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**AGRICULTURAL TRADE AND
STRUCTURAL CHANGE:
THE CASE OF PARAGUAY**

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Agricultural Trade and Structural Change: The Case of Paraguay

Cesar Blanco

Abstract

We study the effect of agricultural trade on structural change. For this purpose, we calibrate a three-sector general equilibrium model to quantify the role of trade in explaining the structural change pattern of Paraguay. This country experienced a significant rise in net agricultural exports as a percentage of aggregate output during the period 1962–2012. We find the following results. First, international trade is crucial to explaining the composition of employment in this country. The model including trade explains 84.7% of the changes in employment shares during this period, while the model without trade can only account for 36.1% of the changes. Second, employment in agriculture remains large in order to satisfy foreign demand, even as the expenditure share of consumption in this sector declines. Third, in the long run employment shifts directly from agriculture into services, bypassing manufacturing.

JEL Code: O41, O47, O13, Q17.

Keywords: Structural change, Agricultural employment, Agricultural trade.

1 Introduction

The shift of economic activity from agriculture to manufacturing and later to services has been described by Kuznets (1973) as one of the main features of economic growth. More recently, Gollin et al. (2004) and Herrendorf et al. (2013), among other authors, show evidence of structural change across a wide cross-section of countries. These studies conclude that the size of the agricultural sector declines as income grows. To account for this fact, the literature has mostly focused on a closed-economy setting. In this paper we ask how agricultural trade affects the path of structural change. We argue that employment in agriculture remains large in countries with increasing net agricultural exports in order to satisfy foreign demand, while employment in manufacturing remains low due to imports.

Kongsamut et al. (2001) introduce minimum consumption requirements in a multi-sector model to explain structural change in a closed-economy. In this setting, non-unitary income-elasticity across sectors is the driver of structural change.¹ Since income-elasticity of agricultural goods is below one, the fraction of consumption expenditure declines as income expands. In a closed-economy, where sectoral output and consumption are equalized in every period, this is followed by a decline in employment demand in agriculture. Therefore, structural change is driven by demand factors. Alternatively, Ngai and Pissarides (2007) and Acemoglu and Guerrieri (2008) consider supply-side factors. The former relies on differences in productivity growth rates across sector, while the later in different capital intensities. If productivity grows faster in agriculture and/or the capital intensity is higher, the relative price of agricultural goods with respect to manufactures declines. The result is a reduction in the value of minimum consumption requirements in agriculture, and a further decline in employment demand.

In an open-economy, however, consumption and output are allowed to differ. Given comparative advantage in production of agricultural goods, a sufficient increase in foreign demand can offset the effects of productivity gains and higher income, which would otherwise lower employment in agriculture. At the same time, imports of manufacturing goods lower the need of employment in this sector. Therefore, foreign demand compensates the decline in domestic consumption of agricultural goods as a percentage of total expenditures.

To quantify the role of agricultural trade in explaining the path of structural change,

¹Herrendorf et al. (2013) provide a complete overview of the structural change drivers.

we consider a structural change model and calibrate it to match the pattern observed in Paraguay. This country experienced a significant rise in net agricultural exports as a percentage of aggregate output, during the period 1962–2012. The model includes non-homothetic preferences as in Kongsamut et al. (2001). According to Swiecki (2013), these preferences are key to accounting for structural change at an early stage of development. On the technology side, we allow for differences in productivity growth rates and capital intensities across sectors, as in Ngai and Pissarides (2007) and Acemoglu and Guerrieri (2008). We enhance the model by including international trade in agricultural goods and manufacturing. The model is calibrated to match initial values in the data and is used to simulate the time path of endogenous variables. We find that trade is crucial to account for the pattern of structural change observed in Paraguay.

Matsuyama (1992) has already argued that the link between agricultural productivity and employment in agriculture is positive in an open-economy with comparative advantage in this sector. His approach is purely theoretical, as opposed to this paper where we provide an empirical quantification on the role of agricultural trade on structural change. Still, this open-economy view is an exception in the structural change literature that has been mostly centered on the closed-economy case. Recently, however, there has been a shift of attention to small open economies with comparative advantage in manufacturing. In fact, in a follow up paper Matsuyama (2009) notes that a simultaneous rise in manufacturing productivity and employment in this sector is at odds with a closed-economy assumption. Using a theoretical model, he shows that a small open-economy, with growing manufacturing productivity, does not have to experience declining employment in this sector.

