration, except for the employment share of agriculture which is closer to the data by these criteria. In addition, the correlation of the models industrial employment share with that in the data declines significantly with a lower $\rho$. Overall, our baseline value of $\rho = 0.75$, or an elasticity of four, seems to generate the most accurate prediction for employment shares relative to the data of the three alternatives we consider.

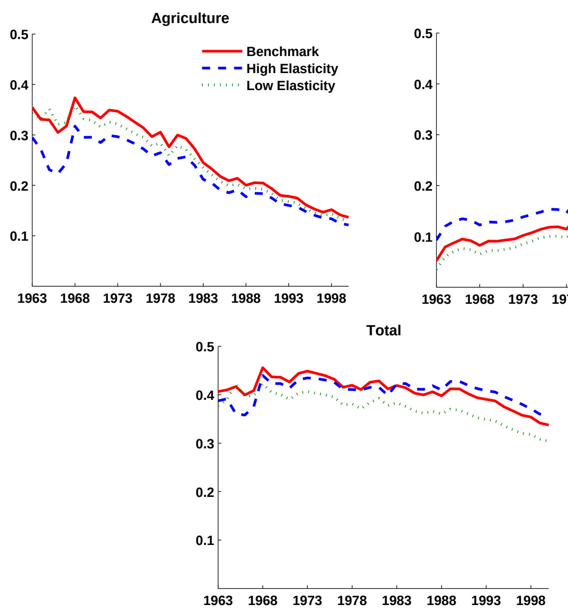
Figures 15a and 15b show the impact of alternative values of $\rho$ for export and import shares of sectors in GDP over time. With respect to export to GDP ratios for agriculture and industry shown in Figure 15a, and for total exports as a portion of GDP, our baseline intermediate value generates ratios that lie broadly between those produced by a higher and lower elasticity. A higher (lower) value of $\rho$, in general, generates export shares that are more (less) volatile. Export to GDP ratios with a higher (lower) elasticity fall by more (less) when export ratios decline, and rise by more (less) when they increase. Import to GDP ratios, shown in Figure 15b, exhibit the same expected tendency to be more volatile the higher is $\rho$. Here, however, while our baseline models industrial import share in GDP and its total import to GDP ratio lie between the values produced for higher and lower $\rho$, its agricultural import share in GDP is highest throughout the sample. Agricultural imports in GDP, as we show in Section 5, are most strongly influenced the relative size of subsistence consumption in Korea.

**Table 7:** Model Performance Measures for South Korea: Sensitivity to Armington Elasticity

| Benchmark Open Economy | | | | |
|---|---|---|---|---|
| | Employment Shares | | | |
| Performance Measure | Agriculture | Industry | Services | Total |
| Sum of Squared Errors | 0.105 | 0.093 | 0.0931 | 0.291 |
| Root Mean Squared Error | 0.0526 | 0.049 | 0.0495 | 0.088 |
| Correlation Coefficient | 0.963 | 0.757 | 0.937 | |
| **High Elasticity-$\rho$=0.875** | | | | |
| | Employment Shares | | | |
| Performance Measure | Agriculture | Industry | Services | Total |
| Sum of Squared Errors | 0.260 | 0.158 | 0.285 | 0.702 |
| Root Mean Squared Error | 0.083 | 0.064 | 0.087 | 0.136 |
| Correlation Coefficient | 0.952 | 0.835 | 0.943 | |
| **Low Elasticity-$\rho$=0.5** | | | | |
| | Employment Shares | | | |
| Performance Measure | Agriculture | Industry | Services | Total |
| Sum of Squared Errors | 0.077 | 0.153 | 0.099 | 0.329 |
| Root Mean Squared Error | 0.045 | 0.063 | 0.051 | 0.093 |
| Correlation Coefficient | 0.977 | 0.641 | 0.924 | |




(a) Export to GDP Ratio by Sector




(b) Import to GDP Ratio by Sector

**Figure 15:** Sensitivity of Trade to Alternative Values of $\rho$

## E Appendix 5 - Data Appendix

**I. SECTOR DEFINITIONS**

Agriculture corresponds to ISIC divisions 1-5; includes forestry, hunting, and fishing, as well as cultivation of crops and livestock production.

Industry corresponds to ISIC divisions 10-14, 15-37, 40-41, 45; includes mining, manufacturing, public utilities and construction.

Services correspond to ISIC divisions 50-55, 60-64, 65-74, 75-99; includes wholesale and retail trade (including hotels and restaurants), transport, storage and communication, finance, insurance and real estate and community, social and personal services.

