The Role of Trade in Structural Transformation[*]

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Abstract

This paper examines the effects of international trade on structural transformation and economic growth. I introduce international trade into a neoclassical growth model with two sectors, agriculture and nonagriculture. A key feature of the model is the low-income elasticity of the agricultural good. As a consequence, in the closed economy model, as countries get richer, labor moves out of agriculture and into the other sector. International trade can accelerate this transition for countries with low agricultural productivity because it allows them to import food and thus reduce their agricultural employment. I calibrate and simulate the model to show it can match three different structural transformations: the United States in the 20th century, the United Kingdom in the 19th century, and South Korea for nearly the last 50 years. The results show that trade had large effects in the United Kingdom, and smaller but positive effects in South Korea. Agricultural production subsidies and agricultural import tariffs reduced the role of trade in South Korea. Without these policies, the volume of trade would have been larger and the country would have experienced a faster transformation as well as higher real income growth and higher welfare.

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1 Introduction

Poor countries have much larger agricultural sectors than rich ones. In 2000, the average share of employment in agriculture was 75% in the lowest income decile countries, while it was below 5% in the highest decile countries.[1] The same pattern can be seen over time in individual countries, although the timing of the structural transformation differs. For example, the United States had more than 80% of the labor force in the agricultural sector in 1810, around 50% in 1870, and around 20% in 1920, while in Japan the shares were 80% in 1870 and around 50% in 1920. However, notably, Japan's per capita incomes in 1870 and 1920 were similar to those in the United States in 1810 and 1870, so the pattern is very similar in the two countries based on income if not in timing.[2]

This paper examines the effects of international trade on the pace of structural transformation. Countries closed to international trade in agricultural goods have to produce the entirety of the food they consume. As a result, a country with low productivity in the agricultural sector is forced to allocate a large fraction of its productive resources to that sector, and its agricultural sector is larger than in a country with higher agricultural productivity. Aggregate productivity, as a consequence, is also low in such a country, even if its productivity outside agriculture is high. This has led many authors to conclude that a rise in agricultural productivity is a necessary condition for the start of industrialization.[3] On the other hand, countries open to international trade can import a fraction of the food they consume. Countries with low productivity in agriculture but higher productivity outside that sector can reduce the fraction of labor in agriculture, accelerating their structural transformation. This labor reallocation increases their aggregate productivity, thereby increasing capital accumulation and raising their rate of economic growth.

In principle, international trade can either increase or reduce the transformation speed of

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[1] See, for example, Caselli (2005), Gollin, Parente, and Rogerson (2004), or Restuccia, Yang, and Zhu (2008). Data sources: Heston, Summers, and Aten (2006), Rao et al. (1993).

[2] See Lucas (2009) for some plots illustrationing this relation. Data sources: Kuznets (1966), **?**).

[3] See Matsuyama (1992) for a summary of this view.

a poor country, depending on its comparative advantage with respect to the rest of the world. There is, however, some evidence that poor countries have a comparative disadvantage in agriculture. In particular, in 1985, the top decile of countries were on average thirty times more productive than the lowest decile of countries in the aggregate and fifty times more productive in the agricultural sector.[4] Also, the relative price of the agricultural sector goods is typically higher in poor countries. In 1985, the relative price of agricultural goods was, on average, two times larger in the lowest decile of countries than in the highest decile of countries.[5] These two pieces of evidence suggest that, if they are open to international trade, poor countries are likely to be net food importers. Data on food trade shows in fact they are: in 2004, 72% of poor countries were net food importers and 28% were net food exporters, while 61% of industrial economies were net food importers and 39% net food exporters.[6]

This paper has two main contributions. First, it develops a model that allows us to determine the importance of international agricultural trade in the structural transformation of a country. Second, it quantifies the role played by international trade in two specific cases: the United Kingdom in the 19th century and South Korea in the last 50 years.

I introduce international trade into a general equilibrium, neoclassical growth model with two sectors, agriculture and the rest of the economy. In the model, preferences are such that consumers spend a large fraction of their income in the agricultural good when they are poor. Under autarky, then, a low income country employs most of its productive resources in agriculture. As technological change occurs and capital accumulates, consumers get richer and the productive resources are reallocated from the agricultural sector to the nonagricultural one. Under international trade, if the relative price of the agricultural good is higher domestically than in the international markets, the country imports the agricultural good and its agricultural sector shrinks. Since the nonagricultural sector is more capital

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[4] See, for example, Caselli (2005), and Restuccia, Yang, and Zhu (2008). Data sources: Heston, Summers, and Aten (2006), Rao et al. (1993). 1985 is the only year for which data on agricultural production measured at international prices is available.

[5] Data sources: Heston, Summers, and Aten (2006) for the aggregate prices and income per capita, Rao et al. (1993) for the agricultural sector prices.

[6] See **?**). Data sources: UN Comtrade Statistics (http://comtrade.un.org/).

intensive, this reallocation increases capital accumulation, which affects positively the income growth rate of the country. On the other hand, if the opposite relation between the domestic and the international price holds, international trade has the opposite effect and the country increases its agricultural employment share.

Next, the model is used to study three structural transformations: the United States during the period 1890 - 2007, South Korea during the period 1963 - 2007, and the United Kingdom during the period 1800 - 1900. Comparing these three cases is an interesting exercise because the time periods are very different, and the countries also have important differences in terms of their comparative advantage and attitude towards agricultural trade. The United States has a rich endowment of agricultural land and its net agricultural exports have been positive for most of the period, although small relative to its own production. The United Kingdom started its industrial transformation earlier than the United States and it has a poorer land endowment. It imported a large fraction of its agricultural consumption from abroad during the 19th century, which had large benefits for the country.[7] Finally, South Korea still had a very large agricultural sector in 1960, but it has experienced a very rapid structural transformation since then. It has been one of the main net agricultural importers in the recent years among middle-income countries, in spite of the agricultural protection policies that were introduced.[8]

Figure 1 plots the evolution of the agricultural employment share at each income level for the three countries. We can see that the agricultural employment share was approximately 80% at the beginning of the 19th century in the United States, while in the United Kingdom it was below 40%. It has been continuously decreasing in both countries over the last 200 years, and it is now less than 2%. In South Korea, the speed of the structural transformation has been much faster; the agricultural employment share was approximately 80% at 1950, 65% in 1960 and is currently less than 8%, a decrease that took more than 150 years in the United States. However, since the growth in per capita income has also been much faster in

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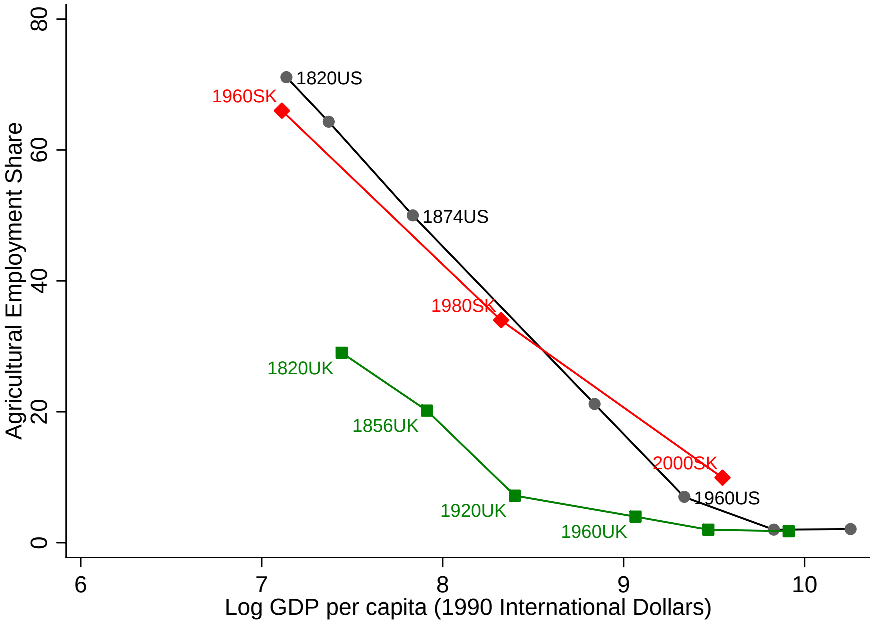
[7] See Stokey (2001) for a study of the Industrial Revolution in the United Kingdom.

[8] See See **?**).

South Korea, when agricultural employment share is plotted against income per capita the speed of transformation looks actually slower than in the United States. Moreover, when compared to another food importer like the United Kingdom, we can see that the size of the agricultural sector at each income level is not particularly low.

Figure 1: United States, United Kingdom, South Korea comparison

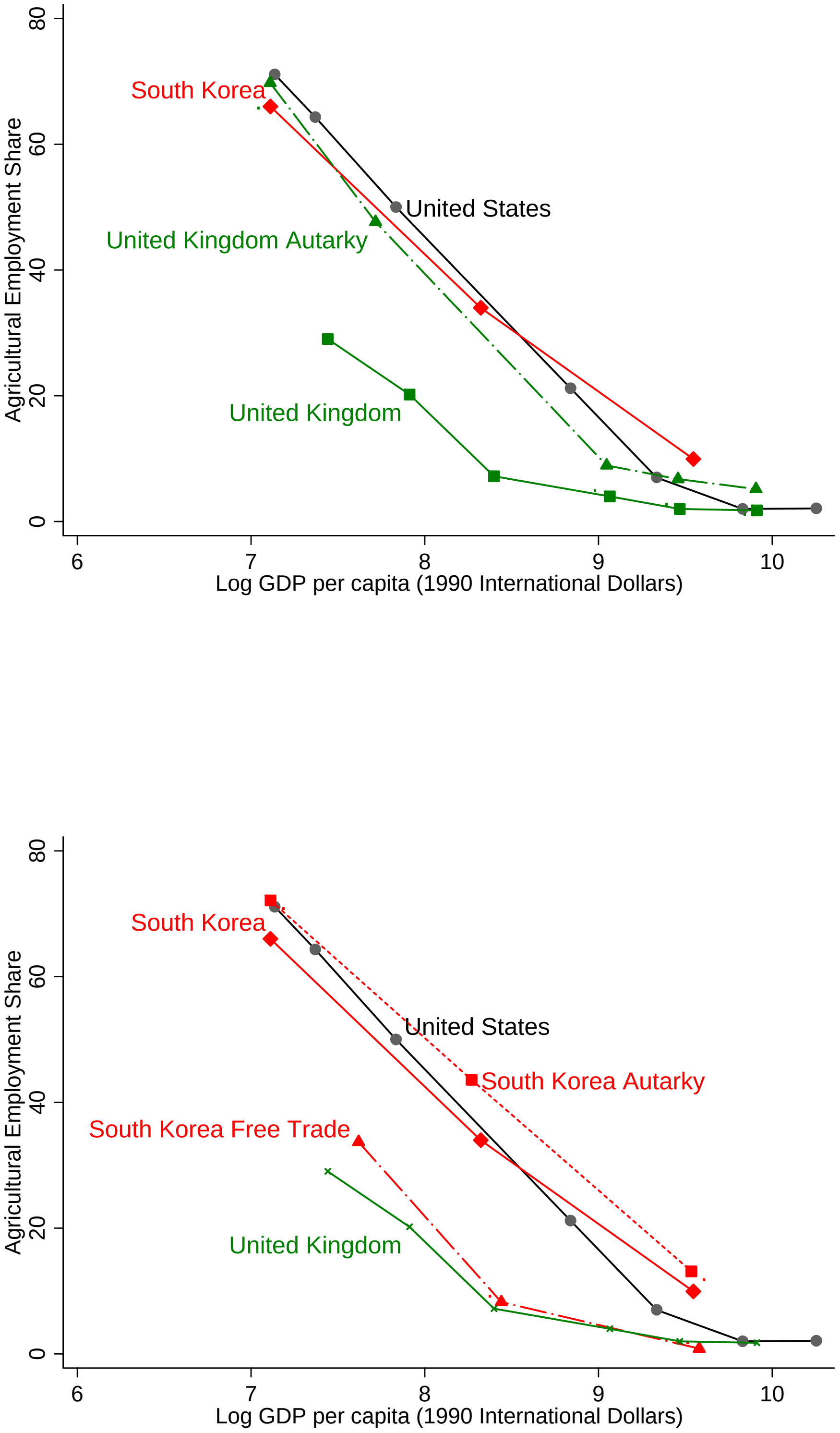


Main Results. The results of the paper show that the model developed here can replicate the structural transformation for these three cases with the same calibration. In the case of the United States, the simulations show the importance of its high agricultural productivity growth for its transition. In the case of the United Kingdom, trade was extremely important for its early structural transformation and it had huge effects on the intertemporal welfare of households. If the country had been in autarky, the agricultural employment share in 1800 would have been around 80% instead of 35%, and during the 19th the agricultural employment share would have been 1.5 times higher on average. The intertemporal welfare gain from international trade is equivalent to a 5.5% increase in the yearly consumption expenditures under autarky. In South Korea, trade played a positive role in its structural transformation but its effects were smaller than in the United Kingdom; the initial employment share in the agricultural sector was 62% and would have been 72% in autarky, and the gains in intertemporal welfare are equivalent to a 0.4% increase in the autarky consumption expenditures. Moreover, if South Korea had not adopted policies to protect its agricultural sector from foreign competition, the volume of trade would have been much larger and the country would have experienced an even faster transformation. The agricultural employment share in the last 50 years would have been almost 3/4 lower on average, and it would have dropped below 10% by 1979 instead of 2002. The intertemporal gain in intertemporal welfare from being open to international trade in this case would have been almost as large as in the United Kingdom.

These results are summarized graphically in figure 2, which plots the agricultural employment share at each income level in the data and in the counterfactual simulations. In the first plot we can see that if the United Kingdom had been under autarky, its agricultural employment share at each income level would have been very similar to the one observed in the United States. In the second plot we can see that if South Korea had been under autarky, its agricultural employment share at each income level would have been even higher than the one observed in the United States; if it had been completely open to international trade, on the other hand, its agricultural employment share at each income level would have been very similar to the one observed in the United Kingdom.

The rest of the paper is organized as follows. Section 2 contains a review of the related literature. Section 3 describes the two-sector growth model, for both closed and open economies. Section 4 simulates the closed economy model for the United States over the last 120 years, and describes the effects of changing the evolution of productivity. Section

Figure 2: Main Results - United Kingdom



5 simulates the open economy model for South Korea over the last 50 years, and quantifies both the role actually played by international trade and the role it would have played under different agricultural polices. Section 6 repeats the quantification exercise for the United Kingdom during the 19th century. Section 7 concludes.

1.1 Related Literature

There is a large body of literature that, like my paper, analyzes the structural transformation of countries. Until recently, however, most of the articles in this literature did the analysis in a closed economy context while my paper does it in an open economy context.

The main focus of many of these articles is to study why structural transformation occurs and what are the main forces behind it. One important example is Hansen and Prescott (2002) which presents a theoretical model where countries use a land-intensive technology in the early stages of development because the modern technology is not profitable to operate; as the stock of usable knowledge grows, countries experience a transition because firms start adopting the modern technology, and the living standards improve. In Lucas (2004), the migration out of agriculture occurs because wages for skilled workers are higher in urban areas and because urban areas are good places to accumulate human capital. Kongsamut, Rebelo, and Xie (2001) present a model in which differences in the income elasticity of demand for the different goods originate the sectoral movements observed in the data; in particular, if the income elasticity is lower than one for agriculture, equal to one for manufactures, and higher than one for services, the model is able to generate both a balanced growth path in long-run as well as the massive labor reallocation from agriculture into manufactures and services observed in the United States and other countries. Ngai and Pissarides (2007) study a multi-sector model of growth with differences in the TFP growth rates across sectors, and show that if the utility function has unit intertemporal elasticity of substitution and an elasticity of substitution across final goods different than one, the model is consistent with both sectoral labor reallocation and aggregate balanced growth; moreover, if the elasticity of substitution across final goods is lower than one, then there is an increase of the employment share of sectors with low TFP growth, a process known as "Baumol's cost disease". Acemoglu and Guerrieri (2008) show that a model with constant elasticity of substitution between sectors and Cobb-Douglas production function in each sector is consistent with an asymptotic equilibrium where the interest and the capital income are constant, even if the factor proportions are different across sectors; at the same time, if the elasticity of substitution between sectors is lower than one, the model generates more rapid employment growth in the less-capital intensive sectors and more rapid output growth in the more capital-intensive sectors because of capital deepening. Caselli and Coleman II (2001) argue that another important element to explain the structural transformation of the United States is the long-run decline of the relative cost of acquiring nonagricultural skills for farm-born individuals, which may be consequence of technological progress and scale economies in transportation, improved quality of education, increased life expectancy, and school desegregation; this decline led to a downward shift in the farm-labor supply curve, which makes the decrease in farm employment consistent with the increase in farm wages observed in the data. Finally, Herrendorf, Rogerson, and Valentinyi (2009) show that a Stone-Geary utility function provides a very good fit to the structural transformation data of the United States over the period 1947 - 2007 when using data on final consumption expenditure from the NIPA tables; however, when using data of consumption value added at sectoral level, a homothetic utility function with no substitution between categories proved the best fit to the data.