In a related paper, Uy et al. (2013) investigate the effect of international trade on structural change in the Republic of Korea. In this country, comparative advantage in manufactures and the expansion of international trade allowed more resources to be allocated to this sector to satisfy foreign demand. They find that a combination of non-homothetic preferences and trade can account for most of the structural change pattern in this country. Without trade their model is unable to explain the reduction in employment share allocated to the agricultural sector. Other models of structural change in an open-economy, using the Republic of Korea as a study case, are considered by Betts et al. (2013), Teignier (2014), and Sposi (2015). They all conclude that trade is important to explain the Republic of Korea's structural change.

In an earlier paper, Echevarria (1995) relates trade to the composition of output and economic growth. She calibrates a three-sector model and shows that trade increases

growth at low levels of income, but slows it down at higher levels, if a country specializes in agricultural goods production. Stokey (2001), on the other hand, develops a multi-sector model and shows that trade, among other factors, had an impact on the share of manufacturing goods in aggregate output during the British industrial revolution. More recently, Swiecki (2013) studies the determinants of structural change in a panel of 45 countries. He finds that international trade is important to explain structural change in individual countries.

The contribution of this paper is to quantify the role of agricultural trade in the pattern of structural change. We show that increasing net exports in agriculture affect employment composition in three ways. First, structural change out of agriculture is effectively slowed down. Second, it prevents a shift of employment from agriculture into manufacturing. Third, in the long run employment shifts directly from agriculture into services.

The rest of the paper is organized as follows. We briefly describe the economy of Paraguay in the next section. Section 3 introduces the model. Section 4 shows the quantitative analysis, including the calibration and simulation. Finally, Section 5 concludes.

2 Data Description

Using data from the United Nations Food and Agricultural Organization (FAO), we compute net agricultural exports as a percentage of gross domestic product (GDP) for all countries available in the database. We find 12 countries with net agricultural exports of 5% of GDP or more, as of 2012. These countries are listed in Table 1. There are four countries with increasing net agricultural exports since 1970. We take Paraguay as a representative country of this group.

Figure 1 shows the evolution of GDP per capita in Paraguay (at constant national prices) taken from the Penn World Tables 8.1 during the period 1962–2011. We can observe a period of rapid growth between 1962 and 1981, stagnation until 2002, and moderate growth after 2003. On average, GDP per capita grew at a moderate rate of 1.8% per year.

In this paper, we consider the shift of employment across sectors as the measure of structural change. Figure 2 shows the composition of employment by sector in Paraguay. Employment in agriculture steadily declined from 55.1% in 1962 to 27.5% in 2002, and remained around that point until 2012. Employment in services rose from 25.6% in 1962

to 56.7% in 2012. Meanwhile, employment in manufacturing remained almost flat at 20% until the early 1990s and declined to 16% in 2012. There are two distinctive characteristics in this pattern. First, most of the labor in agriculture shifted directly into services, bypassing manufacturing. Second, despite a significant decline in agricultural employment, it remains large when compared to advanced economies where it has declined to less than one-digit levels. We argue that this pattern is, in part, related to the rise of net agricultural exports.

We construct a time series for net agricultural exports and net manufacturing imports in relation to aggregate output. We use data from United Nations Comtrade Database and complement it with data from the Central Bank of Paraguay (CBP).² Figure 3 shows that until mid-1980s net agricultural exports averaged 6.1% of output while net manufacturing imports were slightly higher. From that point, there is an increasing trend in net agricultural exports followed by an increase in net manufacturing imports. By 2012, net agricultural exports accounted for 18.2% of aggregate output.³ This is a three-fold increase with respect to 1962. In the same figure, we can observe that international trade is near balanced from the second half of 1980s until 2012. Later in this paper, we will assume balanced trade based on this observation. As in McMillan and Rodrik (2011), we take the large share of exports that is accounted for by agricultural goods as evidence of revealed comparative advantage in this sector.

The rise in net agricultural exports observed in Figure 3 is attributed to an increase in exports of oilseeds, meats, and cereals.⁴ The combined net exports of these products increased from 0.7% of aggregate output in 1962 to 13.4% in 2012. In addition, we consider electricity exports as part of net agricultural exports, which increased from 0% of GDP in 1962 to 4.5% of GDP in 2012.⁵ If not included, we would observe a widening difference between net agricultural exports and net manufacturing imports. Figure 4 breaks down the composition of net agricultural exports into the agricultural component and the electricity component. The increase in net agricultural exports, excluding electricity, is still sizable. It increases from 6.2% of aggregate output in 1962 to 13.7% in 2012, a more than two-fold increase.

