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# Trade, Reform, and Structural Transformation in South Korea

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# Trade, Reform, and Structural Transformation in South Korea[a]

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We develop a two country, three-sector model to study the effects of trade policies for Korean structural change from 1963 through 2000. The model features Armington trade, import tariffs, and export subsidies. Tariff liberalization increases imports and total trade, especially agricultural imports, intensifying Korean industrialization. Subsidy liberalization lowers exports and trade, especially industrial exports, attenuating industrialization. These effects of policy reform are individually powerful, but offset each other. Relative to a "no reform" regime which maintains 1963 tariff and subsidy rates forever, observed trade reform produces comparable but lower trade volumes, a larger agricultural and lower industrial employment share, and slower industrialization. "Complete reform", lowering tariffs and subsidies to zero from 1963 onwards, substantially increases trade volumes and facilitates industrialization.

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

**Key Words**: Trade policy, comparative advantage, industrialization, structural change.

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# 1 Introduction

Increased international trade, export promotion, and trade liberalization policies have been coincident with massive changes in the structure, as well as the size, of the South Korean economy since 1963. Structural change has been temporally associated with shifts in trade policy in other Asian countries as well, including China, the remaining "Tigers" - Hong-Kong, Singapore, and Taiwan - and the East Asian "Tiger Cubs" - Indonesia, Malaysia, the Philippines, and Thailand. Among these countries, Korea's development strategy in the late 1960s and 1970s represents a quintessential example of how export subsidies and tariffs were combined across sectors and over time to incentivize industrialization. Concurrent with high export subsidies, a falling agricultural tariff rate, and relatively high industrial tariff rate through 1979, the employment share of agriculture in Korea declined dramatically and that of the industrial sector rose. While growth in Korea's industrial employment share continued until 1991, well after dramatic industrial tariff reductions and the elimination of export subsidies, subsequently de-industrialization was observed. The goal of this paper is to quantify the role that trade policies played for these sectoral reallocations of employment - "structural change" - in Korea from 1963 through 2000.

Several recent studies of the structural change accompanying the Korean growth miracle have measured the role of openness and of trade costs, broadly defined, for the pace and attributes of this transformation. However, none have isolated or measured the evolution of Korea's tariff and subsidy policies over time and sectors, nor the role of this evolution for industrialization. The current paper seeks to fill this void. Our contribution is three-fold. First, we construct time-series data on Korean export subsidy and tariff rates by sector for the period 1963 through 2000. Second, we apply these data to a quantitative general equilibrium model which delivers a clear mapping from trade policies to structural variables. Third, our general equilibrium model features value-added production and consumption, and hence we carefully construct and use value added rather than gross trade flows by sector for Korea. Alternative counterfactual policies that we simulate in the calibrated model demonstrate that, although reforming one policy instrument at a time - tariff or subsidy rate - has powerful consequences for international trade and structural change, the impact of Korea's actual trade reform is muted because the effects of tariff and subsidy reform offset each other.

Specifically, we develop a two-country, three sector model of structural change with the three sectors being agriculture, industry and services. Each sector's final consumption good is produced




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in Armington fashion by combining the domestic and foreign varieties of the sector's good. Variety suppliers produce their country's variety via a Ricardian technology, using labor which is the only production factor. Hence, there is Armington motivated trade in varieties, but we assume that there is no trade in the final consumption goods. The weights assigned to the two varieties in each sector's Armington aggregation technology reflect all real costs of trade, except those we explicitly model as trade policies. The higher the weight on the domestic variety - higher "home bias" - the higher are the real costs of importing the foreign variety. We assume that prohibitively high trade costs preclude trade in service varieties. We also assume that trade is balanced. In each country a representative household, which supplies labor in-elastically to production of domestic varieties, derives utility from consumption of the three sectors' final goods and faces a subsistence consumption requirement for the agricultural good. Lastly, in each country, a government 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 expenditure is rebated to households as a lump-sum transfer.

The employment share of a sector is the sum of domestic and foreign final good producers' expenditure on that country's variety of the sector's good, relative to total domestic value added. These expenditures are determined by four factors: (i) the sector and country specific degrees of home bias faced by domestic and foreign final good producers; (ii) the producer price of domestic relative to foreign variety adjusted for tariffs and subsidies, which influence the relative intensity of the domestic variety's use; (iii) relative consumer prices of final goods within a country, which influence the consumption expenditure on a sector's final good; (iv) domestic and foreign incomes inclusive of net transfers which dictate the level of total consumption expenditure in each country on the three final goods. Three crucial parameters influence the qualitative and quantitative responses of variety expenditure to these factors.

The larger is the Armington elasticity of substitution between varieties the more responsive is the expenditure of final good producers to a change in their relative price, whether due to a change in relative labor productivity and wage rates across countries - which determine relative producer prices - or to a change in a tariff or subsidy rate. In addition, we follow the structural change literature in assuming that final consumption goods of the three sectors are gross complements in preferences so that the elasticity of substitution between final consumption goods is less than one. Consequently, changes in the consumer price of a sector's final good cause that sector's consumption share to move in the same direction. Finally, the non-homotheticity in preferences, reallocates domestic consumption expenditure away from the income inelastic good agriculture - and into the income elastic goods - industry and services.

We calibrate the model to sectoral data from Korea and the OECD over the period 1963 to 2000. We estimate and input Korean and OECD time series of sector-specific labor productivity, tariff rates, and export subsidy rates. Notably, there is insufficient data for us to estimate Korean agricultural subsidies and we are forced to use industrial subsidy rates in both traded good sectors. The Armington aggregator weights are matched to a sample of average expenditures on domestic and imported goods for each traded good sector and country, after controlling for measured trade policies and the relative price of imports observed in the data. Finally, the subsistence level of agriculture is calibrated to match the 1963 employment share of agriculture observed in Korea. Since in our model all production is simply value added, we compute new bilateral value added trade flows between Korea and the OECD and use these in our calibration.

This benchmark version of the model generates sectoral reallocations of employment in Korea that are qualitatively and quantitatively similar to those in the data. Specifically, the model captures the magnitude of decline in Korean agriculture's employment share well, forecasting 108 percent of the actual decline. It over-predicts Korean industry's 1963 employment share, and hence under-predicts the initial service sector share. Nonetheless, from 1965 until 1980 the model's forecast for industry's employment share moves very closely with the data and captures more than 75 percent of the observed increase. It also captures almost 90 percent of the decline in industry's employment share - de-industrialization - after 1991. However, the benchmark forecast for industry's employment share peaks in 1980 and declines thereafter, while the actual peak occurs in 1991. As a result, services account for a larger fraction of employment towards the end of the sample period than actually observed. In addition, the model predicts value added trade volumes between the OECD and Korea over the sample period that are quantitatively similar to those in the data. Finally, the model predicts an international pattern of trade and specialization that favors Korean industry at every date in the sample, reflecting not only the measured pattern of comparative cost advantage in estimated labor productivities, but also higher estimated Korean home bias in industry relative to agriculture and the converse pattern in the OECD, and the relative importance of agricultural subsistence expenditure in Korea.

Several counterfactual experiments quantify the impact for structural change of Korea's trade policies. First, we counterfactually maintain tariffs at their high 1963 values throughout the sample, abstracting from the changes and reform that subsequently occurred, while inputting our original data series for subsidy rates and OECD tariffs. Maintaining 1963 tariffs, which are relatively high in agriculture compared to the benchmark model, increases protection and reduces imports of Korean varieties - especially in agriculture - triggering a trade surplus. Trade balance is restored because the increase in Korean demand for domestic varieties and decline in Korean demand for OECD varieties increase Korea's demand for labor, wage rate, and producer prices relative to those in the OECD. The resulting loss of international competitiveness for Korean exports, especially in the positive net export sector - industry - eliminates the incipient trade surplus that counterfactually high tariffs encourage. Overall, trade is lower, the pattern of trade is compressed, with net exports of industry and net imports of agriculture reduced, industrialization in Korea is significantly muted, and agriculture's employment share increased relative to the benchmark model and the data. By contrast, counterfactually maintaining subsidies at their high 1963 levels while inputting our original tariff series increases trade volumes, intensifies the pattern of trade, magnifies the pace and magnitude of industrialization in Korea, and reduces agriculture's employment share relative to the benchmark economy and data. Counterfactually high 1963 subsidies raise Korean exports, and especially the exports of the internationally competitive sector - industry, inducing a trade surplus. The increase in OECD demand for Korean relative to OECD goods restores trade balance, by stimulating relative Korean labor demand, wages, producer prices, and hence imports. In both counterfactuals, the disproportionately large response of Korea's agricultural imports and industrial exports is largely due to the higher estimated Korean home bias in industry relative to agriculture and the converse pattern in the OECD. The larger income elasticity of the industrial final good, compared to agriculture, works to reinforce these responses in the tariff counterfactual and offset them in the subsidy counterfactual.

Evidently, the effects of tariff and subsidy reform for trade volumes, trade patterns, and structural change are opposing. Consequently, the trade and structural change generated by the actual Korean trade reform of both tariffs and subsidies simulated in the benchmark economy are surprisingly similar to those of a counterfactual "no reform" economy in which neither tariffs nor subsidies are reformed and both instruments remain at their 1963 values. The "no reform" economy demonstrates, however, that the effects of maintaining 1963 subsidies in increasing the competitiveness of industry dominate those of maintaining 1963 tariffs for reducing it. The magnitude of agriculture's employment share is counterfactually low throughout the sample, and industrialization counterfactually rapid, although both features are muted in the "no reform" economy relative to the "no subsidy reform" experiment due to simultaneously higher tariffs. Post 1963 subsidy reform in Korea disproportionately harmed the competitiveness of the industrial sector relative to the benefits conferred by tariff reform.

We find that if Korea had instead conducted trade reform "shock therapy", setting all tariff and subsidy rates to zero in 1963 and holding them there, trade volumes would have almost doubled relative to both the "no reform" and benchmark economies. Structural change in the "complete reform" economy is, however, almost indistinguishable from that in the "no reform" economy. This is because the evolution of relative variety prices and variety expenditure shares are almost identical across sectors in the two counterfactuals. When Korean trade policies are zero, international labor productivity differentials across sectors and sectoral differences in OECD tariffs solely determine this evolution. In the "no reform" economy, 1963 Korean subsidies are always the same across sectors and although the 1963 tariff rate is slightly higher in agriculture than in industry, the magnitude of this difference is insufficient to distort relative variety prices across sectors compared to the "complete reform" economy. Absolute magnitudes of policy trade barriers are irrelevant for sectoral allocations; sectoral differences matter.

Our analysis substantively contributes to a growing literature exploring the role of international trade for sectoral allocations of employment and value added. Most closely related to our work are Sposi (2014), Teignier (2014) and Uy, Yi and Zhang (2013). Like these authors, we find that a benchmark open economy model performs empirically substantially better than a closed economy variant, however our trade policy measurement and analysis is unique. Sposi's multi-country, three sector model, and that of Uy, Yi and Zhang (2013), features iceberg trade costs that incorporate tariff and subsidy policies in principle. However, relative to our framework, the iceberg technology delivers identical mappings of trade and all other transactions costs to structural variables, and ignores distortions of competitive equilibrium from socially optimal allocations arising from net tariff revenue rebates. Although he does not measure export subsidies, Sposi allocates a portion of the iceberg costs to estimated tariffs and finds that tariffs, measured and modeled this way, are not quantitatively important in influencing Korea's structural change. Teignier (2014) develops a small open economy, two sector model of Korean structural change, where agriculture and non-agriculture are the two sectors. While he can address neither industrial sector trade policy directly nor interactions of sectoral trade policies as we do, Teignier argues that had agricultural trade barriers been absent accelerated movements of resources out of agriculture would have resulted, which is consistent with our "shock therapy" counterfactual result. Finally, Connolly and Yi (2015) also analyze the effects of Korea's trade policies for structural variables in a general equilibrium setting. However, theirs is an analysis of the role of trade policy for economic growth, rather than for structural change. They use a neoclassical capital accumulation model, in contrast to our static Ricardian framework, and deliberately abstract from sectoral reallocation.

## 2 Structural Change and Trade Reform in South Korea

Prior to 1963, Korea was essentially a closed economy, characterized by high unemployment and inflation, and large budget and balance of payments deficits. Import substitution policies overtly encouraged production for domestic rather than for export markets, and international trade between Korea and the rest of the world was small.

The high barriers to imports imposed by Korea in the 1950s were systematically removed starting in 1968, with selective quantitative barrier and tariff reductions for agricultural products. Substantial industrial tariff reductions took place between 1973 and 1983, and by 1979 the industrial tariff rate fell below its 1963 value. Tariff reform continued into the 1990s, with the last tariff rate reductions observed in our tariff rate data occurring between 1994 and 1995; the average tariff rate was reduced to 7.9 percent in 1995.

In addition, from 1963, a variety of export promotion policies were enacted. These initially targeted the development of key export industries, with export incentives that included direct cash subsidies, a preferential tax system, a preferential loan system, and various administrative support systems. While the preferential tax system included tariff exemptions on raw materials, intermediate goods, and capital goods devoted specifically to export production, many subsidies increased the profitability of export sales relative to domestic sales by distorting international relative prices. Although export incentives remained in place throughout the 1970s, the scope of subsidies was gradually reduced. 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. While tariff exemptions on imported intermediates were an important element of Korean trade liberalization, we focus on quantifying value added in production and trade and abstract from the role of intermediate inputs, so the export subsidy data we use is net of tariff exemptions on intermediate products. Irrespective of the inclusion or exclusion of tariff exemptions, by 1982 most export subsidies had been eliminated (Nam (1995)) and in our trade policy data, which we describe in detail in section 4, the estimated gross subsidy rate falls to zero in 1981.

Figure 1 shows the evolution of Korean bilateral value added exports and imports by sector and in total with the OECD during the 1963 through 2000 period[1]. A description of our construction of Korea's value added bilateral trade with the OECD is provided in section 4. Although gross trade flows are not a subject of our analysis, the fact that OECD countries accounted for 68 percent of Korean gross exports and 71 percent of Korean gross imports annually on average over this period suggests their importance for the growth of Korean trade after 1963. In addition, we find that Korea exported 13% more current dollar value added to the OECD than she did to all of her trade partners in the world economy, and imported three percent more from the OECD during our sample period. The OECD was a relatively important value added trade partner for Korea.

Figure 1 shows that trade promotion policies in Korea were associated with a dramatic increase in the size and shift in the composition of her bilateral value added trade with the OECD. This trade with the OECD more than doubled over the entire 38 year period, from 10 percent of Korean GDP in 1963 to 21 percent in 2000. It reached a peak of almost 30 percent by the mid-1970s, after a period of very rapid growth in both exported and imported value added. Value added exports rose from less than 2 percent in 1963 to more than 12 percent of GDP in 2000, a more than six fold increase, reaching peaks of 13.7 percent and 15 percent of GDP in 1976 and 1987 respectively. Value added imports increased very little over all, rising from 8.3 percent of GDP in 1963 to 8.9 percent in 2000, however they reached a peak of 15 percent in 1974. Meanwhile, the composition of value added trade shifted heavily in favor of industrial sector exports and imports. Industrial sector value added exports accounted for only 21 percent of total exports of value added in 1963, but for 81.5 percent in 2000. Similarly, industrial sector value added accounted for 59 percent of total value added imports in 1963 and for 83 percent in 2000.

**Figure 1 goes here**

The left panel of Figure 2 shows that Korean trade reform, and the two-fold increase in the size of Korea's bilateral value added trade with the OECD, was accompanied by a dramatic rise in real gross value added (GDP) per worker[2] relative to the OECD. Korean real GDP per worker

[1] 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.

[2] The construction of real GDP per worker is described in detail in section 4.

rose from about 12 percent to roughly 46 percent of that in the OECD, an increase of about 277 percent over the sample period. The right panel of Figure 2 shows that this is associated with 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. The right panel therefore reveals a shift in the pattern of comparative advantage in favor of Korean industrial products after the mid-1970s, when relative industrial productivity in Korea began to grow rapidly.

**Figure 2 goes here**

Figure 3 shows that Korea's export promotion, trade reform, trade growth, relative income growth, and labor productivity growth coincided with substantial structural transformation of the economy. The right panel of the figure shows the evolution of employment shares of the three major sectors of the economy, expressed as a percentage of total employment, and the left panel shows the evolution of GDP shares[3] 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 shares of the industrial and the service sector occurred between 1963 and 2000. Specifically, in 1963 agriculture accounted for 63 percent of 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 "hump" 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 evolve rather differently from employment shares, with services showing much less GDP than employment share growth, and industry greater growth. In our analysis we focus on employment shares, which are more common measures of structural change than GDP shares.