Many other articles in this literature have focused on the study of why countries experience structural transformation at very different dates and the importance of this in explaining income differences across countries. Gollin, Parente, and Rogerson (2007) use a two-sector growth model to quantify the importance of the subsistence requirement for food consumption in explaining the evolution of international incomes; the paper concludes that because of this food requirement, low productivity in the agricultural sector can delay the start of the industrialization process by hundreds of years and explain the huge differences in income observed across countries; the paper also shows that a low growth rate of the agricultural productivity can explain the slow speed of convergence observed in countries at the start of the industrialization process. Restuccia, Yang, and Zhu (2008) also use a two-sector general equilibrium model with food requirements to show that economy-wide productivity differences and barriers to the use of modern inputs in agriculture can account for the high agricultural employment share and the low agricultural labor productivity observed in poor countries, thus explaining the large differences in aggregate productivity between rich and poor countries. Hayashi and Prescott (2008) use a similar model to quantify the effects of Japan's prewar agricultural institutions on its structural transformation for the period 1885 - 1934, which kept the agricultural sector artificially high; the main conclusion is that the barriers that prevented labor from efficiently moving to urban areas can account for a third of the pre-WWII income gap with respect to the United States, because they induced a misallocation of inputs and reduced the incentives to accumulate capital. The paper also considers the possibility of food being a tradeable good in their study, but the main focus, as well as the main quantitative conclusions, assume that food was nontraded.[9]

Some authors like Mundlak (2000) have recognized that agricultural products are tradeable, and there are some articles that have studied the structural transformation of countries in an open economy context. One important difference with respect to my paper is that most of these articles are only theoretical. One of the first studies is Matsuyama (1992), which argues for an economy open to foreign trade, low productivity in the agricultural sector or lack of arable land is likely to foster its industrialization process of a country, instead of slowing it down as it would be the case if it was closed. The main focus of the article is to theoretically study the role of agricultural productivity in economic development using a two-sector growth model with learning by doing in the manufacturing sector; the model predicts the relationship between agricultural productivity and growth to be positive for closed economies and negative for open economies. Another important article for my

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[9] Other important papers in this literature are Buera and Kaboski (2008), Buera and Kaboski (2009a), Duarte and Restuccia (2010), Echevarria (1997), Laitner (2000), Vourvachaki (2009).

analysis is Shin (1990), which studies the relationship between structural change and economic development, focusing on the cases of South Korea and the United States; it concludes that including trade in his two-sector growth model might be very useful to explain some characteristics of the South Korean experience, such as the rapid decrease in the sectoral share of agriculture. Another important contribution is Echevarria (2008), which presents an open economy two-sector growth model where preferences are nonhomothetic and TFP growth only occurs in the non-primary sector; the analysis concludes that in the long run countries specialize in one sector or the other depending on the TFP differentials, and that as the global economy develops fewer and fewer countries export primary goods. Galor and Mountford (2008) develop a unified theory of growth where international trade accelerates the transition to sustained economic growth in technologically advanced economies and it delays the transition in technologically inferior economies because of its effects on the sectoral composition; in the former, trade enhances industrial production and human capital accumulation, while in the latter trade enhances the production of of unskilled, non-industrial goods and increases population growth. Yi and Zhang (2010) use a two-country, three-sector model to study structural change in an open economy, and conclude that trade can generate a "hump" pattern in manufactures employment share. Stokey (2001) deserves a special mention because of its influence on my analysis, since it is also a quantitative exercise and it also studies the industrialization of the United Kingdom. The goal of the paper is to quantify the effects of international trade and other factors on the structural transformation transformation of the United Kingdom, and the main conclusion is that foreign trade played an important role in the Industrial Revolution of the country; the growth in food imports between 1780 and 1850 accounts for 100% of the decline in agricultural production, 25% of the increase in manufactures production, 20% of the increase in energy production, and 50% of the increase in real wage; moreover, if the country had remained under autarky, the relative price of agricultural goods would have increased by 43% instead of the 22% observed. Another quantitative paper in this literature is Stefanski (2009), which constructs a multi-sector multi-country growth model to measure the effects of the structural transformation in India and China on the international price of oil; the paper finds that it accounts for up to 25% of the oil price increase in the OECD between 1970 and 2007 but it will not lead to higher oil prices permanently. Similarly, Ungor (2009) uses a two-country three-sector model to study the impact of China's industrialization on the manufactures employment share of the United States between 1978 and 2005, and finds that it accounts for more than 50% of the decline of the U.S. industrial employment share.

My paper is also related to the body of literature that studies the role of agriculture in accounting for the large aggregate productivity differences observed across countries. Sachs (2001) shows empirically that, in general, economies in tropical zones not only are poorer than those in temperate zones but are also less productive in agriculture due to climate-related factors like soil fragility, high prevalence of crop pests and parasites, higher rates of plant respiration, and scarcity of water. Moreover, as Caselli (2005) and Restuccia, Yang, and Zhu (2008) explain, differences in labor productivity in the nonagricultural sector are much smaller than differences in agricultural labor productivity, which implies that the labor force of poor countries is allocated to the sector in which they are particularly unproductive. Caselli (2005) establishes that, if all countries had the same agricultural labor productivity as the United States, world income dispersion would actually disappear; alos, according to the development accounting exercise performed in the paper, almost all the variation in agricultural labor productivity comes from differences in agricultural total factor productivity and, hence, not much is attributable to differences in the amounts of observable inputs employed in the agricultural sector by the various countries. According to Vollrath (2009), data show large differences in marginal products of similar factors within many developing countries, suggesting that too many factors are allocated to low productivity work in agriculture; the paper uses a two-sector decomposition of the economy to estimate these misallocations in accounting for the cross-country income distribution, and shows that variation across countries in the degree of misallocation accounts for 30–40% of the variation in income per capita and up to 80% of the variation in aggregate TFP. **?**) show that differences in schooling across sectors can only account for a small fraction of the observed wage gap between rural and urban areas and that this gap seems to be explained by the particularly low quality of human capital in rural areas, which can be interpreted as the outcome of low parental human capital or low quality of schooling; this adjustment mainly affects poor countries, which are typically the ones with large wage gaps and large rural population and, as a consequence, the adjustment widens cross-country differences in human capital and increases the role of human capital in explaining cross-country income differences. Lagakos and Waugh (2009) argue that the relative labor productivity differences in the agricultural and nonagricultural sectors observed across countries arise when sector-neutral efficiency differences combine with subsistence food consumption needs to prevent workers in poor countries from specializing in the sector where they are most productive; the authors calibrate a two-sector growth model where workers are heterogenous in their ability to produce output in the two sectors and preferences have a subsistence food requirement and conclude that the model explains nearly seventy five percent of the productivity differences in agriculture and nonagriculture between the 90th and 10th percentile of countries.[10]

2 Structural Transformation Model

2.1 Model Setup

In this section, I present the theoretical model[11], first for a closed economy and then for a small open economy. The closed economy version is used to describe structural transformation in the United States and how structural transformation would have proceeded in South Korea and United Kingdom if they had remained closed. The small open economy version is

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[10] Articles like Young (1995), Hsieh (2002), Connolly and Yi (2009) and Deardorff and Park (2009) are also related to mine because they study the growth experience of South Korea.

[11] Hayashi and Prescott (2008) use a similar model. It is also related to other two-sector growth models in the literature like Echevarria (1997, 2007), Gollin, Parente, Rogerson (2007), or Matsuyama (1992).

similar to the closed economy except that the country can trade with the rest of the world. I use it to describe structural transformation in South Korea and United Kingdom.

One of the sectors in the economy is agriculture, which produces a good that is only used for consumption. The other is the nonagricultural sector, which produces a good that is used for consumption as well as investment. In the model, there is a representative household with $N(t)$ infinitely-lived members, who derive utility from consuming the agricultural and the nonagricultural good. The household's size grows at constant rate n, and without loss off generality $N(0)$ is set equal to 1. $c_a(t)$ and $c_n(t)$ denote the amount of agricultural and nonagricultural good consumed by each member, ρ denotes the intertemporal discount rate. The instantaneous utility function is a variation of the Stone-Geary utility function:

$$U(0) = \int_0^\infty e^{-(\rho-n)t} \left[u(c_a(t)) + \log(c_n(t)) \right] dt \tag{1}$$

and

$$u(c_a) = \begin{cases} \mu_0 \log\left(c_a(s) - \underline{c_a}\right) & \text{if } c_a(s) \leq c_a^* \\ B + \mu_1 \log\left(c_a - c_a^* + A\right) & \text{if } c_a(s) > c_a^* \end{cases} . \tag{2}$$

$\underline{c_a}$ denotes the minimum consumption level for the agricultural good, which can be interpreted as the subsistence level.[12] μ_0 is the relative weight on agricultural consumption when this consumption is low. When agricultural consumption is higher than c_a^*, the relative weight on the agricultural consumption becomes μ_1, where $\mu_1 < \mu_0$. The constants A and B are defined as

$$A = \frac{\mu_1}{\mu_0}\left(c_a^* - \underline{c_a}\right), \quad B = \mu_0 \log\left(c_a^* - \underline{c_a}\right) - \mu_1 \log\left(\frac{\mu_1}{\mu_0}\left(c_a^* - \underline{c_a}\right)\right)$$

and they guarantee that the function $u(.)$ is continuous and differentiable at c_a^*.

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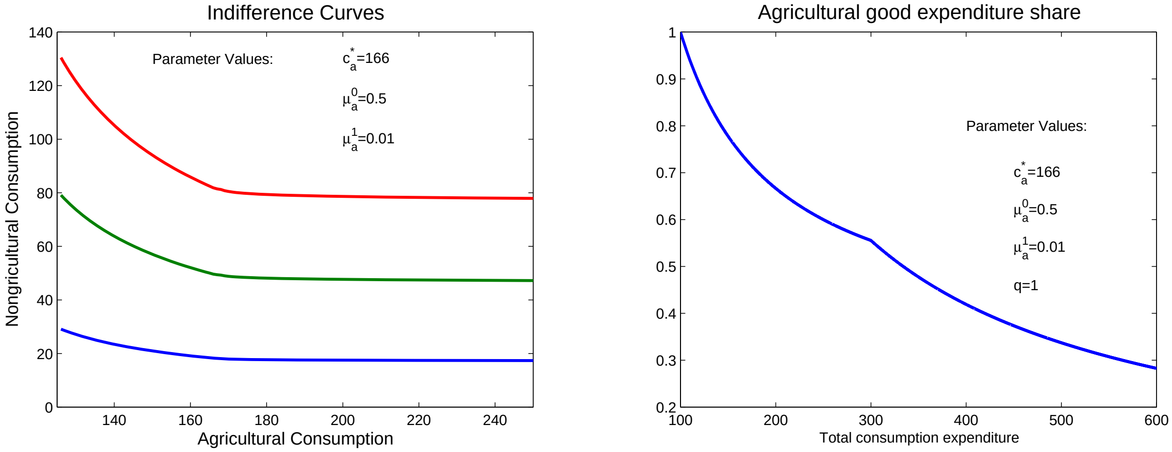
[12] My analysis is for economies where agricultural consumption is higher than the subsistence level $\underline{c_a}$, but one may think of $\underline{c_a}$ as the minimum consumption people need to survive. Thus, if population is such that the amount of agricultural good available is not less than $\underline{c_a}$, population would adjust. However, this is beyond the analysis of this paper because in this paper population evolves exogenously.

Figure 3 graphically illustrates some properties of the preferences, with the parameters μ_0 and μ_1 taking the same values as in sections 4 - 6. The change in the relative weight increases the concavity of the function $u(.)$ at c_a^*, so that the marginal utility of agricultural consumption above c_a^* is lower than if the weight did not change. It also decreases the marginal rate of substitution at c_a^*, as the first the first plot shows. The second plot shows that the agricultural consumption expenditure is continuous and decreasing both below and above c_a^*.

Figure 3: Graphical Description of Preferences



The preferences in (2) are able to fit the data in sections 4 - 6 better than preferences that have a constant weight on agricultural consumption, or preferences that assume a satiation level in the agricultural good consumption.[13]

Households own capital and land, which is supplied inelastically to firms together with their labor.[14] Households choose the amount to save each period, and the amount of consumption of both goods. Since both labor and capital are perfectly mobile across sectors, there is a unique wage rate $w(t)$ and a unique capital rental rate $r(t)$. Households' income

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[13] Gollin, Parente, and Rogerson (2007), Laitner (2000), and Stokey (2001), for example, use preferences with a satiation point.

[14] In the model, all the members of the household work so that total employment is equal to total population. In the simulations, the variables employment and population are taken from the data, so they are not necessarily the same.

also includes the land rents, which are denoted by $p_l(t)\,L$, with $p_l(t)$ denoting the price per unit of land and L denoting the total land available.

Equation (3) shows the per capita budget constraint of the representative household, with the price of the nonagricultural good normalized to 1, k denoting the per-capita capital stock, δ the capital depreciation rate, n the population growth rate, and q the relative price of the agricultural good at time t. Note that all variables depend on time, except for δ, n, and L.

$$\frac{dk}{dt} = w + (r - \delta - n)\,k + p_l L e^{-nt} - q c_a - c_n. \tag{3}$$

The optimization problem of the household consists of choosing $[c_a(t)\,,\ c_n(t)\,,\ k(t)]_{t>0}$ to maximize equation (1) subject to the budget constraint in (3) and k_0 given. The optimal consumption mix is given by equation (4), the optimal growth rate of nonagricultural consumption by equation (5) and the optimal evolution of the capital stock is given by equation (3), together with the boundary conditions $k(0) = k_0$ and the transversality condition in Equation (6).

$$\begin{aligned} \frac{1}{\mu_0}\frac{\left(c_a - \underline{c}_a\right)}{c_n} &= q \text{ if } c_a \leq c_a^* \\ \frac{1}{\mu_1}\frac{\left(c_a - c_a^* + A\right)}{c_n} &= q \text{ if } c_a > c_a^* \end{aligned} \tag{4}$$

$$\frac{dc_n}{dt} = c_n\,(r - \delta - \rho) \tag{5}$$

$$\lim_{t\to\infty}\left\{ e^{-\int_0^t (r(s)-n-\delta)ds}\,\frac{k(t)}{c_n(t)} \right\} = 0. \tag{6}$$

There are also many identical firms in each sector, which rent labor and capital to maximize profits. The production function for the agricultural good in per capita terms is

$$y_a = A_a f^a\left(k_a, n_a, L_a e^{-nt}\right) \tag{7}$$

where

$$f^a\left(K_a, N_a, L_a\right) = k_a^{\eta} n_a^{\beta}\left(L_a e^{-nt}\right)^{1-\eta-\beta}.$$

A_a denotes the total factor productivity, k_a the capital stock per capita, n_a the labor input per capita, and L_a the total land employed in that sector.

The production for the nonagricultural sector is

$$y_n = A_n f^n\left(k_n, n_n\right) \tag{8}$$

where

$$f^n\left(K_n, N_n\right) = K_n^{\alpha} N_n^{1-\alpha}$$

with A_n denoting total factor productivity in the nonagricultural sector, k_n the per capita stock of capital, and n_n the labor input per capita used in that sector.[15]

Productivity grows exogenously in both sectors, and the productivity growth rate is not necessarily the same:

$$\frac{\dot{A}_j}{A_n} = \gamma_j > 0,\ j = a, n.$$

In order to maximize their profits, firms choose to employ an amount of inputs such that the value of their marginal productivity is equal to its price in both sectors

$$r = q_j \frac{\partial y_j}{\partial k_j},\ j = a, n \tag{9}$$

$$w = q_j \frac{\partial y_j}{\partial n_j},\ j = a, n \tag{10}$$

$$p_l = q \frac{\partial y_a}{\partial\left(L_a e^{-nt}\right)} \tag{11}$$

where q_a is equal to q, and q_n is equal to 1.

Finally, for both the closed and open economy, the production factor markets clear at

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[15] Since firms exhibit constant returns to scale, the total number of firms is irrelevant for the equilibrium. Therefore, we can solve the equilibrium as if there was a representative firm in each sector.

every point in time:

$$n_a + n_n = 1 \tag{12}$$

$$k_a + k_n = k \tag{13}$$

$$L_a = L. \tag{14}$$

2.2 Closed Economy Equilibrium

Under autarky, the endogenous relative price adjusts so that the amount supplied of both goods is equal to the amount demanded.[16] The two output market clearing conditions for a closed economy are:

$$A_a f^a \left(k_a, n_a, L_a e^{-nt}\right) = c_a \tag{15}$$

$$A_n f^n \left(k_n, k_n\right) = c_n + \frac{dk}{dt} + nk + \delta k. \tag{16}$$

Definition 1. *A competitive equilibrium for the closed economy, given* k_0 *and the exogenous variables* (A_a, A_n, N)*, are prices and quantities* $[q, w, r, p_l, y_a, y_n, c_a, c_n, n_a, n_n, k_a, k_n, k]_{t>0}$*, satisfying the consumers' optimization conditions (4) - (6), the firms' optimization conditions (9) -(11), and the market equilibrium conditions (12) -(16).*

As technology grows in both sectors, capital accumulates and production of both goods increases. If population growth is not too high, then per capita consumption increases over time, not only for the nonagricultural good but also for the agricultural good. As a result, the nonhomothetic component of the preferences becomes less and less important over time,

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[16] The market clearing condition in equation (16) is actually redundant, since it can be obtained from the budget constraint in equation (3), using the fact that $w + rk = qy_a + y_n$, and the fact that $y_a = c_a$.

and in the limit consumers behave as if their preferences were

$$u\left(c_a, c_n\right) = \mu_1 \log\left(c_a\right) + \log\left(c_n\right). \tag{17}$$

Note that this may not be the case if population growth is very high because there are decreasing returns to scale in agricultural good production. For the preferences in (17), the equilibrium system is consistent with a Balanced Growth Path where all the variables grow at constant but not necessarily common rates. The solution to the system is the unique path that converges to it. If

$$\left(1 - \eta - \beta\right) n < \frac{\eta}{1 - \alpha}\gamma_n + \gamma_a \tag{18}$$

the solution to the equilibrium described above with the preferences in (2) converges to the same Balanced Growth Path. The next theorem states this idea more formally, and appendix A contains a more detailed explanation.

Theorem 1. *If the condition in equation (18) is satisfied,then the Competitive Equilibrium defined in equations (4) - (6), (9) -(11) and (12) -(16) has a unique Balanced Growth Path, where the fraction of labor and capital allocated to both sectors are positive and constant, and the growth rates of capital, consumption and the relative price are*

$$\frac{\dot{k}}{k} = \frac{\dot{c}_n}{c_n} = \frac{1}{1 - \alpha}\gamma_n$$

$$\frac{\dot{c}_a}{c_a} = \gamma_a + \frac{\eta}{1 - \alpha}\gamma_n - \left(1 - \eta - \beta\right) n$$

$$\frac{\dot{q}}{q} = \left(1 - \eta - \beta\right) n + \frac{1 - \eta}{1 - \alpha}\gamma_n - \gamma_a$$

Moreover, for any initial condition, the economy converges asymptotically to this Balanced Growth Path.

2.3 Open Economy Equilibrium

In the open economy there is trade in final goods, but there is no international borrowing or lending of capital.

The consumer optimization conditions are obviously the same as in the closed economy. The firms' optimization conditions are also the same, unless the international price is such that the country specializes in the agricultural good production. Note that specialization in the nonagricultural good is not possible in the short run because the production factor land can only be used in the agricultural production.

The market clearing conditions for inputs are also the same, but the market clearing conditions for the two final goods are now different: total production of agricultural good is equal to consumption plus net agricultural exports x_a, and total production of nonagricultural good is equal to consumption plus net exports x_n plus total investment.

$$A_a f^a \left(k_a, n_a, L_a e^{-nt}\right) = c_a + x_a \tag{19}$$

$$A_n f^n \left(k_n, n_n\right) = c_n + x_n + \frac{dk}{dt} + nk + \delta k. \tag{20}$$

Because of the balanced trade assumption, the value of net agricultural exports x_a plus the value of net nonagricultural exports x_n is zero at every date:

$$q x_a + x_n = 0 \tag{21}$$

Also, the country is assumed to be small relative to the rest of the world, so it takes the international relative price as given. In other words, both q and $\gamma_q \equiv \dot{q}/q$ are exogenous. The value of net exports is endogenously determined by the model.

Definition 2. *A competitive equilibrium for the small open economy, given* k_0 *and the exogenous variables* $(A_a,\ A_n,\ N,\ q)$*, are prices and quantities* $[w,\ r,\ p_l,\ y_a,\ y_n,\ c_a,\ c_n,\ x_a,\ x_n,\ n_a,\ n_n,\ k_a,\ k_n,\ k]_{t>0}$*, satisfying the consumers' optimization conditions (4) - (6), the firms'* *optimization conditions (9) -(11), and the inputs' market equilibrium conditions (12) - (14) and the goods' market equilibrium conditions (19) - (21).*

As it was the case for the closed economy model, if population growth is not too high compared to the productivity growth rates, in the limit, consumers behave as if their preferences were the ones presented in equation (17). As a result, when the preferences are the ones presented in equation (2), the solution to the equilibrium system is also the unique path that converges to the homothetic preferences Balanced Growth Path. Assuming that the agricultural price is not high enough to imply specialization in the agricultural good, the characteristics of this balanced growth path depend on the values of the exogenous variables growth rates. The next theorem states this idea more formally, and appendix B contains a detailed explanation.

