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. To do so, international trade is introduced into a two-sector neoclassical growth model. The two sectors are agriculture and the rest of the economy, and a key feature of the model is the low income elasticity of the agricultural good. 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 reduce their agricultural production. The model is calibrated and then simulated for three different countries: the United States over the 20th century, the United Kingdom over the 19th century, and South Korea over the last 50 years. The results show that trade had large effects on structural transformation in the United Kingdom, and positive but smaller 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 both a faster transformation and higher welfare.

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1 Introduction

Poor countries have much larger agricultural sectors than rich ones[1]. In 2000, the average share of employment in agriculture was 75% in the 10% poorest countries, while it was below 5% in the 10% richest countries. The same pattern appears over time in individual countries, although the timing of the structural transformation differs. The United States had more than 80% of its 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, since Japan's per capita incomes in 1870 and 1920 were similar to those in the United States in 1810 and 1870, the pattern is very similar in the two countries except for the 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 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 some of the food they consume from abroad. 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 a poor country, depending on its comparative advantage with respect to the rest of the

[1] See, for example, Caselli (2005), Gollin, Parente and Rogerson (2004), or Restuccia, Yang and Zhu (2008). Data sources: Penn World Table version 6.2, Food and Agriculture Organization.

[2] See Lucas (2007) for some plots illustrating this. Data sources: Kuznets (1996), Maddison (2003).

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

world. There is, however, some evidence that poor countries have a comparative disadvantage in agriculture. In particular, in 1985, the 10% richest countries were on average 30 times more productive than poor countries in the aggregate and 50 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, 2 times larger in the 10% poorest countries than in the 10% richest countries[5]. These two pieces of evidence suggest that, if they are open to international trade, poor countries should be net food importers. Data on food trade shows in fact they are: in 2004, 72% of the poor countries were net food importers and 39% net food exporters, while 61% of the industrial economies were net food importers and 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 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.

International trade is introduced into a general equilibrium, neoclassical growth model with two sectors, agriculture and the rest of the economy. In the model, the 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 than in the international markets, the country imports the agricultural good and its agricultural sector shrinks. Since the nonagricultural sector is more capital intensive, this reallocation increases capital accumulation, which affects positively the growth rate

[4] See, for example, Caselli (2005) or Restuccia, Yang and Zhu (2008). Data sources: Penn World Table version 6.2, Rao (1993).

[5] Data sources: Penn World Table version 6.2 for the aggregate prices and income per capita, Rao (1993) for the agricultural sector prices.

[6] See Ng and Aksoy (2008), World Bank Policy Research Working Paper 4457. Data sources: UN Comtrade Statistics.

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.

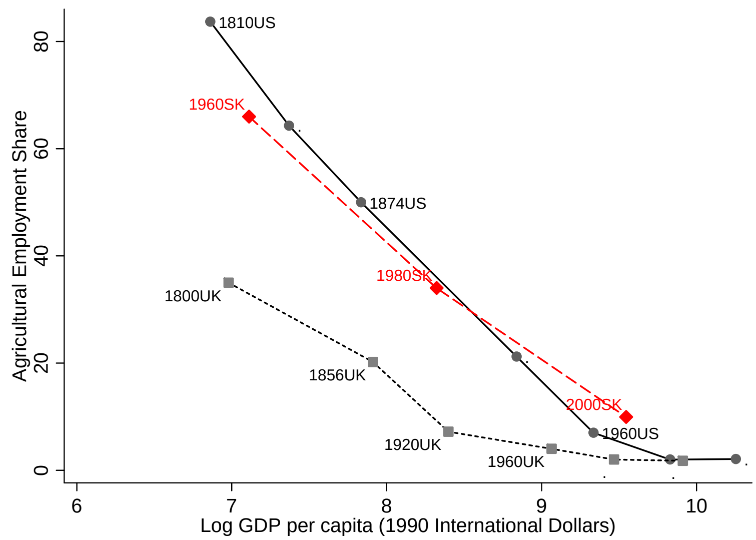
Next, the model is used to study three structural transformations: the United States during the period 1890 - 2007, South Korea during the period 1963 - 2007, and the United Kingdom during the period 1800 - 1900. Comparing these three cases is an interesting exercise because the time periods are very different, and the countries also have important differences in terms of their comparative advantage and their attitude towards agricultural trade. The United States has a rich endowment of agricultural land and its net agricultural exports have been for most of the period positive, although small relative to their own production. The United Kingdom started its transformation even 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 has experienced a very rapid structural transformation in the last 50 years, and it has been one of the main net agricultural importers in the recent years[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, while in the United Kingdom it was below 40%. It has been continuously decreasing in both countries during 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 South Korea, when agricultural employment share is plotted against income per capita the transformation speed looks actually slower than in the United States , as figure 1 shows. Moreover, when compared to another food importer like the United Kingdom, we can see that the size of the

[7]See Stokey (2001) for a study of the Industrial Revolution in the United Kingdom.
[8]See Ng and Aksoy (2008), World Bank Policy Research Working Paper 4457.

agricultural sector at each income level is not low at all.

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



The results show that the model developed here can replicate with the same calibration the structural transformation for these three cases. In the case of the United States, the simulations show the importance of its high agricultural productivity growth. In the case of the United Kingdom, trade was extremely important: its agricultural employment share in 1800 would have been around 80% instead of 35% if the country had been in autarky. In South Korea, trade played a role 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. 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 agricultural employment share much smaller: the initial employment share would have only been 52%, and it would have dropped below 10% by 1979.

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 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.

2 Literature Review

There is a large literature that examines the role of agriculture in economic development and studies the forces behind the process of structural change. Caselli and Coleman (2001), Echevarria (1997, 2007), Gollin, Parente and Rogerson (2002, 2004, 2007), Hansen and Prescott (2002), Hayashi and Prescott (2008), Kongsamut, Rebelo and Xie (2001), Laitner (2000), Lucas (2004, 2007), Matsuyama (1992), Restuccia, Yang and Zhu (2008), Sachs (2001) or Stokey (2001) are some recent examples[9]. Most of them do the analysis in a context of a closed economy. Sachs (2001) argues that economies in tropical zones are, in general, poorer than those in temperate zones, and have lower agricultural productivity due to climate-related factors like the fragility of the soils, the high prevalence of crop pests and parasites, the higher rates of plant respiration, and the scarcity of water. Gollin, Parente, and Rogerson (2004), for example, show that an extended version of the neoclassical growth model including an agricultural sector fails to replicate the enormous disparity in relative output per worker of agricultural and nonagricultural sectors, and incorporate home production into the model. Restuccia, Yang, and Zhu (2008) 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 generate the large agricultural sector labor share observed in poor countries and the large differences in aggregate productivity between rich

[9] Some of the classics are Fisher (1945), Clark (1940), Rostow (1960), Nurske (1953), Lewis (1954), Kuznets (1966), and Jorgenson (1961).

and poor countries. Gollin, Parente, and Rogerson (2007) examine the effect of agricultural policy on development and conclude that low agricultural productivity can delay the start of industrialization and increase the gap relative to the leader.

Hayashi and Prescott (2008) deserves a special mention, since the paper is also a quantitative exercise. Its goal is to quantify the effects of Japan's prewar agricultural institutions on its structural transformation over the period 1885 - 1934, which kept the agricultural sector artificially high. The conclusion is that the barriers that prevented labor to move efficiently 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.

There is also some research studying the role of trade openness in structural change and income growth, and some authors like Mundlak (2000) have recognized that agricultural products are tradable and that countries with low agricultural productivity can benefit from food imports. Matsuyama (1992) argues that the view that high agricultural productivity is a necessary condition for economy development is based on the assumption that the economy is a closed system, but if open to foreign trade, low productivity in the agricultural sector or lack of arable land is likely to foster its industrialization process. The main focus of Matsuyama (1992) is to study theoretically 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 theoretical contribution is Echevarria (2008), which also presents a two-sector growth model with international trade, where preferences are nonhomothetic in the primary sector and TFP growth only occurs in the non-primaries sector. Her 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. Finally, Shin (1990) studies the relationship between structural change and economic development, focusing on the cases of

South Korea and the United States, and argues that including trade to his two-sector growth model might be very useful to explain some characteristics of the South Korean experience, like the rapid decrease in the sectoral share of agriculture.

Stokey (2001) is very related to my work, since its goal is to quantify the effects of international trade and other factors on the structural transformation transformation of the United Kingdom. As the author explains, the United Kingdom imported food and raw materials from 1780 to 1855, with the fraction of imported agricultural goods over the total being 13% in 1780 and 28% in 1850. Her conclusion is that foreign trade played an important role in the Industrial Revolution of the country: the growth in food imports 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. Also, if the country had remained under autarky, tthe relative price of agricultural goods would have increased by 43% instead of the 22% observed. Hayashi and Prescott (2008) also consider the possibility of food being a tradeable good in their study, but the main focus of paper, as well as the main quantitative conclusions, assume that food was nontraded.

Another important influence to this paper comes from the development accounting literature by sector, like Caselli (2005), Cordoba and Ripoll (2004), Restuccia, Yang and Zhu (2008) or Vollrath (2008). These articles take into account the sectoral composition of GDP, instead of assuming that total output is produced by a unique aggregate production function. Caselli (2005), for example, concludes that poor countries have most of their labor force in the sector in which they are particularly unproductive, and that if all countries had the same agricultural labor productivity as the US world income dispersion would actually disappear. Moreover, according to the development accounting exercise he performs, 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.

3 Structural Transformation Model

3.1 Model Setup

In this section I present two theoretical models. The first one is a two-sector neoclassical growth model of a closed economy[10], which I use 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 second is a model of a small open economy, which is similar to the closed economy except that the country can trade with the rest of the world. This model use 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 nonagricultural sector 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 good 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.The amount of agricultural and nonagricultural consumed by each member of the household are denoted $c_a(t)$ and $c_n(t)$ respectively, ρ denotes the intertemporal discount rate. The instantaneous utility function is a variation of the Stone-Geary utility function:

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

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 in-

[10]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).