**Figure 3 goes here**

This structural transformation of the Korean economy is the object of our analysis. We develop a quantitative model which, when calibrated to Korean data and simulated can address the

[3]We describe the construction of the employment and GDP shares in section 4.

question: To what extent was the structural transformation of Korea attributable to the international trade policies adopted there?

## 3 Model

We consider a two country, three sector world economy where the countries are "home" and "foreign" and indexed by *i=h,f.* The three sectors are "Agriculture", "Industry", and "Services" and indexed by *k=A,I,S.* Each sector exclusively produces a single final consumption good - so that final goods are also indexed by k - by aggregating domestically and imported foreign produced varieties of the sector's good. We assume that trade in varieties is balanced, while final goods are not traded. A representative household inhabits each country, derives utility from consumption of the three sectors' final goods, and supplies labor in-elastically to variety production. Labor is mobile across sectors but not countries. A government in each country imposes proportional tariffs on imports, rewards exports of varieties with proportional subsidies, and rebates tariff income net of subsidy expenditure to households as a lump-sum transfer. Consequently, competitive equilibrium allocations of this economy are not, in general, Pareto efficient. Finally, time is discrete and indexed by $t$.

### 3.1 Varieties

A representative perfectly competitive firm in sector $k$ produces the $i$th variety 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 exogenous productivity of labor, $N_{i,t}^{k}$ the number of labor units employed, and $y_{i,t}^{k}$ the level of output, at date $t$, respectively. This representation of sectoral variety production is identical to that employed by Duarte and Restuccia (2010). Variety producers take the prices of output and labor as given, and choose employment to solve the profit maximization problem.

$$\max \quad p_{i,t}^{k} y_{i,t}^{k} - w_{i,t} N_{i,t}^{k}$$
$$\text{s.t.} \quad y_{i,t}^{k} = \theta_{i,t}^{k} N_{i,t}^{k} \text{ , and } N_{i,t}^{k} \geq 0. \quad \text{for} i = h, f, \;\; k{=}A{,}I{,}S \;\text{ and }\; \forall\, t \tag{3.1}$$

Here, $p_{i,t}^{k}$ is the producer price of variety $i$ of good type $k$, and $w_{it}$ is the wage rate in country i at date $t$.

### 3.2 Government

The government in each country sets tariffs and subsidies subject to a balanced budget at every date. Specifically, government $i$ imposes a per unit tariff - $\tau_{i,j,t}^{k}$ - on units of variety $j \neq i$ for sector $k$=$A$,$I$, imported from abroad by domestic final good producers. It also awards subsidies for units of variety $i$ exported by reducing the unit price paid by producer $k$=$A$,$I$ in country $j \neq i$ 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. Since tariff revenue net of expenditure on export subsidies is rebated to the consumer as a lump sum transfer, the budget constraint of government $i$, $i \neq j$ is

$$T_{it} = \sum_k \tau^k_{i,j,t} \frac{p^k_{j,t}}{(1 + s^k_{j,i,t})} y^k_{j,i,t} - \sum_k \frac{s^k_{i,j,t}}{(1 + s^k_{i,j,t})} p^k_{i,t} y^k_{i,j,t} \quad \text{for } k = A, I, \ \forall \ t \quad . \tag{3.2}$$

Here $y^k_{j,i,t}$ is country $i$ imports of variety $j$ of good $k$ and $y^k_{i,j,t}$ is country $i$ exports of variety $i$ to country $j$ of good $k$, $i \neq j$.

### 3.3 Final Goods

A representative perfectly competitive firm in sector $k$ of country $i \neq j$ produces final good $k$ with the production function:

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

Here, $Y^k_{i,t}$ is total final output of good $k$, $y^k_{i,i,t}$ and $y^k_{j,i,t}$ are domestic variety $i$ and imported variety $j$ inputs respectively, $\mu^k_i$ is the weight assigned to the domestic variety, $(1-\mu^k_i)$ is the weight assigned to the imported variety, and $\rho$ reflects the elasticity of substitution between these varieties. We assume that Service varieties are not traded, i.e. $\mu^S_i = 1$ for $i$=$h$,$f$. Following convention in the international trade literature, we assume that the domestic and foreign varieties are substitutes, or $0 < \rho < 1$. The values of $\mu^k_i$ and $\rho$ are important determinants of final good producers' allocation of spending on local and imported varieties of inputs, and hence of the pattern and volume of trade. We think of $\mu^k_i$ 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 proportional tariffs (or foreign country subsidies) which discourage (encourage) imported variety use. They also include any policy barriers such as import quotas, which are excluded from our measures of tariffs and subsidies.

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

$$\max \quad P_{i,t}^k Y_{i,t}^k - p_{i,t}^k y_{i,i,t}^k - \frac{(1+\tau_{i,j,t}^k)}{(1+s_{j,i,t}^k)} p_{j,t}^k y_{j,i,t}$$

$$\text{s.t.} \quad Y_{i,t}^k = \left(\mu_i^k \left(y_{i,i,t}^k\right)^\rho + (1-\mu_i^k)\left(y_{j,i,t}^k\right)^\rho\right)^{1/\rho} \quad . \tag{3.3}$$

$P_{i,t}^k$ is the consumer price index for good $k$, which is derived from the first order conditions of final good producers, and given by[4]

$$P_{i,t}^k = \left(\left(\mu_i^k\right)^{1/(1-\rho)} \left(p_{i,t}^k\right)^{\rho/(\rho-1)} + (1-\mu_i^k)^{1/(1-\rho)} \left(\frac{(1+\tau_{i,j,t}^k)}{(1+s_{j,i,t}^k)} p_{j,t}^k\right)^{\rho/(\rho-1)}\right)^{\frac{(\rho-1)}{\rho}} \tag{3.4}$$

### 3.4 Households

Household $i$ maximizes the lifetime utility function

$$\max \quad U^i(C_i) = \sum_{t=0}^{\infty} \beta^t \frac{C_{i,t}^\psi - 1}{\psi} \quad , \tag{3.5}$$

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

$$C_{i,t} = \left(\xi_A \left(C_{i,t}^A - \bar{A}\right)^\omega + \xi_I \left(C_{i,t}^I\right)^\omega + \xi_S \left(C_{i,t}^S\right)^\omega\right)^{\frac{1}{\omega}} \quad . \tag{3.6}$$

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, and $\bar{A}$ denotes subsistence consumption of Agriculture. In addition, $\xi_k$ is the weight assigned to consumption of final good $k$, $\omega$ 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[5].

Household $i$ maximizes lifetime utility (3.5) by choice of consumption subject to (3.6) and the budget constraint

$$\sum_k P_{i,t}^k C_{i,t}^k = w_{i,t} N_{i,t} + T_{i,t} \quad \forall\, t \quad , \tag{3.7}$$

where $N_{i,t}$ is the household's endowment of labor time (which we normalize to one unit), and $T_{i,t}$ is the lump sum transfer from the government of country $i$ which may be positive or negative,

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

[5] A generalized form of the utility function allowing for non-homothetic preferences in the industrial and service sectors can be expressed as

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

. Uy, Yi and Zhang (2013) find the estimate of $\bar{S}$ to be zero using Korean data. We restrict $\bar{I}$ to be zero following Herrendorf, Rogerson and Valentinyi (2013) depending on the size of tariff revenue relative to the cost of export subsidies. Without loss of generality, we let the foreign produced variety of industrial goods be the numeraire at every date.

### 3.5 Equilibrium

A competitive equilibrium is an allocation $\{N_{i,t}, C_{i,t}, C^A_{i,t}, C^I_{i,t}, C^S_{i,t}\}_{t=0}^{\infty}$ for household $i$; an allocation $\{N^k_{i,t}, y^k_{i,t}\}_{t=0}^{\infty}$ for variety producer $i$ of sector $k$; an allocation $\{y^k_{i,i,t}, y^k_{j,i,t}, Y^k_{i,t}\}_{t=0}^{\infty}$ for final good producer $k$ in country $i$, $i \neq j$; prices $\{w_{i,t}, p^k_{i,t}, P^k_{i,t}\}_{t=0}^{\infty}$ for country $i$ and sector $k$; and exogenous government policies $\{\tau^k_{i,j,t}, s^k_{i,j,t}, T_{i,t}\}_{t=0}^{\infty}$ 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 ((3.5)-(3.7));

(2) Given prices, variety $i$ producer's allocation solves the maximization problem (3.1) $\forall$ $t$;

(3) Given prices, final good $k$ producer's allocation solves the maximization problem (3.3) $\forall$ $t$;

(4) Prices are such that labor markets clear

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

variety markets clear

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

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

and final goods' markets clear

$$Y^k_{i,t} = C^k_{i,t} \ \forall \ t \quad ;$$

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

$$T_{it} = \sum_k \tau^k_{i,j,t} \frac{p^k_{j,t}}{(1 + s^k_{j,i,t})} y^k_{j,i,t} - \sum_k \frac{s^k_{i,j,t}}{(1 + s^k_{i,j,t})} p^k_{i,t} y^k_{i,j,t} \ \forall \ t \quad .$$

### 3.6 Analysis

The first order conditions for a variety producer's profit maximization problem imply that labor is paid its marginal product if that variety is produced so that $p^k_{i,t} = \frac{w_{i,t}}{\theta^k_{i,t}}$.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

$$Z_{i,i,t}^{k}=\frac{p_{i,t}^{k}y_{i,i,t}}{P_{i,t}^{k}Y_{i,t}^{k}}=\left(\mu_{i}^{k}\right)^{\frac{1}{1-\rho}}\left(\frac{p_{i,t}^{k}}{P_{i,t}^{k}}\right)^{\frac{\rho}{\rho-1}}\quad , \tag{3.8}$$

$$Z_{j,i,t}^{k}=\frac{\frac{(1+\tau_{i,j,t}^{k})}{(1+s_{j,i,t}^{k})}p_{j,t}^{k}y_{j,i,t}^{k}}{P_{i,t}^{k}Y_{i,t}^{k}}=\left(1-\mu_{i}^{k}\right)^{\frac{1}{1-\rho}}\left(\frac{\frac{(1+\tau_{i,j,t}^{k})}{(1+s_{j,i,t}^{k})}p_{j,t}^{k}}{P_{i,t}^{k}}\right)^{\frac{\rho}{\rho-1}}\quad . \tag{3.9}$$

For Services $Z_{j,i,t}^{S}=0$. Finally, market clearing for final good $k$ implies that $P_{i,t}^{k}Y_{i,t}^{k}=P_{i,t}^{k}C_{i,t}^{k}$ for $i=h,f$ and $k=A,I,S\ \forall\ t$.

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 expenditure on the consumption composite for country $i=h,f$.

$$E_{i,t}^{k}\equiv\frac{P_{i,t}^{k}C_{i,t}^{k}}{\Xi_{i,t}}=\begin{cases}\dfrac{\xi_{k}^{\frac{1}{1-\omega}}\left(P_{i,t}^{k}\right)^{\frac{\omega}{\omega-1}}}{\sum\limits_{m=\{A,I,S\}}\xi_{m}^{\frac{1}{1-\omega}}\left(P_{i,t}^{m}\right)^{\frac{\omega}{\omega-1}}}\left(1-\dfrac{P_{i,t}^{A}\bar{A}}{\Xi_{i,t}}\right)+\dfrac{P_{i,t}^{A}\bar{A}}{\Xi_{i,t}}\ , & \text{if } k=A\\[2ex] \dfrac{\xi_{k}^{\frac{1}{1-\omega}}\left(P_{i,t}^{k}\right)^{\frac{\omega}{\omega-1}}}{\sum\limits_{m=\{A,I,S\}}\xi_{m}^{\frac{1}{1-\omega}}\left(P_{i,t}^{m}\right)^{\frac{\omega}{\omega-1}}}\left(1-\dfrac{P_{i,t}^{A}\bar{A}}{\Xi_{i,t}}\right)\ , & \text{if } k=I,S\end{cases}\ , \tag{3.10}$$

where $\Xi_{i,t}=\sum\limits_{k}P_{i,t}^{k}C_{i,t}^{k}$ is total final expenditure on the consumption composite.

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

$$\sum_{k=A,I}\frac{1}{1+s_{i,j,t}^{k}}p_{i,t}^{k}y_{i,j,t}^{k}=\sum_{k=A,I}\frac{1}{1+s_{j,i,t}^{k}}p_{j,t}^{k}y_{j,i,t}^{k}\quad . \tag{3.11}$$

That is, the effective world prices at which trade occurs between importing final good producers and exporting variety producers are producer prices adjusted for export subsidies[6].

### 3.6.1 Employment Structure

GDP at factor cost in country $i$ at date $t$ is just the sum of the value of outputs of each sector's variety, $Y_{i,t}=\sum_{k}p_{i,t}^{k}y_{i,t}^{k}$. Profits are zero in equilibrium, and labor is the only production factor, so GDP at factor cost is also measured by labor income at $t$, $Y_{i,t}=w_{i,t}\sum_{k}N_{i,t}^{k}=w_{i,t}N_{i,t}$ .

[6] We do not explicitly model subsidies as being given to exporters as a production subsidy for the sake of simplicity. However, like a production subsidy for exports, subsidies in our framework lower the price for units that are exported relative to units that are sold domestically. Since subsidies affect the price at which a variety reaches the border of the destination market, the balanced trade condition must hold at prices that are inclusive of subsidies. Tariffs, on the other hand, affect the price only after the good has crossed the border, and implicate the consumer prices of imports but not the price at which goods are exchanged across the border. Thus, tariffs do not appear in the balanced trade condition. Alternatively, we can think of our formulation of subsidies as being a simplification of the underlying production technology for exporting, while the tariff is a tax on imports.

Therefore, the GDP and employment share of a sector are identical:

$$\frac{p_{i,t}^k y_{i,t}^k}{Y_{i,t}} = \frac{N_{i,t}^k}{N_{i,t}} \quad .\forall t \tag{3.12}$$

It is worth mentioning that in our framework GDP can be measured in different ways because prices of goods can be measured before or after taxes and subsidies. The use of prices excluding taxes and subsidies yields GDP at factor cost, while the use of prices including taxes and subsidies yields GDP at purchaser prices. We chose to measure the GDP and employment shares of sectors by using GDP at factor cost. Therefore, when we quantify our model we employ as our data counterparts factor cost measures of sectoral and aggregate GDP, and of sectoral GDP per worker, drawn from the World Development Indicators (WDI) database of the World Bank. Also, in our model, while the share of a sector in employment equals its share in GDP at factor cost, this equality does not hold when GDP is measured in purchaser prices. Therefore, the presence of taxes and subsidies can generate a discrepancy between the output and employment share of a sector even with a Ricardian production technology. However, our focus in this paper is on employment shares since they have been the subject of investigation in much of the literature on structural change.

We now characterize the determinants of the economy's structure in terms of the employment 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 domestic consumption and exports valued at factor cost, or

$$p_{i,t}^k y_{i,t}^k = p_{i,t}^k \left( y_{i,i,t}^k + y_{i,j,t}^k \right) \ \forall \ t \quad ,$$

where exports are zero for services. Dividing this by $w_{i,t} N_{i,t}$ and using (3.12) yields

$$\frac{p_{i,t}^k y_{i,t}^k}{Y_{i,t}} = \frac{N_{i,t}^k}{N_{i,t}} = \frac{p_{i,t}^k \left( y_{i,i,t}^k + y_{i,j,t}^k \right)}{w_{i,t} N_{i,t}} = \left( \frac{p_{i,t}^k y_{i,i,t}^k}{P_{i,t}^k Y_{i,t}^k} \right) \left( \frac{P_{i,t}^k Y_{i,t}^k}{w_{i,t} N_{i,t}} \right) + \left( \frac{p_{i,t}^k y_{i,j,t}^k}{P_{j,t}^k Y_{j,t}^k} \right) \left( \frac{P_{j,t}^k Y_{j,t}^k}{w_{i,t} N_{i,t}} \right)$$

Using (3.8), (3.9), (3.10), the final goods' market clearing conditions, and the budget constraints of households, the share of employment accounted for by sector $k$ at date $t$ equals:

$$V_{i,t}^k = Z_{i,i,t}^k E_{i,t}^k \left( 1 + \frac{T_{it}}{w_{i,t} N_{i,t}} \right) + \left( \frac{1 + s_{i,j,t}^k}{1 + \tau_{j,i,t}^k} \right) Z_{i,j,t}^k E_{j,t}^k \left( 1 + \frac{T_{jt}}{w_{j,t} N_{j,t}} \right) \frac{w_{j,t} N_{j,t}}{w_{i,t} N_{i,t}} \quad , \tag{3.13}$$

where $Z_{i,i,t}^k$ is given by (3.8), $Z_{i,j,t}^k$ can be derived using (3.9), and $E_{i,t}^k$ is given by (3.10). For the service sector, since $\mu_i^k = 1$, $Z_{i,i,t}^S = 1$, and therefore

$$V_{i,t}^S = E_{i,t}^k \left( 1 + \frac{T_{it}}{w_{i,t} N_{i,t}} \right) \quad . \tag{3.14}$$

Equation (3.13) illustrates that the employment share of traded sector $k$ in country $i$ depends on two core forces. One force originates from the consumption side of the economy, and measures the relative magnitude of home and foreign final consumer demand for the sector $k$ good, given by the home and foreign consumption expenditure shares of the sector, $E^k_{i,t}$ and $E^k_{j,t}$. The second force originates from the production side of the economy, and captures the relative magnitude of world producer demand for country *i's* variety of the sector $k$ good. This is measured by the share of country *i's* variety in the expenditure of final good $k$ producers at home and abroad, $Z^k_{i,i,t}$ and $Z^k_{i,j,t}$ respectively. Then the first term on the right-hand side of equations (3.13) and (3.14) is what we call the "domestic effect" for a sector's employment share, which equals the share of value added accounted for by domestic expenditure on the domestic variety of a sector. For the Service sector, which produces the non-traded portion of GDP, the domestic effect is simply the domestic consumption expenditure share of the sector which wholly constitutes its employment share. While Services are not traded, their employment share (3.14) is potentially influenced in an open economy by international trade, because the price of the domestic variety of Services relative to the price indexes of traded goods included in the CPI, is a key determinant of the sector's domestic consumption expenditure share, as seen in (3.10). Analogously, the second term on the right-hand side of (3.13) captures the "foreign effect" for a sector's employment share in a country, which captures the share of domestic value added accounted for by exports of the sector.