Theorem 2. *If (18) holds, then the equilibrium defined in equations (4) - (6), (9) -(11), (12) - (14), and (19) - (21) has a unique Balanced Growth. The characteristics of the Balanced Growth Path, depend on the relationship between* γ_q *and* $\left((1-\eta-\beta)\,n+\frac{1-\eta}{1-\alpha}\gamma_n-\gamma_a\right)$*:*

- *If* $\gamma_q \leq (1-\eta-\beta)\,n+\frac{1-\eta}{1-\alpha}\gamma_n-\gamma_a$

  $$\frac{\dot{k}}{k}=\frac{\dot{c}_n}{c_n}=\frac{\dot{x}_n}{x_n}=\frac{1}{1-\alpha}\gamma_n$$

  $$\frac{\dot{c}_a}{c_a}=\frac{1}{1-\alpha}\gamma_n-\gamma_q$$

  If the relation holds with equality, the fraction of inputs allocated to both sectors is positive and constant, and if the relation holds with inequality the economy specializes in the production of the nonagricultural good.

- *If* $\gamma_q > (1-\eta-\beta)\,n+\frac{1-\eta}{1-\alpha}\gamma_n-\gamma_a$*, the economy specializes in the production of the* *agricultural good, and*

$$\frac{\dot{k}}{k} = \frac{\dot{c}_n}{c_n} = \frac{\dot{x}_n}{x_n} = \frac{1}{1-\eta}\gamma_a + \frac{1}{1-\eta}\gamma_q - \frac{1-\eta-\beta}{1-\eta}n$$

$$\frac{\dot{c}_a}{c_a} = \frac{1}{1-\eta}\gamma_a + \frac{\eta}{1-\eta}\gamma_q - \frac{1-\eta-\beta}{1-\eta}n$$

Moreover, for any initial condition, the economy converges asymptotically to this Balanced Growth Path.

2.4 Structural Transformation in a Closed and an Open Economy

As consumers get richer, the share of consumption expenditures in agricultural good decreases. As a result, in a closed economy, the fraction of labor and capital employed in the agricultural sector tends to decrease over time. In other words, structural transformation takes place.

More formally, in a closed economy equilibrium,

$$\begin{aligned} \frac{n_a}{1-n_a}\left(1-\frac{\underline{c_a}}{c_a}\right) &= \mu_0 \frac{\beta}{1-\alpha}\frac{c_n}{y_n} \quad \text{if } c_a \leq c_a^* \\ \frac{n_a}{1-n_a}\left(1-\frac{c_a^*-A}{c_a}\right) &= \mu_1 \frac{\beta}{1-\alpha}\frac{c_n}{y_n} \quad \text{if } c_a > c_a^* \end{aligned}$$

Hence, if c_n/y_n is constant or decreasing, as agents get richer and agricultural consumption increases, n_a decreases as well for all income levels.[17]

Also, in a closed economy, the relative price of the agricultural good tends to move in the same direction as the agricultural employment share. However, other variables also affect it:

$$q = \frac{A_n}{A_a}\left(Le^{-nt}\right)^{\eta+\beta-1} k^{\alpha-\eta}\Psi\left(n_a\right) \tag{22}$$

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[17] With positive economic growth, we will only observe an increase in the agricultural employment share n_a if the fraction of nonagricultural output spent on consumption increases enough.

where

$$\Psi\left(n_a\right)=\frac{n_a^{1-\eta-\beta}}{\left(\frac{\beta}{\eta}-n_a\left(\frac{\beta}{\eta}-\frac{1-\alpha}{\alpha}\right)\right)^{\alpha-\eta}},\ \Psi'\left(n_a\right)>0.$$

Hence, an increase in total population, for example, increases the agricultural price. Also, if the nonagricultural sector is more capital intensive than the agricultural one, then capital accumulation affects the relative price positively. Finally, if the nonagricultural productivity increases faster than the agricultural productivity, the ratio A_n/A_a increases and the relative price also rises.

When countries open up to international trade, structural transformation is affected since the fraction of productive inputs allocated to the agricultural sector may increase or decrease. It will depend on whether the domestic relative price is higher or lower than the international one. Looking at equation (22) we can say, for instance, that countries with low land endowment or low agricultural productivity are expected to be agricultural importers.

We can also see that, since q is not constant over time, the evolution of the comparative advantage of a country does not only depend on the evolution of the right hand side variables of equation (22). A country with faster productivity growth in the agricultural sector than in the nonagricultural one, for instance, does not necessarily have to become agricultural exporter; if the productivity growth difference is even larger in other countries, the fall in the international price q will prevent that outcome.

Trade affects economic growth first because it increases real income and second because it affects the sectoral composition of the economy. Trade can lead to an increase in the production of the good with high TFP growth or to an increase of the good with low TFP growth. Also, trade can affect capital accumulation positively or negatively. Trade unambiguously increases capital accumulation for nonagricultural exporters because the nonagricultural good is more capital intensive, but it may decrease capital accumulation for agricultural exporters

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At the same time, economic growth may also affect the degree of comparative advantage of a country. For example, a country that accumulates capital faster than its trading partners will tend to experience an increase in its comparative advantage over time if it is a nonagricultural exporter (and a decrease in its comparative advantage if it is an agricultural exporter).

3 Model Calibration and United States Structural Transformation

In this section and the two that follow, I simulate the model and compare the simulations to the structural transformations in the United States during the period 1890 - 2007[18], South Korea during the period 1963 - 2007, and the United Kingdom during the period 1800 - 1900. The parameter values used are the same in all the simulations[19], and the only differences in the three simulations are the exogenous variables and the degree of openness to international trade. Counterfactual simulations are then used to quantify the role of international trade for the cases of South Korea and the United Kingdom.

In this section, I first describe the calibration of the parameters and then I simulate the closed economy model to match the United States data. Although in the real world the United States is not a closed economy, its net agricultural exports are low in relation to its production, so I assume that its agricultural production is equal to its agricultural consumption at every date. As figure 4 shows, during the period 1910 - 2007, the ratio of net agricultural exports over agricultural output is between -5% and 5% for most years, and only during the period 1975-1995 the ratio gets over 10%. [20]

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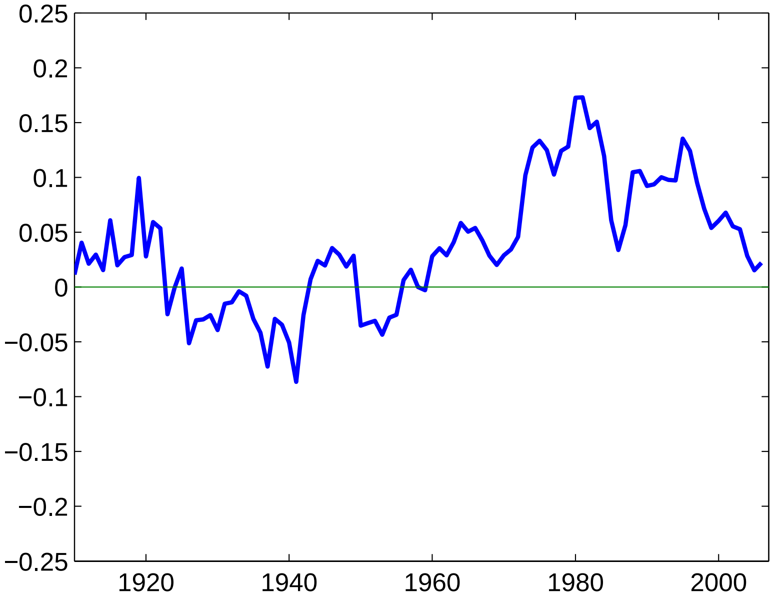
[18] In 1890, agricultural employment in the United States was already less than 40% of total employment, but he lack of reliable data for some variables - like capital stock and sectoral ouptut - makes it difficult to start the analysis earlier.

[19] The preferences parameter $\underline{c_a}$ takes different values for each country, as the next subsection explains in detail.

[20] Net agricultural exports data: Historical Statistics of the United States, Millenial Edition Online (http://hsus.cambridge.org) for period 1910 - 1949; United States Department of Agriculture, Economic Research Service (http://www.ers.usda.gov) for period 1950 - 2007.

Figure 4: US net agricultural exports over agricultural output



There are two main reasons to start with the United States. First, since it is very close to its Steady State by the end of the period, it makes possible to calibrate the parameters that determine the long run. Second, it illustrates the elements behind industrialization for an economy under autarky, such as sectoral productivity growth in the two sectors and capital accumulation.

3.1 Model Calibration

The parameters that must be calibrated are the production functions parameters (η, β, α), the depreciation rate δ, and the preferences parameters (ρ, μ_0, μ_1, $\underline{c_a}$, c_a^*).

The value used for the labor intensity in the nonagricultural good production function, $1 - \alpha$, is $2/3$. This is the customary value used in the literature[21], and it is exactly equal to

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Net agricultural output data: Historical Statistics of the United States for period 1910 - 1928; Bureau of Economic Analysis, Gross Domestic Product by Industry Accounts (http://www.bea.gov) for period 1929 - 2007.

[21] See, for instance, Hayashi and Prescott (2008).

the average labor income share on total nonagricultural income for South Korea during the period 1963-1995.[22]

The value used for the labor exponent in the agricultural good production function, β, is 0.5. This is approximately the average labor income share in total agricultural income for South Korea in the period 1963-1995, and it is within the range of the values used in the literature.[23] The agricultural capital exponent in the agricultural production function, η is 0.1, which is the average income share in the agricultural sector for South Korea the period 1963-1995. This implies an exponent for land in the agricultural production function equal to 0.4, which is also in the range of values used in the literature.[24]

The value used for the depreciation rate parameter δ is 0.1, which corresponds to the average replacement rate of nonresidential structures and producer durables, as discussed in Christensen and Jorgenson (1995).

The value used for the intertemporal discount factor ρ is 0.06, which makes the long run capital output ratio in the model match that of the United States data. This value is slightly larger than the one used in Cooley (1995), which is 0.054, the reason being that the capital data I will use does not include consumer durables or residential buildings.

The value of the preference parameter μ_1 is 0.01, which is chosen to match the long run agricultural employment share as observed in the United States. The preference parameter μ_0 is equal to 0.5, which is chosen to fit the agricultural consumption data for South Korea since this parameter only plays a role at low levels of income.

Since the units of the data are not comparable across countries, the consumption subsistence level parameter $\underline{c_a}$ is independently estimated for each country from their consumption data. The consumption threshold c_a^* is equal to 1.5 times $\underline{c_a}$, which is the relation between the two parameters in the South Korean estimation.

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[22] The income shares series are taken from **?**). See page 79 for the nonagricultural income shares, and page 67 for the agricultural income shares.

[23] Hayashi and Prescott (2008), for instance, use 0.545 for Japan, Caselli and Coleman II (2001) use 0.6 for the United States, and Stokey (2001) uses 0.387 for the United Kingdom.

[24] Hayashi and Prescott (2008), for instance, use 0.1932 for land in Japan, Caselli and Coleman II (2001) use 0.19 for the United States, and Stokey (2001) uses 0.45 for the United Kingdom.

For the case of the United States, the value used for $\underline{c_a}$ is about 60% of the agricultural consumption in 1890, for South Korea it is 85% of its agricultural good consumption in 1963, and for the United Kingdom it is 91% of its agricultural good consumption in 1800.

Table 1 contains a summary of all the parameters and the values used in the simulations.

Table 1: Parameter Values

	Description	**Value**
$\boldsymbol{\alpha}$	Capital share nonagr sector	1/3
$\boldsymbol{\eta}$	Capital share agr sector	0.21
β	Labor share agr sector	0.5
$\boldsymbol{\delta}$	Capital depreciation rate	0.10
$\boldsymbol{\rho}$	Intertemporal discount	0.06
$\boldsymbol{\mu}_0$	Agr good consumption initial weight	0.5
$\boldsymbol{\mu}_1$	Agr good consumption LR weight	0.01
$c_a^*/\underline{c_a}$	Agr consumption parameters ratio	1.5
$\underline{c_a}$	Agr subsistence level consumption	60% c_a 1890 in US 85% c_a 1963 in Korea 91% c_a 1800 in UK

3.2 Exogenous Variables Specification for the United States

To simulate the model, it is also necessary to specify the path of the exogenous variables, both for the sample period and for future periods[25], and give the initial condition for the capital stock. Appendix C contains a detailed explanation of the data sources of the time series used for the United States case.

The exogenous variables of the closed economy model are total population, total employment, agricultural TFP, and nonagricultural TFP. Table 9 and Figure 16 in Appendix C

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[25] It is necessary to specify the exogenous variables' values for periods beyond the sample because the model is simulated for a longer horizon than the sample.

describe and plot them.

The agricultural sector equivalent in the data is the farm sector, and the nonagricultural sector is the rest of the economy.

The initial value for capital is the actual value of nonresidential capital stock from the data for the year 1890, which is equal to two times the nonagricultural output.

The time series used in the simulation for total population N is obtained directly from the data but eliminating the high-frequency fluctuations. The sample period growth rate is almost 2% at the beginning of the period and decreases to around 1%, which is also the value assumed for future periods.

The employment-to-population ratio is approximated using a linear trend, and takes an initial value of 35% and increases during the sample period until 45%, which is assumed to be the value for future periods.

The agricultural and nonagricultural Total Factor Productivity series used in the simulations are also obtained by smoothing the data. Since there is no direct data on total factor productivity, it is first necessary to estimate it from the available data. It is done here by using the Cobb-Douglas production functions from equations (7) and (8), as well as data on value added and employment by sector. Agricultural and nonagricultural capital stocks are inferred from data on aggregate capital assuming that both labor and capital are efficiently allocated across sectors, since the data on sectoral capital stocks is not complete and the different data sources do not seem to be compatible. The growth rates are increasing during the sample period, with the agricultural TFP growth rate starting at 0.5% and increasing to 6%, and the nonagricultural growth rate starting at 0.2% and increasing to 1.5%. The future growth rates are the average of the last 10 years, which is 5.7% for the agricultural TFP and 1.44% for the nonagricultural TFP.

3.3 United States Simulation Results

In this section the results of the closed economy model simulations are presented and compared to the actual US data. In Figure 5 we can see these comparisons for the fraction of employment in the agricultural sector, agricultural production per capita, nonagricultural production per capita, aggregate capital stock, and agricultural relative price.

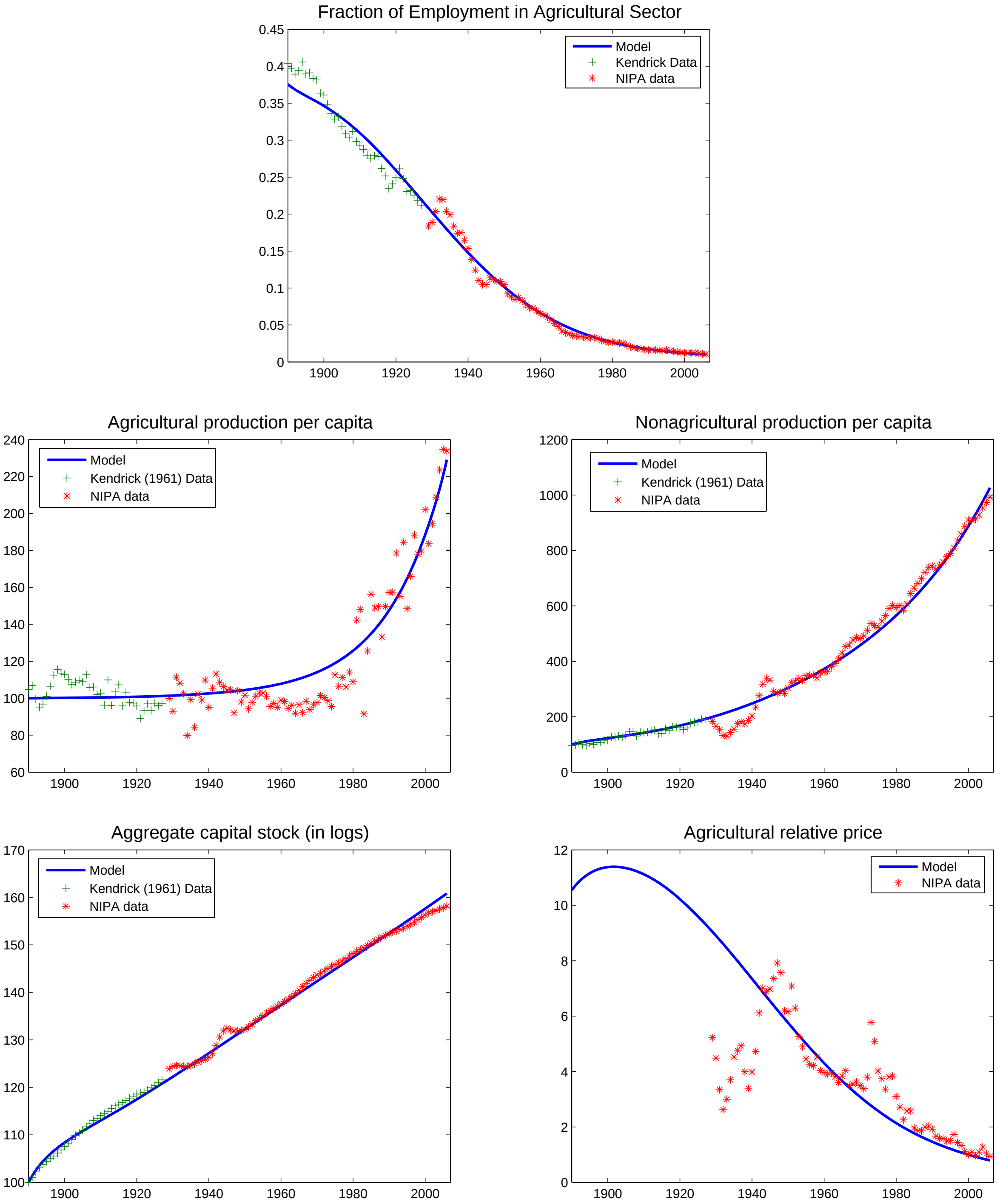
The model is able to successfully replicate the agricultural employment share data, although it seems to slightly underpredict it in the initial years. The model also matches closely the agricultural production data, although it overpredicts the data during the period 1950 - 1980. The nonagricultural production data is also well matched, with the exception of the period 1930 -1950 which corresponds to the Great Depression and the second world war. The fit of the model is also good in terms of the aggregate capital stock. The agricultural price data of the last 60 years is also well matched, but the model overpredicts the data during the Great Depression and underpredicts the data during the second world war. This fluctuations in the relative price are related to the fact that the nonagricultural sector TFP is below its trend during the Great Depression years and above its trend during the second world war years, as we can see in Figure 16 in appendix C.