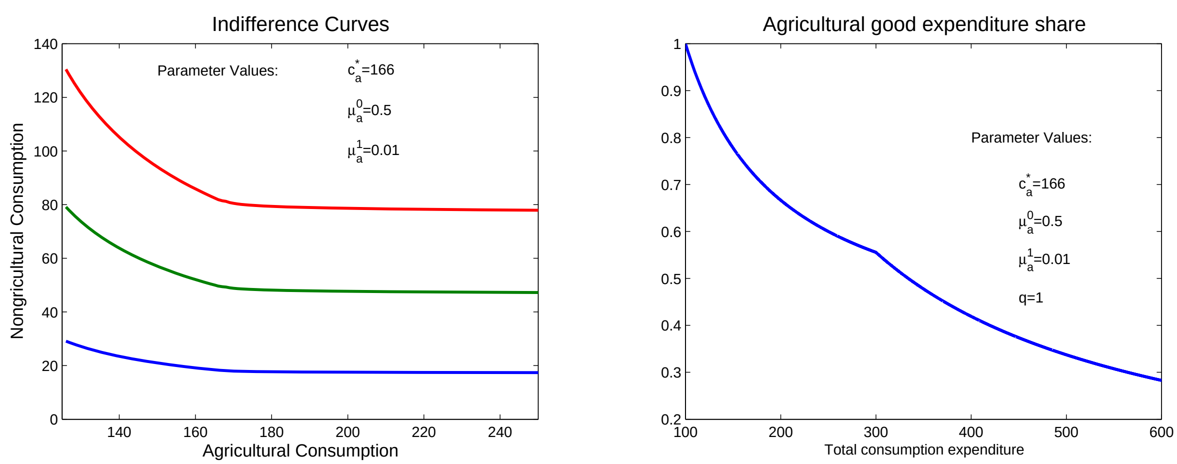
terpreted as the subsistence level[11]. μ_0 is the relative weight on agricultural consumption when this consumption is low. When agricultural consumption is higher than c_a^*, the relative weight on the agricultural consumption becomes μ_1, where $\mu_1 < \mu_0$. The constants A and B are defined as

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

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

Figure 2 illustrates graphically 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 relate 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 2: Graphical Description of Preferences



[11]My analysis focuses on economies where agricultural consumption is higher than the subsistence level $\underline{c_a}$, but one may think of it as the minimum consumption people need to survive. If population is such that the amount of agricultural good available is not enough, then population would probably adjust, but this is beyond the analysis of this paper because population evolves exogenously here.

The preferences in (2) is 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[12].

Households own capital and land, which is supplied inelastically to firms together with their labor[13]. 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 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.

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

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).

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

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

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

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

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

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

$$f_a\left(K_a, N_a, L_a\right) = k_a^{\alpha_a} n_a^{\beta_a}\left(L_a e^{-nt}\right)^{1-\alpha_a-\beta_a}$$

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

$$F^n\left(K_n, N_n\right) = K_n^{a_n} N_n^{1-\alpha_n}$$

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[14].

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

[14] 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.

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, both in the closed and open economy, the production factor markets clear at every point in time:

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

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

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

3.2 Closed Economy Equilibrium

Under autarky, the endogenous relative price adjusts so that the amount supplied of both goods is equal to the amount demanded[15]. 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*

[15]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 $y_a = c_a$.

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, and in the limit consumers behave as if their preferences were

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

Note that this may not be the case if population growth is very high because of the fact that there are decreasing returns to scale in the 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

$$(1 - \alpha_a - \beta_a)\, n < \frac{\alpha_a}{1 - \alpha_n}\gamma_n + \gamma_a \tag{18}$$

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 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*

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

$$\frac{\dot{c}_a}{c_a} = \gamma_a + \frac{\alpha_a}{1-\alpha_n}\gamma_n - (1-\alpha_a-\beta)\, n$$

$$\frac{\dot{q}}{q} = (1-\alpha_a-\beta)\, n + \frac{1-\alpha_a}{1-\alpha_n}\gamma_n - \gamma_a$$

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

3.3 Open Economy Equilibrium

In the open economy there is trade in final goods, but there is no 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, assuming that the international price is below the level at which 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 every date:

$$qx_a + x_n = 0 \tag{21}$$

Also, the country is assumed to be small relative to the rest of the world, so it takes the international relative price as given. Thus, both so that both q and $\gamma_q \equiv \dot{q}/q$ are exogenous, and 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 $\left((1-\alpha_a-\beta_a)\,n + \frac{1-\alpha_a}{1-\alpha_n}\gamma_n - \gamma_a\right)$:*

- *If* $\gamma_q \leq (1-\alpha_a-\beta_a)\,n + \frac{1-\alpha_a}{1-\alpha_n}\gamma_n - \gamma_a$

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

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

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 nonagricultural good.

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

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

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

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

3.4 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, that is structural transformation takes place.

More formally, in a closed economy equilibrium,

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

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[16].

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

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

where

$$\Psi\left(n_a\right) = \frac{n_a^{1-\alpha_a-\beta_a}}{\left(\frac{\beta_a}{\alpha_a} - n_a\left(\frac{\beta_a}{\alpha_a} - \frac{1-\alpha_n}{\alpha_n}\right)\right)^{\alpha_n-\alpha_a}}$$

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 also 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 is 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 depend only 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 have to become agricultural exporter necessarily. The reason is that if the productivity growth difference is even larger in other countries, the fall in the international price q will prevent it.

[16] Only if there are periods in which the fraction of nonagricultural output spent on consumption increases by enough we will observe an increase in the agricultural employment share n_a in spite of the income growth.

Trade affects economic growth 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 increase or decrease capital accumulation: for nonagricultural exporters trade increases capital accumulation, since the nonagricultural good is more capital intensive, but for agricultural exporters trade decreases it.

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).

4 Model Calibration and United States Structural Transformation

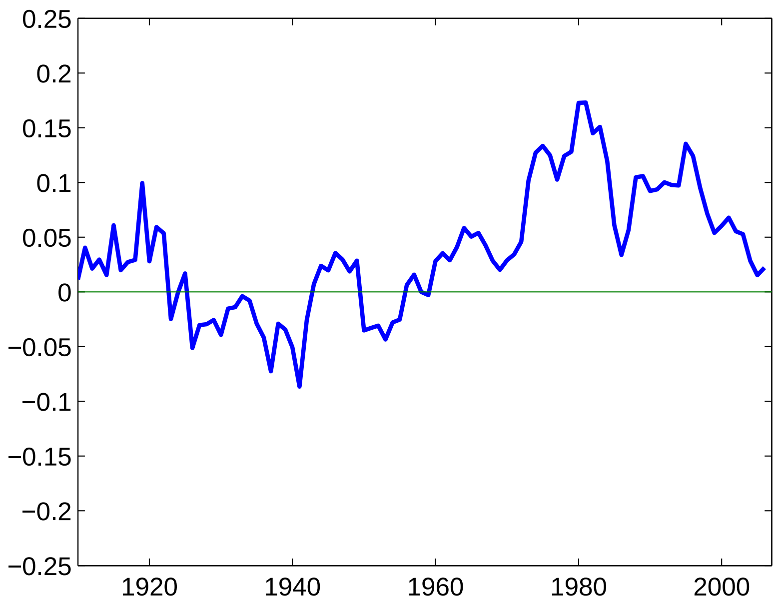
In this section and the two that follow, I simulate the model and compare the simulations to the structural transformations in the United States during the period 1890 - 2007, South Korea during the period 1963 - 2007, and the United Kingdom during the period 1800 - 1900. The parameter values used are the same in all the simulations[17], and the only difference in the three simulations is the time path of 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 closed economy model to match the United States data. Although the United States is not a closed economy, its net agricultural exports are low in relation to its production, so

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

I assume that its agricultural production is equal to its agricultural consumption at every date. 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%. This ratio is shown in figure 3[18].

Figure 3: 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 it possible to calibrate the parameters that determine the long run. Second, it illustrates the elements behind industrialization under autarky, like productivity growth in the two sectors and capital accumulation.

In 1890, agricultural employment in the United States was 40% of total employment, and it is currently around 1%. The lack of reliable data for some variables like capital stock and

[18]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.

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.

sectoral ouptut makes it difficult to start the analysis earlier.

4.1 Model Calibration

The parameters that must be calibrated are the production functions parameters (α_a, β_a, α_n), 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, $1 - \alpha_n$, is 2/3. This is the customary value used in the literature[19], and it is exactly equal to the average labor income share on total nonagricultural income for South Korea during the period 1963-1995[20].

The value used for the labor exponent in the agricultural good production function, β_a, 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[21]. The agricultural capital exponent in the agricultural production function, α_a 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[22].

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 is the value that makes the long run capital output ratio in the model match 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.

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

[20] The income shares series are taken from Kim and Hong (1997), published by the Korea Development Institute. See page 79 for the nonagricultural income shares, and page 67 for the agricultural income shares.

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

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

The value of the preference parameter μ_1 is 0.01, which is chosen so that the the model is able to match the long run agricultural employment share, as observed in the United States. The preference parameter μ_0 is equal to 0.5, and it is chosen to fit the agricultural consumption data for South Korea since it only plays a role for 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 Korea estimation.

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**
$\boldsymbol{\alpha}_n$	Capital share nonagr sector	1/3
$\boldsymbol{\alpha}_a$	Capital share agr sector	0.21
β_a	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

4.2 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), 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 7 and figure 15 in Appendix C 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 in 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 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 and 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 until 6%, and the nonagricultural growth rate starting at 0.2% and increasing until 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.

4.3 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 4 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 replicate quite successfully the agricultural employment share data, although it seems to slightly underpredict it in the initial years. The model also matches pretty 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 WWII. The fit of the model is also quite 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 WWII. This fluctuations in the relative price are probably related to the fact that the nonagricultural sector TFP is below its trend during the Great Depression years, and above its trend during the WWII years as we can see in figure in appendix C.15

4.4 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 4: Model Simulation vs United States Data