### 3.6.2 Structural Change in the Open Economy

By structural change, we refer to (secular) change over time in the employment shares of sectors. We have seen that the employment share of a traded good sector depends on the share of spending on the domestic variety by the sector's final good producers, and the share of total consumer spending on that sector's final good, both at home and abroad. Time variation in these shares - and hence structural change - derives from three main sources.

First, the assumption that preferences are non-homothetic, as a result of the parameter $\bar{A}$ which measures subsistence consumption of Agriculture, exerts a powerful influence on final consumption spending patterns. It implies that the income elasticity of Agricultural consumption is less than one, while that of Industry and Services exceeds one. As a result, and as equation (3.10) shows, the share in total consumption spending of Agriculture declines while the shares of Industry and Services tend to increase with economic growth which raises the total consumption expenditure of a country relative to the value of subsistence consumption.

Second, the final consumption expenditure share of a sector depends on its relative final consumer price. The magnitude and direction of a sector's consumption spending response to changes in its relative price are dictated by the elasticity of substitution between final goods in preferences, and hence by the parameter $\omega$. In our calibrated model, and throughout the structural change literature, this elasticity is assumed to be sufficiently small that final goods are gross complements, i.e. $\omega$ is negative so that a decrease in the relative price of final good $k$ results in a decline in its expenditure share. This reallocates labor away from sectors with relatively fast productivity growth and hence falling relative prices, and in favor of sectors with relatively slow productivity growth and rising relative prices. For example, relatively rapid productivity growth and a declining relative price in Agriculture during the early stages of development are associated with a decline in the employment share of Agriculture relative to Industry and Services. This exodus of labor from Agriculture with economic growth is reinforced by the non-homotheticity in preferences. In addition, if industrial sector productivity rises relative to service sector productivity during economic development, one would expect to observe a slowing pace of industrialization and an increasing rate of resource allocation into services. Gross complementarity of final goods is therefore at least consistent with the decline of agriculture, the "hump-shape" in industry's share of employment, and growth in service sector employment observed in Korea.

The third mechanism producing structural change in our model is attributable to the openness of the economy. There are three ways in which openness effects structural change. First, the presence of income effects in trade partners due to non-homothetic preferences affects foreign final consumption shares. For example, as Korean income grew its OECD trade partners would tend to experience declining Korean demand for OECD agricultural goods, and increasing Korean demand for OECD industrial goods. Both of these phenomena are observed in our data; Korean imports of OECD agricultural products fall and imports of industrial products rise over our sample period. Second, complementarity in preferences among final goods means that a relatively undeveloped country experiencing rapid productivity growth in Agriculture would tend to see a rise in its consumption shares of Industrial and Service sector goods. Hence OECD trade partners of Korea would tend to experience initially increasing Korean demand for OECD Industrial relative to Agricultural goods, reinforcing the income effect we described. The value added trade data presented in Section 2 provides some support for this.

Finally changes in international relative variety prices confronted by final good producers affect their relative expenditures on home and foreign varieties. For example, a decline in the relative price of country $i$'s variety of good $k$ causes both domestic and foreign final good producers to substitute towards it, and both the domestic and foreign effect of this for sector $k$'s employment share are positive. In addition, the magnitude of this mechanism depends on the elasticity of substitution between varieties measured by the Armington elasticity, $\rho$. For example, using the definition of final good price indexes in (3.4) and the first order conditions of variety producers, we re-write the domestic variety expenditure shares for country $i$ GDP of domestic ($Z^k_{i,i,t}$) and foreign final good producers ($Z^k_{i,j,t}$), for $k$=$A$,$I$, and $i$=$h$,$f$ $i \neq j$ in (3.13) as

$$Z^k_{i,i,t} = \left(\mu^k_i\right)^{\frac{1}{1-\rho}} \left(\frac{p^k_{i,t}}{P^k_{i,t}}\right)^{\frac{\rho}{\rho-1}} = \left[1 + \left(\frac{1-\mu^k_i}{\mu^k_i}\right)^{\frac{1}{1-\rho}} \left(\frac{(1+\tau^k_{i,j,t})}{(1+s^k_{j,i,t})}\frac{w_{j,t}}{w_{i,t}}\frac{\theta^k_{i,t}}{\theta^k_{j,t}}\right)^{\frac{\rho}{\rho-1}}\right]^{-1}, \tag{3.15}$$

$$\begin{aligned} Z^k_{i,j,t} &= \left(1-\mu^k_j\right)^{\frac{1}{1-\rho}} \left(\frac{1+s^k_{i,j,t}}{1+\tau^k_{j,i,t}}\right)^{\frac{1}{1-\rho}} \left(\frac{p^k_{i,t}}{P^k_{j,t}}\right)^{\frac{\rho}{\rho-1}} \\ &= \left(\frac{1+s^k_{i,j,t}}{1+\tau^k_{j,i,t}}\right)\left[1 + \left(\frac{\mu^k_j}{1-\mu^k_j}\right)^{\frac{1}{1-\rho}} \left(\frac{(1+s^k_{i,j,t})}{(1+\tau^k_{j,i,t})}\frac{w_{j,t}}{w_{i,t}}\frac{\theta^k_{i,t}}{\theta^k_{j,t}}\right)^{\frac{\rho}{\rho-1}}\right]^{-1}. \end{aligned} \tag{3.16}$$

In (3.15), since we assume that foreign and domestic varieties are substitutes so that $0 < \rho < 1$, 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 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 employment rises due to more intensive domestic use of the domestic variety and a larger domestic effect. This will occur when the sector $k$ domestic tariff rate increases relative to the foreign subsidy rate, when domestic sector $k$ labor productivity increases relative to that abroad, and when relative domestic wage falls. Similarly, in (3.16), increases in domestic subsidies relative to foreign tariffs, in relative domestic labor productivity, and a decrease in the relative domestic wage promote a lower relative price and more intensive use of the domestic variety abroad, the foreign effect for sector $k$ increases, and the share of sector $k$ in country $i$ employment rises as a result. Clearly, the higher is $\rho$ and hence the larger the elasticity of substitution between domestic and imported varieties, $1/(1-\rho)$, the larger is the impact of changes in relative variety prices for sector $k$'s variety use and share of employment.

## 4 Calibration and Data

We calibrate the model of Section 3 to data from South Korea and the OECD. In our calibration, we treat Korea as the home country and the OECD as the foreign country. Wherever OECD aggregate data is not available to calibrate the parameters of the model, we substitute US data as a proxy and note in the text where this is necessary. 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

First we discuss our construction of some key data series, and their sources.

**Value Added and GDP**: We measure the GDP of a sector with sectoral value added data from the World Development Indicators (WDI) statistics, 2003. These data are measured at factor cost and are reported in current and constant 1995 US dollars, with the following definitions of sectors. Agriculture corresponds to ISIC divisions 1-5; these include forestry, hunting, and fishing, as well as cultivation of crops and livestock production. Industry corresponds to ISIC divisions 10-14, 15-37, 40-41 and 45; these include mining, manufacturing, public utilities and construction. Services correspond to ISIC divisions 50-55, 60-64, 65-74 and 75-99; these include wholesale and retail trade (including hotels and restaurants), transport, storage and communication, finance, insurance and real estate and community, and social and personal services. Missing values of constant 1995 dollar -"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 these two sectors, respectively. Real value added by sector for OECD member countries is only available from 1971 onwards. We impute the missing data for 1963-70 by using each sector's growth rate of real value added between 1971 and 2000. The resulting sectoral real GDP time-series are used compute labor productivity by sector for Korea and the OECD, as we describe below. We compute the GDP shares of sectors presented in Section 2 using the WDI's current dollar sectoral and aggregate GDP data [7].

We construct aggregate real GDP measured in 1995 constant US dollars for Korea and OECD member countries using aggregate real value added at factor cost series, in current and constant 2000 US dollars, drawn from the WDI online database. For each country, we first compute a value added deflator with 2000 as the base year, dividing current dollar by constant 2000 US dollar value added, and then shift the base year from 2000 to 1995. The resulting deflator series allows us to compute gross value added in constant 1995 US dollars. This ensures compatibility of aggregate

[7] Kuznets (1966) found that nominal and real GDP shares of sectors exhibited very similar qualitative behavior. However, Herrendorf et al. (2013) found that while this was true of almost every country, Korea's nominal manufacturing GDP share exhibited a hump-shape like the employment share of the sector, while the real GDP share of the sector continued to grow beyond the nominal share's peak, implying a substantial decline in the relative price of manufacturing goods. Despite our broader sectoral definition, the nominal GDP share of industry in Figure 3 also displays a hump shape, albeit a muted one relative to the employment share of the sector. We elect to present the nominal GDP shares of sectors, and focus in any case on matching the employment shares of sectors in our analysis.

real value added with our measures of sectoral real value added which are measured in constant 1995 US dollars. Real GDP per worker for Korea is then computed by dividing aggregate real value added by total Korean employment. Real GDP per worker for the OECD is constructed as a weighted average of individual countries' aggregate real gross value added per worker, where the weights are the share of that country's employment in total OECD employment. Figure 2 displays the ratio of Korean to OECD real GDP per worker. Construction of the employment data is discussed next.

**Employment**: The Groningen Growth and Development Centre (GDDC) 10 sector database provides data on employment in each of 10 sectors in Korea. We aggregate employment in these ten sectors into employment in Agriculture, Industry & Services using the ISIC sectoral classifications described above, and total employment is simply the sum of employment across all sectors. The sectoral employment shares for Korea, which we display in Figure 3 and are the targets for our model, are derived by dividing employment in each of the three sectors by total employment for the period 1963-2000. Data on employment by sector for the OECD are constructed from the OECD Annual Labor Force Statistics database which reports civilian employment in each sector by member country. We first aggregate sectoral employment for each country using the ISIC sectoral classifications described above. We then impute missing observations for sectoral employment in every country for the years 1963-70 by using the growth rate of employment in each sector for each country between 1971 and 2000. Finally, OECD employment by sector is obtained by summing employment across all member countries for each sector. Total OECD employment is just the sum of sectoral employment numbers.

**Value Added Trade**: To derive the value added trade flows between Korea and OECD by sector we use two data sources. The first is Robert Feenstra's Trade Data, SITC Revision 2, from which we obtain the *gross* imports and exports of Korea with respect to the OECD for agriculture and for manufacturing for our entire sample period. Agriculture is defined as the sum of SITC product categories 0, 1, 2, and 4, minus 27 and 28. Industry is the sum of Fuels and Mining - SITC categories 3 plus 27, 28, and 68, Manufacturing - SITC categories 5,6,7, and 8 minus 68, and all other SITC codes. Gross imports of Korea from the OECD are constructed as the sum of Korea's imports from each country in our list of OECD member countries [8]. Similarly, gross exports of Korea to the OECD are constructed by summing Korea's exports to each member country in the

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

OECD. The second data source is Johnson and Noguera (2014) "A Portrait of Trade in Value Added over Four Decades"[9], which provides information on bilateral value added and gross trade for Korea with 41 trade partners, including some OECD countries and other major emerging economies, from 1971 to 2009. However, the set of OECD partner countries of Korea is smaller in the Johnson and Noguera (2014) data than in the Feenstra data so we do not directly use the value added trade flows of Johnson and Noguera (2014). Instead, we impute bilateral value added trade flows between Korea and our OECD countries as follows.

First, for agriculture and industry separately, we derive a ratio of value added to gross bilateral trade flows using the Johnson and Noguera (2014) data. Johnson and Noguera provide value added and gross trade flows for agriculture, non-manufacturing industrial production and manufacturing industrial production, and services, so we aggregate trade for the two industrial production sectors to be consistent with our definition of sectors. For each sector and year, we compute value added exports and imports, and gross exports and imports, between Korea and "the OECD" by summing each trade flow measure across the OECD member countries that are included in the data set. Then, for each sector and each year for the period 1971 to 2000, we take the ratio of total value added exports from Korea to "the OECD" to total gross exports, and total value added imports of Korea from "the OECD" to total gross imports. While a crude approximation, we assume that from 1963 to 1970 the value added to gross export and import ratios take their 1971 values. Finally, we estimate value added exports from Korea to our more comprehensive set of OECD member countries for each sector, and for the sample period 1963-2000, by multiplying sector-specific value added-to-gross export ratios and Korea's gross exports to the OECD in that sector that we have computed using Feenstra's data. An identical procedure, multiplying sector-specific value added-to-gross imports ratios and the gross imports of Korea from the OECD that we computed using Feenstra's data yields value added imports of Korea from the OECD.

### 4.2 Data Inputs for the Model

There are three time-series that we directly input to our benchmark model of Korea's trade policy reform and structural change.

**Labor Productivity by Sector**: We divide real value added in each sector by employment in that sector for Korea for 1963-2000 to get a time series of sectoral labor productivity. Real value added per worker by sector in the OECD is computed as the weighted average of member countries'

[9] We are extremely thankful to Robert Johnson for providing the data on South Korea.

real value added per worker in that sector, where the weights are the share of a member country's sectoral employment in total OECD employment in that sector.

**Tariff Rates**: Complete annual average tariff rate estimates by sector are unavailable for the 1963-2000 sample period for Korea. Furthermore, tariff rates are usually available for the manufacturing sector and not the whole industrial sector. As a result, we use manufacturing sector tariff rates as a proxy for industry's tariffs. There are three studies that provide tariff rates for both manufactures and agricultural products; Nam (1980) for 1968, Kim (1996) for the period 1983-94, and the Bank of Korea for the period 1994-2000. By splicing the Kim (1996) and Bank of Korea data, we have complete time series of tariff rates for the two sectors from 1983-2000. For the period 1963-82 we have to combine data from different sources, and use an extrapolation methodology to construct sectoral tariff rates (time series are presented in Table 1), which we now explain.

*Industrial Tariff Rates*: Nam (1980) is the only source that provides estimates of tariff rates in both sectors for any year prior to 1983, and hence the 1968 estimates he provides are the only source of information on the relative size of tariff rates across sectors from 1963 through 1982 - information that is invaluable for our analysis. Lee (1995), provides an estimated average manufacturing sector tariff rate for each of the following sub-periods: 1962-67, 1968-72, 1973-76 and 1979-83. We compute the factors by which these average manufacturing tariff rates changed between sub-periods, and apply these "growth factors" to extrapolate Nam (1980)'s 1968 manufacturing tariff rate estimate - backwards and forwards - to construct data for the missing years. For example, using Lee (1995)'s average tariff rates for for 1962-67 and 1968-72, we compute the factor by which the average manufacturing tariff rate changed between the two sub-periods. We then apply this growth factor to Nam (1980)'s 1968 value of the manufacturing tariff rate to extrapolate it backward. Since Lee (1995)'s data are averages over the sub-periods, as a simplification we assume that the extrapolated value applies to each year of the sub-period 1963-67, and that Nam (1980)'s 1968 value applies to each year during 1968-72. We use the same methodology to obtain the growth factor between 1968-72 and 1973-76 and then the extrapolate Nam (1980)'s data forward for 1973-76. Again, the extrapolated value is assumed to apply to each year during 1973-76. Finally, we calculate the growth factor between 1973-76 and 1979-83 and use it to extrapolate the 1973 tariff rate forward to derive the tariff rate for the 1979-83 period. Since Lee (1995) does not provide any estimates for 1977 and 1978, we are forced to assume that the extrapolated value for 1973-76 applies to these two years as well.