3.4 United States Counterfactuals

Next, I compare the agricultural employment share evolution in the baseline simulation with the one predicted by the model under different initial productivity levels and different productivity growth rates.

Figure 6 shows the effects of changing the initial productivity levels. If initial productivity in the agricultural sector had been half of what it was, the agricultural employment share would have been much higher. A lower initial productivity in the nonagricultural sector, on the other hand, also increases the agricultural employment share but with much smaller effects. When productivity is lower, agents are poorer and they allocate a larger

Figure 5: Model Simulation vs United States Data



fraction of their resources in the agricultural sector because of the low income elasticity of the agricultural good. But we can see that a low agricultural productivity leads to a much larger increase of the agricultural employment share than a low nonagricultural productivity.

Figure 6: United States Simulations: Changes in Initial Productivity Level

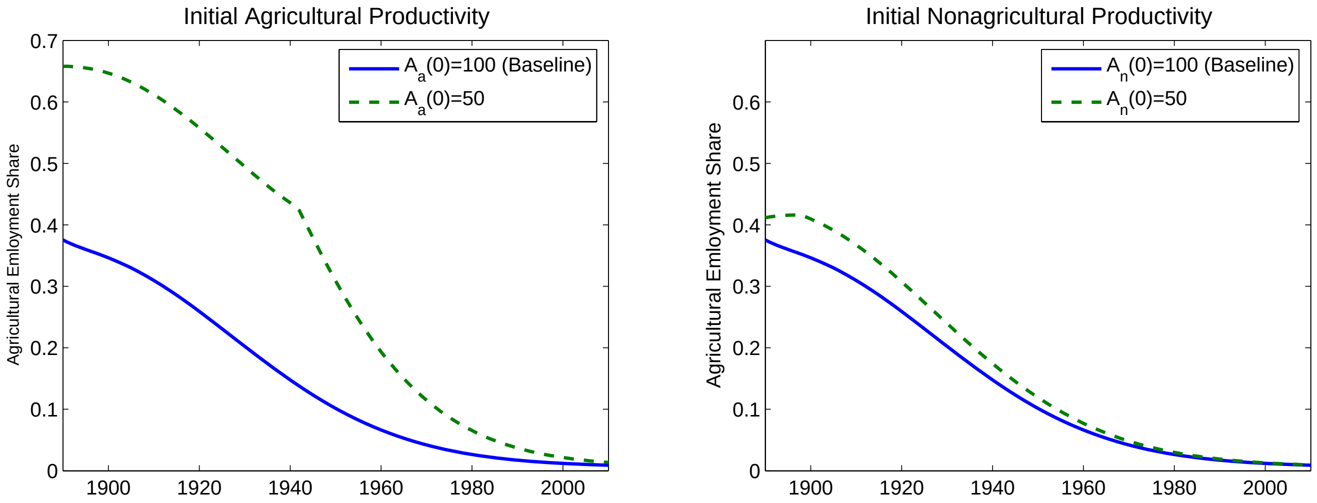
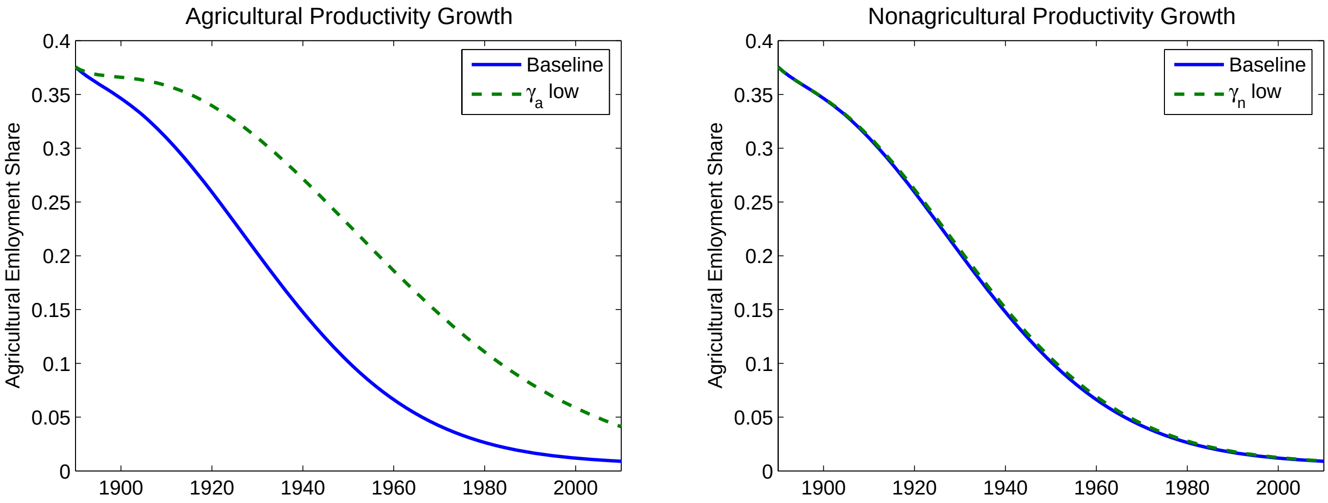


Figure 7 shows the effects of changing the productivity growth rates. We can see that a decrease in the agricultural productivity growth rate by half leads to a slower transformation process, but the same decrease in the nonagricultural productivity growth rate has almost no effect on the agricultural employment share.

4 South Korea Structural Transformation

In this section, I simulate the open economy model using South Korean data for the exogenous variables. The goal is to replicate the data using the model simulation and then quantify the role played by international trade.

Figure 7: United States Simulations: Changes in Productivity Growth



4.1 Exogenous Variables Specification

The agricultural sector is defined in the data as Agriculture, Forestry and Fishing, and the nonagricultural sector is composed by all other parts of the economy.

The initial capital stock is its actual value in the data for 1963[26], which is equal to 2.87 times the nonagricultural output level.

The exogenous variables that need to be specified in the open economy simulations are total population, total employment, agricultural TFP, and nonagricultural TFP, as well as the agricultural relative price. Appendix D offers a detailed description of the data sources of the time series used to compute them. Table 11 summarizes each of the exogenous variables, and Figure 17 shows the exogenous variables used in the simulations together with the data.

As previously, total population, N, is taken directly from the data, although the high frequency fluctuations are eliminated using the Hodrick-Prescott filter. The growth rate of total population is around 2.5% initially and 0.5% by the end of the period. The population growth after 2007 is assumed to be constant and equal to 0.5%, which is approximately the

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[26] Capital stock data is available for the period 1962-1995 from **?**) as described in appendix D.

average population growth in the last 10 years. Figure 17 in Appendix D shows both the actual population time series and the data approximation used in the simulations.

Total employment, E, is again approximated by estimating the employment-to-population ratio with a linear trend, and then multiplying this ratio by the variable N. Its initial value is equal to 27% of the total population, and its final value is close to 50%.

Agricultural and nonagricultural TFPs are assumed to have constant growth, since the data does not show any important trends. The growth rates chosen for both are the ones that allow the simulated production variables fit the actual production variables. As we can see in Figure 17 in Appendix D, these growth rates are a very close approximation to the ones of the measured data.[27]

Finally, the relative agricultural price is also measured in the data, eliminating the high frequency fluctuations using the Hodrick-Prescott filter. Since there is no data on the relative agricultural price directly available, the procedure used to measure it is dividing the agricultural GDP deflator by the nonagricultural GDP deflator. In other words, the nominal agricultural GDP is divided by the real agricultural GDP to estimate the agricultural price, the nominal nonagricultural GDP is divided by the real nonagricultural GDP to estimate the nonagricultural price, and the agricultural relative price is the ratio of the two. Its growth rate during the sample period ranges form -0.023 to -0.012, and its future growth is assumed to be 0.0216 which is equal to the average growth of the last 10 years. Figure 8 plots the measured data and the variable used in the simulations.

Government Policies. There are studies documenting the efforts of the Korean government to protect the agricultural sector and increase the income of agricultural producers. The two main policy tools have been agricultural production subsidies[28] and the agricultural

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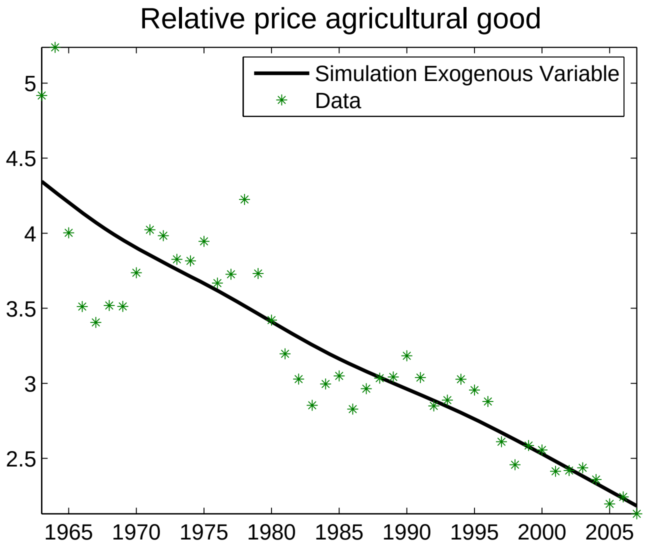
[27] For agricultural TFP, the average growth rate of the measured time series is 0.033 and the value used in the simulations is 0.032. For nonagricultural TFP, the average growth rate of the measured time series is 0.02 and the value used in the simulations is 0.021. The reason why I do not use the average estimated in the data is to get the best possible fit for the agricultural net imports, which is important to have meaningful counterfactual exercises. Also, the measurement error is likely to be large for the measured sectoral TFPs series.

[28] According to the OECD report "Agricultural Policies at a glance" (2008) production subsidies were

Figure 8: South Korea Agricultural Relative Price



import tariffs, which according to the United States Department of Agriculture 104% in 1990 for the aggregate agricultural sector.[29] To improve the fit of the model, a production agricultural subsidy σ_a is introduced, together with a lump sum tax to households τ to ensure that the government budget is balanced every period:

$$\sigma_a(t)\, q(t)\, Y_a(t) = N(t)\, \tau(t)\,.$$

In the simulation, I use $\sigma_a = 0$ until 1972 because no subsidies seem to be used prior to that date and $\sigma_a = 0.10$ from 1973 onwards, since using a higher value increases agricultural production and agricultural employment unrealistically.

With respect the agricultural import tariff, denoted t_a, its value does not affect the simulation at this point because I am already using data on the domestic relative price. Moreover, I assume that the import tariffs do not affect the households budget constraint,

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equal to 56% in 1980 and 65% in 2000, but other studies estimate lower values.

[29] See Diao, Dyck, Skully, Somwaru, and Lee (2002), which computes the tariff equivalent rate taking into account not only explicit import tariff rates but also quantitative restrictions such as direct government bans and quotas.

which implies that either the tariffs do not generate revenues or that the revenues are not transferred to households. In fact, according to the USDA article mentioned above, “support to Korean agriculture is principally manifested by border measures” and, for example “the tariff rate on rice in 1975 and 1990 (5 percent) does not reflect the extremely high barrier posed by complete government control over rice imports or direct subsidies to production”.[30]

4.2 South Korea Simulation Results

In this section the outcome of the simulated model is compared with the actual South Korean data. Figure 9 shows this comparison for six different variables: fraction of employment in the agricultural sector, agricultural production per capita, agricultural consumption per capita, agricultural net imports, nonagricultural production per capita, and aggregate capital stock. Note that the variables agricultural production per capita and nonagricultural production per capita are plotted starting at 100 to facilitate the reading of the figures.

In the first two subplots, one can easily see the effects of the agricultural production subsidy in 1972; both the agricultural employment share and the agricultural production per capita have a sudden increase. Obviously, the subsidy also affects the net agricultural imports, since the sudden increase in agricultural production also leads to a sudden decrease in net agricultural imports. The introduction of the subsidy helps the model to the data, especially in the case of the agricultural production, but the main conclusions do not depend on it.

In the agricultural consumption subplot, one can see the consequences of the preferences used; around 1980 agricultural consumption per capita reaches the level c_a^* and it starts growing more slowly after that date.

In general, the model with the parameter values described above is able to capture the main aspects of the structural transformation process of South Korea during the period 1963-2007.

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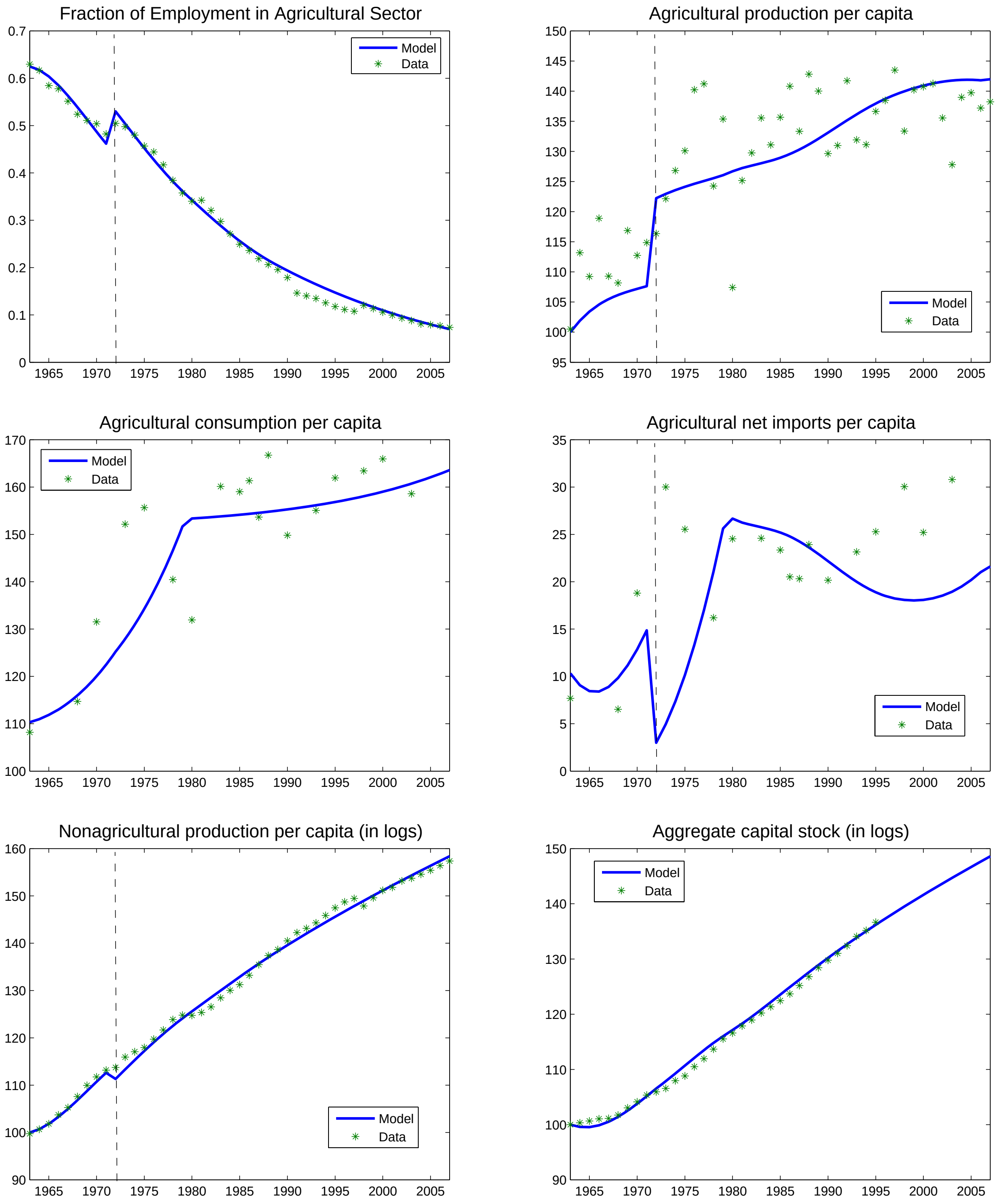
[30] See Diao, Dyck, Skully, Somwaru, and Lee (2002), page 3.

Figure 9: Model Simulation vs South Korea Data



4.3 Policy Experiments: Autarky and Free Trade

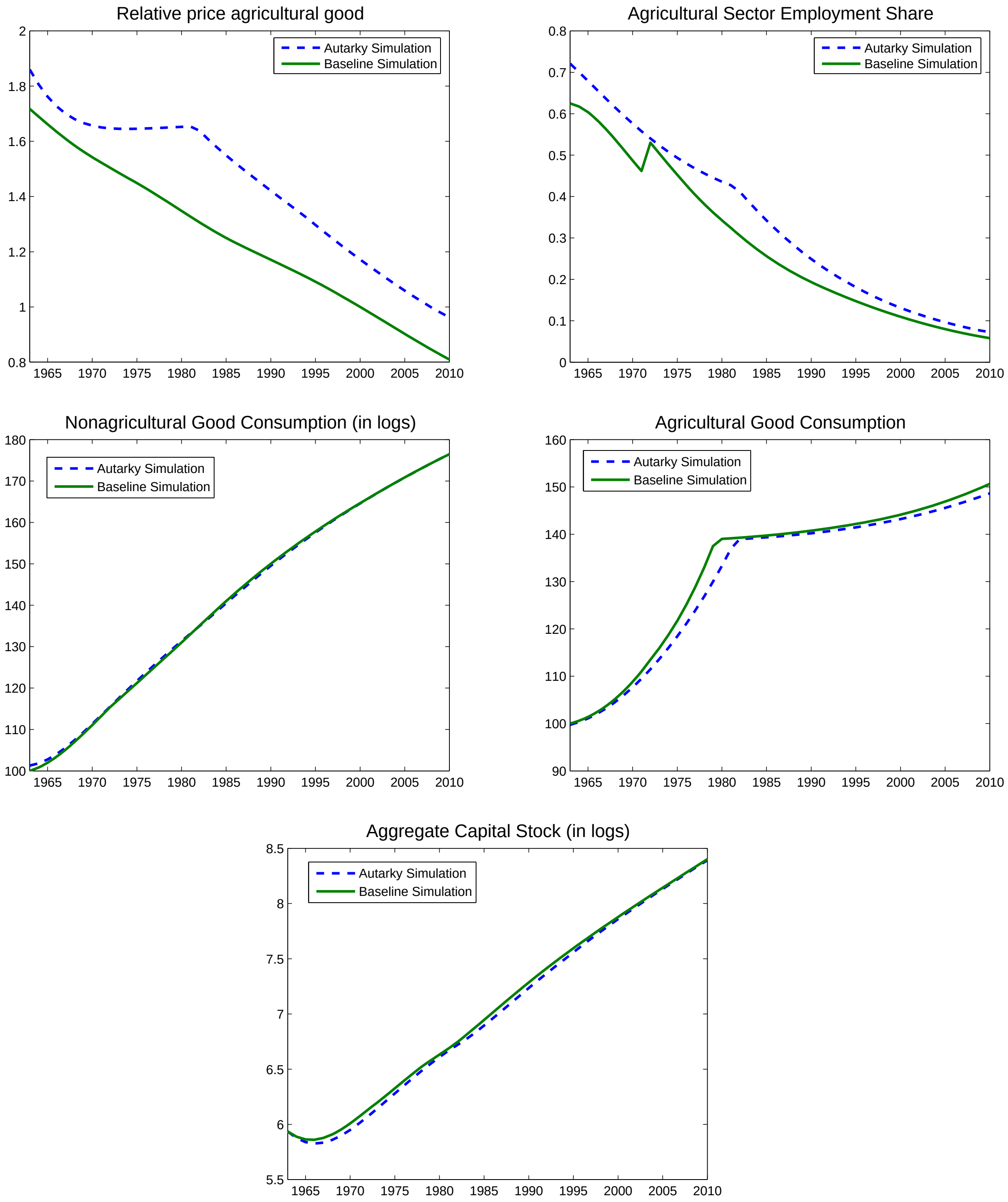
I perform two counterfactual exercises to evaluate the importance of international trade, which offers South Korea the possibility of importing part of the agricultural goods they consume, in the structural transformation process. The first consists of comparing the actual development process of South Korea with a situation where South Korea is not open to international trade and has to produce all the agricultural good consumed by itself. The second consists of comparing the actual development process of South Korea with a situation where no agricultural policies are implemented to protect the agricultural sector and reduce dependency on foreign agricultural imports.