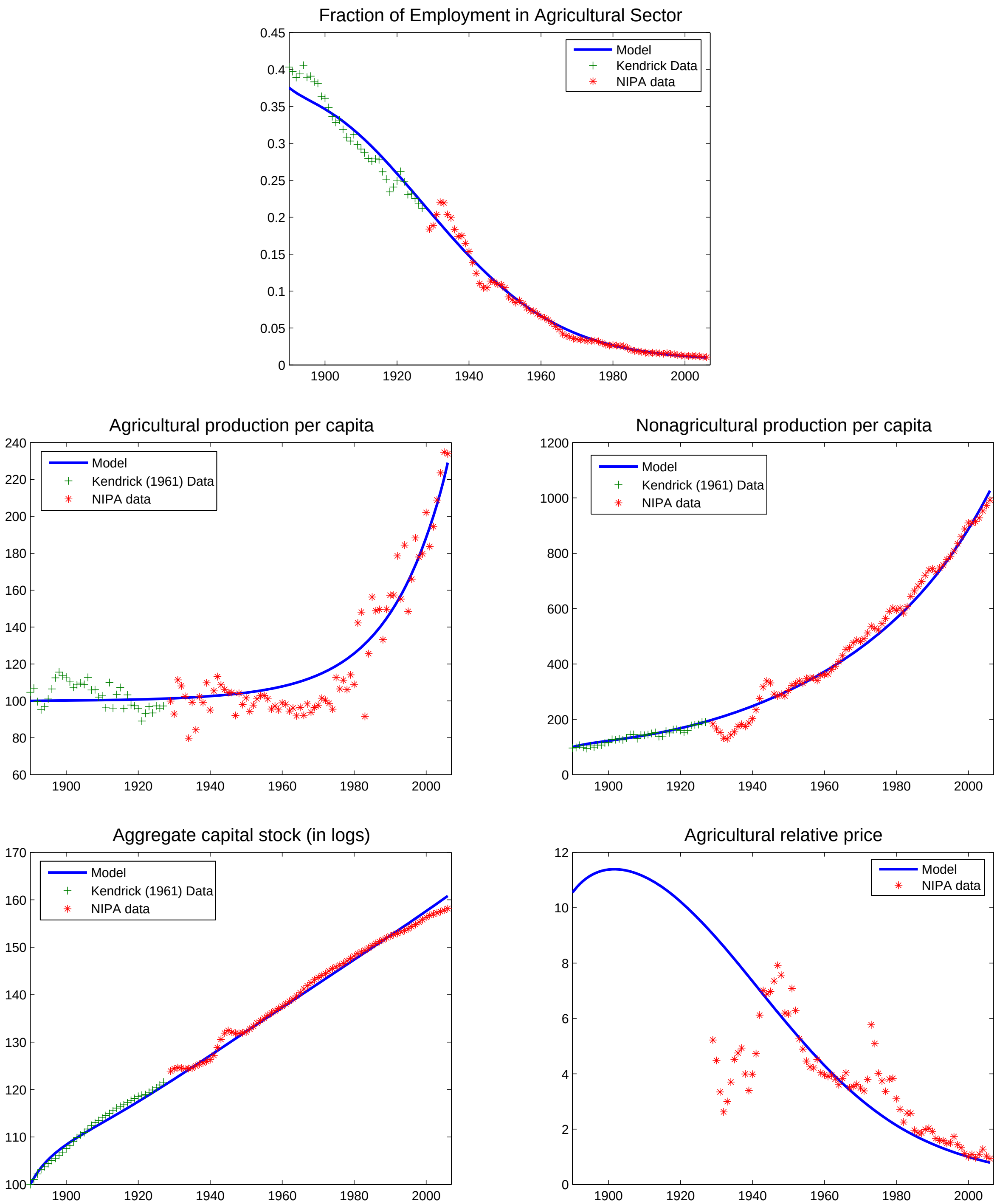


Figure 5 shows the effects of changing the initial productivity levels. If initial productivity in the agricultural sector had been half of what it was, the agricultural employment share would have been much higher. A lower initial productivity in the nonagricultural sector, on the other side, also increases the agricultural employment share but the effects are much smaller. When productivity is lower, agents are poorer and they allocate a larger fraction of their resources in the agricultural sector because of the low income elasticity of the agricultural good. However, we can see that it is a low agricultural productivity what leads to a very large agricultural employment share.

Figure 5: United States Simulations: Changes in Initial Productivity Level

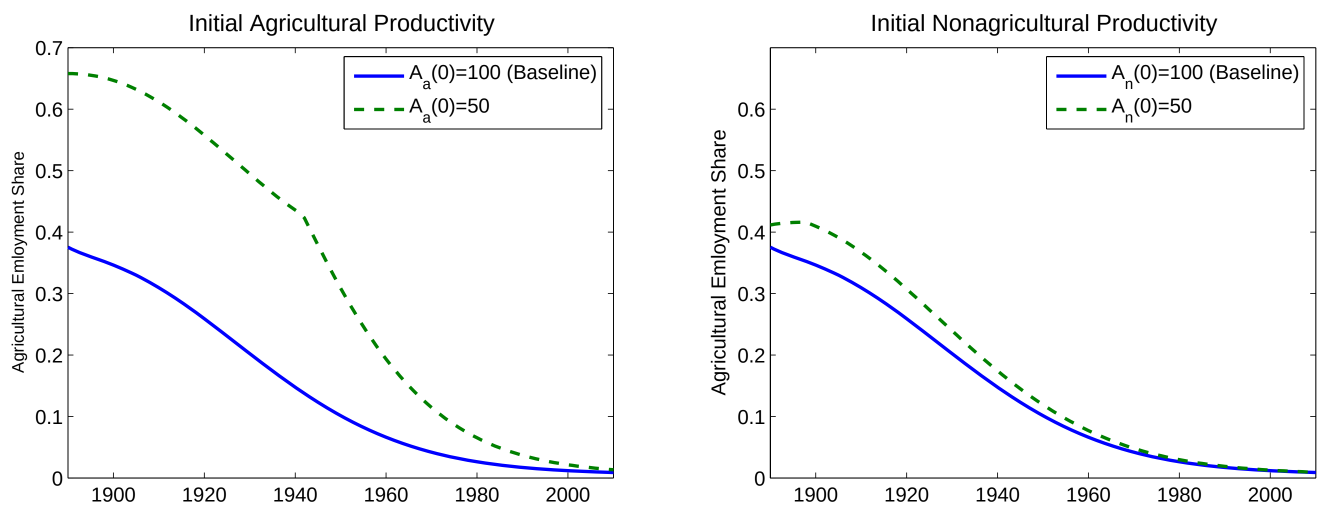
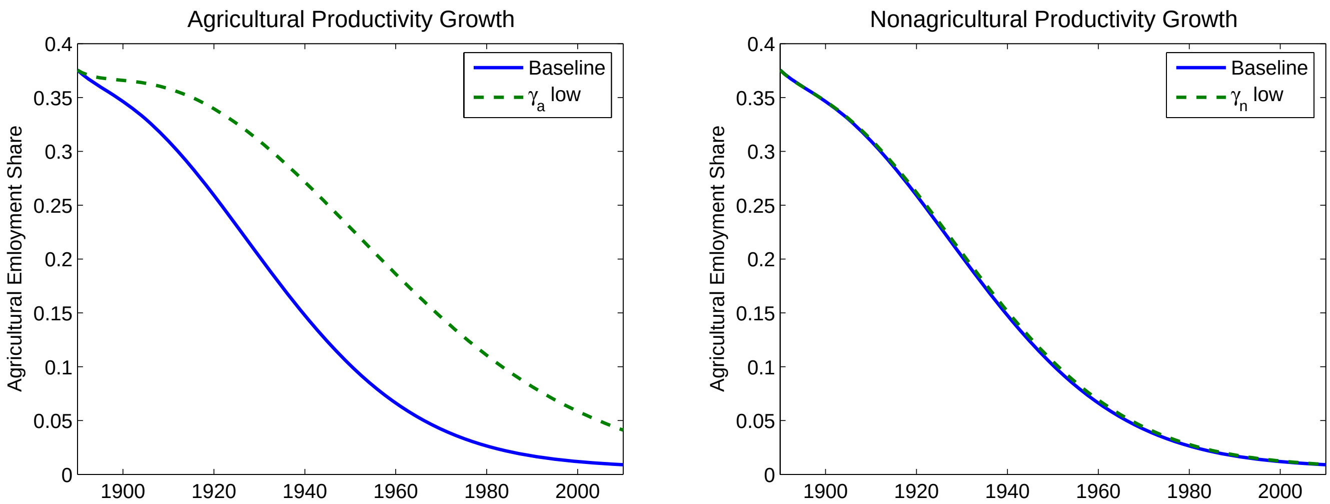


Figure 6 shows the effects of changing the productivity growth rates. We can see that a decrease in the agricultural productivity growth rate by half leads to a slower transformation process, but the same decrease in the nonagricultural productivity growth rate has almost no effect on the agricultural employment share.

Figure 6: United States Simulations: Changes in Productivity Growth



5 South Korea Structural Transformation

In this section, I simulate the open economy model using South Korea 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.

5.1 Exogenous Variables Specification

The agricultural sector is defined in the data as Agriculture, Forestry and Fishing, and the nonagricultural sector is the rest of the economy.

The initial capital stock is its actual value in the data for the year 1963[23], which is equal to 2.87 times the nonagricultural output level.

The exogenous variables that need to be specified in the open economy are total population, total employment, agricultural TFP, and nonagricultural TFP, as before, together with the agricultural relative price. Appendix D offers a detailed description of the data

[23] Capital stock data is available for the period 1962-1995 from the Korea Development Institute, as described in appendix D.

sources of the time series used to compute them. Table 9 summarizes each of the exogenous variables, and figure 16 shows the exogenous variables used in the simulations together with the data.

As before, 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 average population growth of the last 10 years. Figure 16 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%.

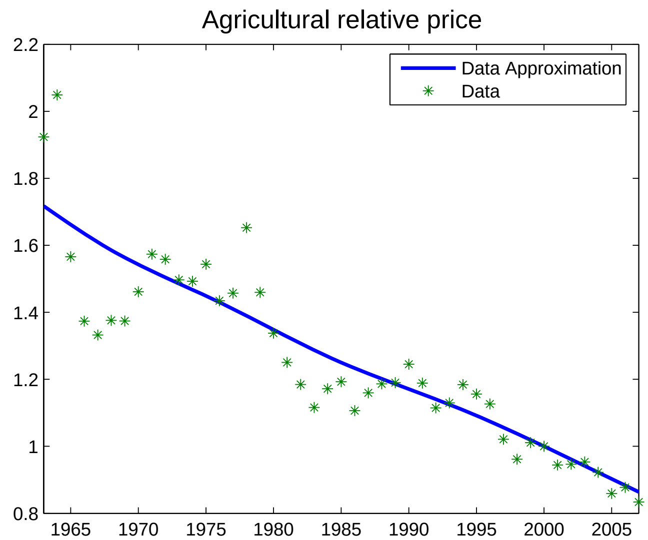
Agricultural and nonagricultural TFPs are assumed to have constant growth, since the data do not show any important trend. The growth rates chosen for both are the ones that make the simulated production variables fit the actual production variables. As we can see in figure 16 in Appendix D, these growth rates are a very close approximation to the ones of the measured data[24].

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

[24] For the 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 the 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 not to use the average estimated in the data is to get a good fit of 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.

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 7 plots the measured data and the variable used in the simulations.

Figure 7: South Korea Agricultural Relative Price



Government Policies

There is a large literature documenting the efforts by the Korean government to protect the agricultural sector and increase the income of the agricultural producers. The two main policy tools have been the agricultural production subsidies, which according to the OECD estimates[25] were 56% in 1980 and 65% in 2000, and the agricultural import tariffs, which according to the United States Department of Agriculture[26] were 64% in 1975 and 104% in 1990 for the aggregate agricultural sector[27]. 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 make

[25] See the OECD report "Agricultural Policies at a glance", 2008.

[26] See the USDA Agricultural Economic Report number 809 "Structural Change and Agricultural Protection: Costs of Korean Agricultural Policy, 1975 and 1990", 2002.

[27] The USDA study computes the tariff equivalent rate, which takes into account not only explicit import tariff rates but also quantitative restrictions, like direct government bans and quotas.

sure 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, 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".

5.2 South Korea Simulation Results

In this section the outcome of the simulated model is compared with the actual data. Figure 8 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, 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 jump up. 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 fitting 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 grows more slowly after that date.

