Trade, Reform, and Structural Transformation in South Korea

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PRELIMINARY AND INCOMPLETE

Abstract

We develop a quantitative, two-country, three-sector model to evaluate the impact of trade and trade liberalization for structural transformation. We provide an analytical characterization of the employment and GDP share of each sector in terms of domestic and international factors. We calibrate the model to data from South Korea and the OECD, and ask whether the contraction in observed agriculture employment and GDP shares, and growth in employment and GDP shares of the industrial sector, in South Korea between 1962 and 2000 would have occurred in the absence of trade. Our preliminary results show that while a closed economy model with non-homothetic preferences and differential productivity growth across sectors can account for much of the contraction in the employment and GDP share of agriculture in South Korea, it cannot account for the growth in the employment and GDP shares of the industrial sector. Our two-country model, calibrated to match import ratios from the post trade liberalization era in South Korea, can account for all of the growth of the GDP share of industry in South Korea, and a substantial portion of the growth of the employment share of industry. The model also out-performs a variant based on calibration to pre-liberalization import ratio data.

JEL Codes: F16, F43,O14,O41
Keywords: Trade liberalization, structural change, trade costs, growth.
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1. Introduction

Most models of structural change, developed primarily to account for the decline of agriculture and rise of industry in developing countries, fall into two classes. The first class of models focuses on preferences – "demand" factors - as a source of structural change. These models assume non-homothetic preferences which, even when technological change or productivity growth across sectors is neutral, generate sectoral re-allocations of resources. The intuition is that when income elasticities of demand are not unitary, as economies/consumers grow richer reallocation of resources across sectors occurs due to differences in the marginal rate of substitution in preferences across goods. Examples of these models are seen in Caselli and Coleman II (2001) and Gollin, Parente and Rogerson (2002). The second class of models concentrates on "supply" side reasons for structural change, emphasizing the role of differential sectoral productivity growth across sectors in generating structural transformation, assuming homothetic preferences. Baumol (1967), Ngai and Pissarides (2007), and Acemoglu and Guerrieri (2008) are examples of this class of models. Others, for example Rogerson (2008), employ a hybrid version of structural transformation models: uneven technological change across sectors coupled with non-homothetic preferences generates sectoral re-allocations of resources.

In general, the results of this research suggest that while uneven technological change successfully generates resource reallocations between industry and services, non-homothetic preferences are required to produce a movement of resources out of agriculture. For example, in countries such as the US and UK which followed traditional patterns of industrialization and growth and where de-industrialization has occurred most recently, declines in the employment share of manufacturing are easily accounted for by rising productivity in this sector. When industrial and service sector outputs are complements, relatively rapid productivity growth in manufacturing pushes labor out of this sector and into services, unless increases in productivity also lead to an increase in demand for manufacturing goods.

However recent work has emphasized that these results are a partial representation of what is happening in a broader cross section of countries. Matsuyama (2009) argues that in mature economies such as Germany and Japan, faster increases in manufacturing productivity have not produced declining employment shares of the sector. Additionally, some smaller emerging countries such as South Korea, Hong Kong, Taiwan have witnessed little decline in the employment share in the manufacturing sector despite rising productivity growth. These observations do not necessarily imply rejection of the sector-specific productivity growth model, however; Matsuyama argues that inter-dependence between economies can account for them. For example, productivity growth in the South Korean manufacturing sector can shift its comparative advantage toward manufacturing, so that the net effect on its national employment share can be positive or ambiguous.

In this paper, we examine the role of international trade for sectoral re-allocations of employment and GDP in a three-sector, two-country hybrid model of structural change. Non-homothetic preferences over agricultural goods permit large re-allocations of resources out of agriculture and into industry and services, even in the absence of trade. However, the evolution of relative sectoral labor productivities over time drives domestic re-allocations of labor and output between industry and services and, under trade, also the pattern of comparative advantage relative to a second country. We provide an analytical characterization of the role of domestic factors vs. international factors in generating sectoral shares of employment and GDP in our open economy model.

In addition, we assume that trade liberalization policies are well captured by changes in the parameters of the aggregator function (Armington, 1969) which describes consumer preferences over home and foreign produced units of a given sector's output. Simplistically, trade liberalization which reduces the cost of imports to home consumers (exports to foreign consumers) means consumers are more willing to consume foreign (home) produced goods. This assumption allows us to quantitatively evaluate the impact of trade liberalization for sectoral shares of employment and GDP by calibrating the parameters of the aggregator function to pre and post liberalization data as we describe below.

To evaluate the quantitative performance of the model we calibrate it to data from South Korea and the OECD for the period 1962 through 2000, and simulate the impact of observed average rates of sectoral productivity growth in the two trade partners. Larger trade flows, and trade liberalization policies, have been coincident with massive changes in the structure and size of the South Korean economy since the 1960's. We ask the quantitative questions. 1. What was the contribution of trade to structural transformation in South Korea? 2.

What was the contribution of trade liberalization, as we measure it, to structural transformation in South Korea?

To answer the first question, we compare the performance of a baseline variant of the two-country model to a variant of the model in which the South Korean economy is closed to international trade in matching observed employment and output shares of each sector. To provide a preliminary answer to the second question, we calibrate post-liberalization values of the weights assigned by consumers to home and foreign produced goods to match post-liberalization values of import ratios for each sector, re-calibrate the weights to match pre-liberalization values of import ratios, and compare the performance of the model in matching observed sectoral allocations of employment and GDP under the alternative calibrations. The date of liberalization for South Korea is taken to be 1968, the date assigned by Sachs and Warner (1995).

We find that our baseline two-country model, calibrated to match import ratios in the post 1968 liberalization era, substantially out-performs a closed economy version of the model. While both closed and open economy variants of the model are capable of re-producing much of the substantial decline in the employment and output shares of agriculture over the period 1963 through 2000 in South Korea, only our open economy variant can generate the observed growth in industry's share of employment and output over the same period. The open economy model also outperforms the closed economy model according to several quantitative measures of the model's "goodness of fit". We draw the tentative conclusion that accounting for the impact of international trade is important in being able to account for sectoral reallocations in South Korea. Our model suggests that international trade is important in several regards for explaining open economy structural transformation: in particular, the behavior of relative productivities - and hence relative prices – of sectoral outputs across countries has important effects for consumption expenditures by home and foreign consumers on the outputs of different sectors.

We also ask how the baseline model performs in matching South Korean structural transformation data relative to a version of the model in which the weights assigned by consumers to domestically produced and imported varieties of each sector's final output are calibrated to match data on import expenditure ratios in the pre-liberalization data, 1962 through

1967. We find that the pre-liberalization calibration, like the closed economy model, is unable to capture the growth of industrial sector employment and GDP as well as the baseline open economy model and its overall performance, by almost every measure of goodness of fit, is weaker than that of the baseline model. However, in this case, the pre-liberalization calibration of the model produces a substantial over-prediction of industrialization and under-prediction of the growth of services. Using post-liberalization intelligence to measure the implied costs of trade between South Korea and the OECD is important in being able to capture the observed patterns of industrialization of South Korea – however, at this preliminary stage in our analysis we are still in the process of characterizing the source of the differences.

Our work is closely related to that of Ungor (2010), who uses a two-country three sector open economy model to examine the impact of Chinese manufacturing growth on the structure of the US economy. His results imply that an open economy model which allows for trade with China accounts for 85.1 percent of de-industrialization in the US between 1992 and 2005, while a closed economy variant of the model accounts for only about 37.4 percent. Yi and Zhang (2010) examine structural change in an open economy framework. They focus on the role of trade in generating the 'hump' shaped pattern seen in the share of employment in the manufacturing sector despite of having the largest productivity growth, but do not provide a quantitative assessment of the importance of trade in driving structural transformation.

Section 2 presents our model and provides an analytical characterization of the sources of sectoral employment and output shares in terms of domestic and international factors. Section 3 describes the South Korean liberalization experience and shows the data. Section 4 outlines our calibration techniques, Section 5 our results, and Section 6 concludes.

2. MODEL

We consider a three sector, two country world economy. Each country is inhabited by an infinitely lived representative agent with perfect foresight, who consumes a single consumption composite and supplies labor in-elastically to production. Agents and hence countries are indexed by i. We call the countries "home" and "foreign", and index them by i, $i=h,f$.

The final consumption good is a composite comprising consumption of three types of good called Agriculture, Industry and Services and indexed by k, with $k = A, I, S$. Each type of good is produced exclusively by a representative perfectly competitive firm in the k^{th} sector.

Labor is the sole production factor, and labor productivity can differ across sectors, countries and time. The perfectly foreseen, infinite sequence of labor productivities of each sector in both countries is assumed to be exogenous. Labor effort is immobile across countries, but mobile across sectors within a country. The goods produced by all three sectors can be traded. In the baseline model trade is assumed to be balanced at every date.

2.1 Agents

Agent *i* maximizes his lifetime utility function,

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

where consumption composite $C_{i,t}$ is a function of three types of final consumption,

$$C_{i,t} = \left(\xi_{\mathrm{A}}(A_{i,t} - \overline{A}_i)^{\omega} + \xi_{\mathrm{I}} I_{i,t}^{\omega} + \xi_{\mathrm{S}} S_{i,t}^{\omega}\right)^{\frac{1}{\omega}} . \tag{2}$$

Here, $A_{i,t}$, $I_{i,t}$ and $S_{i,t}$ are agent *i*'s consumption of the outputs of Agriculture, Industry, and Services respectively at date t, and $\overline{A}_i$ denotes subsistence consumption of Agriculture. In addition, ξ_{k} is the weight that an agent assigns to consumption of good type *k*, ω governs the elasticity of substitution in consumption between the three types of good, and in the lifetime utility function ψ governs the elasticity of inter-temporal substitution. Preference parameters are assumed to be identical across countries.

Agent *i* allocates consumption of each type of good across units of that good produced in his own country and "abroad". This allocation is determined by the Armington aggregators for each type of consumption, given by

$$A_{i,t} = \left[\mu_{i,A} A_{i,i,t}^{\rho} + (1-\mu_{i,A}) A_{i,j,t}^{\rho}\right]^{\frac{1}{\rho}} \tag{3a}$$

$$I_{i,t} = \left[\mu_{i,I} I_{i,i,t}^{\rho} + (1-\mu_{i,I}) I_{i,j,t}^{\rho}\right]^{\frac{1}{\rho}} \tag{3b}$$

$$S_{i,t} = \left[\mu_{i,S} S_{i,i,t}^{\rho} + (1-\mu_{i,S}) S_{i,j,t}^{\rho}\right]^{\frac{1}{\rho}} . \tag{3c}$$

Here, $A_{i,i,t}$ is consumption of agricultural goods by agent *i* that are locally produced, and $A_{i,j,t}$ is agent *i*'s consumption of agricultural goods produced abroad and imported. Analogous notation is adopted for consumption of industrial and service sector products. In addition, $\mu_{i,k}$ is the weight assigned by the agent in country *i* to consumption of good type *k* produced domestically,

$1\text{-}\mu_{i,k}$ is the weight assigned by agent i to consumption of good type k produced abroad and imported, and ρ reflects the elasticity of substitution between locally produced and imported units of each type of good. Following convention in the international trade literature, we assume that the domestic and foreign varieties are substitutes, or $0<\rho<1$. The weight $\mu_{i,k}$ is often said to measure the degree of "home bias" in preferences. Together, the values of $\mu_{i,k}$ and ρ determine the impact of preferences and of trade technology and policy for the consumer's allocation of spending across local and imported varieties of each type of good. If $\mu_{i,k}=1$, for $i=f,h$, then good k is not traded.