*Agricultural Tariff Rates*: Unfortunately, there is no other source of earlier agricultural tariff rates from which we could extrapolate that for 1968 reported by Nam (1980). However, Collins and Park (1989*a*) present data on simple average tariff rates for South Korea for the period 1952-1984. Though not a continuous time series, estimates for 1962, 1968, 1973, and 1979 are provided. We construct agricultural tariff rates by (a) assuming that the aggregate tariff rate in each period is a simple average of the manufacturing and agricultural tariff rate, (b) extrapolating the 1968 aggregate tariff rate for Korea which is also reported by Nam (1980) using "growth factors" based on the data from Collins and Park (1989*a*), and (c) inferring agricultural tariff rates from the industrial and average tariff rates that we have constructed, using assumption (a). As in the case of manufacturing tariffs, we compute a growth factor between 1962 and 1968 based on the Collins and Park (1989*a*) estimates, and then use it to extrapolate backward the 1968 estimate of the aggregate tariff rate from Nam (1980), yielding an estimate for 1962. As in the case of manufacturing, we assume this extrapolated average tariff rate for the economy applies to every year from 1963 to 1967. Repeating this methodology for periods 1968 to 1973 and 1973 to 1979 gives us the average tariff rate in 1973 and in 1979. The 1973 estimate is applied to each year during the period 1973 to 1978 and the 1979 estimate is applied to each year during the period 1979 to 1983. Lastly, the average tariff rate for 1968 comes from Nam (1980) and applies to every year from 1968 to 1972. We then derive the tariff rate for agriculture for every year during the period 1963 to 1982 from our estimated manufacturing and aggregate tariff series.

We proxy average tariff rates by sector imposed by the OECD on Korean imports by the simple average effective import tariff rates by sector imposed by the US on Korean imports. These data are obtained from the World Integrated Trade Solution (WITS) - Trade Analysis and Information System (TRAINS) - database of the World Bank. The data are only available from 1988 through 2010, so we must construct tariff rates for the period 1963 through 1987. We compute a constant annual growth rate, calculated for the 1989-2010 period, and then extrapolate backwards to derive annual tariff rates on agricultural (defined as food plus agricultural raw materials) and manufacturing imports for the period 1963-1987.

Our estimated agricultural and manufacturing tariff rates for Korea and the OECD are presented in Table 1.

**Table 1 goes here**

**Subsidy Rates**: To measure export subsidy rates by sector in Korea, we use the industrial gross subsidy rate calculated from 1963 through 1980 by Collins and Park (1989*b*), net of tariff exemptions. Industrial export subsidies include direct cash subsidies, export dollar premiums, direct tax reduction, preferential interest rates, indirect tax exemptions, and tariff exemptions on intermediate and capital goods. We exclude tariff exemptions because our model features value added production without intermediate inputs. The Collins and Park series suffers from missing observations, after 1980, for indirect tax exemptions, however, it is widely believed that quantitatively significant subsidies ended in Korea during the 1980s, the Collins and Park net subsidy estimates are zero after 1980, and Nam (1995) argues that all export subsidies were eliminated by 1982. Unfortunately, we are unaware of any estimates of average agricultural subsidy rates although they were reputedly large, as Teignier (2014) reports, and so we assume in our benchmark calibration that agricultural subsidies are awarded at the same rate as in industry. 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 they are also both zero in the OECD, in our benchmark calibration subsidy rates do not distort the pattern of comparative advantage. We present the original subsidy rates in Table 2. The last column of this Table displays the measure of subsidies - gross subsidies net of tariff exemptions - that we use in our calibration.

**Table 2 goes here**

### 4.3 Preference Parameters

The curvature parameter in household preferences, $\psi$, determines the representative household's elasticity of inter-temporal substitution. We follow Backus, Kehoe and Kydland (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, Rogerson and Valentinyi (2013) and are computed from final consumption expenditure data. The values we use are $\xi_A = 0.02, \xi_I = 0.17, \xi_S = 0.81$. In addition, we let $\omega = -0.175$ implying that the three types of final good are complements in preferences.

Herrendorf, Rogerson and Valentinyi (2013) emphasize the need for consistency of the production and consumption sides of multi-sector models of structural change. They argue that each sectoral consumption argument of the utility function may be viewed as either i) final consumption expenditure on the goods of a sector, which includes the value of intermediate inputs regardless of the sectors they originate from or ii) consumption of the value added of that sector, which is reflected in the final goods produced by all three sectors. Models such as ours which use value added production functions - with no intermediate inputs used in production - are consistent with ii) but not with i), while models with inter-sector input-output structure are consistent with i). In the former case, Herrendorf, Rogerson and Valentinyi (2013) argue that extracting the value added component of each sector that goes into final consumption is the appropriate way to measure the consumption data used to calibrate the parameters of the utility function, and develop a method for doing so. Given that our sectoral production functions are value added, ideally we would use utility function parameters estimated from extracted consumption value added data, rather than those estimated using final consumption expenditure data. However, in our model, consumption on the value added of a sector includes value added of that sector produced abroad, through the Armington aggregator. An important assumption made by Herrendorf, Rogerson and Valentinyi (2013) in computing the consumption value added of a sector is that the input requirements for home and foreign producers of that value added are the same - an assumption which is violated by the country-specific labor productivities of our model. Rather than attempt to develop a new method for estimating consumption value added in our environment, which is beyond the scope of this paper, we experimented by using an average of the final expenditure and value added consumption weights that Herrendorf, Rogerson and Valentinyi (2013) compute. Our results were qualitatively identical and quantitatively very similar and we do not report them here.

Finally, 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 544.73. This implies that in 1963 the subsistence level of consumption of agricultural goods accounted for 76 percent of total final consumption expenditure and 98.5 percent of consumption expenditure on agricultural goods in Korea.

### 4.4 Trade Parameters

In our model, the Armington weights, $\mu_i^k$, are assumed to capture all primitive preference and technological factors 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. We manipulate (3.8) and (3.9) to get the following expressions:

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

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

We then calibrate the values of $\mu_i^k$ and $(1-\mu_i^k)$ by using data to estimate the right hand sides of (4.1) and (4.2) for each sector $k = \{A, I\}$ and country. 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 $1-\mu_{i,t}^k$, and apply the following normalizations in each period to ensure that the values of the weights sum to unity, $\widetilde{\mu_{i,t}^k} = \left[\frac{\mu_{i,t}^k}{\mu_{i,t}^k + (1-\mu_{i,t}^k)}\right]$ and $1-\widetilde{\mu_{i,t}^k} = \left[\frac{1-\mu_{i,t}^k}{\mu_{i,t}^k + (1-\mu_{i,t}^k)}\right]$. Annual data measuring the variables on the right hand side of these expressions go back to 1971. Normalized parameter values for 1963-1970 are computed by extrapolating backwards from 1971 using the growth rates of the estimated normalized parameter values for 1971-2000. The final calibrated values are full sample averages of the normalized estimates for each sector and country.

Specifically, to compute the share of spending on the domestic variety in the numerator of the first term of (4.1), we subtract a sector's value added exports from its nominal value added. For both Korea and the OECD, sectoral nominal value added data sources are the same as those we used to compute labor productivities. Total spending on the two varieties, in the denominator of the first term on the right hand side of (4.1), is constructed as the sum of value added and spending on value added imports, less value added exports, in each sector. The second term in equation (4.1) is the producer price of the domestic variety relative to the consumer price index of sector $k$ in country $i$. To measure these, we use Korean producer price indexes by sector obtained from the Bank of Korea, and US producer price indexes by sector from the Bureau of Labor Statistics, while 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, Rogerson and Valentinyi (2013).

To compute the share of spending on the foreign variety of sector $k$ in the first term of (4.2), we use our data on value added imports by sector, and the same measure of total spending by sector for the denominator as we constructed for (4.1). The second term of (4.2) reflects the price of the imported variety relative to the consumer price index of sector $k$ in country $i$. For Korea we use import price index data by sector from the Bank of Korea. For the OECD, we proxy the price of the Korean variety imported by the OECD by the export price index data by sector from the Bank of Korea. Our measures of value added imports yield a good estimate of the numerator in the first term of (4.2). The import price data that we use to calibrate the second term, by contrast, are measured inclusive of "cost, insurance and freight" (CIF), and presumably any export subsidies, 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). Since the data do not allow us to measure non-tariff barriers explicitly by sector, our measures of $\mu_i^k$ will capture trade barriers due to non-tariff trade policy measures such as import quantity controls.

Our calibration of trade costs, captured by the Armington weights, uses not only data on trade flows but also data on prices of domestically and imported varieties. In contrast, Sposi (2014) and Uy, Yi and Zhang (2013) rely solely on trade flows to impute the iceberg trade costs in their models. Both, Sposi (2014) and Uy, Yi and Zhang (2013) match trade flows to compute trade barriers. Thus, we bring to bear more information in inferring trade costs compared to other recent open economy models of structural change. Waugh (2010) and Anderson and Wincoop (2003) argue that inclusion of price data matters for the magnitude of as well as the asymmetry in bilateral trade costs.

The resulting values of the Armington weights by sector are shown in Table 3.

**Table 3 goes here**

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, Kehoe and Kydland (1994) and Zimmermann (1997) use an elasticity of 1.50. By contrast, Yi (2003) shows an elasticity of 12 or more is needed to explain the growth in trade volumes that results from tariff reductions. Eaton and Kortum (2002) find a range of 3.6 to 12.8. However, Simonovska and Waugh (2014) show that the small sample size of the price data used in Eaton and Kortum (2002) strategy results in a small sample bias. Correcting for this bias, they find a lower estimate of 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.

## 5 Results

### 5.1 The Benchmark Open Economy Model

The first row of Figure 4 plots employment shares by sector predicted for Korea for the period 1963 through 2000 by a benchmark economy calibrated as we describe in Section 4, with our estimated time-series of tariffs, subsidies and labor productivity as inputs for the simulation. The figure compares these predictions to those observed in the data.

The model matches closely the magnitude of decline in the employment share of agriculture. The model predicts a slightly larger decline, than actually observed, from 0.63 in 1963 to 0.06 in 2000, or 109% of the actual decline. The model qualitatively matches the hump-shape in the employment share of industry, and quantitatively reproduces much of the magnitude of increase and decline, but dramatically mis-times the peak. While over-predicting the initial, 1963 industrial employment share at 0.20 compared to 0.11 in the data, the model produces an immediate decrease to 0.12 in 1965 and 0.14 in 1966, values almost identical to the actual shares of 0.13 in 1965 and 0.14 in 1966. Industry's employment share is forecast to then increase to a peak of 0.30 in 1980, tracking the data almost exactly for these years, subsequently declines to a low of 0.23 in 1983, flatten and fluctuate a little, and finally equal 0.26 in 2000. In the data, by contrast, industry's share of employment peaked a decade later and at a higher value, in 1991 at 0.36, and then slowly declined to a low of 0.28 in 1998, rising to 0.29 in 2000. Because the model's 1963 employment share is too high, it can generate only 10 percentage points, or 40 percent, of the observed 25 percentage point increase in industry's employment share from 1963 to its peak. However, since the predicted employment share declines to 0.14 by 1965, the model captures 78 percent of the increase observed in the data from 1965 to the peak. In addition, comparing the magnitudes of decline from the peak to subsequent low - the downward portion of the industry's employment share "hump" - the model captures 7 percentage points, or 87.5 percent, of the 8 percentage point decline in the data.

The benchmark model inevitably underestimates services' 1963 share of employment in 1963 at 0.17 compared to 0.25 in the data - the mirror image of its overestimation of industry's 1963 share. However, the forecast share of services for 1964 is 0.25, only 2 percentage points shy of the data, and then increases almost exactly with the data until 1971 when both are 0.34. In 1972, a decline in services' employment share (and increase in agriculture's) occurs in the data which persists through 1976 and is not captured by the model. Subsequently, however, services' employment share in the data recovers and the actual and predicted share resume increasing at roughly equal rates. From 1963 through 2000, the forecast 51 percentage point increase in services' employment share is more than 140 percent of the 36 percentage point increase actually observed. However, from 1976 onwards the model forecasts 87 percent of the 32 percentage point increase seen in the data. The benchmark economy captures qualitatively and quantitatively quite well the trend in services' employment share, but overestimates the total increase in part due to its low 1963 share prediction.

By contrast, a closed economy counter-factual experiment, in which we recalibrate the subsistence consumption of agriculture to match the 1963 employment share of agriculture, accurately predicts the initial shares of industry and services. The 1963 industrial sector employment share is overestimated in not only the benchmark but every other open economy variant of the model that we simulate, including one in which Korean trade policies are counterfactually set equal to zero. As we demonstrate below, this is attributable to the initial pattern of trade forecast by our open economy models, which excessively favors Korean industry. Additionally, the benchmark forecast of a decrease in industry's employment share in 1964 and 1965 is not seen in experiments that we describe below in which Korean tariffs and subsidies are held constant counterfactually at the 1963 level. We infer that this forecast results from a sharp decline in industrial subsidies in the benchmark economy from 1963 to 1965, as can be seen in Table 2.

**Figure 4 goes here**

Table 4 records the values of some goodness of fit summary statistics[10]. 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 (RMSE) respectively. We also present the summation of SSE's over sectors, the "total" SSE, and the associated "total" RMSE for the model. While there is no absolute criterion for a "good" SSE or RMSE - they are measured in variable specific units - these statistics are useful for comparing the forecasting accuracy of our benchmark to counter-factual models, and even to other models of structural change in Korea. The statistics presented in the third row of the table are the sample correlation

[10]The sum of squared errors statistic, for outcome variable $X_t$, is defined as $SSE = \sum_{t=1}^{T}(X_t - \hat{X}_t)^2$ where $T$ is the number of years in the sample, $X_t$ is the data value at date t, and $\hat{X}_t$ is the model's predicted value for $X_t$. 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.

coefficients between the model's predicted time series for the employment share of a sector and that in the data, and measure the similarity of annual fluctuations in the two. The sample correlations are all very large and positive. They are higher for agriculture and services than for industry reflecting the counterfactual decline in industry's predicted share from 1963 through 1965 and mis-timing of industry's employment share peak. The SSE and RMSE are smallest for agriculture and largest for services. Our RMSE statistics measuring deviations between the model and data's sectoral employment shares are quantitatively comparable to those obtained by Uy, Yi and Zhang (2013), who develop a similar model measuring structural change in Korea. Our benchmark model generates an RMSE for the employment share of Korean agriculture of 0.04, somewhat lower than the 0.059 they find. However, our model generates RMSE statistics for industry and services of 0.061 and 0.084 respectively, somewhat higher than the 0.037 and 0.06 their model generates.

**Table 4 goes here**

The second and third rows of Figure 4 show the benchmark model's performance in matching value added imports and exports by sector, and total value added imports and exports, as a fraction of GDP. Value added exports to GDP for each sector are exactly the "foreign effect" for the Korean employment and GDP share of that sector described in Section 3. The value added imports to GDP for each sector are equal to the "foreign effect" for the OECD employment share of that sector, multiplied by the ratio of OECD to Korean GDP.

The model matches very closely total imports to GDP, and while it over-predicts total exports in GDP until about 1973, subsequently tracks the data closely on average. Overall, the benchmark forecast for the magnitude of value added trade is quite accurate. The model is less successful in predicting the trade by sector. While it matches the magnitude of value added agricultural exports to GDP in the early and late years of the sample, and the magnitude of industrial value added exports to GDP mainly in the late years of the sample, it substantially over-predicts value added Korean imports to GDP in agriculture and under-predicts this ratio for industry. It is easy to see that the time series fluctuations in industry's exports to GDP ratio closely mirror those in industry's employment share in the benchmark model, and in the data. It is harder to see, but nonetheless also true, that fluctuations and the downward trend in agriculture's predicted exports to GDP ratio are very similar to those in agriculture's employment share in the benchmark model and the data. The calibrated benchmark model correctly predicts that the "foreign effect" strongly influences fluctuations in the total employment share of traded goods in Korea. However, it forecasts an excessive initial value for the foreign effect of industry, and this generates the excessive 1963 employment share of the sector.

The relative magnitudes of export and import shares by sector and the implied pattern of trade between Korea and the OECD are determined by several factors. Sectoral productivity differentials across countries measure comparative cost advantage and, adjusted for tariffs and subsidies, determine the scope for international specialization. The importance of agricultural subsistence consumption in Korea relative to the OECD limits this scope, as do the Armington weights and unobserved barriers to trade that they measure. The OECD exhibits higher home bias for agricultural goods than for industrial goods while Korea has higher home bias for industrial than for agricultural goods. Overall, the model predicts that Korea is a net exporter of industrial goods to the OECD and net importer of agricultural goods from the OECD at every date in our sample. The higher are the net exports of a sector, the more labor specializes in that sector, and the larger is its employment share.