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

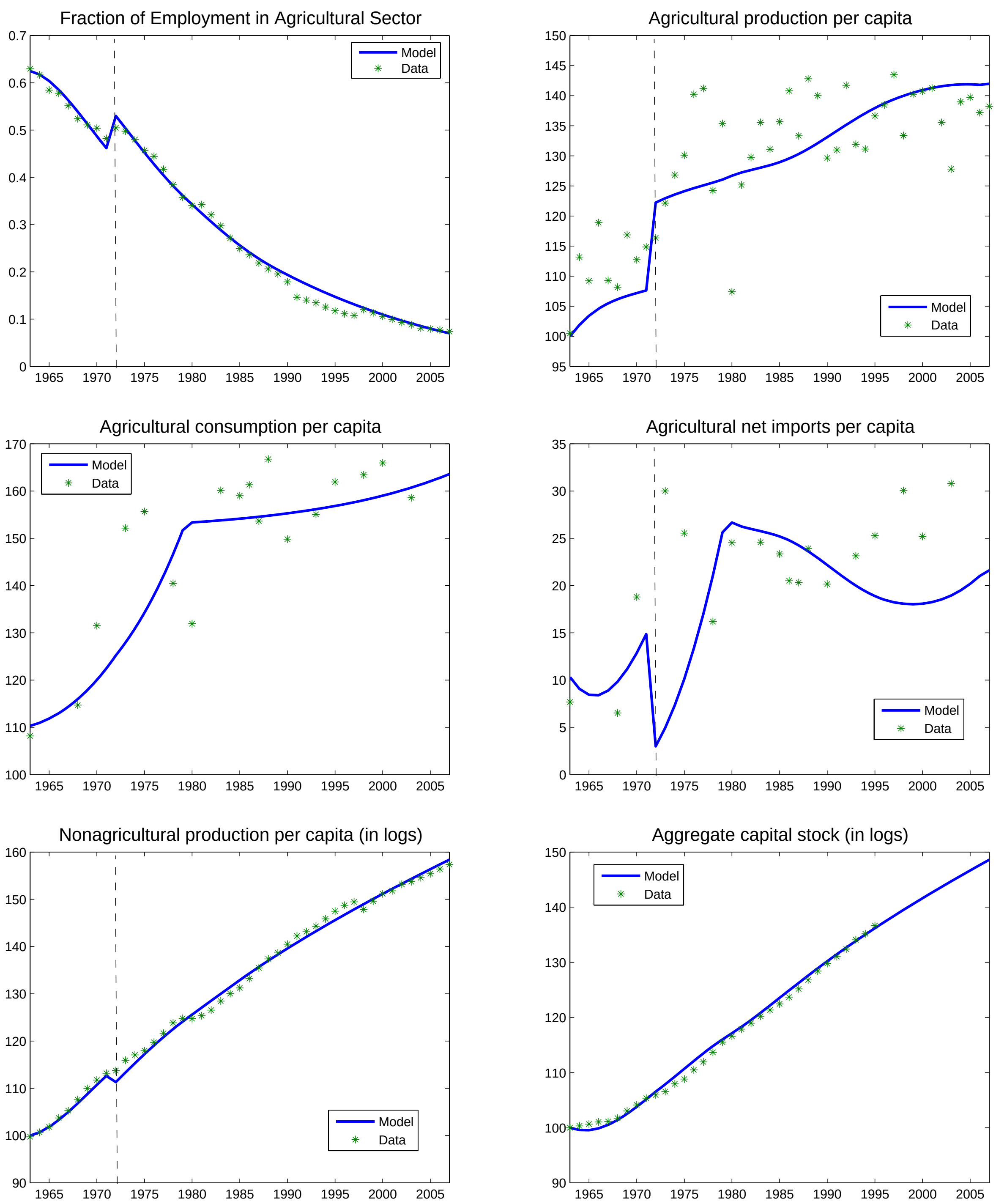
5.3 Policy Experiments: Autarky and Free Trade

To evaluate the importance of international trade, which offers South Korea the possibility of importing part of the agricultural good consumed, for its structural transformation process, I perform two counterfactual exercises. The first one 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 one 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 its dependency from 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 the 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 9 shows how the autarky model simulation compares with the South Korea simulation: the agricultural relative price would have been significantly larger, the agricultural

Figure 8: Model Simulation vs South Korea Data



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 than it actually was, 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.

Table 3 shows that 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 yearly consumption expenditures.

The second counterfactual exercise, which I label as 'No Agricultural Policy' or 'Free Trade', predicts what would have been the South Korea development process if there had been no government policies trying to protects the agricultural sector by introducing a production subsidy 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 already using data on domestic prices and I assumed it did not generate any income for the country What I do here is to 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 price in the US is 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 110%. Figure 10 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 9: South Korea: Baseline Simulation vs Autarky Simulation

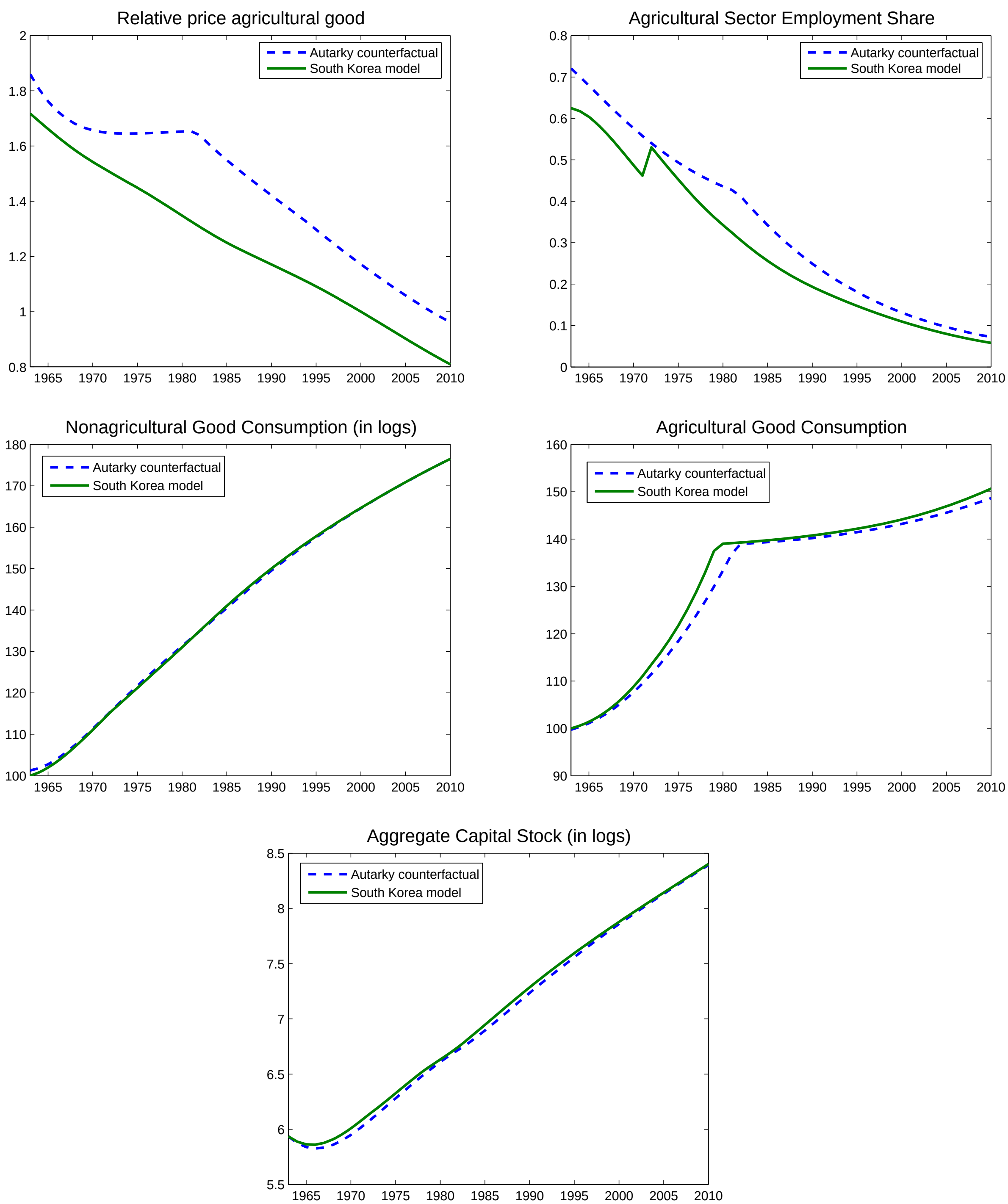


Figure 10: Agricultural Relative Price with and without Agricultural Import Tariffs

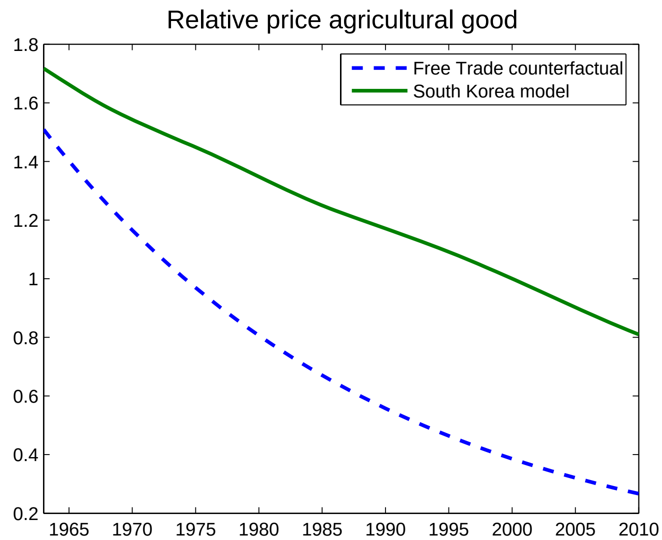
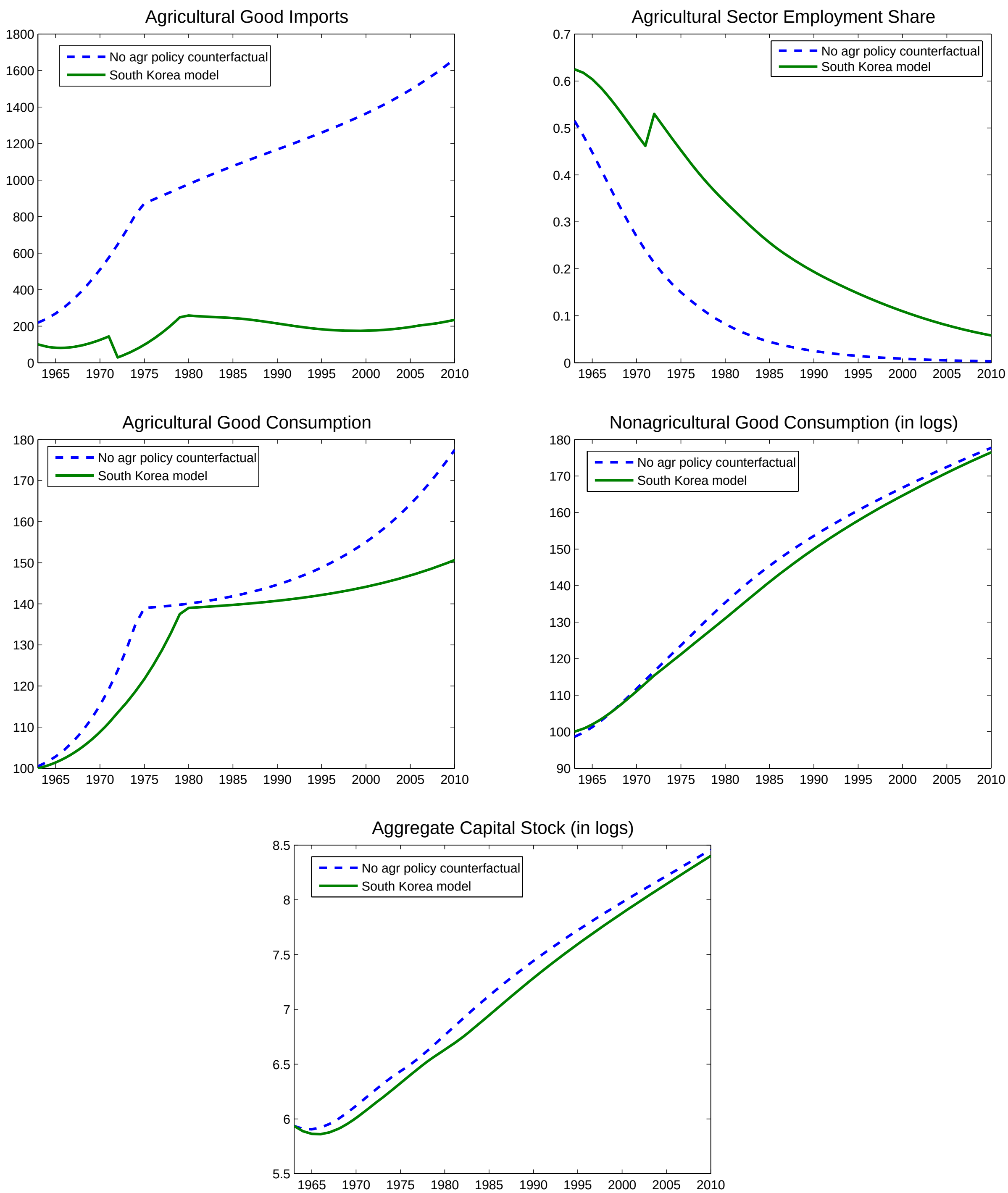