Consumer i maximizes his lifetime utility subject to the budget constraint

$$p_{i,A,t}A_{i,i,t} + p_{i,I,t}I_{i,i,t} + p_{i,S,t}S_{i,i,t} + p_{j,A,t}A_{i,j,t} + p_{j,I,t}I_{i,j,,t} + p_{i,S,t}S_{i,j,t} \le w_{i,t}N_{i,t} \quad (4)$$

which must be satisfied at every date and implies that aggregate trade is balanced. Here $w_{i,t}$ is the wage rate, $p_{i,k,t}$ is the price of good k produced in country i and $p_{j,k,t}$ is the price of good k produced in country j, We arbitrarily let labor effort in the foreign country be the numeraire at every date, so that all prices are expressed in units of foreign labor, and $w_{f,,t}=1$ for all t.

In addition, we define $P_{i,k,t}$ as the price of the sector k Armington aggregate for consumer i given by

$$P_{i,A,t}= \left[\mu_{i,A}{}^{1/1-\rho}(p_{i,A,t})^{\rho/(\rho-1)} + (1-\mu_{i,A})^{1/1-\rho}(p_{j,A,t})^{\rho/(\rho-1)}\right]^{(\rho-1)/\rho} \quad (5a)$$

$$P_{i,I,t}= \left[\mu_{i,I}{}^{1/1-\rho}(p_{i,I,t})^{\rho/(\rho-1)} + (1-\mu_{i,I})^{1/1-\rho}(p_{j,I,t})^{\rho/(\rho-1)}\right]^{(\rho-1)/\rho} \quad (5b)$$

$$P_{i,S,t}= \left[\mu_{i,S}{}^{1/1-\rho}(p_{i,S,t})^{\rho/(\rho-1)} + (1-\mu_{i,S})^{1/1-\rho}(p_{j,S,t})^{\rho/(\rho-1)}\right]^{(\rho-1)/\rho} \quad (5c)$$

2.2 Firms

A representative perfectly competitive firm produces each type of good in each country. Firms take the prices of goods, and of the factor of production, labor, as given. Each good is produced using labor in a linear (Ricardian) technology:

$$Y_{i,A,t} = \theta_{i,A,t}N_{i,A,t} \quad (6a)$$

$$Y_{i,I,t} = \theta_{i,I,t}N_{i,I,t} \quad (6b)$$

$$Y_{i,S,t} = \theta_{i,S,t}N_{i,S,t} \quad (6c)$$

where $\theta_{i,k,t}$ denotes the productivity of labor in sector k in country i at date t, $N_{i,k,t}$ denotes the number of units of labor employed in sector k in country i at date t, and $Y_{i,k,t}$ denotes the number of units of output produced in sector *k* in country *i* at date *t*. The problem confronted by sector *k* in country *i* is to maximize profits subject to the production technology;

$$
\begin{aligned}
&Max \quad p_{i,k,t}Y_{i,k,t} - w_{i,t}N_{i,k,t} \\
&s.t. \\
&Y_{i,k,t} = \theta_{i,k,t}N_{i,k,t} \\
&N_{i,k,t} \geq 0
\end{aligned} \tag{7}
$$

2.3 Feasibility

Feasibility for labor in country $i = f,h$ in period *t* requires that

$$N_{i,A,t} + N_{i,I,t} + N_{i,S,t} \leq N_{i,t}. \tag{8}$$

In addition, the output of each good produced in country *i* cannot be exceeded by the sum of consumption across the two countries. For $i = f,h$, $i \neq j$, and for all *t*

$$Y_{i,A,t} \geq A_{i,i,t} + A_{j,i,t} \tag{9a}$$

$$Y_{i,I,t} \geq I_{i,i,t} + I_{j,i,t} \tag{9b}$$

$$Y_{i,S,t} \geq S_{i,i,t} + S_{j,i,t} \tag{9c}$$

2.4 Equilibrium

A competitive equilibrium is sequences of allocations for agent *i*, $i=f,h$, $i \neq j$, $\{A_{i,i,t}, A_{i,j,t}, I_{i,i,t}, I_{i,j,t}, S_{i,i,t}, S_{i,j,t}, A_{i,t}, I_{i,t}, S_{i,t}\}_{t=0}^{\infty}$, allocations for sectors in country *i*, $i=f,h$, $\{N_{i,A,t}, N_{i,I,t}, N_{i,S,t}, Y_{i,A,t}, Y_{i,I,t}, Y_{i,S,t}\}_{t=0}^{\infty}$, and prices $\{w_{i,t}, p_{i,A,t}, p_{i,I,t}, p_{i,S,t}, P_{i,A,t}, P_{i,I,t}, P_{i,S,t}\}_{t=0}^{\infty}$ for $i = h,f$ such that

i) given prices, agent *i*'s allocations solve the maximization problem described by (1) through (4) for $i=f,h$;

ii) given prices, sector *k*'s allocations solve the maximization problem given by (7);

iii) prices are such that labor markets clear for all $t \geq 0$, $i=f,h$:

$$N_{iAt} + N_{iIt} + N_{iSt} = N_{it},$$

and international goods markets clear for all $t \geq 0$, $i,j = f,h$:

$$Y_{i,A,t} = A_{i,i,t} + A_{j,i,t}$$

$$Y_{i,I,t} = I_{i,i,t} + I_{j,i,t}$$

$$Y_{i,S,t} = S_{i,i,t} + S_{j,i,t}$$

2.5 Analysis

The first order conditions for sector *k*'s profit maximization problem imply that the quantity of each sector's good produced and the quantity of factors hired in the sector satisfy, in equilibrium:

$$w_{it} \geq p_{i,k,t}\theta_{i,k,t}, \qquad \text{with equality if } Y_{i,k,t} > 0 \text{, for all } j.$$

These equations simply state that labor is paid its marginal product in sector k if the k^{th} good is produced and the price of the k^{th} good is then given by

$$p_{i,k,t} = w_{i,t}/\theta_{i,k,t}, \tag{10}$$

implying that relative prices in country *i*, when all goods are produced, are simply the inverse of relative productivities,

$$\frac{p_{i,A,t}}{p_{i,I,t}} = \frac{\theta_{i,I,t}}{\theta_{i,A,t}} \tag{11a}$$

$$\frac{p_{i,S,t}}{p_{i,I,t}} = \frac{\theta_{i,I,t}}{\theta_{i,S,t}}. \tag{11b}$$

We focus on equilibria in which all goods are produced in both countries (as we observe in our data from South Korea and the OECD aggregate). The first order conditions from the utility maximization problem of consumer *i* with respect to consumption of agricultural goods imply that

$$\frac{\mu_{i,A}}{1-\mu_{i,A}}\left(\frac{A_{i,i,t}}{A_{i,j,t}}\right)^{\rho-1} = \frac{p_{i,A,t}}{p_{j,A,t}} \quad , \tag{12}$$

or that the inverse of the import ratio is given by

$$\frac{p_{i,A,t}A_{i,i,t}}{p_{j,A,t}A_{i,j,t}} = \left(\frac{\mu_{i,A}}{1-\mu_{i,A}}\right)^{\frac{1}{1-\rho}}\left(\frac{p_{i,A,t}}{p_{j,A,t}}\right)^{\frac{-\rho}{1-\rho}} \tag{13a}$$

and similarly for sector $k=\{I,S\}$,

$$\frac{p_{i,I,t}I_{i,i,t}}{p_{j,I,t}I_{i,j,t}} = \left(\frac{\mu_{i,I}}{1-\mu_{i,I}}\right)^{\frac{1}{1-\rho}}\left(\frac{p_{i,I,t}}{p_{j,I,t}}\right)^{\frac{-\rho}{1-\rho}} \tag{13b}$$

$$\frac{p_{i,S,t}S_{i,i,t}}{p_{j,S,t}S_{i,j,t}} = \left(\frac{\mu_{i,S}}{1-\mu_{i,S}}\right)^{\frac{1}{1-\rho}}\left(\frac{p_{i,S,t}}{p_{j,S,t}}\right)^{\frac{-\rho}{1-\rho}} \tag{13c}$$

Relative expenditures on each type of good are given by

$$\frac{P_{i,A,t}(A_{i,t}-\overline{A}_i)}{P_{i,I,t}I_{i,t}}=\left(\frac{\varepsilon_A}{\varepsilon_I}\right)^{\frac{1}{1-\omega}}\left(\frac{P_{i,A,t}}{P_{i,I,t}}\right)^{\frac{-\omega}{1-\omega}} \tag{14a}$$

$$\frac{P_{i,S,t}S_{i,t}}{P_{i,I,t}I_{i,t}}=\left(\frac{\varepsilon_S}{\varepsilon_I}\right)^{\frac{1}{1-\omega}}\left(\frac{P_{i,S,t}}{P_{i,I,t}}\right)^{\frac{-\omega}{1-\omega}} \tag{14b}$$

Using equations (5), (12) and (13) we derive the following expressions for the share of total expenditure on good type *k* assigned to units produced in country *j* by consumer *i*, $Z^i_{j,k,t}$:

$$Z^i{}_{j,k,t}=\mu_{i,k}{}^{\frac{1}{1-\rho}}\left(\frac{p_{i,k,t}}{P_{i,k,t}}\right)^{\frac{-\rho}{1-\rho}}\ i=j \tag{15a}$$

$$Z^i{}_{j,k,t}=(1-\mu_{i,k})^{\frac{1}{1-\rho}}\left(\frac{p_{j,k,t}}{P_{i,k,t}}\right)^{\frac{-\rho}{1-\rho}}\ i\neq j \tag{15b}$$