The autarky counterfactual exercise is performed by simulating the closed economy model, in which domestic demand is equal to domestic supply for both goods, and the agricultural relative price is endogenously determined to ensure market clearing. It is important to note that, when simulating the closed economy model, all parameters and endogenous variables are kept identical, so that population, employment or productivity growth are not affected by openness to trade. Also, the agricultural production subsidy is not included.

Figure 10 shows how the autarky model simulation compares with the South Korean baseline simulation; the agricultural relative price would have been significantly larger, the agricultural employment share would have been somewhat larger, the agricultural consumption would have been slightly lower, the nonagricultural consumption would have been approximately the same, and the capital stock would have been lower.

A summary of these results is presented below in Table 2. As we can see in the third row, according to this counterfactual exercise, if South Korea had remained under autarky, the agricultural relative price q would have been about 16.5% larger on average during the sample period 1963-2007, the agricultural employment share n_a would have been 21% on average, the nonagricultural consumption would have been almost the same, and the agricultural consumption would have been 1.13% lower.

Figure 10: South Korea: Baseline Simulation vs Autarky Simulation



The second counterfactual exercise, which I labeled as 'No Agricultural Policy' or 'Free Trade', predicts what would have been the South Korea development process if there had been no government policies attempting to protect the agricultural sector via a production subsidies and import tariffs. As explained above, the subsidy used in the South Korea simulation was equal to 0 until 1972 and 10% from 1973 onwards. The agricultural import tariffs were not specified in the South Korea simulation since I was using data on domestic prices and I assumed it did not generate any income for the country. To generate the times series of the relative price under free trade, I use the average growth rate of the relative agricultural price in the United States data for the period 1963–2007 -which is equal to -3.7%- with the underlying assumption that the prices in the US are the same as in the world markets. Then, I choose the level of the relative price to match the implicit tariff rate estimated by the USDA for the year 1990, which is equal to 104%. Figure 11 compares the agricultural relative price used in this counterfactual simulation with the one observed in the data, and it shows it has both a lower level and a faster decrease.

Figure 11: Agricultural Relative Price with and without Import Tariffs

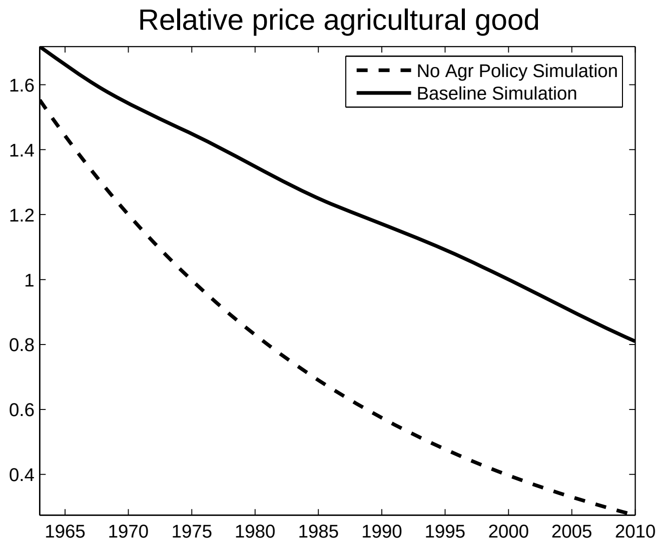


Figure 12 shows the comparison of this free trade counterfactual with respect to the

South Korean baseline simulation. The first plot compares the agricultural net imports and it shows that South Korea would have had a much higher level of net agricultural imports. The second plot compares the agricultural sector employment share and it shows that South Korea would have had a much lower agricultural employment share. The third plot compares the agricultural consumption per capita and it shows that South Korea would have had a significantly higher agricultural consumption per capita. The fourth plot compares the nonagricultural consumption per capita, which would have been somewhat higher. And the fifth plot compares the capital stock per capita, which would have been significantly higher if South Korea had no production subsidies and no import tariffs.

These results are also summarized in table 2. The fourth row shows that if South Korea had not introduced the agricultural production subsidy but had kept the same import tariffs, its agricultural employment share would have been about 17% lower on average during the sample period 1963-2007, the nonagricultural consumption per capita would have been 0.65% larger on average, and the agricultural consumption per capita would have been almost the same. It also shows that the GDP growth rate would have been quite similar. The fifth row shows that if South Korea had no agricultural production subsidy and no agricultural import tariffs, during the sample period 1963-2007, its agricultural relative price would have been 42% lower, its agricultural employment share 73% lower, its nonagricultural consumption 11% higher, and its agricultural consumption 5.5% larger.

Economic Growth Analysis. Average real income growth during the sample period has also been slightly higher than it would have been under autarky, and it would have even higher under free trade: the average growth rate in real income has been 1.05 times larger what it would have been under autarky, and would have been 1.2 times larger without agricultural policies. The results are presented in table 3 where real income growth is computed as nominal income growth minus the change in the consumption price index.

Welfare Analysis. Next, I measure the increase in intertemporal welfare the represen-

Figure 12: South Korea: Baseline Simulation vs No Agricultural Policy Simulation

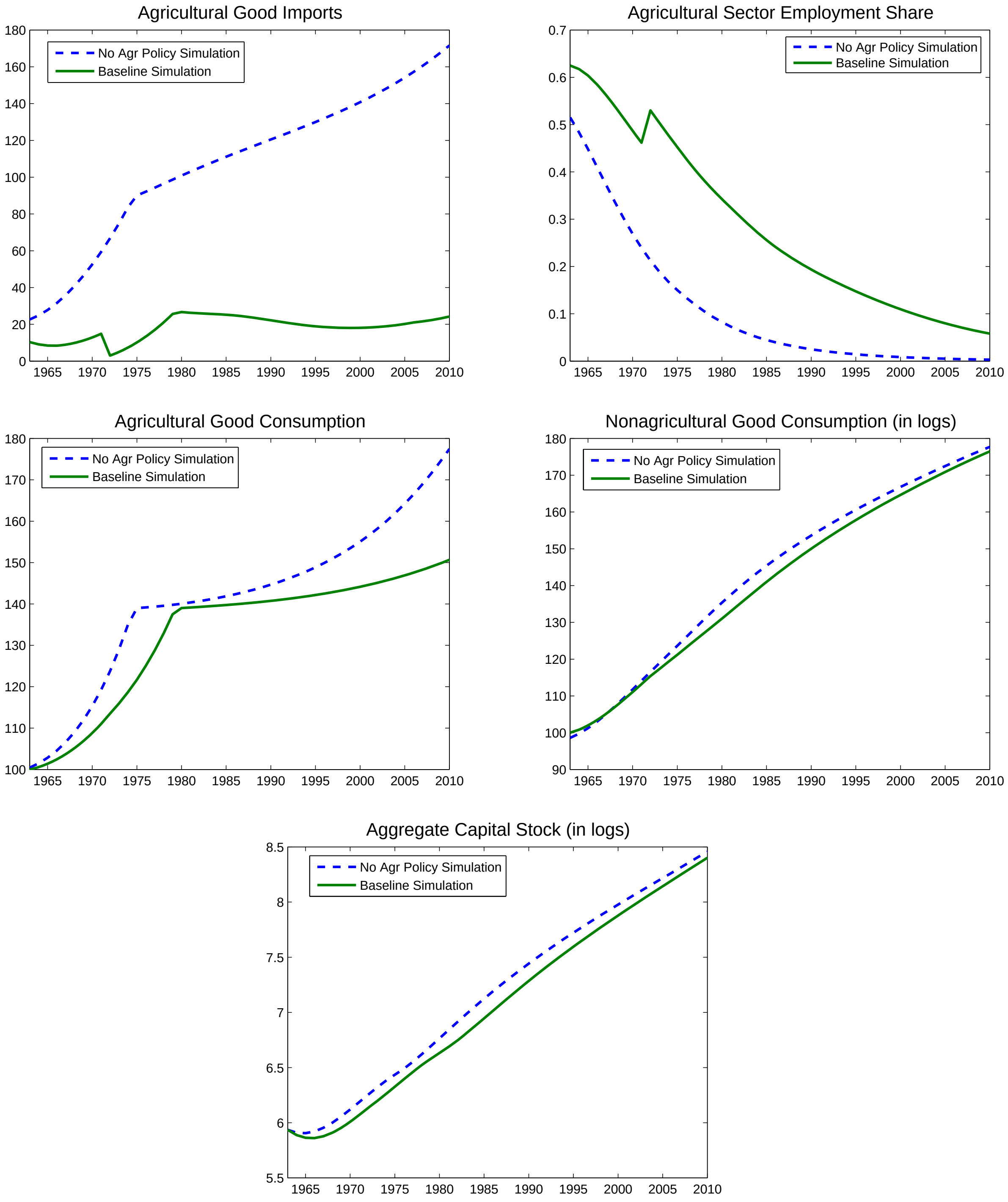


Table 2: South Korea - Sample Period Results Comparison

%	q gap (avg)	n_a gap (avg)	c_n gap (avg)	c_a gap (avg)	k gap (avg)
Baseline Simulation	0	0	0	0	0
Autarky Simulation	16.5	21	0.3	-1.1	-3.5
No subsidy Simulation	0	-17	0.65	0.04	2.8
No Agr Policy Simulation	-42	-73.4	10.9	5.5	12.1

Table 3: South Korea - Real Income Growth

Autarky	Baseline	No subsidy	No Agr Policy
4.5%	4.71%	4.72%	5.47%

tative household experiences in the different scenarios with respect to autarky. To do it, I compute the increase in the autarky yearly consumption expenditures that delivers the same increase in intertemporal welfare as opening up to international trade in the three different different situation.

Table 4 shows the results. The gain in intertemporal welfare that South Korea experienced because it was open to international trade is equivalent to a 0.4% increase in the autarky yearly consumption expenditures. In other words, the representative consumer in 1963 is indifferent between getting open to international trade or remaining under autarky but increasing the consumption expenditure by 0.4% every year. If there had not been agricultural production subsidies, the gain would have been the equivalent of a 0.5% annual increase in the consumption expenditures. And if there had not been agricultural production subsidies or agricultural import tariffs, the gain in intertemporal welfare with respect to autarky would have been equivalent to a 5.5% increase in the annual consumption expenditures.

Table 4: South Korea - Intertemporal Welfare Gain

Autarky	Baseline	No subsidy	No Agr Policy
0	0.4%	0.45%	5.4%

5 United Kingdom Structural Transformation

In this section, I first simulate the open economy model using United Kingdom data of the period 1800 - 1900 for the exogenous variables. Then, I simulate the closed economy model to see what would have occurred if the United Kingdom had not had access to foreign imports of agricultural goods. Stokey (2001) finds that international trade had an important contribution in the industrial revolution of the United Kingdom. The exercise here provides a verification on her conclusions, using a somewhat different model.

5.1 Exogenous Variables Specification

As it was the case for South Korea, the agricultural sector is defined as Agriculture, Forestry and Fishing, since this is the most disaggregated sector available for the majority of the variables, and the nonagricultural sector is all the other sectors of the economy.

The initial capital stock is its actual value in the data for the year 1800[31], which is equal to 2.52 times the nonagricultural output level.

The exogenous variables and the data sources used to construct them are described with more detail in appendix E. Total population, N, is the HP filtered data from different sources. Its growth rate during the sample period starts at around 1.6% and is equal to 0.8% by the end of the period. The population growth after 1900 is assumed to be constant and equal to 1%, which is equal to the average population growth of the last 10 years of the sample period.

Total employment, E, is approximated by estimating the employment-to-population ratio

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[31] Capital stock data is available for that period from Feinstein (1988), as described in appendix E.

with a linear trend, and then multiplying this ratio by the variable N. Its initial value is equal to 28% of the total population, and its final value is close to 45%.

Agricultural and nonagricultural TFPs are assumed to have constant growth, and the values used for the growth rates are the ones that help the simulated production series fit the actual production data. The agricultural TFP growth rate is equal to 1.25% and the nonagricultural TFP equal to 0.65%. As we can see in figure in Appendix E , these growth rates are a close approximation to the measured ones, which are obtained using the Cobb-Douglas production functions and data on value added and employment by sector. As before, agricultural and nonagricultural capital stocks are inferred from data on aggregate capital and assuming that both labor and capital are efficiently allocated across sectors.

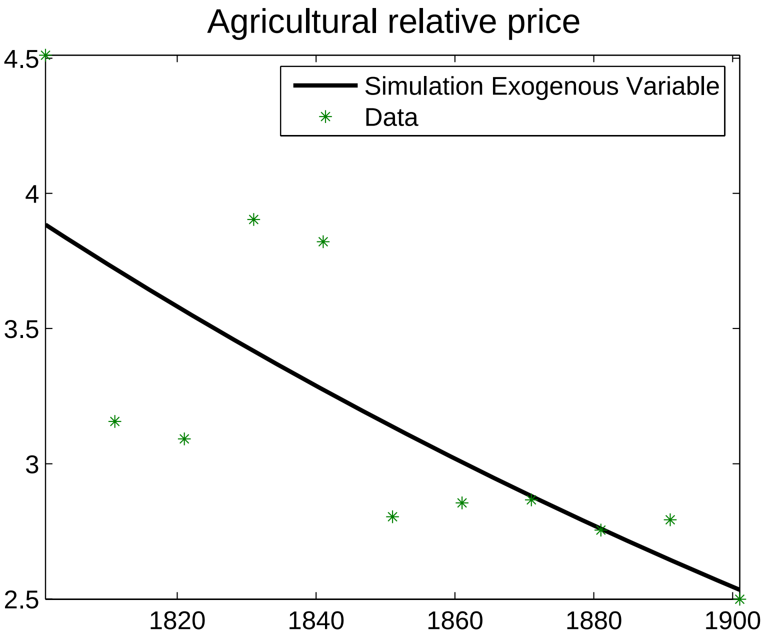
Finally, the relative agricultural price is obtained by fitting a constant-growth curve to the United Kingdom data. As in the other cases, the relative price is measured as the ratio of the agricultural GDP deflator over the nonagricultural GDP deflator. Its growth rate both during the sample period and in future periods is equal to -0.43%, which is the average growth in the available data. Figure 13 plots the measured data and the variable used in the simulations.

5.2 United Kingdom Simulation Results

In this section the outcome of the simulated model is compared with the actual data. Figure 14 shows this comparison for six different variables: fraction of employment in the agricultural sector, agricultural production per capita, agricultural consumption per capita, agricultural net imports, nonagricultural production per capita, and aggregate capital stock. Note that the initial value of the agricultural production per capita, the nonagricultural production per capita and the capital stock are normalized to 100 to facilitate the reading of the figures.

The first plot shows the agricultural employment share, and we can see that the model is able to capture the main features of the data, although it overpredicts the data initially

Figure 13: United Kingdom Agricultural Relative Price

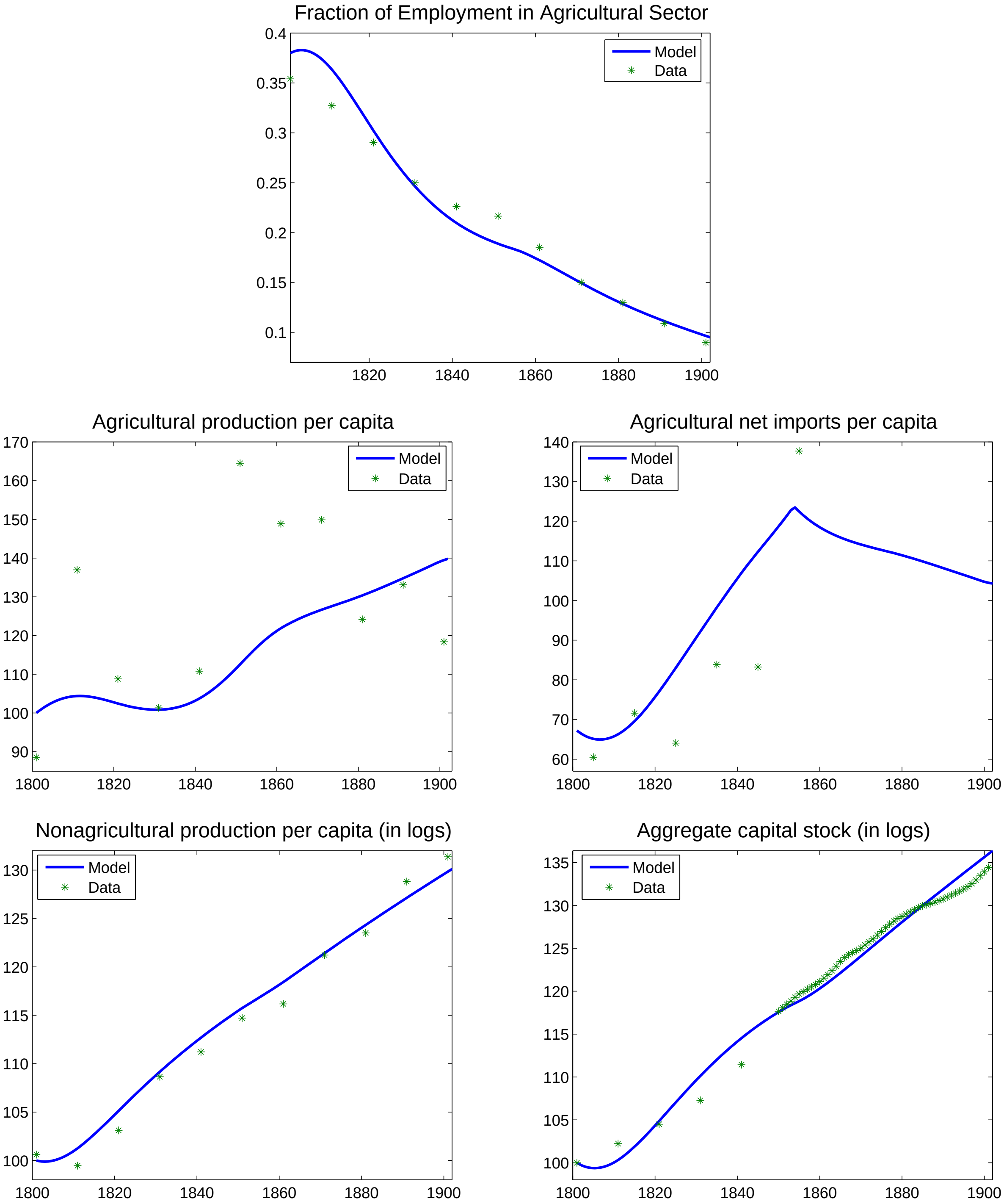


and then it underpredicts it around 1850. The variable in the second plot is agricultural production per capita, and it shows that the model is able to get close to the data, although the data is very volatile in this case. The third plot compares the net agricultural imports series from the model simulation and from the data, and it shows a good fit except for the last observation available. The data availability, however, is shorter for the case of this variable than for the others. The fourth and fifth plot show the model is also able to match the data for the nonagricultural production variable and the aggregate capital stock.