The value added trade balances of agriculture and industry for our benchmark model, evaluated at world prices, are shown in the last row of Figure 4. At world prices, trade must be balanced. Since agriculture is predicted to run value added trade deficits throughout the sample, industry generates exactly offsetting surpluses. In the data, and as can be inferred from the graphs in the second and third rows of Figure 4, Korean agriculture in fact ran value added trade surpluses with the OECD from 1972 until 1995. Conversely, Korean industry's OECD value added trade was systematically in deficit until 1983 after which a surplus emerged and - from 1983 through 2000 - fluctuated around trade balance. Our balanced trade assumption is obviously inaccurate period by period, but not too far from the data on average; Korea in fact ran a small value added trade deficit on the sum of agricultural and industrial goods trade over our sample period, amounting to about 1 percent of GDP.

### 5.2 Closed Economy Experiment

Closing the economy and comparing its forecasting performance to that of our benchmark open economy is a measure of how important openness to trade and measured trade policies are for Korean structural transformation. To close the economy, we set $\mu^k_{KOR} = \mu^k_{OECD} = 1$ for all $k$, effectively assuming that trade costs are prohibitively high. In terms of our model, only the "domestic effect" of each sector matters for a sector's employment share. Income effects for domestic consumption expenditure, and domestic relative productivity and associated relative sectoral price changes are the sole sources of structural change.

This counterfactual model fails to match the employment share data in all three sectors by a wide margin, as shown in Figure 5. In part, this reflects the fact that the preference parameter $\bar{A}$ is maintained at the value required to match agriculture's initial employment share in the benchmark open economy. The closed economy model vastly under-predicts this initial employment share, and the initial employment shares of industry and services are both much too high as a result. Furthermore, labor gradually moves out of agriculture directly into the service sector, allowing for essentially no industrialization. An implication of these results is that domestic sectoral productivity growth differentials, and the domestic relative price and consumption expenditure share changes they engender, are insufficiently large to generate industrialization or de-industrialization. If income were sufficiently low that expenditure on subsistence agricultural consumption comprised a large fraction of it, then strong income effects arising from economic growth would cause the consumption expenditure shares and consequently employment shares of industry and services to grow over time as agriculture shrank. However, in 1963, the value of subsistence consumption is only 21 percent of total income in the closed economy as compared to 76 percent in the open economy model. Income is higher in the closed than open economy because Korean labor demand and wages are solely determined by domestic consumer demand for Korean varieties, rather than by the relatively low global demand produced by low Korean home bias and very high OECD home bias as determined by our calibrated Armington weights. Hence, domestic sectoral productivity growth differences between agriculture and services generate the only action; a movement of resources from agriculture to services[11].

The overall poor performance of the closed economy counterfactual in matching the data is measured by the SSE and RMSE statistics in Table 4. For industry and services, the RMSEs in the closed economy experiment rise by 82 percent and 219 percent respectively relative to the benchmark economy. For agriculture, the RMSE is more than 300 percent higher than in the benchmark. The total RMSE in the closed economy is 226 percent higher than that in the open economy model[12].

[11] When $\bar{A}$ is re-calibrated in the closed economy setting to match the initial employment share of agriculture, the expenditure on subsistence consumption is 62% of income in 1963. A larger income effect generates significantly more growth in industry's employment share that is larger than in the version where $\bar{A}$ is not re-calibrated. Nonetheless, it can generate only 32 percent of the maximum increase in industry's employment share (from 1963 to 1990) -n 8 percentage points of 25 in the data - and none of the subsequent decrease (1991 to 2000).

[12] In the version of the closed economy model where $\bar{A}$ is re-calibrated, the RMSE for industry and services is 127 percent and 42 percent higher than in the benchmark open economy, respectively. For agriculture the RMSE declines by about 26 percent compared to the benchmark. Despite this recalibration, compared to the benchmark model the total RMSE is more than 60 percent higher, largely due to the tepid predicted industrialization.

**Figure 5 goes here**

Finally, the bottom right graph in Figure 5 shows the growth rate of Korean GDP per capita predicted by the benchmark and closed economy model relative to the data. Allowing for international trade dramatically improves the ability of the model to match real income growth. Between 1963 and 2000, real GDP per capita measured in 1995 dollars actually grew from 4,037 dollars to 30,179 dollars, or by a factor of 7.5. In the benchmark economy, real GDP per capita grew by a factor of 4.24, which accounts for 62 percent of the growth seen in the data, while in the closed economy model real GDP per capita grew by a factor of 2.63, which accounts for just 47 percent of this growth.

### 5.3 Trade Policy Counterfactuals

We conduct several counterfactual policy experiments to clarify the role of Korean tariff and subsidy policies, and their liberalization, during the sample period, for structural change.

#### 5.3.1 The Role of Korea's Tariff Policy

Figure 6 depicts the effects of abstracting from all changes in tariff rates that took place after 1963. Tariff rates are counterfactually held at their 1963 levels for the entire sample period. Since tariff rates in the data and benchmark model are unchanged between 1963 and 1967, the effects of this experiment emerge only after 1967.

Starting with the first row of Figure 6, in the data and benchmark model, agricultural sector tariff rates decline systematically throughout the sample period except for a single year increase in 1983. Hence, maintaining 1963 tariffs results in a systematically higher relative price of the OECD imported variety of agriculture. Final good producers in Korea therefore switch to the cheaper domestic variety, and agricultural imports decline. By contrast, tariffs in Korea's industrial sector are higher between 1968 and 1978 than they are in 1963. Counterfactually maintaining the 1963 industrial tariff rate therefore reduces the price of the imported OECD variety of industry relative to the Korean variety during this period. In 1979, the industrial tariff rate in the data and benchmark model finally falls below the 1963 rate and the relative price of industrial imports is higher in the counterfactual model. Expenditure switching by Korean final good producers increases Korean industrial imports from 1968 through 1978, and decreases them after 1978. However, total imports are lower in the counterfactual relative to the benchmark model at every date. The decline in agricultural imports dominates quantitatively from 1968 to 1978, reflecting a larger positive disparity between the 1963 and actual tariff rate in agriculture than negative disparity in industry.

Lower total imports imply there is an incipient Korean trade surplus at every date. Korean exports must decline and/or the fall in imports attenuated for trade to be balanced. Trade balance is achieved by the relative income and price effects of the shift in Korean, and hence world, demand from OECD to Korean varieties resulting from counterfactually high Korean tariffs. First, higher Korean demand for domestic varieties increases Korean production and labor demand, and hence wages, wage income, and per capita GDP. At the same time, lower Korean import demand for OECD varieties reduces OECD production, labor demand, wages, and per capita GDP. The effect for relative Korean income is shown in the second row of Figure 6. Korean expenditure rises, mitigating the decline in imports, and OECD expenditure falls reducing Korean exports. Second, a higher relative Korean wage rate increases the producer prices of Korean relative to OECD varieties. This shifts world demand for Korean and OECD varieties in the opposing direction than maintaining 1963 Korean tariff rates does, reducing demand for Korean and increasing demand for OECD varieties. Korea's exports decline, and the decline in imports from the OECD initiated by 1963 tariffs is reduced. Together, these two mechanisms counter Korea's incipient trade surplus.

Overall, Korean imports, exports, and total trade fall relative to the benchmark economy (third and fourth row of Figure 6). In addition, industry's net exports and agriculture's net imports decline, although insufficiently to alter the benchmark pattern of trade. This "compression" of pattern of trade is attributable to three factors. First, high 1963 agricultural relative to industrial tariffs compared to those in the benchmark economy disproportionately reduce Korea's agricultural imports. Second, maintaining 1963 tariffs results in higher relative price of the OECD imported variety for both sectors, but the smaller Korean home bias in agriculture as compared to that in industry amplifies the decline in imports in the agricultural sector. Additionally, Korean industrial exports decline disproportionately more than agricultural exports because OECD final good producers' relatively low home bias in industry amplifies their response to an increase in the producer price of Korean varieties. Third, higher Korean wage income is reinforced by higher net tariff revenue (second row of Figure 6), increasing Korean total expenditure and marginally reducing the importance of subsistence spending on agriculture. This biases demand in favor of industrial and service sector goods, marginally offsetting the decline in industrial sector imports. Conversely, lower net tariff revenue in the OECD reinforces the decline in Korean industrial exports.

Together, these three factors imply a stronger positive domestic effect for agriculture than industry (third row of Figure 6) and a stronger negative foreign effect for industry than agriculture.

Consequently, the magnitude of Korea's specialization in and the employment share of industry decline, and the employment share of agriculture increases throughout the sample period relative to the benchmark economy, as the bottom right graph of Figure 6 illustrates. Services' employment share barely changes. Its domestic expenditure share is reduced by higher tariff rates on traded goods which reduce its relative price due to complementarity of final goods, but positive income effects offset this. The model's forecasting accuracy, shown in Table 4, declines markedly relative to the benchmark model, with the RMSE for industry's employment share increasing by 42 percent and the total RMSE of the model by 9 percent. Korea would have generated only 4 percentage points or 16 percent of the 25 percentage point increase in industry's employment share from 1963 to 2000 (compared to 40 percent in the benchmark economy), or 12 percentage points and 50 percent of the 24 percentage point increase from 1965 to 2000 (compared to 78 percent in the benchmark). Similarly, only 4 percentage points or 50 percent of Korea's de-industrialization is captured by this counterfactual model, compared to 87.5 percent in the benchmark economy.

**Figure 6 goes here**

#### 5.3.2 The Role of Korea's Subsidy Policy

The panel of graphs in Figure 7 depicts the effects of maintaining subsidy rates at their 1963 - and maximum - values in both sectors. As they are in the benchmark economy, subsidy rates are the same across sectors at all dates. Counterfactually high subsidies, by reducing the price of Korean relative to OECD varieties confronted by OECD final good producers, increase exports in both agriculture and industry. An incipient trade surplus results, necessitating higher Korean imports and/or an attenuation of higher exports to balance trade. The increase in OECD, and hence world, demand for Korean relative to OECD varieties provides the mechanism for this. Korean production, labor demand, and wages rise, while those of the OECD decline (second row of Figure 7). Korean wage income and expenditure increase, while OECD wage income and expenditure decline. At the same time, higher relative Korean wages raise the producer prices of both Korean varieties relative to those in the OECD. Together, these income and relative price effects increase Korean imports, mitigate the increase in Korean exports induced by higher subsidies, and balance international trade.

Since subsidy rates are the same across sectors in both the benchmark economy and counterfactual experiment, they are not responsible for any change in the relative international competitiveness of industry and agriculture as fixed 1963 tariff rates are. Nevertheless, transmission of higher subsidies and lower export prices to Korean export demand is amplified for industry because of lower OECD industrial than agricultural sector home bias, and Korea's industrial exports rise more than those of agriculture (fourth row of Figure 7). Conversely, the increase in Korean imports resulting from relatively low OECD producer prices is larger in agriculture than industry on account of lower agricultural home bias of Korean final good producers (third row of Figure 7). Increased Korean relative to OECD wages, in conjunction with agriculture's relatively low income elasticity, somewhat offsets the increase in agriculture's net imports and industry's net exports. This income effect is weakened by the negative transfers caused by maintaining 1963 subsidies (second row of Figure 7) and, overall, the home bias effect dominates. Industry's net exports and agriculture's net imports rise (third row of Figure 7), agriculture suffers a disproportionately weaker domestic and foreign effect compared to industry (third row of Figure 7), and the employment share of industry rises and that of agriculture falls throughout the sample, relative to the benchmark economy as the bottom right panel of Figure 7. Finally, negative net tariff income is sufficient to reduce services' employment share.

Table 4 shows that the model's forecasting accuracy declines relative to the benchmark model, with the total RMSE of the model increasing by more than 20 percent, and substantial increases in the RMSEs for both agriculture and industry. The speed and magnitude of industrialization is counterfactually high early in the sample. However, relative to the benchmark economy this experiment is better able to match the overall increase in industry's employment share, as the model generates 21 percentage points or 84 percent of the 25 percentage point increase in industry's employment share from 1963 to 2000 and 87.5 percent of Korea's de-industrialization. This result suggests that our subsidy measure may underestimate the degree of protection afforded industry by the policy, possibly because we use the same (industrial) subsidy rate in both sectors due to data availability limitations.

**Figure 7 goes here**

### 5.4 The Role of Trade Policy Liberalization: "No Reform"

Having analyzed the effects of keeping tariff and subsidy rates unchanged at their 1963 levels individually, we now evaluate the effects of combining the two experiments and maintaining both rates at their 1963 values as though Korea undertook no trade policy reform at all. As we have seen, the two policies have opposing effects on trade volumes and the pattern of trade. Therefore, when both tariff and subsidy rates remain at 1963 levels, the net impact for trade and structural change depends on the relative magnitudes of change in each policy instrument and on which policy instrument's transmission dominates. Figure 8 shows that the effects of maintaining counterfactually high 1963 subsidies dominate the effects of maintaining 1963 tariffs. Specifically, exports in both sectors increase in the counterfactual compared to the benchmark model, and more so in industry than in agriculture. This increase can only be due to the effect of higher (1963) subsidies. Because exports in both sectors increase, total imports must rise and/or the increase in exports must be attenuated to balance trade. Again, this is achieved by the shift in world demand in favor of Korean varieties, and Korean production, labor demand, and wages increase relative to the OECD, compared to the benchmark model. Relative Korean expenditure and producer prices in all sectors rise, increasing Korean imports and mitigating the increase in Korean exports produced by counterfactually high subsidies. This balances aggregate trade.

On balance, the net exports of industry rise and those of agriculture fall relative to the benchmark economy as we see in the 1963 subsidy rate experiment, but the effects here are muted because tariffs are also counterfactually high. Industry's employment share rises somewhat, and that of agriculture falls, from 1964 onwards. Services' domestic consumption expenditure share is essentially unaffected by the alternative trade policies we analyze; a small decline in services' relative consumer price because of (generally) higher tariffs on traded goods tends to decrease her domestic consumption expenditure share, but higher Korean income increases it at the expense of agriculture due to non-homothetic preferences. Services' employment share is marginally reduced, however, due to a small negative net tariff income transfer from the government, relative to the benchmark economy. Higher subsidies with higher exports raise subsidy expenditure slightly more than higher tariffs with higher imports raise tariff income.

Because of the temporal pattern of trade reform measured in the benchmark economy, over time the predictions of the counterfactual model for employment shares become more similar to those of the benchmark. From 1964 through 1967, counterfactually high subsidies do not have to compete at all with the effects of counterfactually high tariffs, because tariff reform does not begin until 1968. Industry's net exports and employment share are substantially higher in the counterfactual than in the benchmark model, and agriculture's lower. From the date of the first tariff rate changes in 1968 through 1978, the gap between the counterfactual and benchmark predicted employment shares declines relative to the first four years of the counterfactual trade policy regime as there is some offset to higher subsidies from relatively high agricultural tariffs that dominate slightly lower industrial tariffs. This exerts downward pressure on imports and, for balanced trade, exports. In 1979, the gap in predictions of the counterfactual and benchmark models narrows further as industry's 1963 tariff rate is now higher than that in the data and benchmark model, and the downward pressure on Korean imports and exports, and especially industrial exports, is increased. From 1981, export subsidies are eliminated in the benchmark economy so the maximum boost to exports from counterfactually high subsidies is reached at that date. However, tariff reform continues through the end of the sample. The downward pressure on imports and exports, due to counterfactually high tariffs is thus increasingly potent in opposing the effects of counterfactually high subsidies. By 2000, the predicted employment shares of industry and agriculture in benchmark and counterfactual models almost converge.

The RMSE of the model increases and its predictive accuracy decreases marginally relative to the benchmark economy, as Table 4 shows. There are small decreases in the RMSEs for industry and services and a substantial increase in that for agriculture. The correlations of agriculture and industry decline, while that for services increases a little. These statistics do not reflect the significant differences we observe in the predicted pattern of industrialization relative to the data, and especially the counterfactually high level of industrial employment in the first half of the sample. This model predicts 12 percentage points or just 48 percent, of the 25 percentage point increase in industry's employment share after 1963, and only 5 percentage points, or 62.5 percent, of its 8 percentage point subsequent maximum decline.

Overall, these three counterfactual experiments demonstrate that Korean tariff reform after 1963 provided a relatively high degree of protection for Korean industry, promoting its international competitiveness and employment share, but this was more than offset by Korean subsidy reform which disproportionately reduced the competitiveness and employment share of the sector. Korean industrialization would have been greater and more rapid had she not undertaken the pattern of simultaneous reform of both instruments observed in the benchmark economy and data, and especially if she had maintained high export subsidies and reformed only tariffs after 1963. More generally, although reforming one instrument at a time has powerful consequences for international trade and structural change, Korea's actual trade reform that is simulated by the benchmark economy has muted consequences because the effects of tariffs and subsidy reform offset each other.