The share of each type of good in total consumption expenditure is obtained using the expressions for relative expenditures given by (14a) and (14b)

$$E_{i,A,t}=\frac{P_{i,A,t}(A_{i,t}-\overline{A}_i)}{P_{i,t}C_{i,t}}=\frac{1-\dfrac{P_{i,A,t}\overline{A}_i}{P_{i,t}C_{i,t}}}{1+(\dfrac{\varepsilon_I}{\varepsilon_A})^{\frac{1}{1-\omega}}(\dfrac{P_{i,I,t}}{P_{i,A,t}})^{\frac{\omega}{\omega-1}}+(\dfrac{\varepsilon_S}{\varepsilon_A})^{\frac{1}{1-\omega}}(\dfrac{P_{i,S,t}}{P_{i,A,t}})^{\frac{\omega}{\omega-1}}}+\frac{P_{i,A,t}\overline{A}_i}{P_{i,t}C_{i,t}} \tag{16a}$$

$$E_{i,I,t}=\frac{P_{i,I,t}I_{i,t}}{P_{i,t}C_{i,t}}=\frac{1-\dfrac{P_{i,A,t}\overline{A}_i}{P_{i,t}C_{i,t}}}{1+(\dfrac{\varepsilon_A}{\varepsilon_I})^{\frac{1}{1-\omega}}(\dfrac{P_{i,A,t}}{P_{i,I,t}})^{\frac{\omega}{\omega-1}}+(\dfrac{\varepsilon_S}{\varepsilon_I})^{\frac{1}{1-\omega}}(\dfrac{P_{i,S,t}}{P_{i,I,t}})^{\frac{\omega}{\omega-1}}} \tag{16b}$$

$$E_{i,S,t}=\frac{P_{i,S,t}S_{i,t}}{P_{i,t}C_{i,t}}=\frac{1-\dfrac{P_{i,A,t}\overline{A}_i}{P_{i,t}C_{i,t}}}{1+(\dfrac{\varepsilon_A}{\varepsilon_S})^{\frac{1}{1-\omega}}(\dfrac{P_{i,A,t}}{P_{i,S,t}})^{\frac{\omega}{\omega-1}}+(\dfrac{\varepsilon_I}{\varepsilon_S})^{\frac{1}{1-\omega}}(\dfrac{P_{i,I,t}}{P_{i,S,t}})^{\frac{\omega}{\omega-1}}} \tag{16c}$$

2.6 Structural Change

National income (output) in country *i* is the weighted sum of outputs in each sector

$$Y_{i,t} = p_{i,A,t}Y_{i,A,t} + p_{i,I,t}Y_{i,I,t} + p_{i,S,t}Y_{i,S,t}$$

Since there are zero profits in equilibrium, and labor is the only production factor,

$$Y_{i,t} = w_{i,t} \times \left(N_{i,A,t} + N_{i,I,t} + N_{i,S,t}\right)$$

or

$$Y_{i,t} = w_{i,t} N_{i,t}$$

Therefore, the share of sector *k* in national income of country *i* is the employment share of sector *k* in total employment:

$$\frac{p_{i,k,t}Y_{i,k,t}}{Y_{i,t}} = \frac{N_{i,k,t}}{N_{i,t}}. \qquad (17)$$

We now derive the fundamental determinants of these sectoral shares.

In the case of agriculture, for example, we know that

$$p_{i,A,t}Y_{i,A,t} = p_{i,A,t}\left(A_{i,i,t} + A_{j,i,t}\right). \qquad (18)$$

Together, (17) and (18) imply that

$$\frac{p_{i,A,t}Y_{i,A,t}}{Y_{i,t}} = \frac{p_{i,A,t}\left(A_{i,i,t} + A_{j,i,t}\right)}{w_{i,t}N_{i,t}} \qquad (19)$$

and using (15) we have the following expression for the sectoral shares of agriculture in GDP and employment:

$$\frac{p_{i,A,t}Y_{i,A,t}}{Y_{i,t}} = \mu_{i,A}{}^{\frac{1}{1-\rho}}\left(\frac{p_{i,A,t}}{P_{i,A,t}}\right)^{\frac{\rho}{\rho-1}}\frac{P_{i,A,t}A_{i,t}}{w_{i,t}N_{i,t}} + (1-\mu_{j,A})^{\frac{1}{1-\rho}}\left(\frac{p_{i,A,t}}{P_{j,A,t}}\right)^{\frac{\rho}{\rho-1}}\frac{P_{j,A,t}A_{j,t}}{w_{i,t}N_{i,t}} \qquad (20)$$

Noting that

$$\frac{p_{iAt}A_{it}}{w_{it}N_{it}} = E_{iAt} \qquad (21a)$$

and

$$\frac{p_{jAt}A_{jt}}{w_{it}N_{it}} = E_{jAt}\,\frac{w_{jt}N_{jt}}{w_{it}N_{it}} \tag{21b}$$

the share of sector k in GDP is therefore

$$V_{i,k,t} = \mu_{i,k}{}^{\frac{1}{1-\rho}}\left(\frac{p_{i,k,t}}{P_{i,k,t}}\right)^{\frac{\rho}{\rho-1}}E_{i,k,t} + (1-\mu_{j,k})^{\frac{1}{1-\rho}}\left(\frac{p_{i,k,t}}{P_{j,k,t}}\right)^{\frac{\rho}{\rho-1}}E_{j,k,t}\,\frac{w_{j,t}N_{j,t}}{w_{i,t}N_{i,t}} \tag{22}$$

If $\mu_{i,k} = 1$, for all k, then country i is a closed economy. In this case, the share of each sector in GDP and employment is solely determined by its domestic consumption expenditure share, $p_{i,k,t} = P_{i,k,t}$ and $V_{i,k,t} = E_{i,k,t}$ for $k = \{A, I, S\}$. However, for an open economy, expenditure shares in the trading partner also affect the share of a sector in GDP and employment in country i.

To see the role of international trade for the sectoral composition of a country's output and employment, we consider the simple case in which $\bar{A}_i = 0$ for $i = \{f,h\}$. Then, the consumption expenditure shares of each sector, given by (16a) through (16c) are given simply by

$$E_{ikt} = \frac{1}{\sum_{m\in A,I,S}\left(\frac{\varepsilon_m}{\varepsilon_k}\right)^{\frac{1}{1-\omega}}\left(\frac{P_{imt}}{P_{ikt}}\right)^{\frac{\omega}{1-\omega}}} \qquad \forall k = A, I, S \tag{23}$$

and since the consumer price index is

$$P_{it} = \left[\varepsilon_A{}^{1/1-\omega}P_{iAt}{}^{\omega/1-\omega} + \varepsilon_I{}^{1/1-\omega}P_{iIt}{}^{\omega/1-\omega} + \varepsilon_S{}^{1/1-\omega}P_{iSt}{}^{\omega/1-\omega}\right]^{(\omega-1)/\omega} \tag{24}$$

we obtain

$$\frac{1}{\varepsilon_k^{\frac{1}{1-\omega}}}\left(\frac{P_{it}}{P_{ikt}}\right)^{\frac{\omega}{1-\omega}} = \sum_{m\in A,I,S}\left(\frac{\varepsilon_m}{\varepsilon_k}\right)^{\frac{1}{1-\omega}}\left(\frac{P_{imt}}{P_{ikt}}\right)^{\frac{\omega}{1-\omega}} \tag{25}$$

Thus the consumption expenditure share is given by

$$E_{ikt} = \varepsilon_k^{\frac{1}{1-\omega}}\left(\frac{P_{ikt}}{P_{it}}\right)^{\frac{\omega}{\omega-1}} \tag{26}$$

This is a standard result in a model where agents have homothetic preferences: the consumption expenditure share for each good is negatively (positively) related to its relative price if goods are substitutes (complements) i.e. if $1/1-\omega > (<) 1$. However, the price index for sector k in (16) is not only a function of the domestic variety's price but also that of the foreign variety. Hence, the share of a sector in GDP/labor is

$$V_{i,k,t} = \mu_{i,k}^{\frac{1}{1-\rho}} (\frac{p_{i,k,t}}{P_{i,k,t}})^{\frac{\rho}{\rho-1}} \varepsilon_k^{\frac{1}{1-\omega}} (\frac{p_{i,k,t}}{P_{i,t}})^{\frac{\omega}{\omega-1}} + (1-\mu_{j,k})^{\frac{1}{1-\rho}} (\frac{p_{i,k,t}}{P_{j,k,t}})^{\frac{\rho}{\rho-1}} \varepsilon_k^{\frac{1}{1-\omega}} (\frac{p_{j,k,t}}{P_{j,t}})^{\frac{\omega}{\omega-1}} \frac{w_{j,t} N_{j,t}}{w_{i,t} N_{i,t}} \quad (27)$$

We can now directly compare (27) with the closed economy share of sector *k*

$$V_{i,k,t} = \varepsilon_k^{\frac{1}{1-\omega}} (\frac{p_{i,k,t}}{P_{i,t}})^{\frac{\omega}{\omega-1}} . \quad (28)$$

The first term on the right hand side of equation (27) can be decomposed into two parts:

(a) $\varepsilon_k^{\frac{1}{1-\omega}} \left(\frac{p_{ikt}}{P_{it}}\right)^{\frac{\omega}{\omega-1}}$ is just the consumption expenditure share of sector *k* in country *i*, which we call the "domestic effect" and which is also the sectoral share in a closed economy;

(b) for an open economy, there is also an effect for sector *k*'s share of output and employment of the price of the domestically produced variety of good *k* relative to the price of the Armington aggregate given by $\mu_{ik}^{\frac{1}{1-\rho}} \left(\frac{p_{ikt}}{P_{ikt}}\right)^{\frac{\rho}{\rho-1}}$ the size of which is governed by the home bias parameter and the Armington elasticity, ρ. This we call the domestic relative price effect.

The second term on the RHS reflects foreign country *j* effects for sector *k's* output (labor) share in country *i*. This term can be decomposed into three parts:

(c) $\varepsilon_k^{\frac{1}{1-\omega}} \left(\frac{p_{jkt}}{P_{jt}}\right)^{\frac{\omega}{\omega-1}}$ is the effect of the consumption expenditure share of good *k* in country *j* on the share of output and employment in country *i*, a foreign country consumption expenditure/demand effect;

(d) is the effect of the relative price of good *k* in country *i* relative to the price index of the Armington aggregator for good *k* in country *j*, which depends on the weight that country *j* puts on country *i*'s variety and the Armington elasticity, ρ, and is given by $(1-\mu_{j,k})^{\frac{1}{1-\rho}} (\frac{p_{i,k,t}}{P_{j,k,t}})^{\frac{\rho}{\rho-1}}$.

(e) the product of foreign country *j* effects (c) and (d) are weighted by the size of country *j* relative to country *i*, relative to the domestic country effects, (a) and (b).