Figure 11 shows the comparison of this counterfactual with respect to the South Korea simulation. The first plot compares the agricultural net imports, second plot compares the agricultural sector employment share, the third plot compares the agricultural consumption per capita, the fourth one the nonagricultural consumption per capita, and the fifth one the capital stock per capita. They show that South Korea would have had a much higher level of net agricultural imports, a much lower agricultural employment share, a significantly higher agricultural consumption, a somewhat higher nonagricultural consumption, and a significantly larger capital stock if it 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

Figure 11: South Korea: Baseline Simulation vs No Agricultural Policy Simulation



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.

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 shows that if there had been no agricultural production subsidy, the intertemporal welfare gain of the representative consumer with respect to autarky would have been the equivalent of a 0.5% annual increase in the consumption expenditures. If there had been no agricultural production subsidy and no 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 3: South Korea - Trade Intertemporal Welfare Gain

Autarky	**Baseline**	**No subsidy**	**No Agr Policy**
0	0.4%	0.5%	5.5%

6 United Kingdom Structural Transformation

In this section, I first simulate again the open economy model, in this case using United Kingdom data of the period 1800 - 1900 for the exogenous variables. Then I simulate the closed economy model to ask what would have occurred if the United Kingdom had not had to foreign imports of agricultural products.

Stokey (2001) finds that international trade had an important contribution in the industrial revolution of the United Kingdom. The exercise here provides a check on her conclusions, using a somewhat different model.

6.1 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 most of the data, and the nonagricultural sector is the rest of the economy.

The initial capital stock is its actual value in the data for the year 1800[28], 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, taken from different sources, and its growth rate during the sample period starts 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 approximately 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 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%.

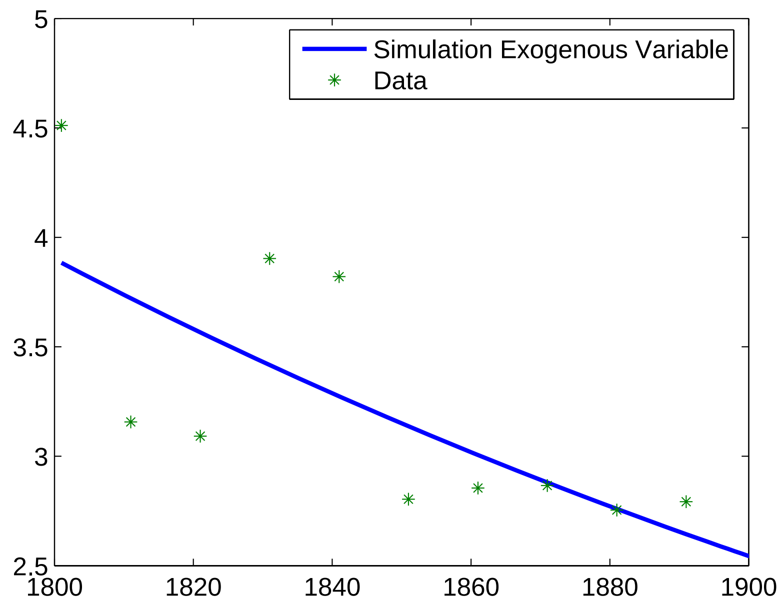
Agricultural and nonagricultural TFPs are assumed to have constant growth, and the values used for the growth rates are the ones that make the simulated production series fit the actual production data, with the agricultural TFP growth rate being equal to 1.25% and the nonagricultural TFP equal to 0.65%. As we can see in figure in Appendix E , these growth rates are a close approximation to the ones of the measured TFPs, which are measured

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

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, since the data on sectoral capital stocks does not seem very reliable.

Finally, the relative agricultural price is taken from the data, imposing a constant growth rate. 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 12 plots the measured data and the variable used in the simulations.

Figure 12: United Kingdom Agricultural Relative Price



6.2 United Kingdom Simulation Results

In this section the outcome of the simulated model is compared with the actual data. Figure 13 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.

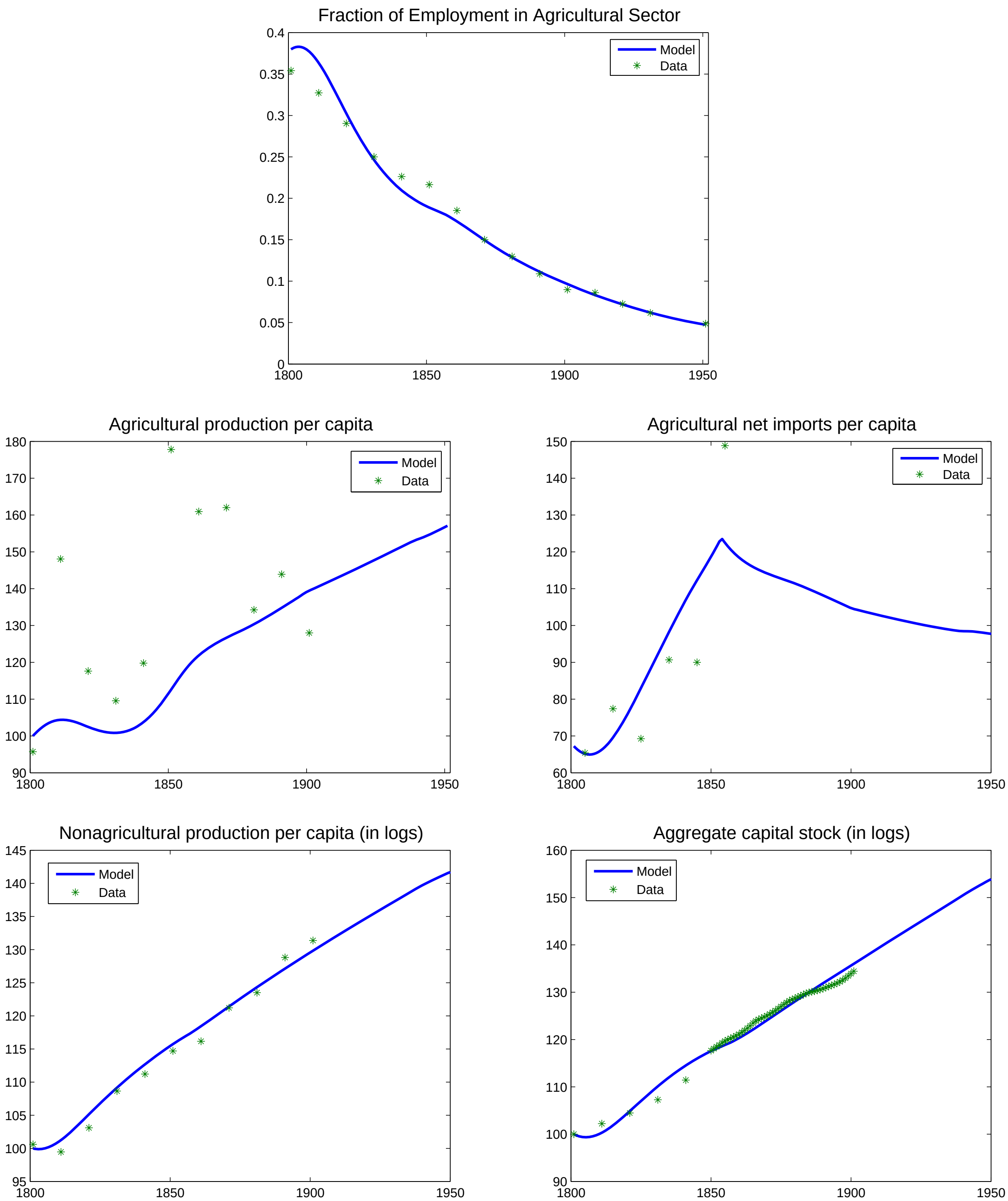
The first plot shows the agricultural employment share, and we can see that the model is able to capture the main features of the data, although it overpredicts the data initially and then it underpredicts it around 1850. The variable in the second plot is agricultural production per capita, and it shows that the model is able to get quite 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.

6.3 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. To predict the transition of process of the United Kingdom under autarky, the closed economy simulation using the same exogenous variables and initial conditions as in the open economy simulation.

Figure 14 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

Figure 13: Model Simulation vs United Kingdom Data



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 4 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 consumption per capita 5.41% lower, and its capital stock 20.8% lower.