**Figure 8 goes here**

### 5.5 Immediate Full Liberalization

In the final experiment, we assume that Korea immediately and completely liberalized her international trade in 1963. Specifically, we set to zero all Korean tariffs on imports and all subsidies to exporting firms in 1963, and hold them there throughout the sample. This experiment represents an upper bound on trade reform in Korea, relative to the lower bound of the previous trade policy experiment; here, full trade liberalization occurs in 1963, there, no reform did. However this experiment does not represent a free trade regime. OECD tariffs remain in the model, and the calibration of the Armington aggregator weights remains unchanged, reflecting all real trade costs confronted by an open Korean economy not measured by our tariff and subsidy time series. The effects of this experiment are shown in Figure 9.

The relative price effect of zero subsidies reduces OECD demand for Korean exports, and that of zero tariffs raises Korean demand for OECD imports. The effect of reducing tariffs, from more than 60 percent to zero, quantitatively dominates that of lowering subsidies, from roughly 40 percent to zero. Overall, higher trade and a large incipient trade deficit result. The deficit must be offset by higher exports and/or lowering imports and this is accomplished via the sharp decline in world demand for Korean relative to OECD varieties produced by the policy. This reduces Korean production, labor demand, wages and wage income relative to the OECD. Lower relative Korean expenditure and producer prices boost exports to the OECD and mitigate imports from the OECD. Overall, exports, imports and total trade increase, while lower Korean factor income further raises trade to GDP ratios (third and fourth rows of Figure 9). Income effects of lower wages and zero net tariff income transfers (second row of Figure 9) - relative to positive transfers in the benchmark economy from 1964 to 2000 - promote lower expenditure shares of industry and services and a higher share for agriculture in Korea, and the reverse occurs in the OECD. These income effects encourage higher Korean trade deficits in agriculture and trade surpluses in industry (third row of Figure 9), relative to the benchmark economy. As income differences decline over time, with gradual trade liberalization occurring in the data and benchmark model, the pattern of trade and specialization is muted.

The pattern of home bias supplements income effects in amplifying industry's competitive advantage, disproportionately increasing industrial exports and agricultural imports. The counterfactual model mirrors the benchmark economy's failure to match the relative magnitude of exports and imports by sector, however. Because it raises all trade levels, the counterfactual magnifies the benchmark over-prediction of industry's exports and agriculture's imports, while somewhat attenuating the benchmark under-prediction of agricultural exports and industry imports. Total value added trade generated in the counterfactual is much larger than in either the benchmark model or the data - value added exports and imports of Korea each would have been almost 20 percent of GDP in 1963, for a total value added trade to GDP ratio in 1963 of about 40 percent. This is 70 percent higher than the nearly 24 percent value added trade to GDP ratio predicted for 1963 by the benchmark model, and quadruple the actual ratio of 10 percent observed in the data. The counterfactual economy over-predicts value added exports and imports as a portion of GDP for every single year in the sample, contrasting starkly with the benchmark economy's ability to match the total imports and total exports quite well on average. Nonetheless, the distance between the counterfactual and benchmark models' predictions for total exports and total imports in GDP narrows over time as the counterfactual and benchmark trade regimes converge, with export subsidies ending in 1981 and the degree of tariff protection in Korea declining systematically. By the year 2000 total value added trade in the counterfactual economy declines to roughly 24 percent of GDP, compared to about 20 percent in the benchmark economy and about 21 percent in the data. This pattern of convergence over time is also apparent in sectoral trade flows.

The bottom right graph of Figure 9 shows the structural change that would have resulted and compares it to the benchmark model and the data. Agriculture's employment share is counterfactually low and lower than predicted by the benchmark model throughout the sample period. Early in the sample, labor moves into industry at a faster rate than in the benchmark economy, and from 1968 until about 1973 at a faster rate than in the data. During these years, actual trade policies are highly protective and differences between the counterfactual and benchmark economy predictions for employment shares are large, but the differences diminish over time as trade is liberalized in the data and benchmark economy. As in the benchmark model, the peak of industry's employment share predicted by the counterfactual, 0.32, occurs in 1980 while the actual peak of 0.36 does not occur until 1990. Additionally, industry's employment share is counterfactually high in most years from 1963 until about 1983, after export subsidies are eliminated. Industrialization would have occurred more rapidly and the industrial sector would have been larger until the mid-1980s than actually observed in Korea, and relative to the benchmark economy, had Korea imposed no tariffs nor offered export subsidies. With no net tariff income at all absent trade policies, the predicted services' employment share of the counterfactual is just slightly lower than that of the benchmark.

Table 4 shows that the RMSE for the employment shares of agriculture and services increase, while that for industry decreases a little. Overall, the performance of the model deteriorates relative to that of the benchmark economy as measured by the RMSE, while the correlation statistics are roughly the same.

**Figure 9 goes here**

## 6 Conclusion

A quantitative open economy model of structural change featuring non-homothetic preferences, Armington trade, and a novel representation of trade policy by sequences of proportional tariffs and subsidies, predicts Korean sectoral employment allocations, and bilateral value added trade volumes with the OECD, which are qualitatively and quantitatively similar to those in the data. By contrast, a variant of the model counterfactually closed to international trade generates neither the industrialization nor de-industrialization that characterized the Korean economy between 1963 and 2000. This isolates two forces generating more realistic structural change in the open economy.

First, because income is initially lower in the open than in the closed economy model, stronger income effects early in the sample contribute to industrialization, and weakening income effects late in the sample contribute to de-industrialization. Lower 1963 wages and wage income are needed when Korea is open to trade with the OECD, because Korea faces a (large) trade partner that has much higher home bias than she does; lower wages increase Korea's international competitiveness and reduce her expenditure, countering the incipient Korean trade deficit implied by her lower home bias. Second, international relative price changes and the expenditure switching they exact slant the pattern of international trade and specialization in favor of Korean industry in the first half of the sample, and against it subsequently. A rapid increase in Korea's industrial relative to agricultural sector labor productivity compared to that in the OECD after 1968 reduced the international relative price of Korean industrial goods, intensifying Korea's competitiveness and specialization in the sector. Korean tariff reform that protected industry relative to agriculture from 1968 until 1983 reinforced industrialization but was marginally dominated by Korean subsidy reform between 1964 and 1980 which disproportionately impaired industrial sector competitiveness. After 1980, both industrial tariff and subsidy reform catalyze de-industrialization.

Despite their contribution to the model's ability to generate de-industrialization, even large trade policy changes cannot penetrate the model's predicted pattern of specialization and trade per se; Korea is a net value added exporter in industry and net value added importer in agriculture at every date and in every open economy counterfactual policy experiment. Lower agricultural than industrial sector home bias in Korea, the converse pattern in the OECD, and the relative importance of Korea's subsistence requirement in agriculture are the primary forces generating the model's predicted 1963 trade pattern, and over time are reinforced by relatively high Korean industrial productivity growth and dampened by Korean income growth. The relatively small effects of tariff and subsidy rate changes for the pattern of trade and specialization partly result from the requirement that trade be balanced. Any incipient net trade between Korea and the OECD precipitated by exogenous policy or productivity sources of international relative price changes across sectors is eliminated by opposing endogenous adjustments in wages and producer prices. This mechanism attenuates sectoral trade flows, and corresponding shifts in the pattern of international specialization, not only muting the role of tariff and subsidy reform for Korea's structural change, but also contributing to a counterfactually flat industry employment share during the 1980s despite relatively rapid productivity growth in the sector. In addition, we find that tariff and subsidy reform have offsetting effects for the relative competitiveness of sectors. Consequently, very different trade policy time profiles result in surprisingly similar structural change predictions.

Our calibration of Armington aggregator weights to sample average trade flows inevitably under-estimates degrees of Korean home bias early in the sample. This exaggerates Korean imports and especially agricultural imports, forcing counterfactually high trade and a pattern of trade that favors Korean industry in 1963. Alternative motivations for international trade might redress these weaknesses, and increase the role for trade policy. The moderate effects of trade reform and premature flattening of industry's employment share are also attributable to the common subsidy series that we input for both sectors which, our results suggest, under-estimates the relative degree of protection afforded Korea's industrial sector after 1980. Developing a separate agricultural export subsidy series might improve the benchmark economy's forecast for the magnitude and the timing of industry's employment share peak. However, relaxing the balanced trade assumption, allowing Korea to fund trade deficits with credit and lend trade surpluses, would increase the sensitivity of sectoral net exports and employment shares to every international relative price change. Finally, to the extent that endogenous labor productivity improvements result from tariff and subsidy reform which we do not model, we under-estimate the role of trade liberalization in effecting structural change. Beyond the scope of the current paper, we leave investigation of these issues for future research.

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# A Appendix - Tables

Table 1: Average Tariff Rates (in %)

| | Imposed by Korea | | Imposed by OECD | |
|---|---|---|---|---|
| Year | Industry | Agriculture | Industry | Agriculture |
| 1963 | 60.72 | 66.55 | 12.8 | 4.2 |
| 1964 | 60.72 | 66.55 | 12.5 | 4.1 |
| 1965 | 60.72 | 66.55 | 12.1 | 4.1 |
| 1966 | 60.72 | 66.55 | 11.8 | 4.1 |
| 1967 | 60.72 | 66.55 | 11.5 | 4 |
| 1968 | 70.6 | 36.5 | 11.3 | 4 |
| 1969 | 70.6 | 36.5 | 11 | 4 |
| 1970 | 70.6 | 36.5 | 10.7 | 3.9 |
| 1971 | 70.6 | 36.5 | 10.4 | 3.9 |
| 1972 | 70.6 | 36.5 | 10.2 | 3.9 |
| 1973 | 67.78 | 32.44 | 9.9 | 3.9 |
| 1974 | 67.78 | 32.44 | 9.7 | 3.8 |
| 1975 | 67.78 | 32.44 | 9.4 | 3.8 |
| 1976 | 67.78 | 32.44 | 9.2 | 3.8 |
| 1977 | 67.78 | 32.44 | 8.9 | 3.7 |
| 1978 | 67.78 | 32.44 | 8.7 | 3.7 |
| 1979 | 49.42 | 29.48 | 8.5 | 3.7 |
| 1980 | 49.42 | 29.48 | 8.3 | 3.7 |
| 1981 | 49.42 | 29.48 | 8.1 | 3.6 |
| 1982 | 49.42 | 29.48 | 7.9 | 3.6 |
| 1983 | 22.6 | 31.4 | 7.7 | 3.6 |
| 1984 | 20.6 | 29.6 | 7.5 | 3.5 |
| 1985 | 20.3 | 28.8 | 7.3 | 3.5 |
| 1986 | 18.7 | 27.1 | 7.1 | 3.5 |
| 1987 | 18.2 | 26.4 | 6.9 | 3.5 |
| 1988 | 16.9 | 25.2 | 6.8 | 3.4 |
| 1989 | 11.2 | 20.6 | 6.6 | 3.4 |
| 1990 | 9.7 | 19.9 | 6.6 | 3.4 |
| 1991 | 9.7 | 19.9 | 6.7 | 3 |
| 1992 | 8.4 | 18.5 | 6.6 | 3.4 |
| 1993 | 7.1 | 17.8 | 6.7 | 3.2 |
| 1994 | 6.2 | 16.6 | 6.7 | 3.2 |
| 1995 | 6.2 | 16.6 | 5.9 | 3.2 |
| 1996 | 6.2 | 16.6 | 5.6 | 3 |
| 1997 | 6.2 | 16.6 | 5.3 | 3 |
| 1998 | 6.2 | 16.6 | 4.7 | 3.1 |
| 1999 | 6.2 | 16.6 | 4.3 | 3.8 |
| 2000 | 6.2 | 16.6 | 4.2 | 3.6 |

# Table 2: Export Subsidies, 1958-85 (annual averages)

| | Won Subsidies Per U.S. Dollar of Export | | | | | | | | | Ratio to Exchange Rate (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Official Exchange Rate (won/dollar) | Direct Cash Subsidies | Export Dollar Premium | Direct Tax Reduction | Interest Rate Preference | Net Subsidies | Indirect Tax Exemptions | Tariff Exemptions | Gross Subsidies | Subsidies Net | Subsidies Gross | Gross Subsidy minus Tariff Exemptions |
| Year | (1) | (2) | (3) | (4) | (5) | (6=2+3+4+5) | (7) | (8) | (9=6+7+8) | (10=6/1) | (11=9/1) | (11=(9-8)/1) |
| 1958 | 50 | 0 | 64 | 0 | 1.2 | 65.2 | 0 | 0 | 65.2 | 130.4 | 130.4 | 130.4 |
| 1959 | 50 | 0 | 84.7 | 0 | 1.3 | 86 | 0 | 0 | 86 | 172 | 172 | 172.0 |
| 1960 | 62.5 | 0 | 83.9 | 0 | 1.2 | 85.1 | 0 | 0 | 85.1 | 136.2 | 136.2 | 136.2 |
| 1961 | 127.5 | 7.5 | 14.6 | 0 | 1 | 23.1 | 0 | 0 | 23.1 | 18.1 | 18.1 | 18.1 |
| 1962 | 130 | 10.3 | 0 | 0.6 | 0.9 | 11.8 | 5.1 | 4.7 | 21.6 | 9.1 | 16.6 | 13.0 |
| 1963 | 130 | 4.1 | 39.8 | 0.8 | 2.9 | 47.6 | 5.3 | 6.6 | 59.5 | 36.6 | 45.8 | 40.7 |
| 1964 | 214.3 | 2.9 | 39.7 | 0.7 | 6 | 49.3 | 7.6 | 10.1 | 67 | 23 | 31.3 | 26.6 |
| 1965 | 265.4 | 0 | 0 | 2.3 | 7.6 | 9.9 | 13.9 | 15.4 | 39.2 | 3.7 | 14.8 | 9.0 |
| 1966 | 271.3 | 0 | 0 | 2.3 | 10.3 | 12.6 | 17.8 | 21.3 | 51.7 | 4.6 | 19.1 | 11.2 |
| 1967 | 270.7 | 0 | 0 | 5.2 | 14.7 | 19.9 | 17.8 | 24.6 | 62.3 | 7.4 | 23 | 13.9 |
| 1968 | 276.6 | 0 | 0 | 3 | 15.2 | 18.2 | 19.9 | 39.6 | 77.7 | 6.6 | 28.1 | 13.8 |
| 1969 | 288.2 | 0 | 0 | 3.7 | 14.7 | 18.4 | 27.4 | 34.3 | 80.1 | 6.4 | 27.8 | 15.9 |
| 1970 | 310.7 | 0 | 0 | 3.5 | 17.3 | 20.8 | 27 | 40.4 | 88.2 | 6.7 | 28.4 | 15.4 |
| 1971 | 347.7 | 0 | 0 | 4.8 | 18.1 | 22.9 | 32.2 | 48 | 103.1 | 6.6 | 29.7 | 15.8 |
| 1972 | 391.8 | 0 | 0 | 1.9 | 10.5 | 12.4 | 26.4 | 66.3 | 105.1 | 3.2 | 26.8 | 9.9 |
| 1973 | 398.3 | 0 | 0 | 1.4 | 7.4 | 8.8 | 21 | 64.4 | 94.2 | 2.2 | 23.7 | 7.5 |
| 1974 | 407 | 0 | 0 | 0 | 8.6 | 8.6 | 22.5 | 55.1 | 86.2 | 2.1 | 21.2 | 7.6 |
| 1975 | 484 | 0 | 0 | 0 | 12.9 | 12.9 | 33.8 | 34.3 | 81 | 2.7 | 16.7 | 9.6 |
| 1976 | 484 | 0 | 0 | 0 | 12.3 | 12.3 | 33.6 | 35.9 | 81.8 | 2.5 | 16.9 | 9.5 |
| 1977 | 484 | 0 | 0 | 0 | 9.4 | 9.4 | 53.1 | 30.6 | 93.1 | 1.9 | 19.2 | 12.9 |
| 1978 | 484 | 0 | 0 | 0 | 11 | 11 | 53.6 | 30 | 94.6 | 2.3 | 19.5 | 13.3 |
| 1979 | 484 | 0 | 0 | 0 | 11 | 11 | 56.6 | 30.3 | 97.9 | 2.3 | 20.2 | 14.0 |
| 1980 | 618.5 | 0 | 0 | 0 | 20.6 | 20.6 | 74.6 | 36.4 | 131.6 | 3.3 | 21.3 | 15.4 |
| 1981 | 686 | 0 | 0 | 0 | 15 | 15 | n.a. | n.a. | n.a. | 2.2 | n.a. | n.a. |
| 1982 | 737.7 | 0 | 0 | 0 | 3 | 3 | n.a. | n.a. | n.a. | 0.4 | n.a. | n.a. |
| 1983 | 781.2 | 0 | 0 | 0 | 0 | 0 | n.a. | n.a. | n.a. | 0 | n.a. | n.a. |
| 1984 | 807.1 | 0 | 0 | 0 | 0 | 0 | n.a. | n.a. | n.a. | 0 | n.a. | n.a. |
| 1985 | 871.7 | 0 | 0 | 0 | 0 | 0 | n.a. | n.a. | n.a. | 0 | n.a. | n.a. |