Focusing on the "foreign country" effect of changes in the relative prices of each variety on structural change in the domestic country, (d), note that - using firms' profit maximization conditions

$$(1-\mu_{j,k})^{\frac{1}{1-\rho}}(\frac{p_{i,k,t}}{P_{j,k,t}})^{\frac{\rho}{\rho-1}} = \frac{1}{1+(\frac{1-\mu_{i,k}}{\mu_{i,k}})^{\frac{1}{1-\rho}}(\frac{w_{j,t}\theta_{i,k,t}}{w_{i,t}\theta_{j,k,t}})^{\frac{\rho}{\rho-1}}}. \quad (29)$$

Since we assume that the foreign and domestic varieties are substitutes, or $0 < \rho < 1$, if $\frac{\theta_{ikt}}{\theta_{jkt}}$ is increasing over time, the price of good *k* produced in the domestic country falls relative to the price of good *k* produced in the foreign country. The consumption expenditure share of the domestic variety in total foreign expenditure on sector *k* goods therefore increases, resulting in a larger reallocation of labor (output) into sector *k* in the domestic country than would occur if foreign agents could not consume domestically produced goods. This is analogous to the reallocation effect referred to by Matsuyama (2009) and, along with the international relative price effect (b) for the domestic consumption expenditure share, illustrates the dynamic effect of changing relative productivities and hence comparative advantage in an open economy setting on structural change. The elasticity of substitution between domestically produced and imported units of each type of good is $1/(1-\rho)$. A higher ρ results in a higher elasticity of substitution and therefore a larger impact of an increase in $\frac{\theta_{ikt}}{\theta_{jkt}}$ on the expenditure share of each variety in total expenditure on sector *k's* good and consequently on the share of sector *k* in aggregate output and aggregate employment.

In the following sections, we simulate the model's predictions for sectoral reallocations over time using measured productivity growth by sector from South Korea and the OECD. We use the decomposition of (a) (the closed economy effect for sectoral reallocation) through (e) to characterize and quantify the importance of South Korean international trade for the sectoral reallocations predicted by the model.

3. STRUCTURAL CHANGE AND TRADE REFORM IN SOUTH KOREA

In order to evaluate the quantitative importance of trade in driving structural change we calibrate the model to data from South Korea and the OECD for the period 1962 through 2000. We select South Korea because it is frequently touted as an example of an economy that has enjoyed rapid structural change and concomitant aggregate growth as a direct result of trade liberalization.

3.1 Background

Until the late 1950s, South Korea was an "inward oriented" economy. High unemployment and inflation, and large budget and balance of payments deficits, characterized macroeconomic performance. Inflation averaged roughly 30 percent during the latter half of the 1950s, and balance of payments deficits were typically 5 to 10 percent of GDP. To combat inflation, the nominal exchange rate of the won against the US dollar was fixed, and to bring the balance of payments under control policy makers relied heavily on import restriction measures such as multiple exchange rates, import licensing, quantitative restrictions and high tariffs on selected items. Though some export incentives were introduced in the 1950s - financing for the purchase of export goods, export bonuses given through preferential foreign exchanges and discounts on railroad freight for example - import substitution policies encouraged production for domestic rather than export markets.

Korea's trade reform began during the early 1960s after Chung He Park took control of the government in 1961, and initially consisted of export promotion policies. The first five year plan was implemented from 1962 with a central focus being the development of key export industries. The exchange rate system was unified in 1961 and the Korean won was devalued from 130 won to 255 won per U.S. dollar in 1964. A comprehensive set of export sector specific incentives were introduced during the 1960s which included a preferential tax system, a preferential loan system, and various administrative support systems. While some of these sector specific incentives simply allowed Korean exporters to buy imported inputs and sell their outputs at world market prices, others were distorting subsidies that enhanced the profitability of export sales relative to domestic sales for domestic firms[1]. In the late 1960's, the Korean government

[1] The preferential tax system involved several components: tariff exemptions on raw materials and intermediate and capital goods for export production, exemptions from indirect taxes for intermediate inputs and export sales, the

also initiated a series of industry specific promotional laws, which initiated the Heavy and Chemical Industry drive in the 1970s, which were not completely abolished until a general Industry Promotion Law was passed in 1986.

In the 1970s, the system of export incentives continued although the scope of subsidies was reduced. For example, a 50 percent reduction in taxes on profits from export earnings was abolished and in 1975, the system of prior tariff exemptions on imported inputs used in export production was changed to a "drawback" system. However, preferential loans for export activities were steadily expanded throughout the 1970s, increasing from 5.1 percent of total domestic credit in 1966 to 20.5 percent in 1978, although the expansion was accompanied by a gradual reduction of interest rate differential between preferential and ordinary loans, and by 1988 only small firms received export related loans. Additional devaluations of the Korean won took place which also promoted exports - from 484 won per U.S. dollar in 1974 to 580 won per U.S. dollar in 1980, and again to 893 won per U.S. dollar in 1985.

While export promotion policies began in 1962, import controls were not relaxed until the late 1960's and substantial tariff reductions took place during the 1980's. In the early 1960's, import controls were actually tightened in order to bring the widening trade deficit under control. The simple average of legal tariff rates reached a peak of nearly 40 percent in 1962 and remained at that level throughout 1960s. Quantity restrictions were also used extensively to control imports although these were reduced significantly in 1967. About 88 percent of all import items were subject to quantity restrictions in the first half of 1967, but in the second half of 1967 more than 60 percent of basic import items became automatically approved for import. However, the approval rate then fell steadily until 1975 when it reached 49.1 percent. There was also price based protection of agriculture, through a high-rice-price policy introduced in the late 1960s. In 1983, the government announced a time-phased import liberalization plan for the period 1983-88. The range of basic tariff rates was to be reduced, and the average basic tariff rate lowered from 23.7% in 1983 to 18.1% in 1988. A new tariff reform plan was prepared for 1989-93, by

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reduction of direct taxes on profits earned through export activities, the introduction of reserve funds to develop new foreign markets and to defray export losses, and the creation of an acceleration depreciation allowance for fixed capital used directly in export production. The preferential loan system provided exporters with access to subsidized short- and long-term credits for their purchase of inputs and financing of fixed investments. Also, generous wastage allowances were granted on imported duty-free raw materials over and above the requirements of actual export production. An export-import linkage system permitting access to otherwise prohibited imports was introduced, and preferential rates were also given on loans for some overhead inputs.

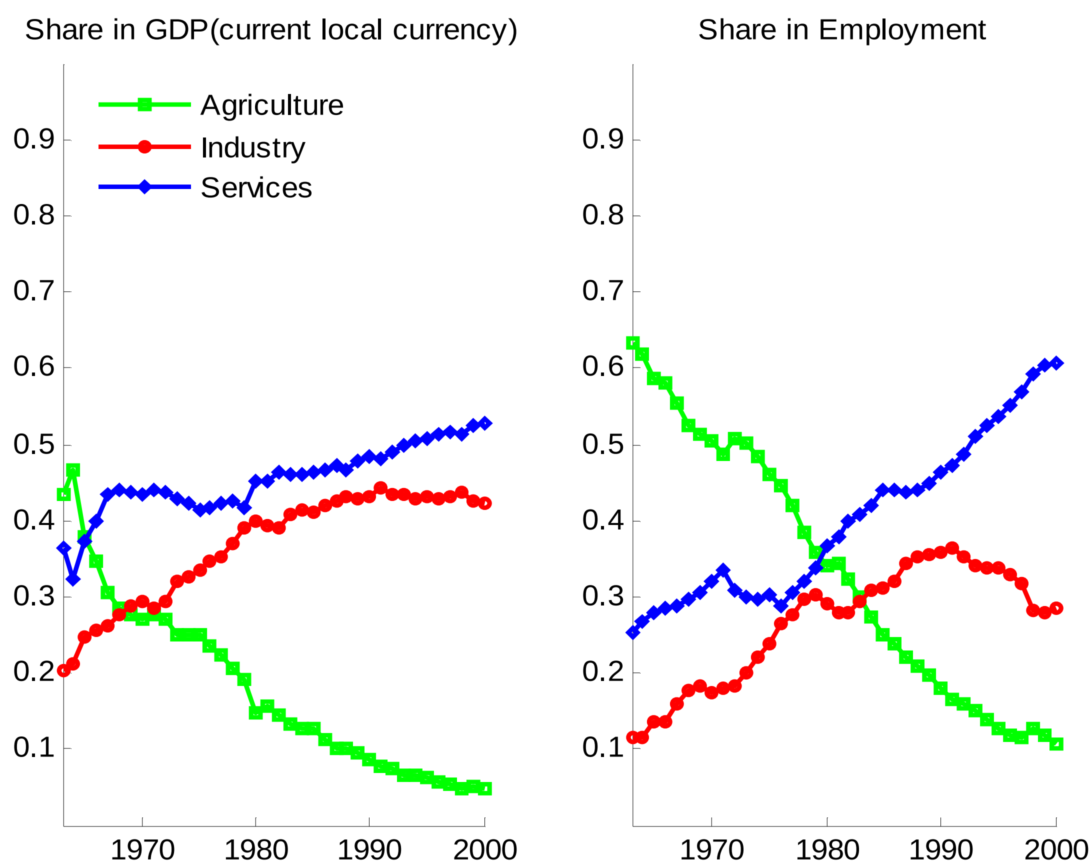
which the average tariff rate was to decrease from 18.1 percent in 1988 to 7.9 percent in 1995.

Since import, as well as export, promotion policies were enacted only during the second half of 1967, in our quantitative work we frequently use 1968 as the benchmark first year of trade liberalization.

3.2 Data

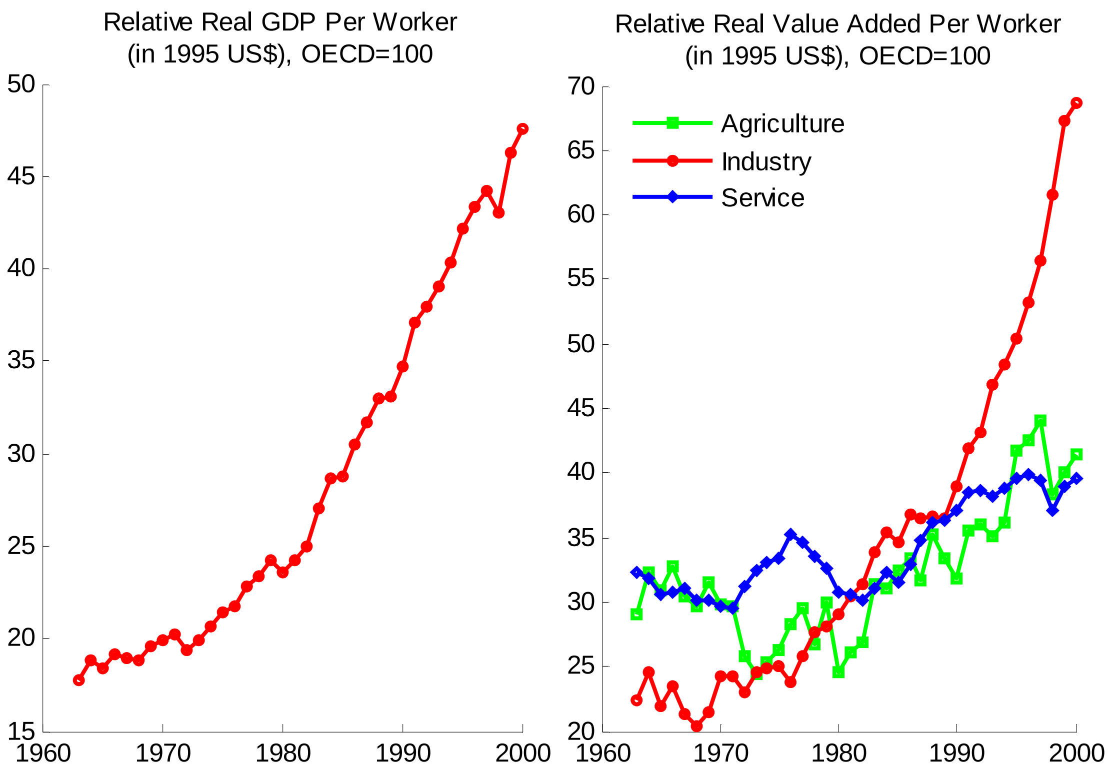
As can be seen in Figure 1, trade reform policies from 1962 through 2000 have been coincident with a substantial decline in the value added and employment share of agriculture, and an increase in the value added and employment share of the industrial sector. Services, although they account for a much larger share of employment in 2000 than the early 1960's, have experienced a fairly "flat" evolution as a share of Korea's GDP, especially when that share is expressed in constant dollars.