Since the trade data are based on SITC Rev2., we map the SITC codes into the ISIC sector definitions.

Agriculture is defined as SITC 0,1,2,4 minus 27, 28;

Industry is the combination of Fuels and Mining - SITC 3 plus 27, 28, 68 -, Manufacturing - SITC 5,6,7,8 minus 68 -, and all other SITC codes.

**II. SOUTH KOREA**

**A. Figures**

**Figure 1 a) Exports to GDP Ratio**
**b) Imports to GDP Ratio**

Bilateral exports and imports for South Korea with the OECD, by sector, are taken from Feenstra's Trade Data SITC Revision 2. The GDP (Value added) data are taken from World Development Indicators (WDI) 2003. Both trade and GDP data are measured in current US $.

**Figure 2 a) Relative Real GDP per Worker**
**b) Relative Real Value Added per Worker by Sector**

Real GDP per worker is proxied by data on real GDP per capita. We obtain these data from WDI for Korea and they are measured in 1995 constant US$. For the OECD, this measure has been constructed as a weighted average of individual countries' GDP per capita, where weights are the share of that country's employment in total OECD employment. GDP data are measured in 1995 constant US$. See attached file 'GDPpercapita_OECD' for details on how this series has been constructed. In order to get relative real GDP per worker we divide the Korean real GDP per worker by that of the OECD.

Similarly, in order to get a relative measure of real value added per worker by sector, we divide real value added by sector per worker in Korea by that of OECD. Real value added per worker by sector is constructed by dividing real value added by employment for each sector. Real value added data measured in 1995 constant US$ is from the WDI 2003, and employment by sector are obtained from the Groningen Growth and Development Centre (GDDC) 10 sector database using the ISIC sectorial classifications as described above. Missing values of real value added in industry and services for Korea for 1963-69 were imputed using the growth rate of real value added, during 1970-80, in industry and services, respectively.

**Figure 3 a) Share in Employment**
**b) Share in Value Added**

Employment shares by sector are constructed using the GDDC 10 sector database. The 10 sectors have been aggregated into Agriculture, Industry & Services as described above. Value added shares by sector have been constructed using nominal value added data by sector measured in current US$. These data have been taken from WDI 2003.

## B. Tables

### Table 1(a): Tariff Measures for South Korea by Sector

We use two different sets of estimates. These estimates have been constructed using data from different sources for different time periods.

Average tariff rates by sector imposed by South Korea, expressed as a percentage per unit of that sector's good imported, are estimated by various authors for alternative sub-sample periods. We construct two time-series for South Korean tariff rates by sector, which deviate only from 1983 onwards. This deviation in the two series from 1983 is due to an adjustment suggested by Nam (1980) to the average tariff rates by sector estimated by Lee (1995). Nam's "adjustment" is reflected in the post 1982 numbers in "Tariff Estimate II", the unadjusted series is "Tariff Estimate I", and both are shown in Table 1.

Sources for and construction method of our tariff series from 1963 through 1982 are as follows. For the years 1963, 1973 and 1979, estimated average agricultural tariff rates are drawn from Collins and Park (1989) and estimated average tariff rates for industry are from Lee (1995). Both sets of numbers are adjusted using Nam (1980). For the year 1968, we use the estimated average tariff rates for both sectors of Nam (1980). For the intermediate years direct estimates are unavailable; we assume that average tariff rates by sector for the years 1964 through 1967 are equal to those estimated for 1963; we assume that average tariff rates by sector for the years 1969 through 1972 are equal to those estimated by Nam for 1968; we assume that average tariff rates by sector for the years 1974 through 1978 are equal to those estimated for 1973; and we assume that average tariff rates by sector for the years 1980 through 1982 are equal to those estimated for 1979.

Average tariff rates for both sectors for the years 1983 through 1994 are taken from Kim (1996), which is a continual annual series. Here, average Tariff Estimate II applies the adjustment suggested by Nam (1980) in each year. For average tariff rates by sector from 1995 through 2000, we use estimates from the Bank of Korea which assumes that tariff rates are constant at the 1994 levels estimated by Kim (1996), again with the Nam (1980) adjustment applied to Tariff Estimate II.

**Table 2: Export Subsidies in South Korea**

These are taken from Collins & Park (1989) for the period 1963-1980. Gross subsidy rates included in this time series include direct cash subsidies, export premiums, direct tax reductions, preferential interest rate reductions, indirect tax exemptions, and tariff exemptions  all expressed as won subsidies per dollar of exports. The series then controls for changes in the exchange rate, the won price of dollars, so that the gross subsidy rate is expressed per unit of exported industrial good.