Table 4: United Kingdom Sample Period Results Comparison

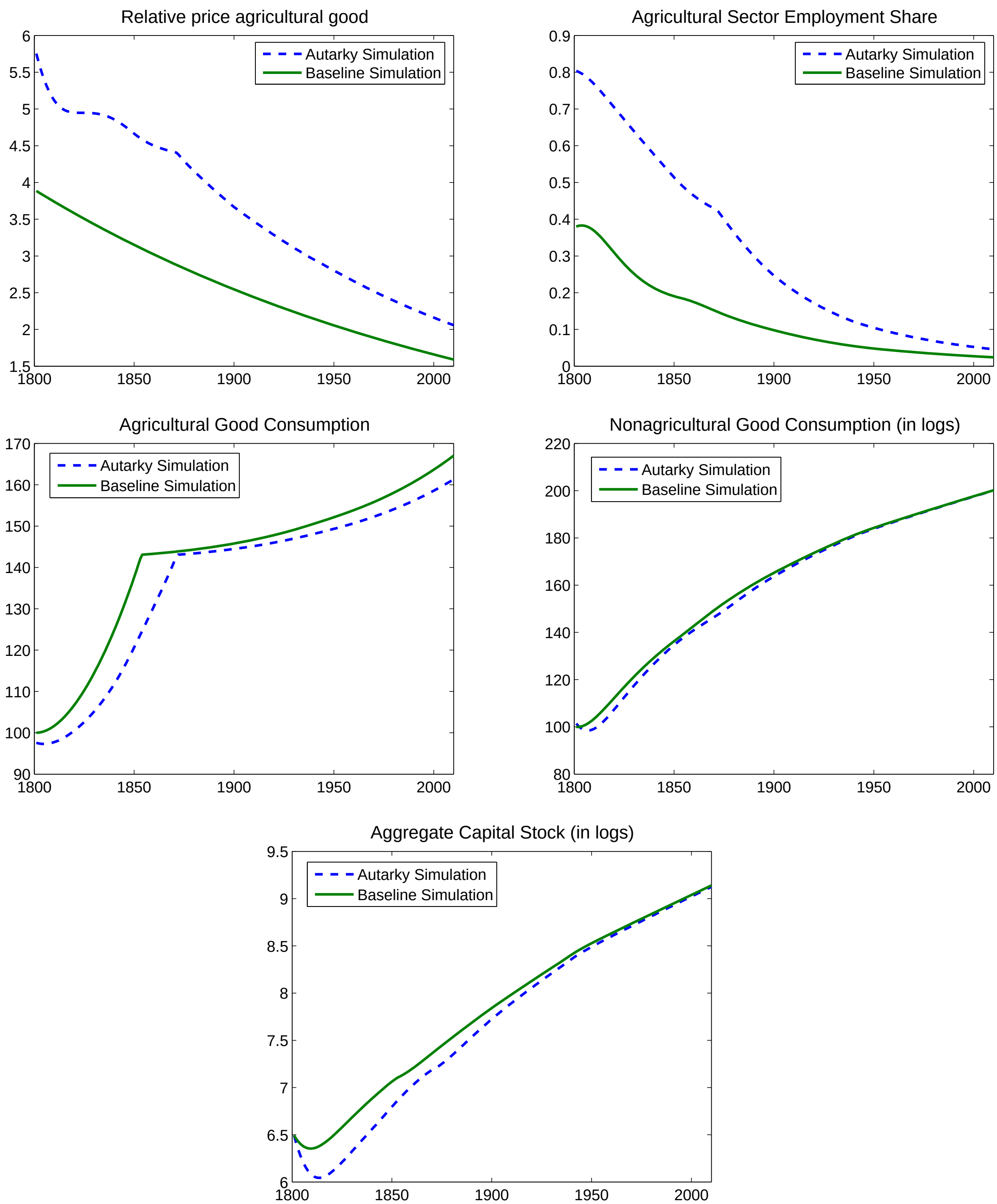
%	**q gap (avg)**	**n_a gap (avg)**	**c_n gap (avg)**	**c_a gap (avg)**	**k gap (avg)**
Baseline Simulation	0	0	0	0	0
Autarky Simulation	45.8	155.7	-10.5	-5.4	-20.8

Table 5 shows the extra intertemporal welfare the United Kingdom enjoyed due to the fact it was open to international trade: compared to the autarky situation, the United Kingdom experienced a gain in welfare equivalent to increasing by 5.5% the annual consumption expenditures.

Table 5: United Kingdom - Trade Intertemporal Welfare Gain

Autarky	**Baseline**
0	5.5%

Figure 14: United Kingdom: Baseline Simulation vs Autarky Simulation



7 Conclusions

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

The 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 be able to match the structural transformation process in the United States during the period 1890-2007. The exercise illustrates the importance of productivity growth, especially in the agricultural sector.

Then, the open economy version of the model is shown to be able to match the structural transformation of the United Kindom during the period 1801-1901, and of South Korea during the period 1963-2007. In both cases, since the relative price of the agricultural good in the international market was lower than the one they would have faced under autarky, the countries imported agricultural goods during the entire sample period, which implies that trade played a positive role in their transformation processes. The model is then simulated under the assumption that countries were under autarky to compare the simulation 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 process, confirming the results Stokey (2001) in a somewhat different model. In particular, if the country had been under autarky, the relative price of the agricultural good would have been 46% larger on average during the sample period, the share of employment in the agricultural sector would have been 156% larger, the nonagricultural good consumption would have been 10% lower on average, the agricultural good consumption would have been 5% lower, and the capital stock would have been 21% lower on average. The intertemporal welfare gain the United Kingdom experienced from the intersectoral trade with the rest of the world is equivalent to a 5.5% increase in the yearly consumption expenditures under autarky.

In the case of South Korea during the last 45 years, the results show that international trade had a negative effect on the agricultural relative price and on the agricultural employment share: the relative price of the agricultural good would have been 17% larger on average if South Korea had been under autarky, and the share of employment in the agricultural sector would have been 21% larger on average. Agricultural and nonagricultural consumption, however, would not have been much different during the sample period, and the intertemporal welfare gain South Korea experienced because of international trade is equivalent to less than a 0.4% increase in the autarky yearly consumption expenditures. The conclusion, therefore, is that the role actually played by international trade is small compared to other factors like total factor productivity in both sectors, and capital accumulation.

However, it is important to note that South Korea had a very active role in protecting its agricultural sector to reduce its dependency from foreign agricultural imports. With that goal, South Korea introduced agricultural production subsidies in the early 70s, and applied tariffs to the agricultural imports during the entire sample period. When the model is simulated without the agricultural production subsidy and without the agricultural import tariffs, it shows that international trade would have played a much larger role and the country would have experienced an even faster structural transformation process. In this counterfactual scenario, the gain in intertemporal welfare compared to autarky is equivalent to an increase of 5.5% in the autarky annual consumption expenditures.

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Appendices

A Closed Economy Analysis

[to be completed]

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 $s_k(t) \equiv \frac{K_a(t)}{K(t)}$.

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

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

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

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

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

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):*

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

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

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

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

Proof. [to be completed]

- If the preferences are the ones in equation (17), imposing that all variables grow at constant rate gives solution shown above.

□

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

$$\begin{aligned}
\widehat{k}(t) &\equiv \frac{k(t)}{A_n(t)^{\frac{1}{1-\alpha_n}}} \\
\widehat{c_n}(t) &\equiv \frac{c_n(t)}{A_n(t)^{\frac{1}{1-\alpha_n}}} \\
\widehat{q}(t) &\equiv \frac{q(t)}{\frac{A_n(t)^{\frac{1-\alpha_a}{1-\alpha_n}}}{A_a(t)L^{1-\alpha_a-\beta_a}}\left(N(t)\right)^{1-\alpha_a-\beta_a}}
\end{aligned}$$

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):*

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

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

$$\widehat{q}(t)\,\alpha_a\frac{(s_e(t))^{\beta_a}}{\left(s_k(t)\widehat{k}(t)\right)^{1-\alpha_a}} = \alpha_n\frac{((1-s_e(t)))^{1-\alpha_n}}{\left((1-s_k(t))\widehat{k}(t)\right)^{1-\alpha_n}} \tag{34}$$

$$\widehat{q}(t)\,\beta_a\frac{\left(s_k(t)\widehat{k}(t)\right)^{\alpha_a}}{(s_e(t))^{1-\beta_a}} = (1-\alpha_n)\frac{\left((1-s_k(t))\widehat{k}(t)\right)^{\alpha_n}}{(1-s_e(t))^{\alpha_n}} \tag{35}$$

$$\begin{aligned}
\left(s_k(t)\widehat{k}(t)\right)^{\alpha_a}(s_e(t))^{\beta_a} &= \begin{cases} z(t)\,\underline{c_a} + \mu_0\frac{\widehat{c_n}(t)}{\widehat{q}(t)} & \text{if } c_a(t) \le c_a^* \\ z(t)\,c_a^* + \mu_1\frac{\widehat{c_n}(t)}{\widehat{q}(t)} & c_a(t) > c_a^* \end{cases} \\
\text{where } z(t) &\equiv \frac{N(t)^{1-\alpha_a-\beta_a}}{A_a(t)\,L^{1-\alpha_a-\beta_a}A_n(t)^{\frac{\alpha_a}{1-\alpha_n}}}
\end{aligned} \tag{36}$$

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

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.*

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

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

$$\widehat{q}^{ss}\alpha_a \frac{\left(s_e^{ss}\right)^{\beta_a}}{\left(s_k^{ss}\widehat{k}^{ss}\right)^{1-\alpha_a}} = \alpha_n \frac{\left(1 - s_e^{ss}\right)^{1-\alpha_n}}{\left(\left(1 - s_k^{ss}\right)\widehat{k}^{ss}\right)^{1-\alpha_n}} \tag{40}$$

$$\widehat{q}^{ss}\beta_a \frac{\left(s_k^{ss}\widehat{k}^{ss}\right)^{\alpha_a}}{\left(s_e^{ss}\right)^{1-\beta_a}} = \left(1 - \alpha_n\right) \frac{\left(\left(1 - s_k^{ss}\right)\widehat{k}^{ss}\right)^{\alpha_n}}{\left(\left(1 - s_e^{ss}\right)\right)^{\alpha_n}} \tag{41}$$

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

Proof. [to be completed]

- steady state of detrended equilibrium system exists as long as solution to the system of equations (38) - (42) exists.
- show that system exhibits saddle path stability (only one path converges to the steady state), computing eigenvalues and showing one positive and one negative...
- argue that all paths in the phase diagram violate the transversality condition.

□

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

Proof. [to be completed]

- if $\left(1 - \alpha_a - \beta_a\right) n < \gamma_a + \frac{\alpha_a}{1-\alpha_n}\gamma_n$, then

  $$\lim_{t\to\infty} \left\{ \frac{\dot{z}(t)}{z(t)} \right\} = \lim_{t\to\infty} \left\{ \left(1 - \alpha_a - \beta_a\right) n < \gamma_a + \frac{\alpha_a}{1-\alpha_n}\gamma_n \right\} = 0$$

  As a result,

  $$\lim_{t\to\infty} \left\{ z(t) \left(c_a^* - A\right) \right\} = 0$$

  which implies that same asymptotic equilibrium system when $\left(c_a^* - A\right) > 0$ and when $\left(c_a^* - A\right) = 0$.

- detrended equilibrium system with $(c_a^* - A) > 0$ also exhibits saddle path stability; therefore, only one path converges to the SS.
- any other path different than the one converging to SS violates transversality condition; therefore, convergent path is the only solution to the detrended equilibrium system.

□

Corollary 1. *The equilibrium solution is also the unique path that converges to the steady state defined in equations (38) - (42).*

B Open Economy Analysis

[to be completed]

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.

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

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

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-.

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

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

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.

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

$$s_e(t) = 1 \tag{48}$$

$$s_k(t) = 1 \tag{49}$$

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 ().

$$s_e(t) = 0 \tag{50}$$

$$s_k(t) = 0 \tag{51}$$

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):*

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

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

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

where $\widetilde{\gamma} \equiv (1-\alpha_a-\beta_a)n + \frac{1-\alpha_a}{1-\alpha_n}\gamma_n - \gamma_a$.