Figure 1



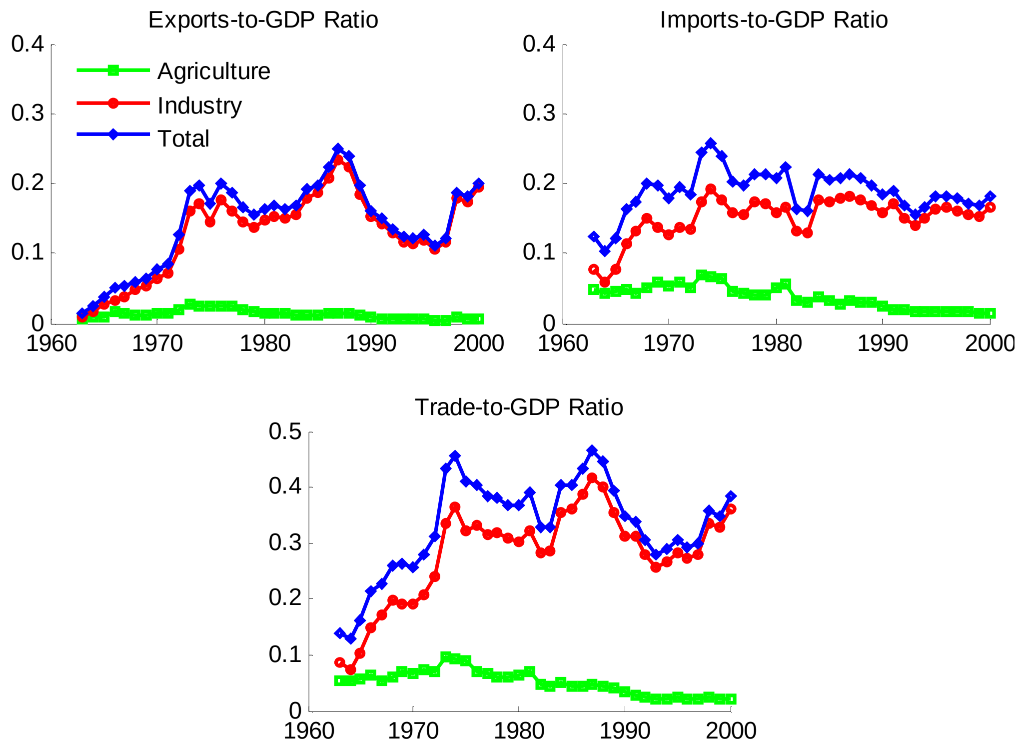
In addition, the country has experienced remarkable growth in GDP and GDP per worker, and in Figure 2 we document that growth relative to that of the OECD over the same time period for total real GDP per worker and for GDP per worker by sector.

Figure 2



At the same time, trade liberalization policies have been associated with a dramatic increase in both imports and exports of the industrial sector in South Korea, shown in Figure 3, and a decline in agricultural imports. (Accurate service sector trade data is unfortunately not available). Korea has consistently run trade deficits in agriculture since 1960, although the deficit has gradually decreased. In the following sections, we use our model to evaluate the extent to which trade reform in South Korea has produced the patterns of sectoral reallocation observed in Figures 1 and 3, which are associated with the growth witnessed in Figure 2.

Figure 3



4. CALIBRATION

We treat 1968 as the first date of liberalization, South Korea as the "home" country, and an OECD[2] aggregate as the foreign country. The OECD accounted for 68 percent of South Korean exports and 71 percent of South Korean imports on average over the period 1962-2000. After 2000, China's external liberalization would inevitably play an important role in Korean trade patterns, and so ending the sample in 2000 for the purposes of focusing on the impact of the trade policies of Korea for Korean development seems reasonable.

4.1 Preference Parameters

The curvature parameter, ψ, determines the representative household's elasticity of inter-temporal substitution. We follow Backus, Kehoe and Kydland (1992) and set ψ=-1 so that

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

$\frac{1}{1-\psi} = 0.5$.

The weight on the consumption of sector k good in the consumption aggregate, ξ_k, and the elasticity of substitution between the three type of goods, ω, are taken from Herrendorf, Rogerson and Valentinyi (2010). Specifically, we take averages of each of the parameters across different specifications, where the authors use data on final consumption expenditures for the US economy. The values we use are $\xi_A = 0.02$, $\xi_I = 0.17$, $\xi_S = 0.78$, and $\omega = -0.5$. Thus, the three goods are assumed to be complements. Obviously, we are implicitly assuming that the OECD aggregate used in this paper has the same consumption expenditure pattern as does the United States which is a reasonable approximation, since most countries in the OECD aggregate have similar income levels.

The subsistence level of consumption of agricultural goods, $\overline{A}_i$, is assumed to be the same for both the home and foreign country. It is chosen to match the share of agriculture in employment in South Korea in 1962.

4.2 Trade Parameters

The weights on the domestic and imported variety in the Armington aggregator for each sector, μ_{ik}, capture all costs of trade which would affect the expenditure on domestic varieties of goods relative to imported varieties, after controlling for the marginal costs of production in the two countries.

Usually trade costs are modeled as iceberg cost of trade, *ala* Samuelson. These capture observable and unobservable variable costs of selling a good in a foreign market relative to selling it in the home market. There are also psychic costs of trade which might originate in greater familiarity of the consumer with the domestic variety relative to the imported variety. These could also be interpreted as costs associated with acquisition of information about imported varieties[3]. These would result in a higher weight on the domestic variety relative to the

[3] There are also sunk and fixed costs specific to international trade. These include costs incurred in learning about the profitability of export opportunities; in making market-specific investments in capacity, product customization, and regulatory compliance; and in setting up and maintaining foreign distribution networks. Models with sunk or fixed costs are focused on understanding the hysteresis phenomenon in exports, the differences between exporting and non-exporting firms, and the dynamics of exporting decision. See Melitz (2003), Roberts and Tybout (1997) and Das, Roberts and Tybout (forthcoming).

foreign variety in total expenditure on a good. Because both iceberg trade costs and psychic costs have unobservable components, one cannot separately identify the two from expenditure on domestic goods relative to imported goods. Therefore, a model with iceberg costs of trade as the only trade barrier is isomorphic to a model with purely psychic costs (captured by Armington aggregator weights) as the only trade barrier. Since we are not interested in the relative importance of the effects of changes in different types of trade costs on trade volumes, we model the sectoral Armington weight as a stand in for all types of trade costs.

We assume, in our benchmark model, that services are not traded which implies that $\mu_{is} = 1$ for $i=h,f$. To calibrate the weights for agriculture and industry, we use (13a) and (13b). The left-hand side of these equations gives the ratio of expenditure on the domestic variety of a good to expenditure on imported variety. This ratio can be computed using sectoral data on value added and trade[4]. The right-hand side is the ratio of marginal costs of production of the two countries.

Using a shooting algorithm, we choose the benchmark μ's so that, given the (endogenous) equilibrium wages of the two countries, the model matches the average ratio of expenditure on the domestic variety to expenditure on the imported variety for sector k in country i for the post-liberalization period, 1968 through 2000. The effect of trade liberalization is measured by recalibrating the μ's to match the average ratio of expenditures on domestic to imported varieties observed in the data for the pre-liberalization period, 1962 through 1967 and comparing results. Obviously, sensitivity analysis to the choice of liberalization date can (and will in future drafts) be conducted. We report detailed results here, however, for the numerical values of the Armington weights derived by application of the shooting algorithm for different sample periods.

A key parameter of the model is ρ since it controls the Armington elasticity or the "elasticity of trade", which is $1/(1-\rho)$. Ruhl (2008) states that 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

[4] Gross output, not value added, would be the ideal measure to use here. But, data on gross output is not available by sector for the entire time period for South Korea, nor for some of the OECD countries.

Armington elasticity of 1.50. By contrast, general equilibrium growth models need large values of the Armington elasticity to explain the growth in trade volumes that results from tariff reductions. Yi (2003) shows that these models need an elasticity of 12 or more to match the magnitude of trade growth observed in post-liberalization data. Ruhl (2008) also observes that empirical work on trade liberalizations, as well as cross section regressions relating trade patterns to tariff and non-tariff barriers, finds values of the Armington elasticity that range from 6 to 15, similar to the ones needed in applied general equilibrium models.

Since our calibration of the Armington weights captures both observable and unobservable trade costs, we set the Armington elasticity to be roughly the lower bound of the range of values suggested by Ruhl (2008) for permanent changes in trade costs in our benchmark model, resulting in $\rho = 0.84$. We also show results for values of the Armington elasticity that are much lower than this, as suggested by Ruhl's work, as quantitatively matching situations in which trade cost changes are believed to be purely temporary.

4.3 Labor Productivity

We calibrate the country and sector specific labor productivity parameter values at each date, θ_{ikt}, as follows.

For each country, we compute the average sectoral labor productivity growth rate for 1962 through 2000. To do this, we divide sectoral value added as our measure of output by sectoral employment data at each date 1962 through 2000, and compute the simple arithmetic mean of the annual growth rate for each sector and country.

We use these computed annual growth rates, together with initial levels, of labor productivity values to derive an annual time series for each sector and country. For the OECD, for each sector *k*, we set the initial value of $\theta_{fk0} = 1$. The initial value of labor productivity in each sector in South Korea is then chosen to match the labor productivity of South Korea relative to that of OECD in each sector in 1962. The remaining values of θ_{ikt} for $t=1963,\ldots,2000$, $i=h,f$ and $k=A,I,S$ are computed from the average sectoral labor productivity growth rates.

Notably, while sectoral value added is not a true measure of sectoral final output – gross output by sector is – given the absence of complete sectoral gross output data, and for the purpose of understanding sectoral transformation, the value added data is justifiable if not ideal as a measure of the magnitude of productive activity in a sector.

5. RESULTS

5.1 Baseline Open Economy Model

In our first set of experiments, we compare the performance of a baseline calibration of our open economy model in accounting for sectoral reallocations to those observed in the data.