**Table 3: Calibrated Values of Armington Weights (with Tariff Estimate I)**

| $\mu_i^k$ | Value |
|---|---|
| $\mu_{KOR}^A$ | 0.36 |
| $\mu_{KOR}^I$ | 0.41 |
| $\mu_{OECD}^A$ | 0.84 |
| $\mu_{OECD}^I$ | 0.77 |

**Table 4: Model Performance Measures for South Korea: Benchmark versus Counterfactuals**

| Benchmark Open Economy - $\overline{A} = 544.73$ | | | | |
|---|---|---|---|---|
| Performance Measure | Agriculture | Industry | Services | Total |
| Sum of Squared Errors | 0.0773 | 0.1375 | 0.2984 | 0.5133 |
| Root Mean Squared Error | 0.0451 | 0.0602 | 0.0886 | 0.1162 |
| Correlation Coefficient | 0.9867 | 0.815 | 0.9488 | |
| Closed Economy - $\mu_i^k = 1 \ \forall \ k, i$ | | | | |
| Performance Measure | Agriculture | Industry | Services | Total |
| Sum of Squared Errors | 1.9598 | 0.4578 | 3.0371 | 5.4547 |
| Root Mean Squared Error | 0.2271 | 0.1098 | 0.2827 | 0.3789 |
| Correlation Coefficient | 0.9909 | 0.8706 | 0.9646 | |
| Tariffs held at 1963 levels | | | | |
| Performance Measure | Agriculture | Industry | Services | Total |
| Sum of Squared Errors | 0.0173 | 0.2785 | 0.3141 | 0.6099 |
| Root Mean Squared Error | 0.0214 | 0.0856 | 0.0909 | 0.1267 |
| Correlation Coefficient | 0.9926 | 0.8285 | 0.9507 | |
| Subsidies held at 1963 levels | | | | |
| Performance Measure | Agriculture | Industry | Services | Total |
| Sum of Squared Errors | 0.4075 | 0.2212 | 0.1145 | 0.7432 |
| Root Mean Squared Error | 0.1036 | 0.0763 | 0.0549 | 0.1398 |
| Correlation Coefficient | 0.9671 | 0.7891 | 0.9532 | |
| Tariffs and Subsidies held at 1963 levels | | | | |
| Performance Measure | Agriculture | Industry | Services | Total |
| Sum of Squared Errors | 0.1745 | 0.1004 | 0.247 | 0.5219 |
| Root Mean Squared Error | 0.0678 | 0.0514 | 0.0806 | 0.1172 |
| Correlation Coefficient | 0.9832 | 0.7862 | 0.9525 | |
| Zero Tariffs and Subsidies | | | | |
| Performance Measure | Agriculture | Industry | Services | Total |
| Sum of Squared Errors | 0.1723 | 0.0996 | 0.2566 | 0.5285 |
| Root Mean Squared Error | 0.0673 | 0.0512 | 0.0822 | 0.1179 |
| Correlation Coefficient | 0.9836 | 0.7922 | 0.9523 | |