5.3 Policy Experiment: Autarky

To quantify the importance of international trade for the structural transformation of the United Kingdom, the open economy simulation presented above is compared to the closed economy simulation where the country has to produce all the goods consumed. The closed economy simulation uses the same exogenous variables and initial conditions as the open

Figure 14: Model Simulation vs United Kingdom Data


Fraction of Employment in Agricultural Sector

Agricultural production per capita

Agricultural net imports per capita

Nonagricultural production per capita (in logs)

Aggregate capital stock (in logs)

economy one.

Figure 15 compares the evolution of the agricultural relative price, the agricultural employment share, the agricultural and nonagricultural consumption, and the capital stock in the open economy simulation to the one in the closed economy simulation. We can see that both the agricultural relative price and the agricultural employment share would have been significantly larger, and the agricultural consumption level, the nonagricultural consumption level and the capital stock would have been significantly lower. The model predicts that the differences in capital stock, nonagricultural consumption, and agricultural employment share vanish over time, but not the differences in agricultural consumption level and the agricultural relative price.

Table 5 presents the average difference for the different variables during the sample period 1800 - 1900: if the United Kingdom had not been open to international trade, its agricultural price level would have been 45.8% larger during the period 1800 - 1900, its agricultural employment share 155.72% larger, its nonagricultural consumption per capita 10.45% lower, its agricultural consumption per capita 5.41% lower, and its capital stock 20.8% lower.

Table 5: United Kingdom Sample Period Results Comparison

%	q **gap (avg)**	n_a **gap (avg)**	c_n **gap (avg)**	c_a **gap (avg)**	k **gap (avg)**
Baseline Simulation	0	0	0	0	0
Autarky Simulation	45.8	155.7	-10.5	-5.4	-20.8

Economic Growth Analysis. The Average real income growth rate during the 19th century would also have been lower, as table 6 shows. In particular, the real income growth rate under free trade was 1.13 times the autarky one.

Welfare Analysis. As I did for South Korea, I next compute the gain in intertemporal welfare from opening up to international trade. Table 7 shows the results; the extra

Figure 15: United Kingdom: Baseline Simulation vs Autarky Simulation

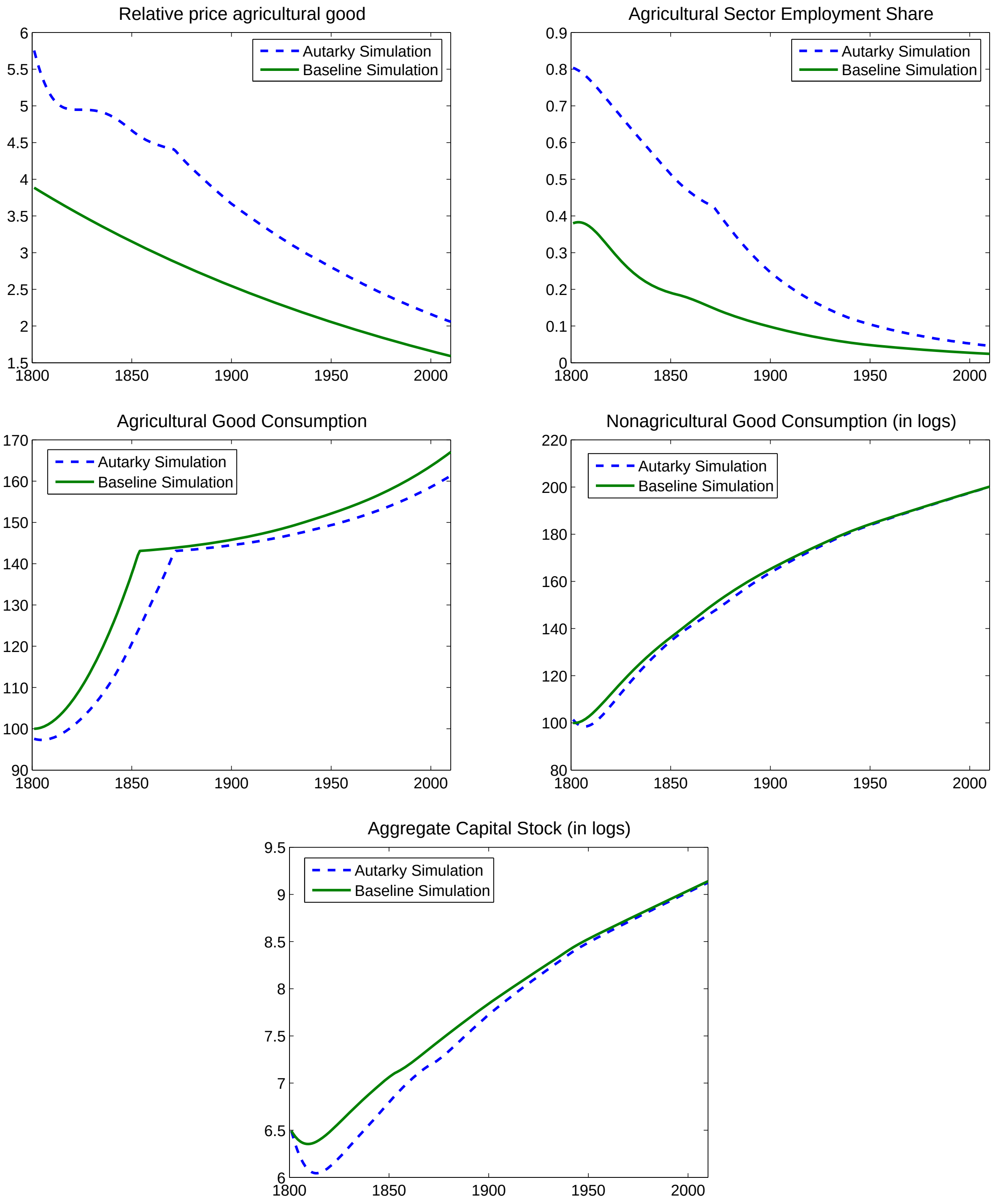


Table 6: United Kingdom - Real Income Growth

Autarky	Baseline
1.28%	1.44%

intertemporal welfare the representative household in the United Kingdom enjoyed because the country was open to international trade is equivalent to a 5.5% annual increase in the autarky consumption expenditures.

Table 7: United Kingdom - Intertemporal Welfare Gain

Autarky	Baseline
0	5.5%

6 Conclusion

To study the importance of international trade in the structural transformation process of countries, I analyze the closed and open economy versions of a neoclassical two-sector growth model. In the autarky version of the model, as countries get richer they experience a sectoral reallocation of production factors from the agricultural sector to the rest of the economy due to the low income elasticity of the agricultural good. International trade may accelerate or slow down this transition process, depending on the relation between international and domestic prices.

This model is then calibrated and simulated using data from the United States, South Korea and the United Kingdom. First, the closed economy simulation is shown to match the structural transformation process in the United States during the period 1890-2007. The exercise illustrates the importance of productivity growth for its transition, especially in the agricultural sector.

Then, the open economy version of the model is shown to match the structural transformation of the United Kingdom during the period 1800-1900, and of South Korea during the period 1963-2007. In both cases, since the relative price of the agricultural good was lower in the international market than in the domestic one, the countries imported agricultural goods during the entire sample period. This implies that trade affected positively their transformation processes. The model is then simulated under autarky to compare the outcomes and quantify the importance of trade in both countries.

In the case of the United Kingdom during the 19th century, the results show that international trade played a very significant role in its industrialization, confirming the results in Stokey (2001) in a somewhat different model. In particular, if the country had been under autarky, the relative price of agricultural goods would have been 46% higher, the share of employment in the agricultural sector would have been 1.5 times higher, the nonagricultural good consumption would have been 10% lower, the agricultural good consumption would have been 5% lower, and the capital stock would have been 21% lower on average during the sample period. The intertemporal welfare gain experienced by the United Kingdom from the intersectoral trade with the rest of the world is equivalent to a 5.5% increase in yearly consumption expenditures under autarky.

In the case of South Korea during the last 45 years, the results show that international trade also had a positive impact on its structural transformation. The relative price of the agricultural good would have been 17% higher on average if South Korea had been under autarky, and the share of employment in the agricultural sector would have been 21% higher on average. Agricultural and nonagricultural consumption, however, would not have been extremely different during the sample period, since the volume of agricultural trade was not very large. The intertemporal welfare gain South Korea experienced because of international trade is equivalent to a 0.4% increase in the autarky yearly consumption expenditures. Therefore, the role actually played by international trade is small compared to other factors such as total factor productivity in both sectors and capital accumulation.

However, it is important to note that South Korea actively protected its agricultural sector to reduce its dependency on foreign agricultural imports. Specifically, South Korea introduced agricultural production subsidies in the early 1970s and applied tariffs to agricultural imports during the entire sample period. When the model is simulated without the agricultural production subsidy and the agricultural import tariffs, it shows that international trade would have played a much larger role and the country would have experienced even faster structural transformation. In this counterfactual scenario, the gain in intertemporal welfare compared to autarky is equivalent to an increase of 5.4% in the autarky annual consumption expenditures.

Through the examples of United Kingdom and South Korea we see that there are large potential benefits from agricultural trade, especially for poor countries with large agricultural sectors. In terms of policy implications, this suggests that policies aimed at increasing international trade in agricultural goods can be very beneficial for some countries. Protectionism towards the agricultural sector has the potential to slow income growth and reduce welfare, as the example of South Korea shows.

There are some natural extensions to this paper. One is to study other recently developed countries and see whether agricultural imports have played a significant role in their structural transformation as well. There is also the potential to use this framework to quantify the costs of protecting the domestic agricultural sector in other countries where agricultural trade is also restricted. Finally, another interesting extension would be to use this framework to study the benefits of food trade between regions with different land quality within the same country, since restrictions on flows of agricultural goods are smaller inside countries.

Appendices

A Closed Economy Analysis

The equilibrium conditions of the closed economy can be simplified to the two dynamic equations (23) and (24) below, plus the three static equations (23) - (27) below. Nonagricultural good consumption c_n is the control variable and per capita capital stock k the state variable, which depend on the endogenous variables $s_e(t) \equiv \frac{N_a(t)}{N(t)}$ and $s_k(t) \equiv \frac{K_a(t)}{K(t)}$.

$$\frac{\dot{c_n(t)}}{c_n(t)} = \alpha(t)\left((1-s_k(t))\,k(t)\right)^{\alpha-1}\left((1-s_e(t))\right)^{1-\alpha} - \delta - \rho \tag{23}$$

$$\dot{k(t)} = A_n(t)\left((1-s_k(t))\,k(t)\right)^{\alpha}\left(1-s_e(t)\right)^{1-\alpha} - (\delta+n)\,k(t) - c_n(t) \tag{24}$$

$$q(t)\,\eta\frac{A_a(t)\,(s_e)^{\beta}\left(\frac{L}{N(t)}\right)^{1-\eta-\beta}}{(s_k(t)\,k(t))^{1-\eta}} = \alpha\frac{A_n(t)\left(1-s_e(t)\right)^{1-\alpha}}{\left((1-s_k(t))\,k(t)\right)^{1-\alpha}} \tag{25}$$

$$q(t)\,\beta\frac{A_a(t)\,(s_k(t)\,k(t))^{\eta}\left(\frac{L}{N(t)}\right)^{1-\eta-\beta}}{(s_e(t))^{1-\beta}} = (1-\alpha)\,\frac{A_n(t)\left((1-s_k(t))\,k(t)\right)^{\alpha}}{\left(1-s_e(t)\right)^{\alpha}} \tag{26}$$

$$A_a(t)\,(s_k(t)\,k(t))^{\eta}\,(s_e(t))^{\beta}\left(\frac{L}{N(t)}\right)^{1-\eta-\beta} = \begin{cases} \underline{c_a} + \mu_0\frac{c_n(t)}{q(t)} \text{ if } c_a(t) \leq c_a^* \\ c_a^* + \mu_1\frac{c_n(t)}{q(t)}\ c_a(t) > c_a^* \end{cases} \tag{27}$$

Lemma 1. *If the preferences are the ones in equation (17), then there exists a Balanced Growth Path where all the variables grow at constant rates, shown in equations (28) - (31):*

$$\frac{\dot{s_e(t)}}{s_e(t)} = \frac{\dot{s_k(t)}}{s_k(t)} = 0 \tag{28}$$

$$\frac{\dot{k(t)}}{k(t)} = \frac{\dot{c_n(t)}}{c_n(t)} = \frac{1}{1-\alpha}\gamma_n \tag{29}$$

$$\frac{\dot{c_a(t)}}{c_a(t)} = \gamma_a + \frac{\eta}{1-\alpha}\gamma_n - (1-\eta-\beta)\,n \tag{30}$$

$$\frac{\dot{q(t)}}{q(t)} = (1-\eta-\beta)\,n + \frac{1-\eta}{1-\alpha}\gamma_n - \gamma_a \tag{31}$$

Lemma 2. *Let* $\left\{\widehat{k}(t), \widehat{c_n}(t), \widehat{q}(t)\right\}$ *be defined as follows:*

$$\begin{aligned}
\widehat{k}(t) &\equiv \frac{k(t)}{A_n(t)^{\frac{1}{1-\alpha}}} \\
\widehat{c_n}(t) &\equiv \frac{c_n(t)}{A_n(t)^{\frac{1}{1-\alpha}}} \\
\widehat{q}(t) &\equiv \frac{q(t)}{\frac{A_n(t)^{\frac{1-\eta}{1-\alpha}}}{A_a(t) L^{1-\eta-\beta}} (N(t))^{1-\eta-\beta}}
\end{aligned}$$

The equilibrium system defined above in equations (23) -(26), together with the initial condition for k_0 *and the transversality condition in equation (6), can be rewritten in terms of this new set of normalized or detrended variables, as shown in equations (32) - (36):*

$$\dot{\widehat{c_n}}(t) = \widehat{c_n}(t)\left[\alpha\left((1-s_k(t))\,\widehat{k}(t)\right)^{\alpha-1}(1-s_e(t))^{1-\alpha} - \delta - \rho - \frac{1}{1-\alpha}\gamma_n\right] \tag{32}$$

$$\dot{\widehat{k}}(t) = \left((1-s_k(t))\,\widehat{k}(t)\right)^{\alpha}((1-s_e(t)))^{1-\alpha} - \left(\delta + n + \frac{1}{1-\alpha}\gamma_n\right)\widehat{k}(t) - \widehat{c_n}(t) \tag{33}$$

$$\widehat{q}(t)\,\eta\frac{(s_e(t))^{\beta}}{\left(s_k(t)\,\widehat{k}(t)\right)^{1-\eta}} = \alpha\frac{((1-s_e(t)))^{1-\alpha}}{\left((1-s_k(t))\,\widehat{k}(t)\right)^{1-\alpha}} \tag{34}$$

$$\widehat{q}(t)\,\beta\frac{\left(s_k(t)\,\widehat{k}(t)\right)^{\eta}}{(s_e(t))^{1-\beta}} = (1-\alpha)\frac{\left((1-s_k(t))\,\widehat{k}(t)\right)^{\alpha}}{(1-s_e(t))^{\alpha}} \tag{35}$$

$$\begin{aligned}
\left(s_k(t)\,\widehat{k}(t)\right)^{\eta}(s_e(t))^{\beta} &= \left\{\begin{array}{c} z(t)\,\underline{c_a} + \mu_0\frac{\widehat{c_n}(t)}{\widehat{q}(t)} \text{ if } c_a(t) \leq c_a^* \\ z(t)\,c_a^* + \mu_1\frac{\widehat{c_n}(t)}{\widehat{q}(t)} \;\; c_a(t) > c_a^* \end{array}\right. \qquad (36) \\
\text{where } z(t) &\equiv \frac{N(t)^{1-\eta-\beta}}{A_a(t)\,L^{1-\eta-\beta}A_n(t)^{\frac{\eta}{1-\alpha}}}
\end{aligned}$$

$$\lim_{t\to\infty}\left\{e^{-\int_0^t(r(s)-\delta-n)ds}\frac{\widehat{k}(t)}{\widehat{c_n}(t)}\right\} = 0 \tag{37}$$

Lemma 3. *If the preferences are the ones in equation (17), then the equilibrium system defined in equations (32) - (36) has a Steady State, where all the variables are constant, defined in equations (38) - (42). Moreover, the solution to this system of equations consists of the path that converges to this Steady State.*

$$\alpha\left((1-s_k^{ss})\,\widehat{k}^{ss}\right)^{\alpha-1}((1-s_e^{ss}))^{1-\alpha} = \delta + \rho + \frac{1}{1-\alpha}\gamma_n \tag{38}$$

$$\widehat{c_n}^{ss} = \left(\left(1 - ss_k^{ss}\right)\widehat{k}^{ss}\right)^{\alpha}\left(\left(1 - s_e^{ss}\right)\right)^{1-\alpha} - \left(\delta + n + \frac{1}{1-\alpha}\gamma_n\right)\widehat{k}^{ss} \tag{39}$$

$$\widehat{q}^{ss}\eta\frac{\left(s_e^{ss}\right)^{\beta}}{\left(s_k^{ss}\widehat{k}^{ss}\right)^{1-\eta}} = \alpha\frac{\left(1 - s_e^{ss}\right)^{1-\alpha}}{\left(\left(1 - s_k^{ss}\right)\widehat{k}^{ss}\right)^{1-\alpha}} \tag{40}$$

$$\widehat{q}^{ss}\beta\frac{\left(s_k^{ss}\widehat{k}^{ss}\right)^{\eta}}{\left(s_e^{ss}\right)^{1-\beta}} = \left(1-\alpha\right)\frac{\left(\left(1 - s_k^{ss}\right)\widehat{k}^{ss}\right)^{\alpha}}{\left(\left(1 - s_e^{ss}\right)\right)^{\alpha}} \tag{41}$$

$$\left(s_k^{ss}\widehat{k}^{ss}\right)^{\eta}\left(s_e^{ss}\right)^{\beta} = \mu_1\frac{\widehat{c_n}^{ss}}{\widehat{q}^{ss}} \tag{42}$$