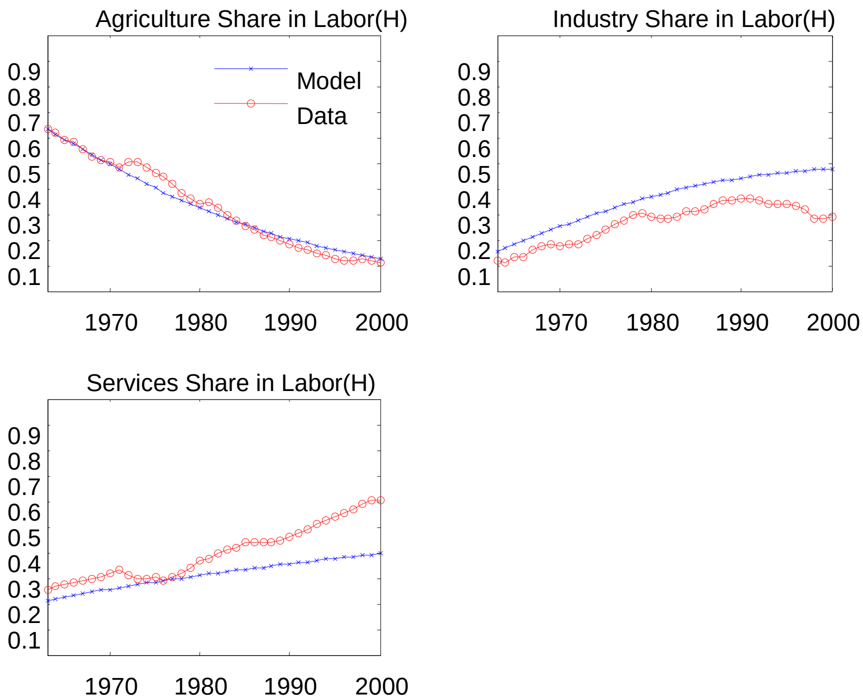
Here, the Armington elasticity parameter, ρ, is 0.84. This implies an elasticity of substitution between domestic and imported varieties of goods produced by Agriculture and Industry of 6.2, the value suggested by the results of Ruhl (2008) for permanent changes in tariffs.

We calibrate values of the Armington weight, or home bias parameter, μ, as described above using a shooting algorithm to match data on the average annual ratio of expenditure on domestic vs. imported varieties of goods for the post-liberalization period 1968 through 2000. This yields the following values of μ: $\mu_{h,A}$ = 0.0397, $\mu_{h,I}$ = 0.0308, $\mu_{f,A}$ = 0.9863, $\mu_{f,I}$ = 0.9878. Initial sectoral labor productivities are calibrated to match initial comparative advantage with respect to the OECD and subsequent levels from average growth rates as we have described.

Finally, recall that trade is assumed to be balanced in the benchmark open economy model; any deficit (surplus) in Agriculture is matched exactly by a surplus (deficit) in Industry at every date. In subsequent drafts, the implications of relaxing this assumption are explored. It is worth noting that while the employment and agricultural shares of each sector are identical in this simple Ricardian model, they are different (in levels) in the data, although they tend to move together over time. Our model's predicted employment and GDP shares are compared to both employment and GDP shares in the data.

As shown in Figure 4, the model qualitatively produces a large decline in the sectoral share of employment in the agricultural sector, and growth in the share of industry and services, as observed in the South Korean data. Quantitatively, it matches well the decline in the employment share of agriculture, somewhat over-predicts the increase in the share of industry and under-predicts the share of services (which we treat as non-traded in this benchmark model). In addition, while the data from South Korea through 2000 do show the beginning of a hump

Figure 4: Baseline Open Economy Model

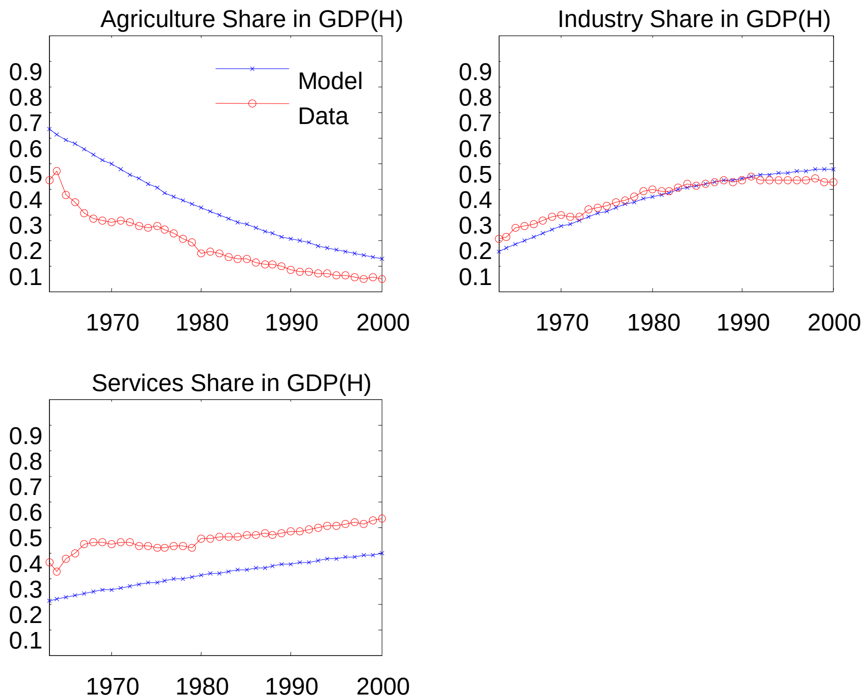


shape in the industrial sector employment share – which starts to decline systematically if slowly from 1991 onwards - in the model there is a gradual flattening of the employment share, but no systematic decline through 2000. Nonetheless, the baseline calibration of parameters for the model captures the direction of change for each sector's employment share, comes reasonably close to measuring the magnitudes in the first half of the sample, but is less quantitatively successful in the second half of the sample for industry and services.

The model is less successful in matching GDP or "output" shares by sector for agriculture and services, however, the model's predicted GDP/employment share for industry matches very closely the GDP share observed in the data. Figure 5 shows these results. The GDP share of agriculture – which is much lower in the data than its employment share – is consistently over-predicted by the model's employment share, while the service sector's share of GDP is under-predicted.

In Table 1, we show the portion of the model's predicted shares of output and employment for each sector that are accounted for by the purely "domestic effect", effect "(a)" in our analytical decomposition described in section 2, compared to the portion of the model's

Figure 5: Baseline Open Economy Model



predicted shares of output and employment for each sector that are accounted for by portions "(b)" through "(e)" which all involve some international influence. Obviously, the share of output and employment in services is 100% accounted for by the purely domestic effect "(a)" since we assume services are not traded. Agriculture shows a significant role for international effects (b) through (e), a role which falls from 34.18% to 9.43% over the sample period. International effects account for 40.24% of the share of industry in employment and output in 1963, and a very similar 37.81% in 2000.

5.2 Comparison: A Closed Economy Model

The quite reasonable success of the baseline model in matching the employment and output shares of agriculture and industry, together with the model decomposition results, suggests that if we completely close our model economy by forcing home bias to be one in all three sectors, there may be a significant deterioration in the performance of the model. In Figure 6, Figure 7 and Table 2, we show the performance of the model when we set $\mu=1$ in all three sectors to that of our baseline model.

Table 1: Baseline Open Economy Model

Baseline Open Economy Model									
Year	Agriculture			Industry			Services		
	Model	*Domestic*	*Foreign*	*Model*	*Domestic*	*Foreign*	*Model*	*Domestic*	*Foreign*
1963	0.63	65.82%	34.18%	0.15	59.76%	40.24%	0.21	100.00%	0.00%
1964	0.61	65.84%	34.16%	0.17	60.04%	39.96%	0.22	100.00%	0.00%
1965	0.59	65.94%	34.06%	0.18	60.26%	39.74%	0.23	100.00%	0.00%
1966	0.57	66.12%	33.88%	0.20	60.45%	39.55%	0.23	100.00%	0.00%
1967	0.55	66.39%	33.61%	0.21	60.60%	39.40%	0.24	100.00%	0.00%
1968	0.53	66.73%	33.27%	0.22	60.71%	39.29%	0.24	100.00%	0.00%
1969	0.51	67.14%	32.86%	0.24	60.80%	39.20%	0.25	100.00%	0.00%
1970	0.49	67.63%	32.37%	0.25	60.87%	39.13%	0.26	100.00%	0.00%
1971	0.47	68.18%	31.82%	0.26	60.92%	39.08%	0.26	100.00%	0.00%
1972	0.46	68.79%	31.21%	0.28	60.96%	39.04%	0.27	100.00%	0.00%
1973	0.44	69.46%	30.54%	0.29	60.99%	39.01%	0.27	100.00%	0.00%
1974	0.42	70.19%	29.81%	0.30	61.01%	38.99%	0.28	100.00%	0.00%
1975	0.40	70.96%	29.04%	0.31	61.02%	38.98%	0.28	100.00%	0.00%
1976	0.38	71.77%	28.23%	0.33	61.03%	38.97%	0.29	100.00%	0.00%
1977	0.37	72.62%	27.38%	0.34	61.05%	38.95%	0.29	100.00%	0.00%
1978	0.35	73.49%	26.51%	0.35	61.06%	38.94%	0.30	100.00%	0.00%
1979	0.34	74.39%	25.61%	0.36	61.07%	38.93%	0.30	100.00%	0.00%
1980	0.32	75.30%	24.70%	0.37	61.09%	38.91%	0.31	100.00%	0.00%
1981	0.31	76.23%	23.77%	0.38	61.12%	38.88%	0.31	100.00%	0.00%
1982	0.30	77.16%	22.84%	0.39	61.15%	38.85%	0.32	100.00%	0.00%
1983	0.28	78.09%	21.91%	0.39	61.18%	38.82%	0.32	100.00%	0.00%
1984	0.27	79.01%	20.99%	0.40	61.22%	38.78%	0.33	100.00%	0.00%
1985	0.26	79.93%	20.07%	0.41	61.26%	38.74%	0.33	100.00%	0.00%
1986	0.25	80.82%	19.18%	0.42	61.30%	38.70%	0.34	100.00%	0.00%
1987	0.23	81.70%	18.30%	0.42	61.36%	38.64%	0.34	100.00%	0.00%
1988	0.22	82.56%	17.44%	0.43	61.41%	38.59%	0.35	100.00%	0.00%
1989	0.21	83.39%	16.61%	0.43	61.47%	38.53%	0.35	100.00%	0.00%
1990	0.20	84.20%	15.80%	0.44	61.53%	38.47%	0.36	100.00%	0.00%
1991	0.20	84.98%	15.02%	0.45	61.59%	38.41%	0.36	100.00%	0.00%
1992	0.19	85.72%	14.28%	0.45	61.66%	38.34%	0.36	100.00%	0.00%
1993	0.18	86.44%	13.56%	0.45	61.72%	38.28%	0.37	100.00%	0.00%
1994	0.17	87.12%	12.88%	0.46	61.79%	38.21%	0.37	100.00%	0.00%
1995	0.16	87.77%	12.23%	0.46	61.86%	38.14%	0.38	100.00%	0.00%
1996	0.15	88.39%	11.61%	0.47	61.92%	38.08%	0.38	100.00%	0.00%
1997	0.15	88.98%	11.02%	0.47	61.99%	38.01%	0.38	100.00%	0.00%
1998	0.14	89.54%	10.46%	0.47	62.06%	37.94%	0.39	100.00%	0.00%
1999	0.13	90.07%	9.93%	0.48	62.13%	37.87%	0.39	100.00%	0.00%
2000	0.13	90.57%	9.43%	0.48	62.19%	37.81%	0.40	100.00%	0.00%

While the closed economy model can capture a substantial portion of decline in the employment and output shares of agriculture in South Korea, as the result of relative domestic productivity/price changes for consumption shares in combination with non-homothetic preferences, it fails to produce any substantial industrialization as our baseline open economy model can. Labor resources in the closed economy model are reallocated from agriculture to services, with little change in the labor and output share of industry over the sample period.