Proof. [to be completed]

- prove that when the preferences are the ones in equation (17), imposing that all variables grow at constant rate in the system of equations (43) - (46) gives solution shown above:
  - from equation (44), in BGP, $\frac{\dot{c_n(t)}}{c_n(t)} = \frac{\dot{k(t)}}{k(t)}$ and $\frac{\dot{x_n(t)}}{x_n(t)} = \frac{\dot{k(t)}}{k(t)}$; also, if $s_e^{ss} < 1$, $\frac{\dot{k(t)}}{k(t)} = \frac{1}{1-\alpha_n}\gamma_n$.
  - from equation (27), if $s_e^{ss} > 0$, $\gamma_q + \gamma_a + (\alpha_a - 1)\frac{\dot{k(t)}}{k(t)} - (1-\alpha_a-\beta_a)n = 0$, which implies that $\frac{\dot{k(t)}}{k(t)} = \frac{1}{1-\alpha_a}\left(\gamma_q + \gamma_a - (1-\alpha_a-\beta_a)n\right)$
  - hence, in order for $0 < s_e^{ss} < 1$, it must be that $\gamma_q = \frac{1-\alpha_a}{1-\alpha_n}\gamma_n + (1-\alpha_a-\beta_a)n - \gamma_a$.

□

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

Proof. [to be completed]

- prove that (see page 6g hand-written notes):
  - when $\gamma_q > \frac{1-\alpha_a}{1-\alpha_n}\gamma_n + (1-\alpha_a-\beta_a)n - \gamma_a$, it must be that $s_e^{ss} = 1$: contradiction with $0 < s_e^{ss} < 1$, contradiction with $s_e^{ss} = 0$.

* $\gamma_q > \frac{1-\alpha_a}{1-\alpha_n}\gamma_n + (1-\alpha_a-\beta_a)\,n - \gamma_a$ implies that $\frac{q(t)}{\frac{A_n(t)^{(1-\alpha_a)/(1-\alpha_n)}}{A_a(t)\left(\frac{L}{N(t)}\right)^{1-\alpha_a-\beta_a}}}$ growing over time.
* as a result, there is no constant s_e^{ss} satisfying

$$\frac{q(t)}{\frac{A_n(t)^{(1-\alpha_a)/(1-\alpha_n)}}{A_a(t)\left(\frac{L}{N(t)}\right)^{1-\alpha_a-\beta_a}}}\alpha_a\frac{\left(s_e^{ss}\right)^{\beta_a}L^{1-\alpha_a-\beta_a}}{\left(s_k^{ss}\widehat{k}^{ss}\right)^{1-\alpha_a}} = \alpha_n\frac{\left(1-s_e^{ss}\right)^{1-\alpha_n}}{\left(\left(1-s_k^{ss}\right)\widehat{k}^{ss}\right)^{1-\alpha_n}}$$

which implies that either $s_e^{ss}=0$ or $s_e^{ss}=1$.
* also,

$$\frac{q(t)}{\frac{A_n(t)^{(1-\alpha_a)/(1-\alpha_n)}}{A_a(t)\left(\frac{L}{N(t)}\right)^{1-\alpha_a-\beta_a}}}\alpha_a\left(\widehat{k}^{ss}\right)^{\alpha_a-1}\left[\lim_{s_e\to 0}\left\{s_e{}^{\alpha_a+\beta_a-1}\right\}\right] > \alpha_n\left(\frac{\frac{1-\alpha_n}{\alpha_n}}{\frac{\beta}{\alpha_a}}\right)^{-\alpha_a}\left(\widehat{k}^{ss}\right)^{\alpha_n-1}$$

which implies that $s_e^{ss}>0$.
* Hence, $s_e^{ss}=1$.

– when $\gamma_q < \frac{1-\alpha_a}{1-\alpha_n}\gamma_n + (1-\alpha_a-\beta_a)\,n - \gamma_a$, it must be that $s_e^{ss}=1$: contradiction with $0<s_e^{ss}<1$, contradiction with $s_e^{ss}=0$.

* $\gamma_q < \frac{1-\alpha_a}{1-\alpha_n}\gamma_n + (1-\alpha_a-\beta_a)\,n - \gamma_a$ implies that $\frac{q(t)}{\frac{A_n(t)^{(1-\alpha_a)/(1-\alpha_n)}}{A_a(t)\left(\frac{1}{N(t)}\right)^{1-\alpha_a-\beta_a}}}$ decreasing over time.
* as a result, there is no constant s_e^{ss} satisfying

$$\frac{q(t)}{\frac{A_n(t)^{(1-\alpha_a)/(1-\alpha_n)}}{A_a(t)\left(\frac{L}{N(t)}\right)^{1-\alpha_a-\beta_a}}}\alpha_a\frac{\left(s_e^{ss}\right)^{\beta_a}L^{1-\alpha_a-\beta_a}}{\left(s_k^{ss}\widehat{k}^{ss}\right)^{1-\alpha_a}} = \alpha_n\frac{\left(1-s_e^{ss}\right)^{1-\alpha_n}}{\left(\left(1-s_k^{ss}\right)\widehat{k}^{ss}\right)^{1-\alpha_n}}$$

which implies that either $s_e^{ss}=0$ or $s_e^{ss}=1$.
* also,

$$\frac{q(t)}{\frac{A_n(t)^{(1-\alpha_a)/(1-\alpha_n)}}{A_a(t)\left(\frac{L}{N(t)}\right)^{1-\alpha_a-\beta_a}}}\alpha_a\left(\widehat{k}^{ss}\right)^{\alpha_a-1} < \alpha_n\left(\widehat{k}^{ss}\right)^{\alpha_n-1}\left(\frac{\frac{1-\alpha_n}{\alpha_n}}{\frac{\beta}{\alpha_a}}\right)^{1-\alpha_n}$$

which implies that $s_e^{ss}<1$.
* Hence, $s_e^{ss}=0$.

□

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.*

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

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

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

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 $s_e(t) = s_k(t) = 1$.*

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

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

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

$$
\frac{q(t)}{\frac{A_n(t)^{(1-\alpha_a)/(1-\alpha_n)}}{A_a(t)\left(\frac{1}{N(t)}\right)^{1-\alpha_a-\beta_a}}} \alpha_a \frac{(s_e(t))^{\beta_a} L^{1-\alpha_a-\beta_a}}{\left(s_k(t)\widehat{k}(t)\right)^{1-\alpha_a}} = \alpha_n \frac{((1-s_e(t)))^{1-\alpha_n}}{\left((1-s_k(t))\widehat{k}(t)\right)^{1-\alpha_n}} \tag{61}
$$

$$
\frac{q(t)}{\frac{A_n(t)^{(1-\alpha_a)/(1-\alpha_n)}}{A_a(t)\left(\frac{1}{N(t)}\right)^{1-\alpha_a-\beta_a}}} \beta_a \frac{\left(s_k(t)\widehat{k}(t)\right)^{\alpha_a} L^{1-\alpha_a-\beta_a}}{(s_e(t))^{1-\beta_a}} = (1-\alpha_n) \frac{\left((1-s_k(t))\widehat{k}(t)\right)^{\alpha_n}}{(1-s_e(t))^{\alpha_n}} \tag{62}
$$

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

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.*

Proof. [to be completed]

- steady state of detrended equilibrium system exists as long as there exists solution to the system of equations defining steady state.
- show that system exhibits saddle path stability (only one path converges to the steady state), computing eigenvalues and showing one positive and one negative...
- argue that all paths in the phase diagram violate the transversality condition.

□

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

Proof. [to be completed]

- if $0<s_e(t)<1$
  - $(1-\alpha_a-\beta_a)\,n<\gamma_a+\frac{\alpha_a}{1-\alpha_n}\gamma_n$ implies

    $$\lim_{t\to\infty}\left\{\frac{\dot{z^1}(t)}{z^1(t)}\right\}=\lim_{t\to\infty}\left\{(1-\alpha_a-\beta_a)\,n<\gamma_a+\frac{\alpha_a}{1-\alpha_n}\gamma_n\right\}=0$$

    As a result,

    $$\lim_{t\to\infty}\left\{z^1(t)\,\underline{c_a}\right\}=0$$

    which implies that same asymptotic equilibrium system when $\underline{c_a}>0$ and when $\underline{c_a}=0$.
  - detrended equilibrium system with $\underline{c_a}>0$ also exhibits saddle path stability; therefore, only one path converges to the SS.
  - any other path different than the one converging to SS violates transversality condition; therefore, convergent path is the only solution to the detrended equilibrium system.
- if $s_e(t)=1$,
  - $(1-\alpha_a-\beta_a)\,n<\gamma_a+\frac{\alpha_a}{1-\alpha_n}\gamma_n$ together with $\gamma_q<\frac{1-\alpha_a}{1-\alpha_n}\gamma_n+(1-\alpha_a-\beta_a)\,n-\gamma_a$ implies that $\alpha_a\gamma_q+\gamma_a>(1-\alpha_a-\beta_a)\,n$; as a result

    $$\lim_{t\to\infty}\left\{z^2(t)\,\underline{c_a}\right\}=0$$

    which implies that same asymptotic equilibrium system when $\underline{c_a}>0$ and when $\underline{c_a}=0$.
- If $s_e(t)=0$,
  - $(1-\alpha_a-\beta_a)\,n<\gamma_a+\frac{\alpha_a}{1-\alpha_n}\gamma_n$ together with $\gamma_q>\frac{1-\alpha_a}{1-\alpha_n}\gamma_n+(1-\alpha_a-\beta_a)\,n-\gamma_a$ implies that $\gamma_q<\frac{1}{1-\alpha_n}n$; as a result

    $$\lim_{t\to\infty}\left\{z^3(t)\,\underline{c_a}\right\}=0$$

    which implies that same asymptotic equilibrium system when $\underline{c_a}>0$ and when $\underline{c_a}=0$.

□

Corollary 2. *The equilibrium solution is also the unique path that converges to Steady State of preferences in equation (17).*

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 6.

Table 6: 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[29] 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[30] for the years 1890 and 1900, and in the National Income and Product Accounts for the subperiod 1929-2007.

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

[30] 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[31] 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[32]. Table 7 summarizes the exogenous variables values.