Lemma 4. *For the equilibrium system with the preferences defined in equation (2), if* $\left(1-\eta-\beta\right)n < \gamma_a + \frac{\eta}{1-\alpha}\gamma_n$*, then the detrended equilibrium system defined in (32) - (36) converges to same equilibrium as the equation (17) preferences case.*

B Open Economy Analysis

The open economy equilibrium can be simplified to two dynamic equations - equations (43) and (44) below - and four static equations, also presented below. The two dynamic equations determine the change in the state variable $k(t)$ and in the control variable $c_n(t)$, as a function of some other endogenous variables. The equations that determine these other endogenous variables vary depending on the country's specialization pattern, as shown below.

$$\frac{\dot{c_n(t)}}{c_n(t)} = r(t) - \delta - \rho \tag{43}$$

$$\dot{k(t)} = A_n(t)\left(\left(1 - s_k(t)\right)k(t)\right)^{\alpha}\left(1 - s_e(t)\right)^{1-\alpha} - (\delta + n)\,k(t) - c_n(t) - x_n(t) \tag{44}$$

If the exogenous relative price $q(t)$ is such that the country produces both goods then the static equations describing the equilibrium are equation (45) below - which defines the interest rate $r(t)$ -, together with equations (25) and (26) above - which state that the value of the marginal product of both factors has to be equal across sectors-, and equation (19) below - which is the agricultural good market clearing condition written in terms of nonagricultural consumption and nonagricultural exports-.

$$r(t) = \alpha \frac{A_n(t)\left(1 - s_e(t)\right)^{1-\alpha}}{\left(\left(1 - s_k(t)\right)k(t)\right)^{1-\alpha}} \tag{45}$$

$$A_a(t)\left(s_k(t)\,k(t)\right)^{\eta}\left(s_e(t)\right)^{\beta}\left(\frac{L}{N(t)}\right)^{1-\eta-\beta} = \begin{cases} \mu_0 \frac{c_n(t)}{q(t)} + \underline{c_a} - \frac{x_n(t)}{q(t)} & \text{if } c_a(t) \leq c_a^* \\ \mu_1 \frac{c_n(t)}{q(t)} + c_a^* - A - \frac{x_n(t)}{q(t)} & \text{else} \end{cases} \tag{46}$$

If the exogenous relative price $q(t)$ is such that only the agricultural good is produced, then the interest rate is defined by equation (47), the agricultural good market clearing condition in equation (46) does not change, and the two other equations defining the equilibrium are (48) and (49) below.

$$r(t) = q(t)\,\eta \frac{A_a(t)\left(s_e\right)^{\beta}\left(\frac{L}{N(t)}\right)^{1-\eta-\beta}}{\left(s_k(t)\,k(t)\right)^{1-\eta}} \tag{47}$$

$$\begin{aligned} s_e(t) &= 1 \qquad (48) \\ s_k(t) &= 1 \qquad (49) \end{aligned}$$

If the exogenous relative price $q(t)$ is such that only the nonagricultural good is produced, then the capital rental rate is defined again by equation (45) above, the agricultural good market clearing condition is still (46), and the other equations are () and ().

$$\begin{aligned} s_e(t) &= 0 \qquad (50) \\ s_k(t) &= 0 \qquad (51) \end{aligned}$$

These equations, together with the boundary conditions $k(0) = k_0$ and the transversality condition in equation (6), are the ones used to find the solution of the model.

Lemma 5. *If the preferences are the ones in equation (17), then the open economy equilibrium is consistent with a Balanced Growth Path, in which all the variables grow at a constant rate. The growth rates of the endogenous variables in the BGP are the ones showed in equations (52) -(54):*

$$\frac{\dot{s_e}(t)}{s_e(t)} = \frac{\dot{s_k}(t)}{s_k(t)} = 0 \tag{52}$$

$$\frac{\dot{k}(t)}{k(t)} = \frac{\dot{c_n}(t)}{c_n(t)} = \frac{\dot{x_n}(t)}{x_n(t)} = \begin{cases} \frac{1}{1-\alpha}\gamma_n \text{ if } \gamma_q \leq \widetilde{\gamma} \\ \frac{1}{1-\eta}\gamma_a + \frac{1}{1-\eta}\gamma_q - \frac{1-\eta-\beta}{1-\eta}n \text{ if } \gamma_q > \widetilde{\gamma} \end{cases} \tag{53}$$

$$\frac{\dot{c_a}(t)}{c_a(t)} = \begin{cases} \frac{1}{1-\alpha}\gamma_n - \gamma_q \text{ if } \gamma_q \leq \widetilde{\gamma} \\ \frac{1}{1-\eta}\gamma_a + \frac{\eta}{1-\eta}\gamma_q - \frac{1-\eta-\beta}{1-\eta}n \text{ if } \gamma_q > \widetilde{\gamma} \end{cases} \tag{54}$$

where $\widetilde{\gamma} \equiv (1-\eta-\beta)\,n + \frac{1-\eta}{1-\alpha}\gamma_n - \gamma_a$.

Lemma 6. *If the growth rate of the exogenous relative price q, denoted by γ_q, is equal to $(1-\eta-\beta)\,n + \frac{1-\eta}{1-\alpha}\gamma_n - \gamma_a$, then the Steady State has positive production of both goods ($0 < s_e^{ss} < 1$, $0 < s_k^{ss} < 1$); if $\gamma_q > (1-\eta-\beta)\,n + \frac{1-\eta}{1-\alpha}\gamma_n - \gamma_a$, then only the agricultural good is produced in the Steady State ($s_e^{ss} = 1$, $s_k^{ss} = 1$); finally, if $\gamma_q < (1-\eta-\beta)\,n + \frac{1-\eta}{1-\alpha}\gamma_n - \gamma_a$, then only the nonagricultural good is produced in the Steady State ($s_e^{ss} = 0$, $s_k^{ss} = 0$).*

Lemma 7. *Let $\widehat{k}(t)$, $\widehat{c_n}(t)$, and $\widehat{x_n}(t)$ be defined as in equations (55) - (57). $\widehat{k}(t)$, $\widehat{c_n}(t)$, and $\widehat{x_n}(t)$, as well as $s_e(t)$ and $s_k(t)$ are constant in the BGP.*

$$\widehat{k}(t) \equiv \begin{cases} \frac{k(t)}{A_n(t)^{1/(1-\alpha)}} \text{ if } \gamma_q \leq \widetilde{\gamma} \\ \frac{k(t)}{\left(A_a(t)q(t)N(t)^{(1-\eta-\beta)}\right)^{1/(1-\eta)}} \text{ if } \gamma_q > \widetilde{\gamma} \end{cases} \tag{55}$$

$$\widehat{c_n}(t) \equiv \begin{cases} \frac{c_n(t)}{A_n(t)^{1/(1-\alpha)}} \text{ if } \gamma_q \leq \widetilde{\gamma} \\ \frac{c_n(t)}{\left(A_a(t)q(t)N(t)^{(1-\eta-\beta)}\right)^{1/(1-\eta)}} \text{ if } \gamma_q > \widetilde{\gamma} \end{cases} \tag{56}$$

$$\widehat{x_n}(t) \equiv \begin{cases} \frac{x_n(t)}{A_n(t)^{1/(1-\alpha)}} \text{ if } \gamma_q \leq \widetilde{\gamma} \\ \frac{x_n(t)}{\left(A_a(t)q(t)N(t)^{(1-\eta-\beta)}\right)^{1/(1-\eta)}} \text{ if } \gamma_q > \widetilde{\gamma} \end{cases} \tag{57}$$

Lemma 8. *The equilibrium system defined in equations (43) -(46) can be rewritten in terms of the detrended variables $\widehat{k}(t)$, $\widehat{c_n}(t)$, and $\widehat{x_n}(t)$, as shown in the equations below. If the country is not specialized and both goods are produced, then the detrended equilibrium system* *consists of equations (58) - (62). If only the agricultural good is produced, the detrended equilibrium system consists of equations (58), (59), and (63) together with equations* $s_e(t) = s_k(t) = 1$.

$$\dot{\widehat{c_n}}(t) = \begin{cases} \widehat{c_n}(t)\left[\alpha\left((1 - s_k(t))\,\widehat{k}(t)\right)^{\alpha-1}(1 - s_e(t))^{1-\alpha} - \delta - \rho - \frac{1}{1-\alpha}\gamma_n\right] & \text{if } \gamma_q \le \widetilde{\gamma} \\ \widehat{c_n}(t)\left[\begin{array}{c} \eta\left(s_k(t)\,\widehat{k}(t)\right)^{\eta-1} s_e(t)^{\beta}\left(\frac{L}{N(t)}\right)^{1-\eta-\beta} \\ -\delta - \rho - \frac{1}{1-\eta}\gamma_a - \frac{1}{1-\eta}\gamma_q - \frac{1-\eta-\beta}{1-\eta}n \end{array}\right] & \text{if } \gamma_q > \widetilde{\gamma} \end{cases} \tag{58}$$

$$\dot{\widehat{k}}(t) = \begin{cases} \left[\begin{array}{c} \left((1 - s_k(t))\,\widehat{k}(t)\right)^{\alpha}(1 - s_e(t))^{1-\alpha} - \widehat{c_n}(t) \\ -\widehat{x_n}(t) - \left(\delta + n + \frac{1}{1-\alpha}\gamma_n\right)\widehat{k}(t) \end{array}\right] & \text{if } \gamma_q \le \widetilde{\gamma} \\ \left[\begin{array}{c} \left((1 - s_k(t))\,\widehat{k}(t)\right)^{\alpha}(1 - s_e(t))^{1-\alpha} - \widehat{c_n}(t) - \widehat{x_n}(t) \\ -\left(\delta + n + \frac{1}{1-\eta}\gamma_a + \frac{1}{1-\eta}\gamma_q + \frac{1-\eta-\beta}{1-\eta}n\right)\widehat{k}(t) - \widehat{c_n}(t) - \widehat{x_n}(t) \end{array}\right] & \text{if } \gamma_q > \widetilde{\gamma} \end{cases} \tag{59}$$

$$\left(s_k(t)\,\widehat{k}(t)\right)^{\eta}(s_e(t))^{\beta} = \begin{cases} \left[\begin{array}{c} (\mu_0\widehat{c_n}(t) - \widehat{x_n}(t))\left(\frac{q(t)}{\frac{A_n(t)^{(1-\eta)/(1-\alpha)}}{A_a(t)\left(\frac{1}{N(t)}\right)^{1-\eta-\beta}}}\right)^{-1} \\ +\underbrace{\left(\frac{(N(t))^{1-\eta-\beta}}{A_a(t)\,(A_n(t))^{\frac{\eta}{1-\alpha}}}\right)}_{\equiv z^1(t)}\underline{c_a} \end{array}\right] & \text{if } c_a(t) \le c_a^* \\ (\mu_1\widehat{c_n}(t) - \widehat{x_n}(t))\left(\frac{q(t)}{\frac{A_n(t)^{(1-\eta)/(1-\alpha)}}{A_a(t)\left(\frac{1}{N(t)}\right)^{1-\eta-\beta}}}\right)^{-1} + \underbrace{\left(\frac{(N(t))^{1-\eta-\beta}}{A_a(t)\,(A_n(t))^{\frac{\eta}{1-\alpha}}}\right)}_{\equiv z^1(t)}c_a^* & \text{else} \end{cases} \tag{60}$$

$$\frac{q(t)}{\frac{A_n(t)^{(1-\eta)/(1-\alpha)}}{A_a(t)\left(\frac{1}{N(t)}\right)^{1-\eta-\beta}}}\eta\frac{(s_e(t))^{\beta}L^{1-\eta-\beta}}{\left(s_k(t)\,\widehat{k}(t)\right)^{1-\eta}} = \alpha\frac{((1 - s_e(t)))^{1-\alpha}}{\left((1 - s_k(t))\,\widehat{k}(t)\right)^{1-\alpha}} \tag{61}$$

$$\frac{q(t)}{\frac{A_n(t)^{(1-\eta)/(1-\alpha)}}{A_a(t)\left(\frac{1}{N(t)}\right)^{1-\eta-\beta}}}\beta\frac{\left(s_k(t)\,\widehat{k}(t)\right)^{\eta}L^{1-\eta-\beta}}{(s_e(t))^{1-\beta}} = (1-\alpha)\frac{\left((1 - s_k(t))\,\widehat{k}(t)\right)^{\alpha}}{(1 - s_e(t))^{\alpha}} \tag{62}$$

$$\left(s_k(t)\widehat{k}(t)\right)^{\eta}(s_e(t))^{\beta}=\begin{cases}\left(\mu_0\widehat{c_n}(t)-\widehat{x_n}(t)\right)+\underbrace{\left(\dfrac{(N(t))^{1-\eta-\beta}}{(q(t))^{\eta}(A_a(t))}\right)^{\frac{1}{1-\eta}}}_{\equiv z^2(t)}\underline{c_a}\ \textit{if}\ c_a(t)\leq c_a^*\\ \left(\mu_1\widehat{c_n}(t)-\widehat{x_n}(t)\right)+\underbrace{\left(\dfrac{(N(t))^{1-\eta-\beta}}{(q(t))^{\eta}(A_a(t))}\right)^{\frac{1}{1-\eta}}}_{\equiv z^2(t)}c_a^*\ \textit{if}\ c_a(t)>c_a^*\end{cases} \tag{63}$$

Lemma 9. *The detrended equilibrium system defined in equations (58) - (63) has a Steady State, where all the variables are constant. The solution to this detrended equilibrium system consists of the path that leads to this Steady State.*

Lemma 10. *If* $(1-\eta-\beta)\,n<\gamma_a+\frac{\eta}{1-\alpha}\gamma_n$, *then the detrended equilibrium system defined in (58) - (63) converges to same equilibrium as the equation (17) case.*

C United States Exogenous Variables and Data Sources

This appendix describes the construction and data sources of the exogenous variables used in the United States simulations. The exogenous variables used in the simulations are total population, total employment, agricultural TFP and nonagricultural TFP. The data sources for other time series used to evaluate the fit of the model with the actual data are also explained. The information is summarized in table 8.

Table 8: Sources United States Data

Variable	Description	Period	Source
N	Total Population	1890-2007	Maddison (2005)
E	Total Employment	1890-1928 1929 - 2007	J.W. Kendrick (1961) National Income and Product Accounts
Y, Y_a	Real GDP by Sector	1890-1928 1929 - 2007	J.W. Kendrick (1961) National Income and Product Accounts
PY	Nominal GDP	1890-1928 1929 - 2007	J.W. Kendrick (1961) National Income and Product Accounts
P_aY_a	Agriculture Nominal GDP	1890:10:1900 1929 - 2007	Historical Statistics of the United States National Income and Product Accounts
N_a, N_n	Employment by Sector	1890 - 1928 1929 - 2007	J.W. Kendrick (1961) National Income and Product Accounts
K, K_a	Real Net Capital Stock by Sector	1890 - 1928 1929 - 2007	J.W. Kendrick (1961) National Income and Product Accounts

Data on total population for the entire sample period 1890-2007 is available in Maddison (2005). Data on total employment is available in Kendrick (1961) for the subperiod 1890-1928, and in the National Income and Product Accounts[32] for the subperiod 1929-2007.

Measures for agricultural and nonagricultural Total Factor Productivity are obtained using the production functions defined in equations (7) and (8),together with data on sectoral real GDP, sectoral employment and sectoral real capital.

Data on real GDP by sector also comes from these two different sources: for the period 1890-1928 data on constant dollars gross value added is available in Kendrick (1961) for both the farm sector and the aggregate economy, and for the period 1929-2007 data on chained dollars gross value added is also available for both the farm sector and the aggregate economy in the National Income and Product Accounts.

Data on gross value added in current prices is available in Kendrick (1961) for the subperiod 1890-1928, and in the National Income and Product Accounts for the subperiod 1929-2007. Data on farm sector gross value added in current prices is available in the Historical Statistics of the United States[33] for the years 1890 and 1900, and in the National Income and Product Accounts for the subperiod 1929-2007.

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[32] http://www.bea.gov.

[33] Historical Statistics of the United States, Millennial Edition Online.

Data on total employment and farm sector employment is available in Kendrick (1961) for the subperiod 1890-1928, and in the National Income and Product Accounts for the subperiod 1929-2007.

Finally, the data used for the aggregate capital stock for the period 1890-1928 is the Real Capital Stock Domestic Economy series minus Farm, Forest and Park Land series, minus Monetary Gold and Silver, and minus Residential Capital Stock in Kendrick (1961). This corresponds to the sum of Structures, Equipment, and Inventories. The data used for aggregate capital stock for the period 1929-2007 is the Chain-Type Quantity Indexes for Net Stock of total fixed series assets minus the Chain-Type Quantity Indexes for Net Stock of private residential assets series, minus the Chain-Type Quantity Indexes for Net Stock of government residential assets in the National Income and Product Accountes. The data used for the agricultural sector capital stock for the period 1890-1928 is the Real Capital Stock Farm Economy series minus Farm Land[34] from Kendrick (1961), and for the period 1929-2007 is the series Chain-Type Quantity Indexes for Net Stock of Private Farms Fixed Assets from the National Income and Product Accounts[35]. Table 9 summarizes the exogenous variables values.