As seen in Table 2, the closed economy model captures 88% of the total decline in agriculture's share of employment from 0.63 to 0.11 over the sample period, compared to 96% that is captured by the baseline open economy model. The closed economy model over-predicts by 21% the total decline in the GDP share of agriculture, while the open economy model over-predicts this by 32%. The closed economy model captures only 33% of the total increase in the industrial sector's employment share from 0.11 to 0.29 over the sample period, and only 27% of the total increase in its share of GDP. The open economy model over-predicts the total increase in industry's share of employment by roughly 80% and the increase in industry's share of GDP by 50%. Finally, the closed economy model over-predicts the total increase in the service sector employment share by 11% and its share of GDP by 135%, while the open economy captures roughly 53% of the total increase in the share of service sector employment, and over-predicts the increase in the share of service sector GDP by just 11%.

Table 3 shows that, according to several quantitative model "goodness of fit" evaluation criteria, the open economy baseline model outperforms the closed economy model. The closed economy performance measures are shown in parentheses. As measured by the sum of squared prediction errors of the model relative to the data by sector, where prediction errors are computed year by year, the open economy model out-performs the closed economy model in predicting employment shares in all three sectors (sum of squared errors is smaller) and outperforms the closed economy model in predicting GDP shares in agriculture, industry and overall (although not in services). The same pattern of results emerges when the root mean squared error of the model relative to the data, computed on the basis of annual prediction errors of employment and output shares, is used as a performance measure. When we compute the correlation coefficient (Kehoe, 2003) for sectoral shares predicted by the model with those observed in the data, where the correlation coefficient weights the performance of the model relative to the data across sectors, the open economy model exhibits a higher overall correlation than the closed economy model both for employment and GDP shares. The percentage of variance of sectoral GDP shares observed in the data which is accounted for by the model (again where the variance decomposition is computed as a weighted vector across sectors as in Kehoe, 2003) is substantially higher for the open economy model, and the percentage of variance of sectoral employment shares is slightly higher for the open economy model. Overall, then, a closed economy version of the model fails to account for the growth of industry in South Korea as a source of GDP and employment and generally underperforms in capturing structural transformation in South Korea relative to an open economy model.

5.3 Comparison: Model Calibrated to Pre-Liberalization Data

In an initial attempt to assess whether accounting for the trade liberalization that occurs in 1968 matters for the performance of the model, we re-calibrated the model to pre-liberalization data as we now describe, and compared the performance of the model under alternative (pre and post liberalization) calibrations.

Figure 6: Closed Economy Model

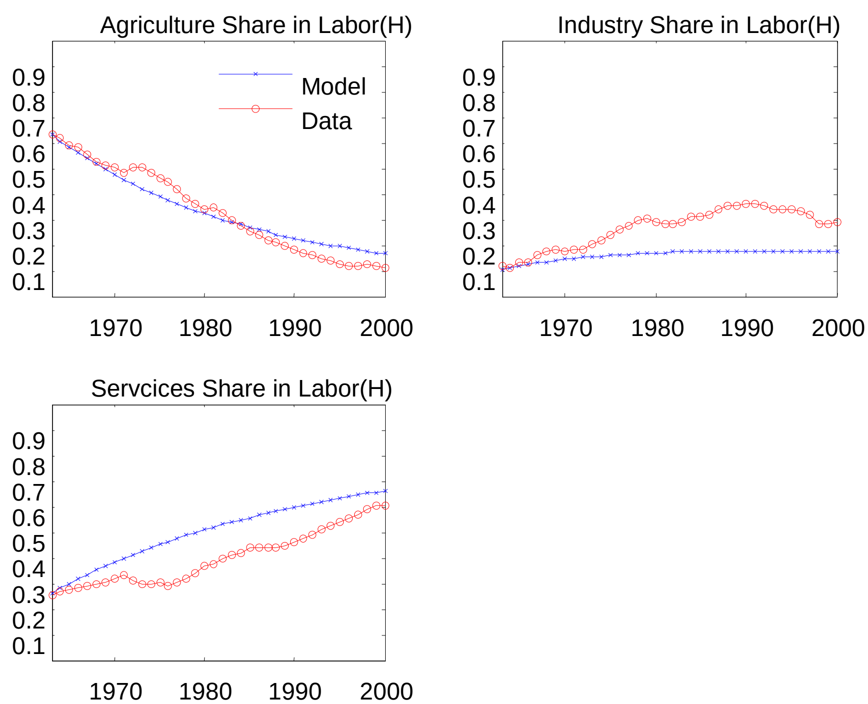
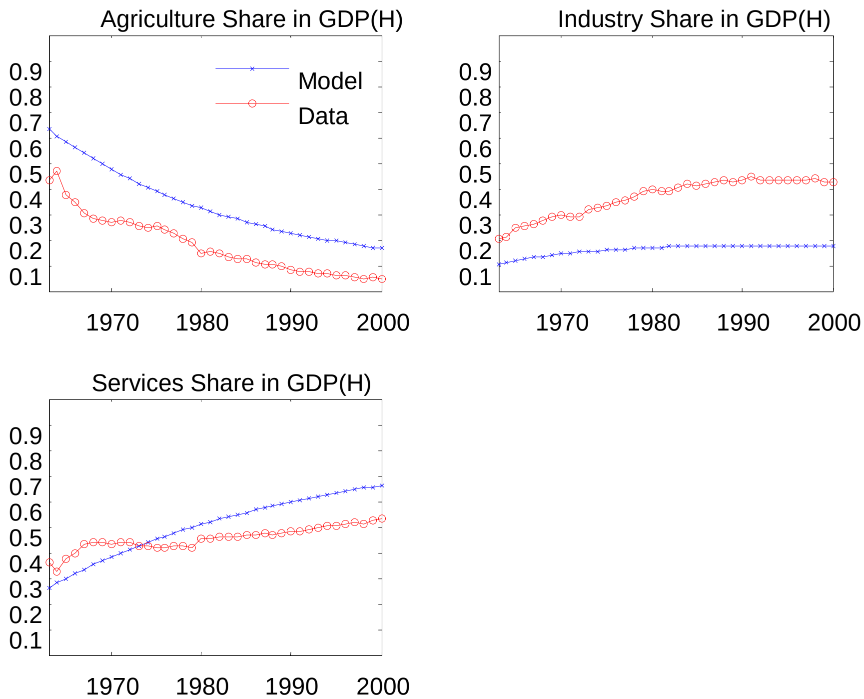


Figure 7: Closed Economy Model



We re-calibrate values of the Armington weight, or home bias parameter, μ, using a shooting algorithm to match data on the average annual ratio of expenditure on domestic vs. imported varieties of goods for the pre-liberalization period in our sample, 1962 through 1967. This yields the following values of μ: $\mu_{h,A}$ = 0.0069, $\mu_{h,I}$ = 0.0068, $\mu_{f,A}$ = 0.9985, $\mu_{f,I}$ = 0.9985. Initial sectoral labor productivities continue to be calibrated to match initial comparative advantage with respect to the OECD and subsequent levels from average growth rates as we have described previously.

What is perhaps surprising about the result of this re-calibration is that matching home bias to the pre-liberalization data yields smaller values of the home bias parameter for South Korea than does matching it to post-liberalization data, although the home bias parameters for the OECD implied by the pre-liberalization sample are larger than for the post-liberalization data. The value of the Armington elasticity, ρ, and other parameters are unchanged in this alternative calibration.

Table 2: Closed Economy Model Employment Shares (Data in Parentheses)

Year	Agriculture	Industry	Services
1963	0.63 (0.63)	0.11 (0.11)	0.26 (0.25)
1964	0.61 (0.62)	0.11 (0.11)	0.28 (0. 27)
1965	0.58 (0.59)	0.12 (0.13)	0.30 (0.28)
1966	0.56 (0.58)	0.12 (0.14)	0.32 (0.28)
1967	0.54 (0.55)	0.13 (0.16)	0.33 (0.29)
1968	0.51 (0.53)	0.13 (0.18)	0.35 (0.30)
1969	0.49 (0.51)	0.14 (0.18)	0.37 (0.31)
1970	0.47 (0.50)	0.14 (0.18)	0.38 (0.32)
1971	0.46 (0.49)	0.15 (0.18)	0.40 (0.34)
1972	0.44 (0.51)	0.15 (0.18)	0.41 (0.31)
1973	0.42 (0.50)	0.15 (0.20)	0.42 (0.30)
1974	0.41 (0.48)	0.16 (0.22)	0.44 (0.30)
1975	0.39 (0.46)	0.16 (0.24)	0.45 (0.30)
1976	0.38 (0.45)	0.16 (0.26)	0.46 (0.29)
1977	0.36 (0.42)	0.16 (0.28)	0.48 (0.30)
1978	0.35 (0.39)	0.17 (0.30)	0.49 (0.32)
1979	0.33 (0.36)	0.17 (0.30)	0.50 (0.34)
1980	0.32 (0.34)	0.17 (0.29)	0.51 (0.37)
1981	0.31 (0.34)	0.17 (0.28)	0.52 (0.38)
1982	0.30 (0.32)	0.17 (0.28)	0.53 (0.40)
1983	0.29 (0.30)	0.17 (0.29)	0.54 (0.41)
1984	0.28 (0.27)	0.17 (0.31)	0.55 (0.42)
1985	0.27 (0.25)	0.17 (0.31)	0.56 (0.44)
1986	0.26 (0.24)	0.17 (0.32)	0.57 (0.44)
1987	0.25 (0.22)	0.18 (0.34)	0.57 (0.44)
1988	0.24 (0.21)	0.18 (0.35)	0.58 (0.44)
1989	0.23 (0.20)	0.18 (0.35)	0.59 (0.45)
1990	0.23 (0.18)	0.18 (0.36)	0.60 (0.46)
1991	0.22 (0.17)	0.18 (0.36)	0.60 (0.47)
1992	0.21 (0.16)	0.18 (0.35)	0.61 (0.49)
1993	0.21 (0.15)	0.18 (0.34)	0.62 (0.51)
1994	0.20 (0.14)	0.18 (0.34)	0.63 (0.52)
1995	0.19 (0.13)	0.17 (0.34)	0.63 (0.54)
1996	0.19 (0.12)	0.17 (0.33)	0.64 (0.55)
1997	0.18 (0.11)	0.17 (0.32)	0.64 (0.57)
1998	0.18 (0.13)	0.17 (0.28)	0.65 (0.59)
1999	0.17 (0.12)	0.17 (0.28)	0.66 (0.60)
2000	0.17 (0.11)	0.17 (0.29)	0.66 (0.61)