**C. Other South Korean Data used in Calibrating the Model:**

**Labor Productivity of a sector**

As we describe in Section 4, this time series is an input to the model, and defined as real value added per worker in that sector. Hence this is constructed as described above for Figure 2.

**Armington Trade Weights**

We have described the construction of the Armington weights (Table 4 in the paper) in detail in Section 4. In this construction we use the following data series for the 1970- 2000 period:

Nominal Value Added by sector data are from WDI 2003, while data on exports by sectors from South Korea to the world are taken from Robert Feenstra's data base (SITC Rev 2).

Data on the producer price index (PPI) and import price index (IPI) by sector are taken from the Bank of Korea The PPI is measured using prices for the domestic market only, and the import price data are measured inclusive of cost, insurance and freight (CIF). The consumer price indexes are constructed using data provided by the OECD Statistics Database, following the methodology described in Herrendorf et al. (Forthcomingb) (Appendix D: Approximate Aggregation of Chained Quantity Indices). See attached file "CPI_Korea" for details on how CPIs for agriculture and industry have been constructed.

**III. OECD**

The OECD aggregate includes Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Italy, Japan, Netherlands, Norway, Portugal, Spain, Sweden, the United Kingdom and United States.

**A. Figures**

**Figure 2 a) Relative Real GDP per Worker**
**b) Relative Real Value Added per Worker by Sector**

Labor productivity in a sector is computed as the weighted average of the individual countries' labor productivity (real value added per worker in that sector), where the weights are the share of a member country in OECD total employment in that sector (which is the sum of employment across all countries in that sector). Real value added (current US $) by sector data are taken from the WDI 2003 and are measured in 1995 constant US$. The data for OECD are available only from 1971 onwards for all countries. We imputed the missing sectorial value added for 1963-70 by using each sectors growth in value added between 1971 and 2000. Data on employment by sector are constructed using OECD Annual Labor Force Statistics database. Missing data for sectorial employment for 1963-70 for the OECD is imputed following the same methodology as in the case for value added. Finally, missing data for sectorial labor productivity for 1963-1970 for the OECD was imputed following the same methodology as in the case for value added and employment. See attached file "LaborProductivitybySector_OECD" for details on how this series has been constructed.

**B. Tables**

**Table 1(b): Tariff Measures for OECD by Sector**

WITSTRAINS database reports tariff rates applied by the US on Korean imports for the period 1989-2010. These are defined as Simple Average Effective Applied Tariff Rate Using a constant annual growth rate calculated for the 1989-2010 period, we construct tariffs on agriculture (defined as food-SITC 0+1+22+4- and agricultural raw materials -SITC 2-22-27-28-) and manufacturing imports for the period 1963-1988.

**C. Other OECD/US Data Used in Calibrating the Model**

**Armington Trade Weights**

We have described the construction of the Armington weights in detail in Section 4. We use the following data series for the 1983 to 2000 period for the US economy: Nominal Value added by sector data are obtained from WDI 2003, while data on sectorial exports from US to the world and sectorial imports of the US from the world are taken from the World Integrated Trade Solution (WITS) database of the World Bank.

Producer price Index data have been taken from the Bureau of Labor Statistics (BLS). For agriculture we use farm products PPI and for industry we use industrial commodities less fuel PPI. The base year for these indexes has been reset to 2000 (original base year was 1982).

Import price indexes of agriculture and industry are constructed using disaggregated IPI of SITC codes and these data are obtained from the BLS. We have computed Agriculture IPI as the product of import shares of SITC 0, 1, 2 (minus 27 and 28) with the corresponding IPI (Note: BLS does not report data on IPI of SITC 4). The industrial IPI is computed as the product of import shares of SITC 3, 5, 6, 7 and 8 with the corresponding IPI. The import shares of the SITC codes are computed using data on US imports from the world (taken from WITS) and the annual IPI are obtained by computing an average of monthly IPI. The base year for the IPIs is 2000. See attached file "IPI_US" for details on how IPIs for agriculture and industry have been constructed.

Consumer price indexes by sector are constructed using data from the Bureau of Economic Analysis, following the methodology described in Herrendorf et al. (Forthcomingb) (Appendix D: Approximate Aggregation of Chained Quantity Indices). See attached file "CPI_US" for details on how CPIs for agriculture and industry have been constructed.