# B Appendix - Figures

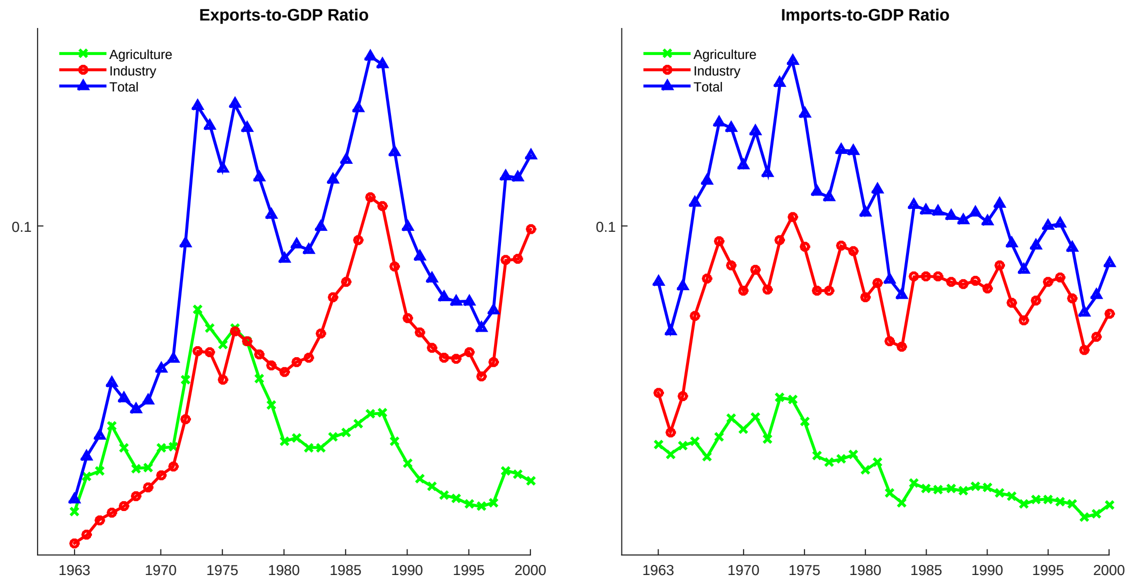


**Figure 1: Evolution of Value Added Trade in South Korea (with OECD), 1963-2000**

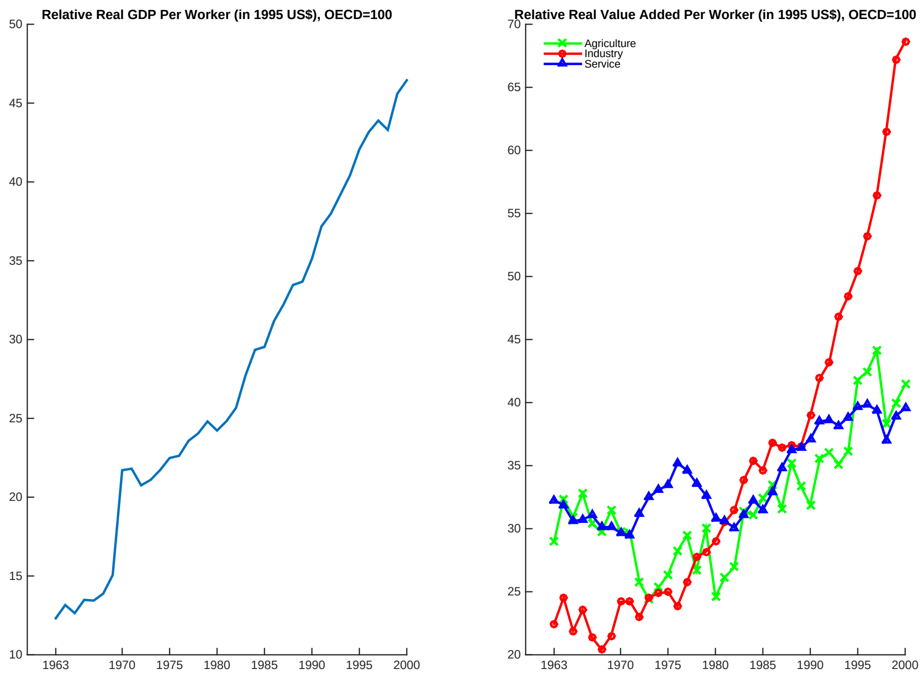


**Figure 2: GDP Per Worker and Labor Productivity in South Korea (relative to OECD), 1963-2000**

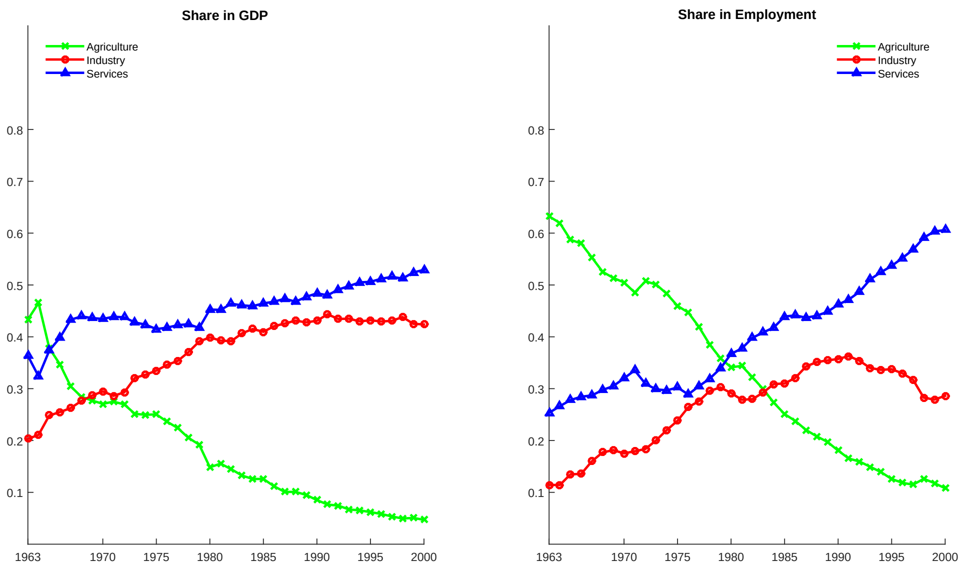


**Figure 3: Structural Change in South Korea, 1963-2000**

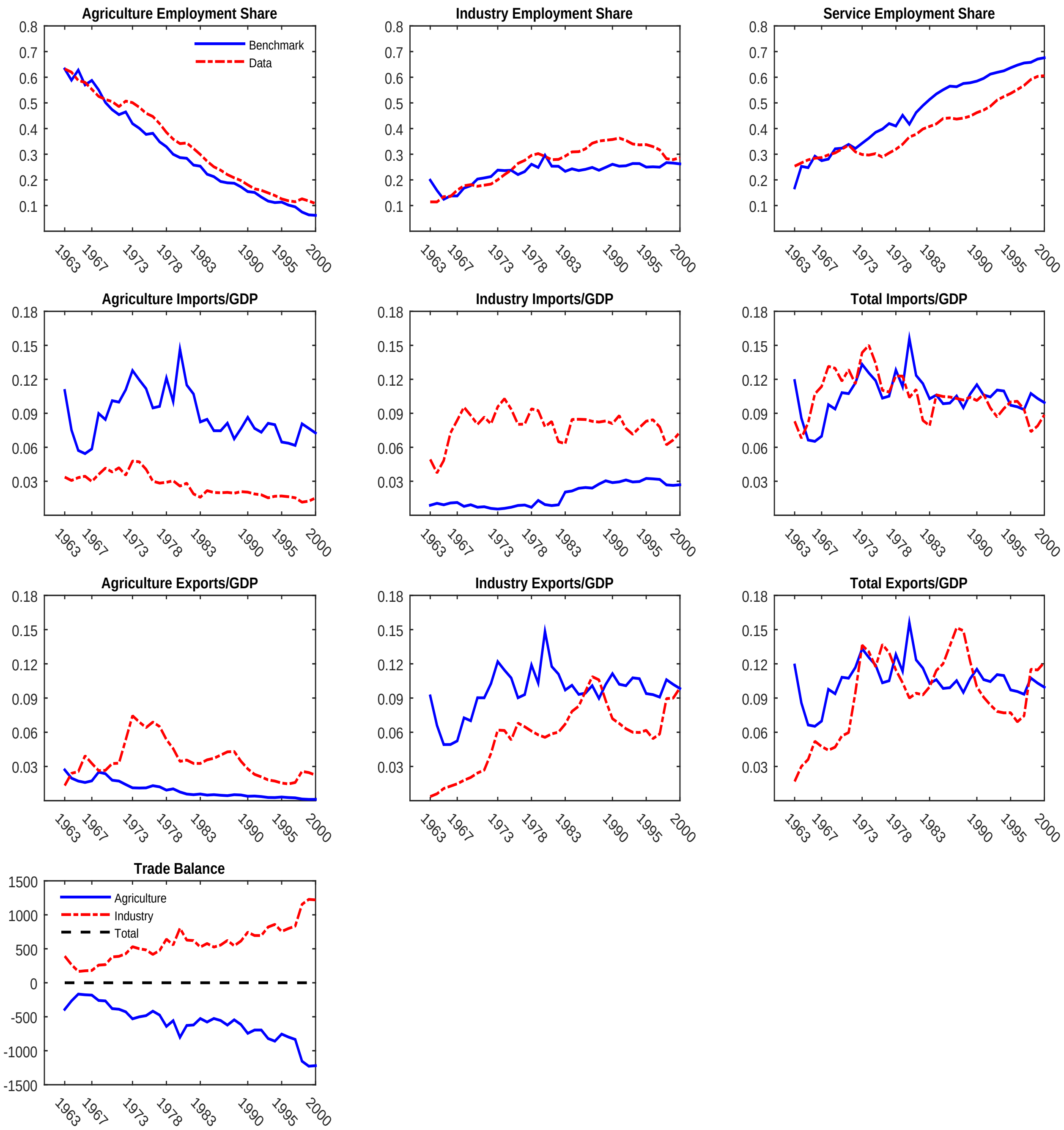


**Figure 4: Benchmark Model versus Data**

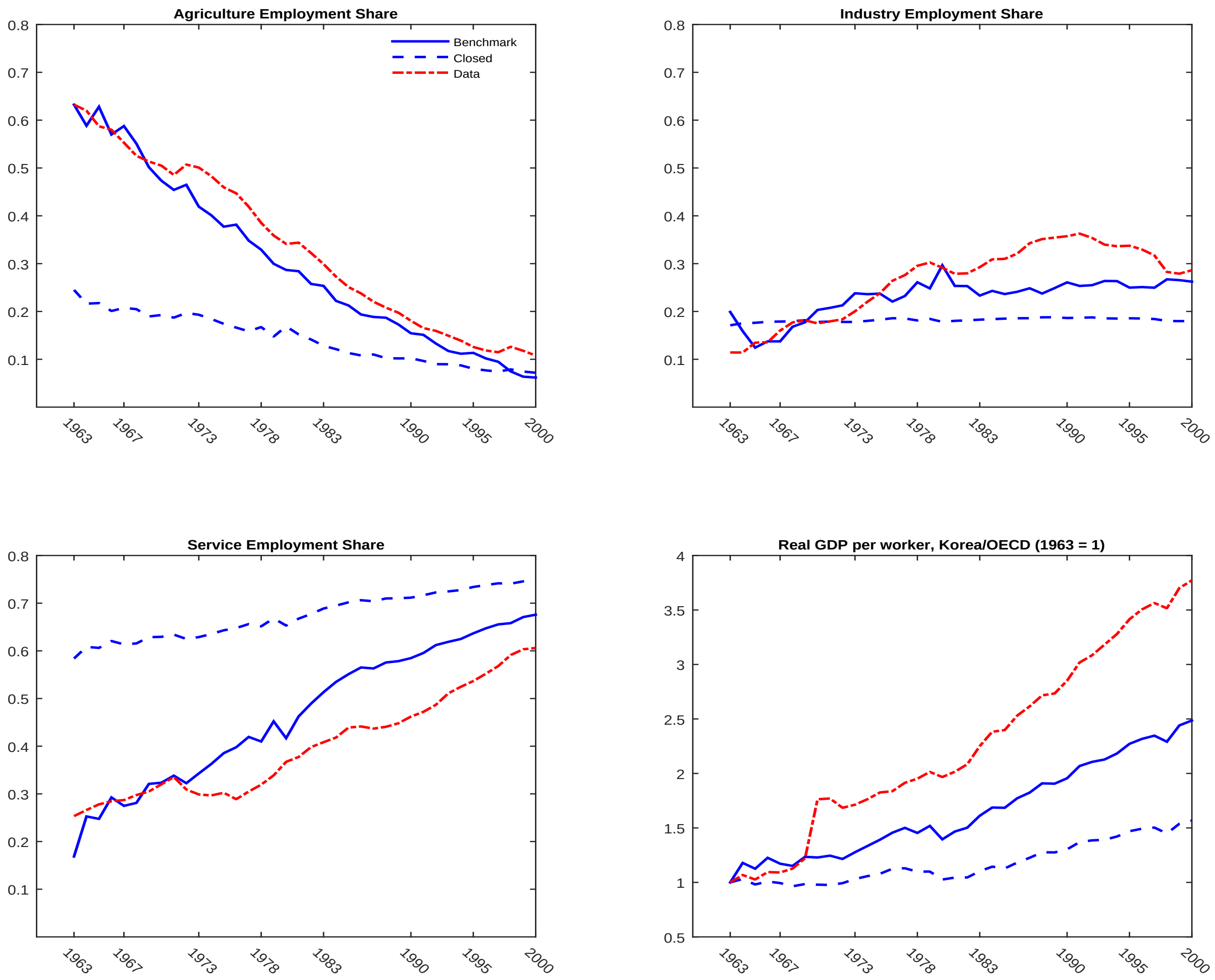


Figure 5: Employment Shares by Sector: Closed vs Benchmark vs Data

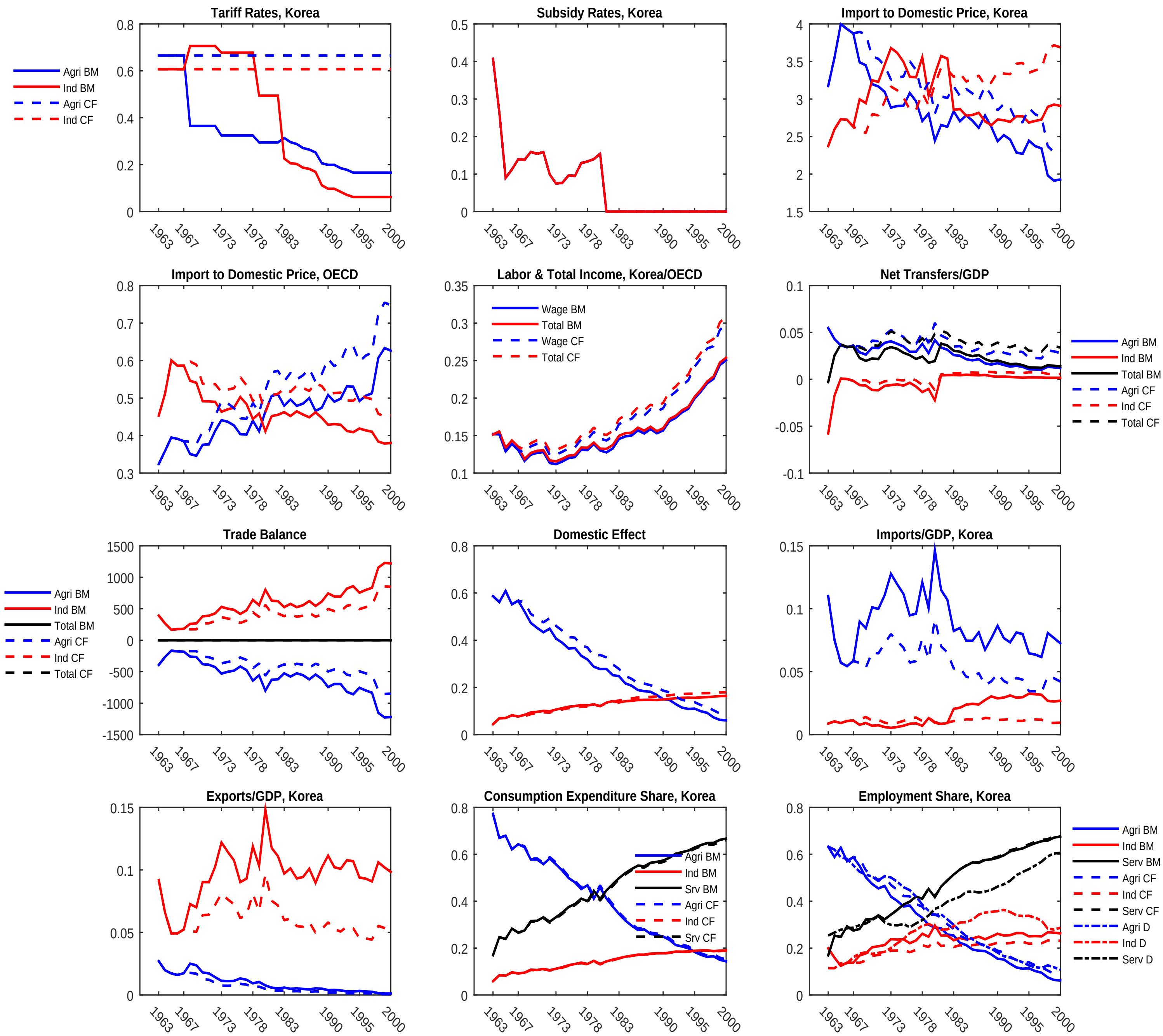


**Figure 6: No Change in Tariff Policy in South Korea**

*Notes:* BM denotes Benchmark, CF denotes Counterfactual, and D denotes Data. Agri denotes Agriculture, Ind denotes Industry, and Serv denotes Service.

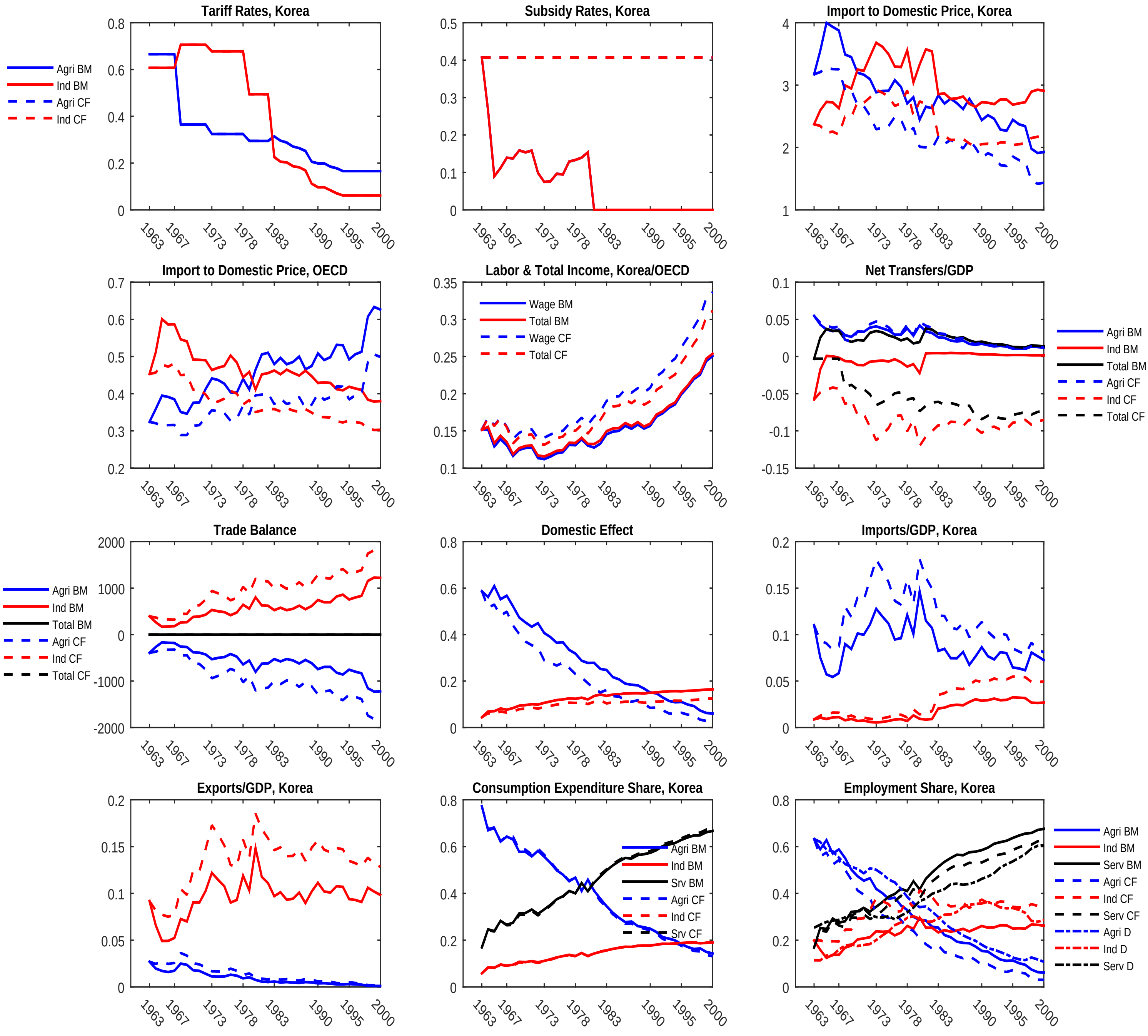


**Figure 7: No Change in Subsidy Policy in South Korea**

*Notes:* BM denotes Benchmark, CF denotes Counterfactual, and D denotes Data.
Agri denotes Agriculture, Ind denotes Industry, and Serv denotes Service.

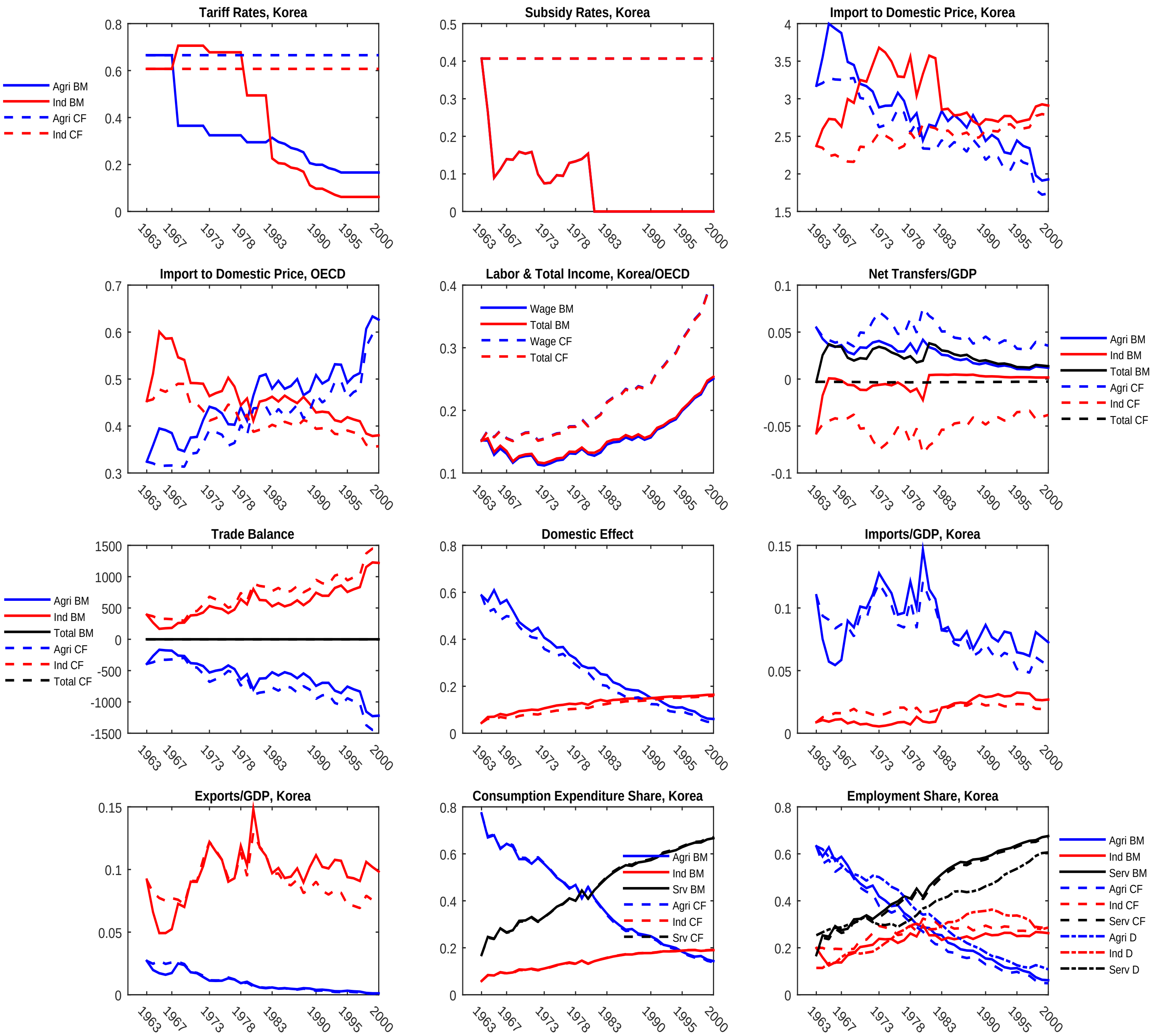


**Figure 8: No Change in Tariff and Subsidy Policies in South Korea**

*Notes:* BM denotes Benchmark, CF denotes Counterfactual, and D denotes Data.
Agri denotes Agriculture, Ind denotes Industry, and Serv denotes Service.

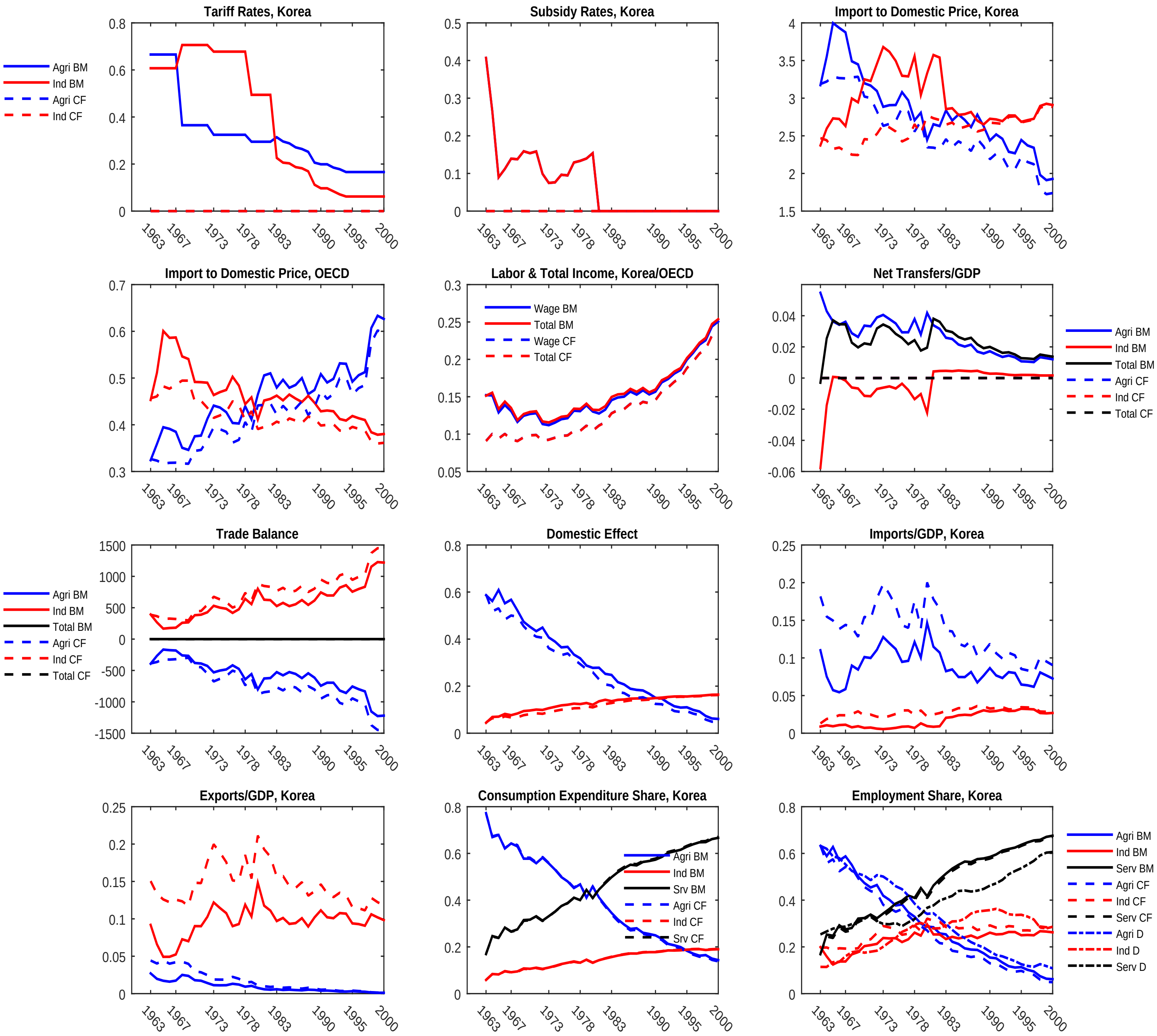


**Figure 9: Full and Immediate Liberalization in South Korea**

*Notes:* BM denotes Benchmark, CF denotes Counterfactual, and D denotes Data. Agri denotes Agriculture, Ind denotes Industry, and Serv denotes Service.