Table 3: Baseline Open Economy vs. Closed Economy

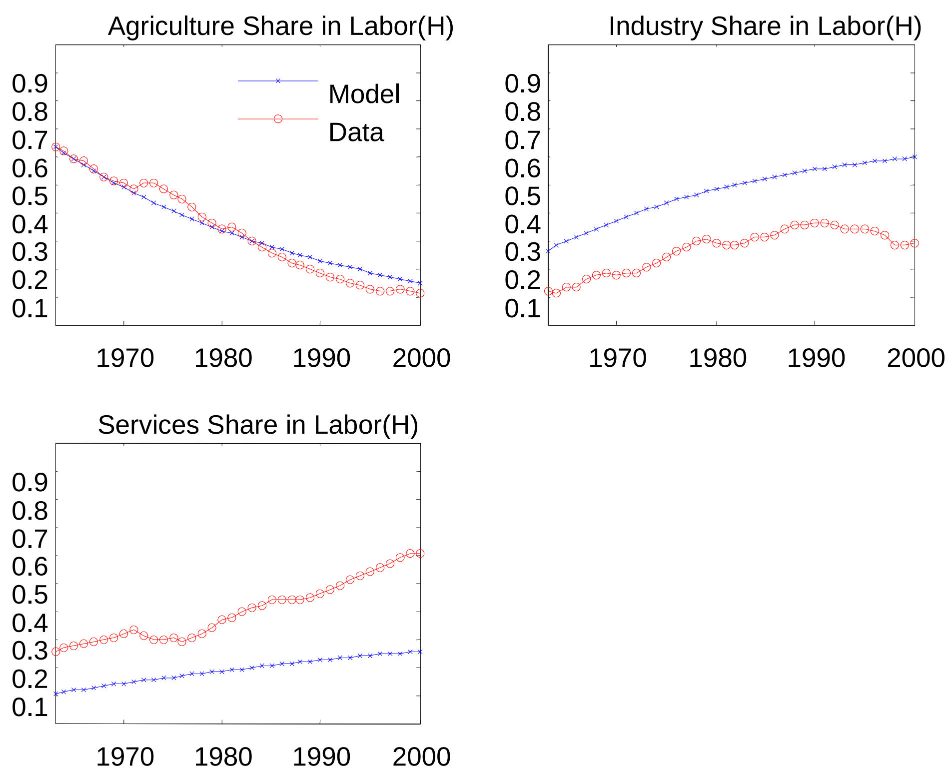
Model Performance: Baseline Model (Closed Economy)								
Performance Measure	**Output Shares**				**Employment Shares**			
	Agri	*Ind*	*Serv*	*Total*	*Agri*	*Ind*	*Serv*	*Total*
Sum of Squared Errors	0.95 (0.98)	0.04 (1.73)	0.77 (0.32)	1.76 (3.03)	0.03 (0.08)	0.38 (0.54)	0.41 (0.48)	0.82 (1.10)
Root Mean Squared Error	0.16 (0.16)	0.03 (0.21)	0.14 (0.09)	0.22 (0.28)	0.03 (0.05)	0.10 (0.12)	0.10 (0.11)	0.15 (0.17)
Correlation Coefficient				0.99 (0.58)				0.92 (0.91)
Variance Decomposition				0.89 (0.58)				0.86 (0.83)

Table 4: Baseline Open Economy vs. Pre-Liberalization Calibration

Model Performance: Baseline Model (Pre-Liberalization Calibration)								
Performance Measure	**Output Shares**				**Employment Shares**			
	Agri	*Ind*	*Serv*	*Total*	*Agri*	*Ind*	*Serv*	*Total*
Sum of Squared Errors	0.95 (1.04)	0.04 (0.45)	0.77 (2.70)	1.76 (4.19)	0.03 (0.06)	0.38 (1.67)	0.41 (1.87)	0.82 (3.60)
Root Mean Squared Error	0.16 (0.17)	0.03 (0.11)	0.14 (0.27)	0.22 (0.33)	0.03 (0.04)	0.10 (0.21)	0.10 (0.22)	0.15 (0.31)
Correlation Coefficient				0.99 (0.87)				0.92 (0.99)
Variance Decomposition				0.89 (0.80)				0.86 (0.98)

Figures 8 and 9 show the patterns of structural transformation implied under pre-liberalization values of home bias for South Korea, and Table 4 replicates Table 3 except with the goodness of fit statistics for the pre-liberalization calibration in parentheses, rather than the closed economy goodness of fit statistics.

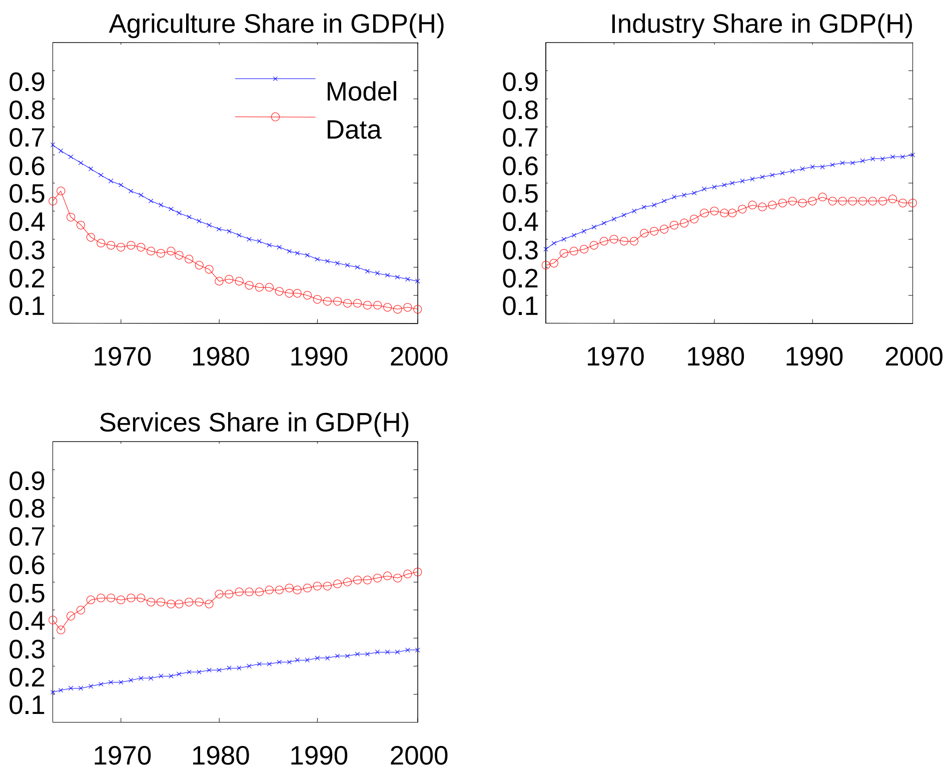
Figure 8: Pre-Liberalization Open Economy Calibration



A comparison of Figures 4 and 8, and Figures 5 and 9, shows that using home bias parameters calibrated to pre-liberalization data has a minor impact on the model's ability to match the employment and output share of agriculture on a year by year basis. The goodness of fit statistics based on prediction errors in Tables 3 and 4 bear out this observation too. Indeed, as we have already seen, year by year movements in agriculture's share of employment and output are almost as well captured by a closed economy model as our baseline open economy model, given all other parameter values and the non-homothetic preferences over agricultural goods.

However, the performance of the model calibrated to pre-liberalization data significantly deteriorates relative to the baseline open economy model in capturing year by year changes in industry's share of employment and GDP (as does a closed economy model), and again this is reflected in the goodness of fit statistics in Table 4. Notably, the growth of industry's share of employment and output is substantially over-predicted by the model calibrated to pre-liberalization data which is rather a strange finding, while the non-traded service sector's shares are substantially under-predicted by the model. Notably, the weighted correlation and variance decomposition statistics suggest that the re-calibrated model performs better than the baseline model overall with regard to matching GDP shares, however the baseline model has a better goodness of fit by these criteria in matching employment shares. Together, the Figures and Table 4 suggest that – for capturing South Korean structural transformation – the open economy baseline model calibrated to post-liberalization data on import expenditure ratios performs significantly better than either the same model calibrated to pre-liberalization expenditure data.

Figure 9: Pre-Liberalization Open Economy Calibration



6. CONCLUSIONS

This preliminary paper develops a simple three-sector, two country quantitative general equilibrium model to analyze the role of trade for South Korea's structural transformation since 1962. In our baseline calibration, we calibrate the weights assigned by consumers to domestically produced and imported varieties of each sector's final output in an Armington

Aggregator to match data on import ratios in the post 1968/post trade liberalization data and compare the performance of the two country model to a closed economy variant. The open economy model systematically outperforms the closed economy model.

In particular, the closed economy model is unable to generate the growth of industrial sector employment and GDP shares in the South Korean economy over the period 1963 through 2000, while the open economy model can almost perfectly capture the GDP share of the sector, and somewhat over-predicts growth in the employment share of the industrial sector. We draw the tentative conclusion that accounting for the impact of international trade is important in being able to account for sectoral reallocations in South Korea. Our model suggests that international trade is important in several regards for explaining open economy structural transformation: in particular, the behavior of relative productivities - and hence relative prices – of sectoral outputs across countries has important effects for consumption expenditures by home and foreign consumers on the outputs of different sectors.

We also ask how the baseline model performs in matching South Korean structural transformation data relative to a version of the model in which the weights assigned by consumers to domestically produced and imported varieties of each sector's final output are calibrated to match data on import expenditure ratios in the pre-liberalization data, 1962 through 1967. We find that the pre-liberalization calibration, like the closed economy model, is unable to capture the growth of industrial sector employment and GDP as well as the baseline open economy model and its overall performance, by almost every measure of goodness of fit, is weaker than that of the baseline model. This suggests that using post-liberalization intelligence to measure the implied costs of trade between South Korea and the OECD is important in being able to capture the observed patterns of industrialization of South Korea. However, by contrast to the closed economy model this alternative calibration of our two-country model actually over-predicts the growth of the industrial sector and under-predicts the share growth of services. At this preliminary stage in our analysis, we are in the process of characterizing the source of these results.

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