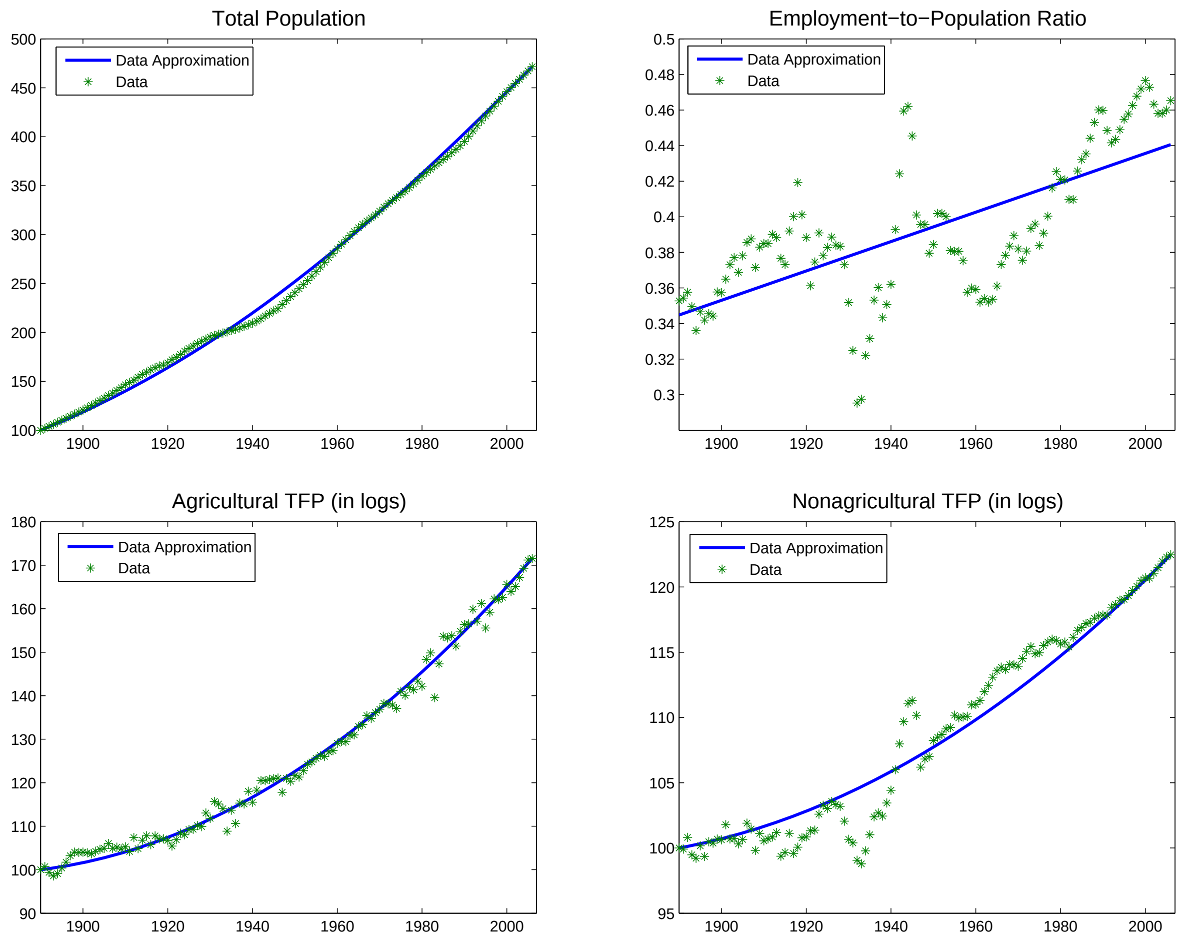
Table 7: Exogenous Variables - United States Simulation

	Variable description	**Initial value**	**Sample period growth**	**Future growth**
$\mathbf{N}$	Population	Normalization	0.018 - 0.009	0.01
$\mathbf{E}$	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

[31] 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.

[32] 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 15: 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 8.

Table 8: 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[33], 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[34] 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

[33] http://www.kosis.kr/eng/index.htm
[34] http://ecos.bok.or.kr/EIndex_en.jsp

sectoral real capital[35]:

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

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

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 Agricultura, 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[36]. 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 16shows, 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 9 summarizes the exogenous variables values.

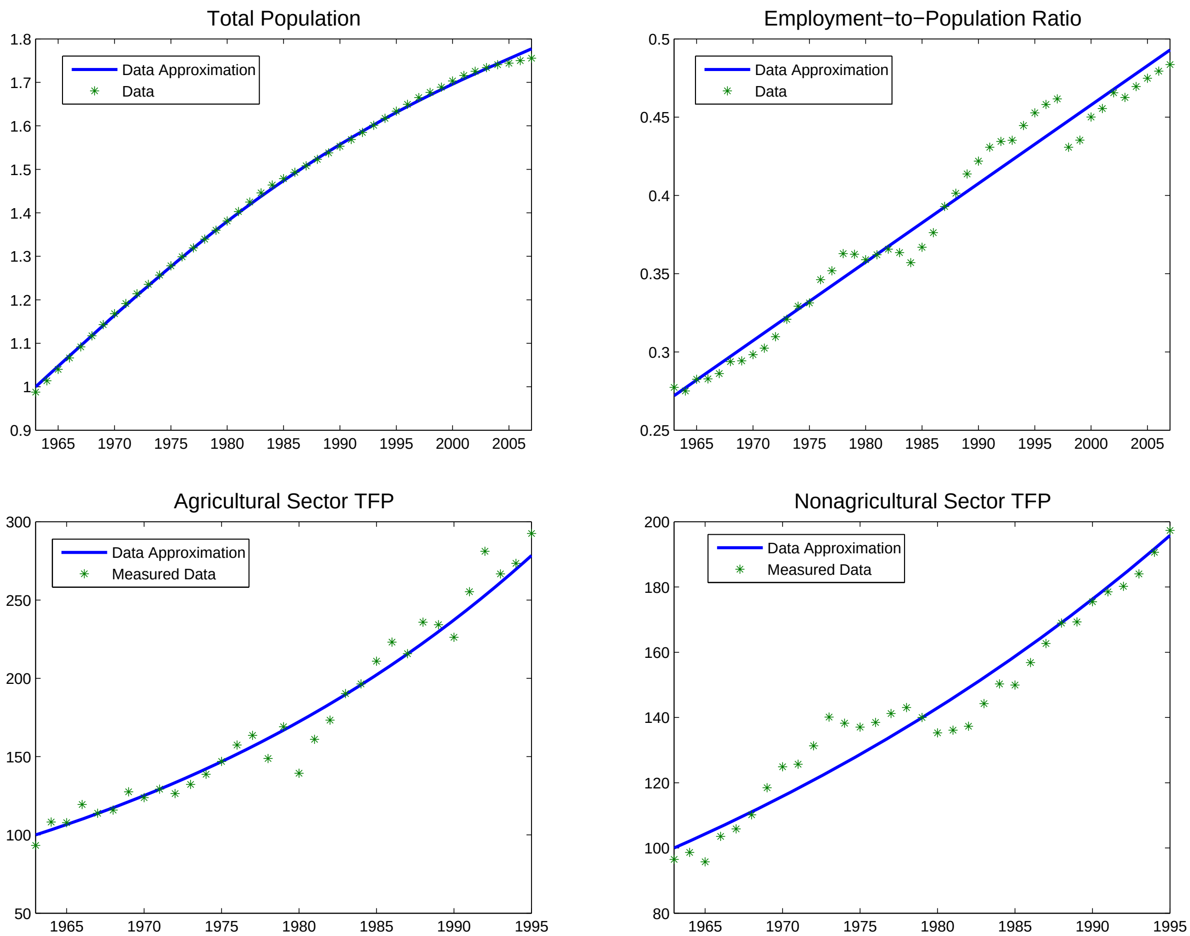
Table 9: Exogenous Variables South Korea simulation

	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

[35] 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 $(1 - \alpha_a - \beta_a)$, but this is not a problem because total land is assumed to be constant.

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

Figure 16: 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 10 summarizes the data sources, and figure 17 plots the exogenous variables used in the simulations together with the measured data.

Table 10: Sources United Kingdom Data

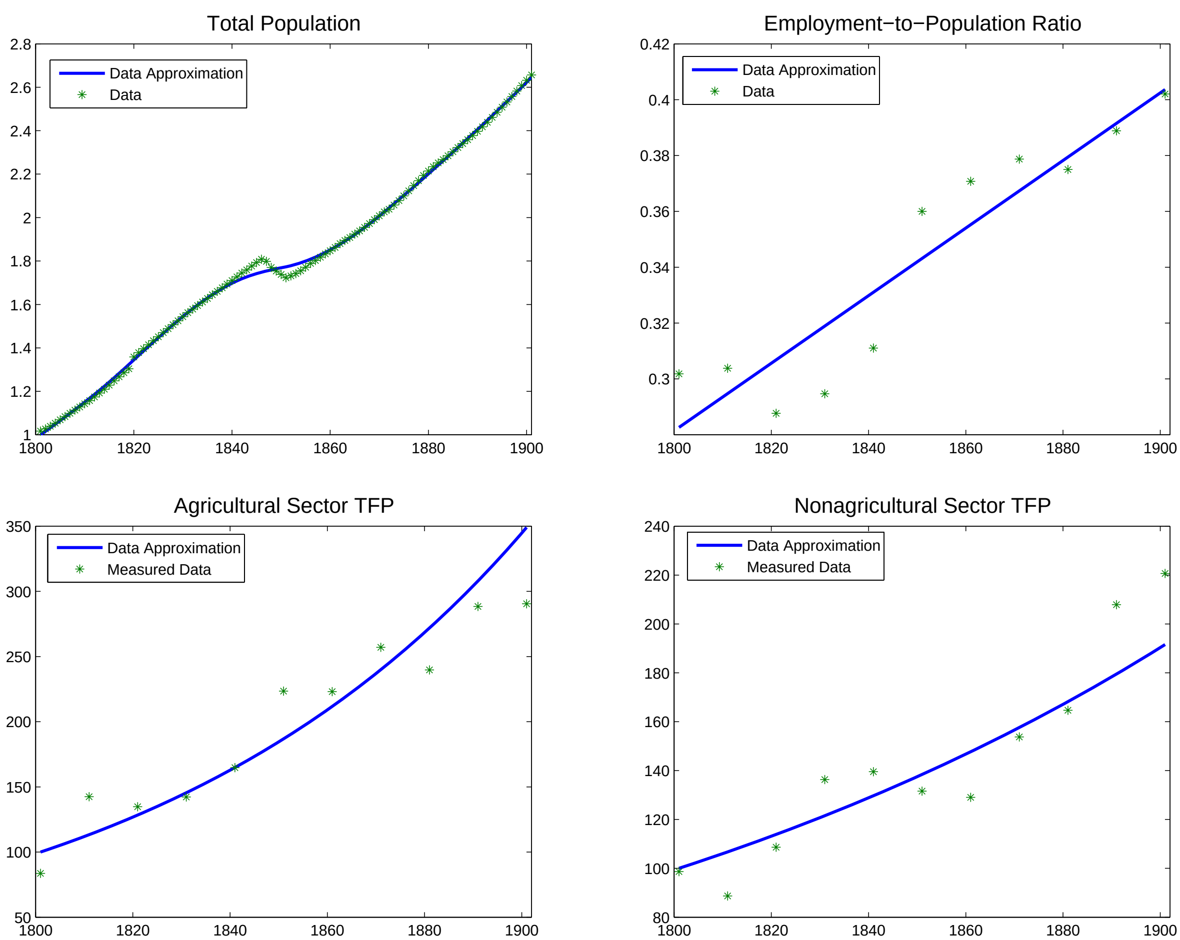
Variable	Variable description	Period	Source
$\boldsymbol{N}$	Total Population	1800 1820-1900	Mitchell (1962) Maddison (2003)
$\boldsymbol{E}$	Total Employment	1800(10)1900	Deane, Cole (1969)
$\boldsymbol{N}_a$	Agriculture Employment	1800(10)1900	Deane, Cole (1969)
$\boldsymbol{PY}$	Nominal GDP	1800(10)1850 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 17: 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 11 summarizes the exogenous variables values.

Table 11: 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