Table 9: Exogenous Variables - United States Simulation

	Variable description	**Initial value**	**Sample period growth**	**Future growth**
N	Population	Normalization	0.018 - 0.009	0.01
E	Employment	35% Population	0.02 - 0.01	0.01
$\mathbf{A}_a$	Agricultural TFP	Normalization	0.005 - 0.06	0.057
$\mathbf{A}_n$	Nonagricultural TFP	Normalization	0.002 - 0.015	0.014

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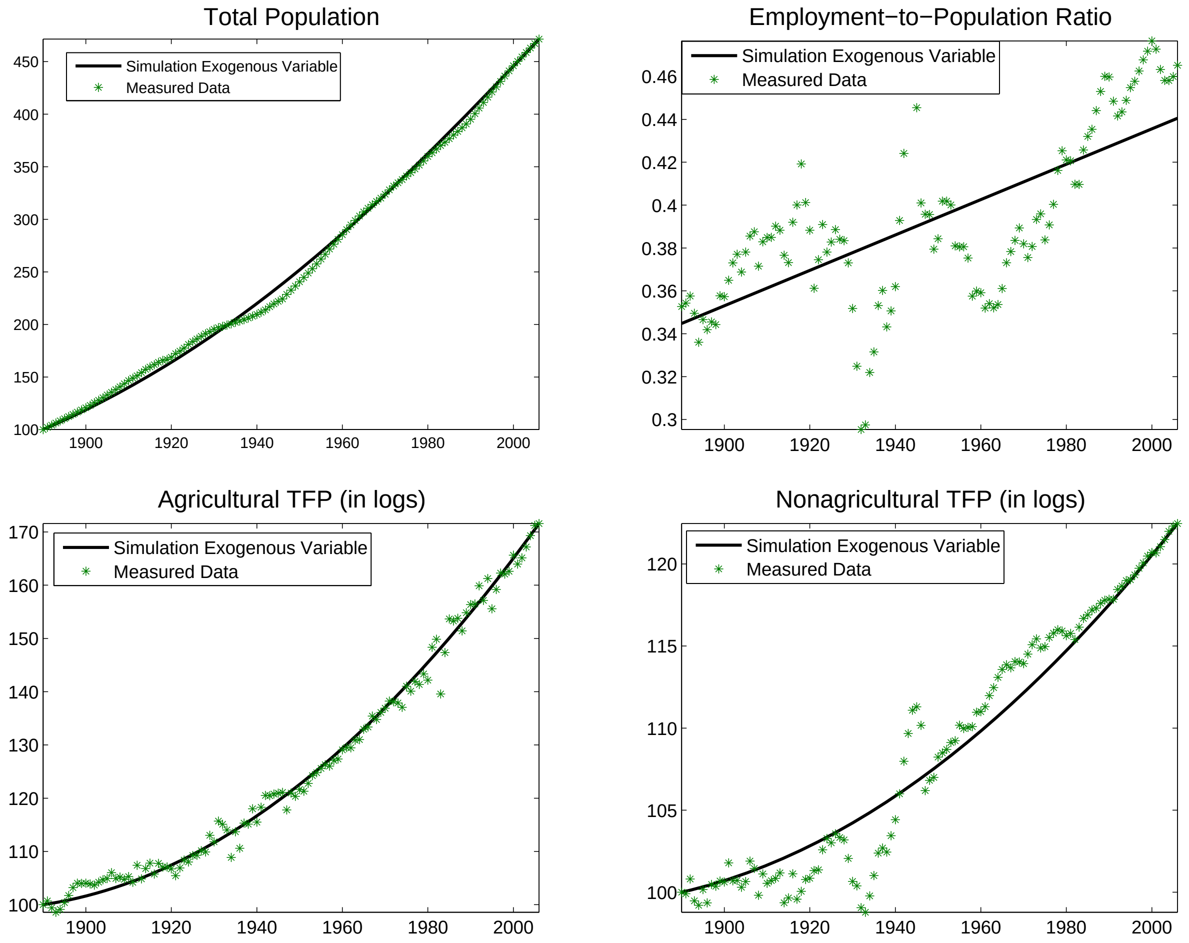
[34] Farm land data is not available for all the years of the 1890-1928 period in Kendrick (1961), but it is estimated to be 92% of Farm, Forest and Park land data series.

[35] Note that the data capital stock data from Kendrick (1961) includes inventories, while the data from the National Income and Product Accounts only includes fixed assets. This is probably not a big problem for the aggregate capital stock, but it may make a significant differnce in the agricultural capital stock. As a result, the capital stock data by sector may not be completely compatible, which is one of the reasons why it is not used to measure sectoral TFP.

Figure 16: Exogenous Variables - United Sates Data



D South Korea Exogenous Variables and Data Sources

This appendix describes the construction and data sources of the exogenous variables used in the open economy model simulations. The exogenous variables used in the simulations are total population, total employment, agricultural relative price, agricultural TFP and nonagricultural TFP. The data sources for other time series used to compare the fit of the model with the actual data are also explained. The information is summarized in table 10.

Table 10: Sources South Korea Data

Variable	Variable description	Period	Source
N	Total Population	1950 - 1970 1960 - 2007	Statistical Yearbooks Bank of Korea
E	Total Employment	1957 - 1970 1963 - 2007	Statistical Yearbooks Korea Statistical Information
P_aY_a, P_nY_n	Nominal GDP by industry	1953 - 2007	Bank of Korea
Y_a, Y_n	Real GDP by industry	1953 - 2007	Bank of Korea
N_a, N_n	Employment by industry	1963 - 2007	Korea Statistical Information Service
P_ax_a	Agricultural net exports	1960 - 2003 (various years)	Statistical Yearbooks Bank of Korea
K	Real net capital stock	1963 - 1995	Korea Development Institute

Data on total population is available from 1960 onwards from the Korean Statistical Information Service[36], and it is available from 1944 to 1966 in the Economic Statistics Yearbook 1970 (Bank of Korea).

Data on total employment is available from 1963 onwards from the Korean Statistical Information Service, and it is available from 1957 in the Statistical Yearbook of the Republic of Korea, year 1960.

Data on the relative price of the agricultural good is not directly available. The way I construct it is by dividing the agricultural sector GDP deflator by the GDP deflator of the rest of the economy, where the sectoral GDP deflator is obtained by dividing nominal GDP data by real GDP data for each sector. Data on current and constant prices GDP by industry is available from the Economic Statistics System of the Bank of Korea[37] starting at 1953. Agricultural sector sector production is Agriculture, Forestry and Fishing GDP, and nonagricultural sector production is total GDP minus the agricultural sector GDP.

Data on agricultural and nonagricultural Total Factor Productivity is obviously not directly available either. Using the production functions defined in equations (7) and (8), one can infer the sectoral TFPs with data on sectoral real GDP, sectoral employment and

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[36] http://www.kosis.kr/eng/index.htm

[37] http://ecos.bok.or.kr/EIndex_en.jsp

sectoral real capital[38]:

$$A_a = \frac{Y_a}{(K_a)^{a_a}\,(N_a)^{\beta}}$$

$$A_n = \frac{Y_n}{(K_n)^{\alpha}\,(N_n)^{1-\alpha}}$$

Real GDP data for each sector is available from the Economic Statistics System of the Bank of Korea from 1953 onwards, as just explained.

Data on total employment and employment in Agriculture, Forestry and Fishing is available from the Korean Statistical Information Service from 1963 onwards. For the period 1957-1960 employment data is available in the Statistical Yearbook of the Republic of Korea, year 1961. Data for aggregate physical capital is obtained from Kim and Hong (1997, Korea Development Institute) for the period 1962-1995.

The capital time series used is the sum of the Net Fixed Capital Stock of Nonresidential Business at 1990 constant prices plus Total Inventories for Nonresidential Business at 1990 Constant Prices[39]. Capital stocks for the agricultural and the nonagricultural sector are also available from the same publication, but instead of using them I created alternative series assuming that both employment and capital are efficiently allocated across sectors.

As explained above, however, the simulations do not use the sectoral TFPs measured this way, but an alternative ones with constant growth in both sectors (0.0315 in the agricultural sector, and 0.0215 in the nonagricultural sector). As figure 17shows, the measured TFPs growth are quite similar to the ones used in the simulations.

Finally, data on net agricultural exports is needed to compute agricultural consumption (which is defined as the sum of the domestic production plus the net agricultural exports). Data on net agricultural exports is obtained from the Input-Output tables published in the Economic Statistics System of the Bank of Korea for many years between 1970 and 2003. Data for the years 1960, 1963 and 1968 is form the Input-Output tables published in the Economic Statistics Yearbook of the Bank of Korea (years 1965, 1966, 1970). Agricultural net exports are defined here as the net exports of crops, livestock breeding, forestry products, and fishery products. Table 11 summarizes the exogenous variables values.

Table 11: Exogenous Variables South Korea simulation

	Variable description	**Initial value**	**Sample period growth**	**Future growth**
$\boldsymbol{N}$	Population	Normalization	(0.025, 0.005)	0.005
$\boldsymbol{E}$	Employment	27% Population	(0.045, 0.015)	0.005
$\boldsymbol{A}_a$	Agricultural TFP	Normalization	0.032	0.032
$\boldsymbol{A}_n$	Nonagricultural TFP	Normalization	0.021	0.021
$\boldsymbol{q}$	Agricultural relative price	Normalization	(-0.023, -0.012)	-0.0216

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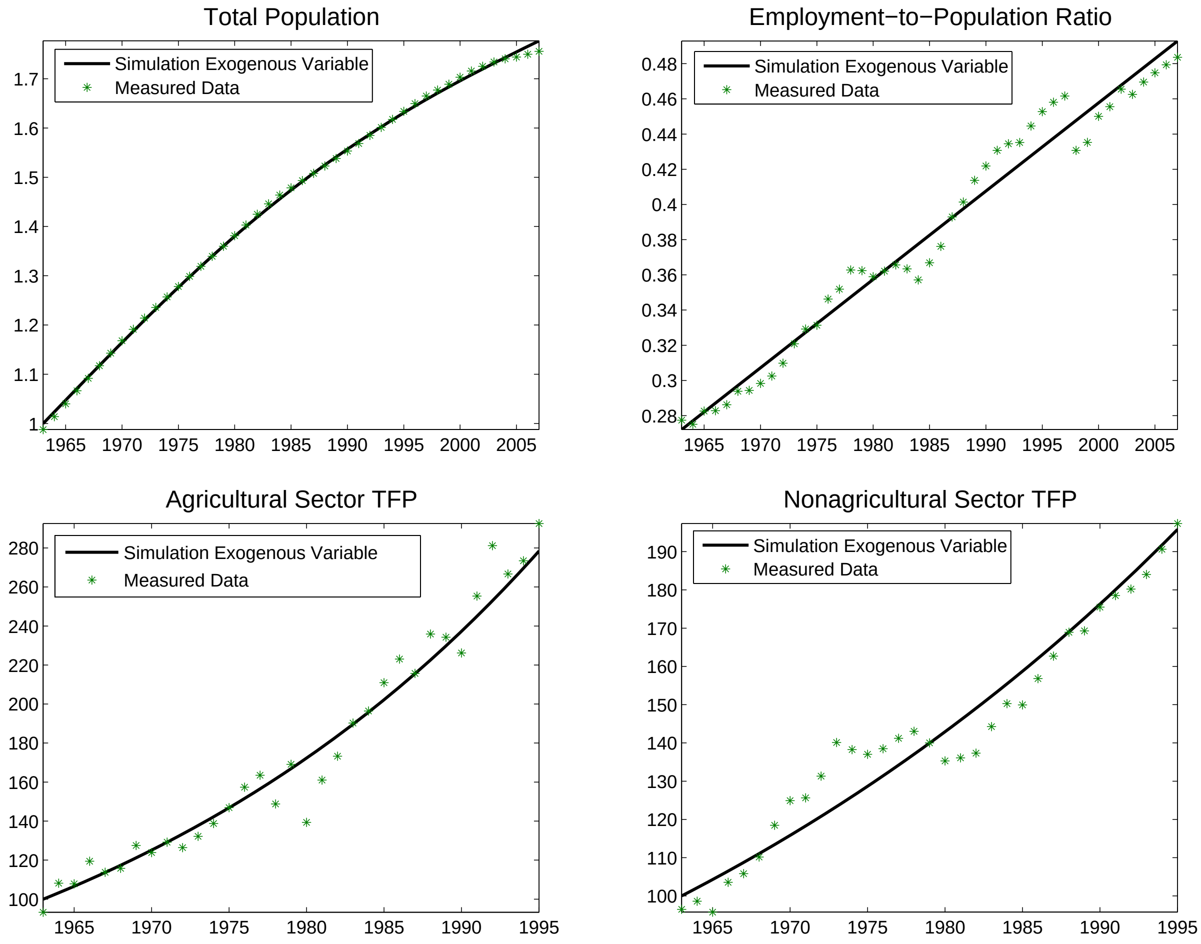
[38] Note that the the measured agricultural TFP in this case corresponds the agricultural TFP defined in equation (7) times total land to the power of $(1 - \eta - \beta)$, but this is not a problem because total land is assumed to be constant.

[39] See pages 166 and 168 of the Korea Development Institute (1997) publication.

Figure 17: Exogenous Variables - South Korea Data



E United Kingdom Exogenous Variables and Data Sources

This appendix describes the construction of the exogenous variables used in the simulations of the United Kingdom, as well as their data sources. Table 12 summarizes the data sources, and figure 18 plots the exogenous variables used in the simulations together with the measured data.

Table 12: Sources United Kingdom Data

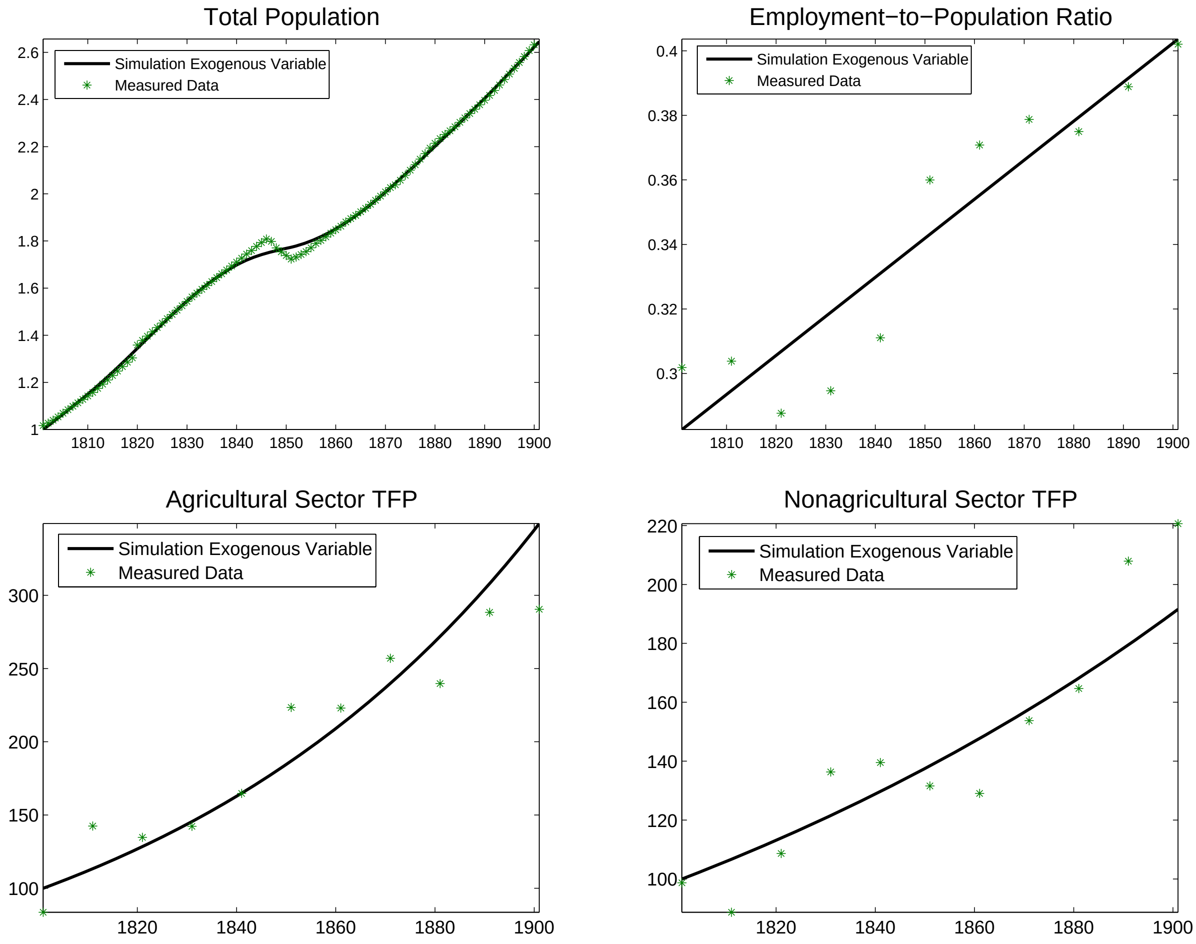
Variable	Variable description	Period	Source
$\boldsymbol{N}$	Total Population	1800 1820-1900	Mitchell (1962) Maddison (2003)
$\boldsymbol{E}$	Total Employment	1800(10)1900	Deane, Cole (1969)
$\boldsymbol{N}_a$	Agriculture Employment	1800(10)1900	Deane, Cole (1969)
$\boldsymbol{PY}$	Nominal GDP	1800(10)1850 1855-1900	Deane, Cole (1969) Mitchell (1962)
$\boldsymbol{P}_a\boldsymbol{Y}_a$	Nominal GDP Agriculture	1800(10)1900	Deane, Cole (1969)
$\boldsymbol{Y}$	Real GDP	1800(10)1850 1855-1900	Deane, Cole (1969) Mitchell (1962)
$\boldsymbol{P}_a$	Agriculture Price Level	1800-1900	Mitchell (1962)
$\boldsymbol{P}_a\boldsymbol{x}_a$	Nominal Agr Net Exports	1805(10)1855	Davis (1979)
$\boldsymbol{K}$	Real Net Capital Stock	1800(10)1850-1900	Feinstein (1988)

To construct the exogenous variables total population and total population, only raw data is used. Data on total population is available for the year 1800 in Mitchell (1962), and for the years 1820-1900 in Maddison (2003). Data on total employment is available in Deane and Cole (1969) for the period 1800 - 1900 at a frequency of ten years.

The data used for the aggregate capital stock, which is available in Feinstein (1988) corresponds to total net stock of domestic reproducible fixed assets minus the category dwellings. This is the sum of industrial and commercial buildings, other nonresidential buildings and works, plant machinery and equipment, rolling stock and vehicles, and ships.

It is possible to construct the exogenous variables agricultural and nonagricultural TFP using the production functions defined equations (7) and (8), together with data on real GDP by sector and employment by sector. Real GDP in agriculture (which corresponds to Agriculture, Forestry and Fishing) can be obtained by dividing nominal GDP in agriculture, which is available from Mitchell (1962), by the price level in agricultural, which is also available from Mitchell (1962) for the sample period 1800 - 1900. Real GDP in the nonagricultural sector can be obtained by substracting the real GDP in agriculture from aggregate real GDP, which is available in Deane and Cole for the period 1800 - 1850 and in Mtichell (1962) for the period 1855 - 1900. Data on employment by sector is available in Deane and Cole (1969) for the entire sample period, and data on aggregate capital stock is available in Feinstein (1988) for the entire sample period. Using data on capital and employment by sector it is possible to infer the level of capital by sector, by assuming that capital is efficiently allocated.

Figure 18: Exogenous Variables - United Kingdom Data



To compute the relative price of the agricultural good I divide the agricultural price level, which is available in Mitchell (1962) for the period 1800 - 1900 by the GDP deflator of the nonagricultural sector. The latter is constructed by dividing nominal GDP outside agriculture by the real GDP outside agriculture, both of which are obtained by substracting the agricultural GDP to the aggregate GDP.

Finally, data on net agricultural imports is also necessary to get agricultural consumption series. Davis (1979) provides data on net agricultural imports, defined as foodstuffs plus raw materials, for the years 1805 - 1855. Table 13 summarizes the exogenous variables values.

Table 13: Exogenous Variables United Kingdom simulation

	Variable description	**Initial value**	**Sample period growth**	**Future growth**
$\boldsymbol{N}$	Population	Normalization	(0.016, 0.008)	0.01
$\boldsymbol{E}$	Employment	28% Population	(0.02, 0.012)	0.01
$\boldsymbol{A}_a$	Agricultural TFP	Normalization	0.0125	0.0125
$\boldsymbol{A}_n$	Nonagricultural TFP	Normalization	0.0065	0.0065
$\boldsymbol{q}$	Agricultural relative price	Normalization	-0.0043	-0.0043

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