We compute relative prices using sectoral value added in nominal and real terms from

²We provide a complete description of the variables in the Appendix: Figures and Tables.

³The value for 2012 differs from that of Table 1 due to electricity exports (4.5%) and differences in product classification (0.5%).

⁴The corresponding Standard International Trade Classification (SITC) rev. 1 divisions are 01, 04, and 22.

⁵According to the SITC, electricity is grouped as a primary product.

the CBP. That is, $p_i = (VAN_i/VAC_i)/((VAN_m/VAC_m))$, where p_i is relative price of sector $i = a, s$ in units of manufacturing goods, VAN is value added in nominal terms, VAC is value added in constant prices. Figure 5 shows the evolution of the relative prices. Both prices decline during the period and the decline is more pronounced for agricultural products. This implies that labor productivity is growing faster in both agriculture and services than in manufacturing.

Finally, Figure 6 shows the capital stock level in the economy with respect to: population (K/L), number of persons engaged (K/E), total factor productivity ($K/(TFP * L)$, $K/(TFP * E)$) and output (K/Y). The data is taken from Pen World Tables 8.1. As the figures indicate, capital per capita accumulates as it transitions from a point below steady state. Therefore, the role of capital accumulation cannot be disregarded.

In the next section, we introduce a model to explain the employment composition in Paraguay. To quantify the role of each driver of structural change, we calibrate the model using data contained in GDP per capita, relative prices, capital per capita, and trade as inputs.

3 The Model

We consider a three-sector general equilibrium model of exogenous growth. There is a representative household with non-homothetic preferences over the commodity set $i = \{a, m, s\}$, where a , m , and s stand for agricultural goods, manufactures, and services, respectively. Households supply labor inelastically to firms. There are Cobb–Douglas production technologies using labor and capital as inputs. We introduce the three main drivers of structural change: non-unitary income elasticities, different productivity growth rates, and different capital intensities. We augment the model by introducing trade in agricultural and manufacturing goods. There are no labor or capital mobility frictions across sectors within countries. There is no population growth and no transportation costs.

3.1 Preferences

The infinitely-lived representative household maximizes the life-time utility given by⁶

$$U = \int_{t=0}^{\infty} e^{-\rho t} \ln [(c_a - \tilde{c}_a)^{\theta_a} (c_m)^{\theta_m} (c_s + \tilde{c}_s)^{\theta_s}] dt,$$

subject to the flow budget constraint

$$w + rK = p_a c_a + c_m + p_s c_s + \dot{K},$$

where c_a , c_m , and c_s denote consumption of agricultural and manufacturing goods and services. The subjective discount factor is given by ρ . The weights assigned to each item in the utility function are given by θ_a , θ_m , and θ_s and satisfy $\theta_a + \theta_m + \theta_s = 1$. The terms \tilde{c}_a and \tilde{c}_s are the minimum requirement parameters and can be interpreted as subsistence consumption in agriculture and home production of services. If $\tilde{c}_a, \tilde{c}_s \neq 0$ preferences are non-homothetic. The rental prices of labor and capital are denoted by w and r , while K stands for capital. Finally, p_a and p_s are the relative prices of the agricultural goods and services in terms of manufactures ($p_m = 1$ for all t).

The solution to the household's problem is characterized by the following equations:

$$p_a c_a = \frac{\theta_a}{\theta_m} c_m + p_a \tilde{c}_a, \quad (1)$$

$$p_s c_s = \frac{\theta_s}{\theta_m} c_m - p_s \tilde{c}_s \quad (2)$$

and

$$\frac{\dot{c}_m}{c_m} = r - \rho. \quad (3)$$

Equations (1) and (2) define the sectoral composition of consumption expenditures in terms of manufacturing goods. Equation (3), the *Euler* equation, determines the time-path of consumption of manufacturing goods.

3.2 Technology

There are three sectors in this economy. In each sector, a representative firm uses labor and capital to produce a homogeneous good. Technologies are given by

$$y_i = K_i^{\alpha_i} (A_i l_i)^{1-\alpha_i}, \quad (4)$$

⁶For notational simplicity, we drop time indexes when possible.

where y_i denotes output in each sector. Capital K_i and labor l_i are the two inputs used for production. The labor-augmenting productivity A_i grows exogenously at a constant rate γ_i . Productivity growth γ_i and capital intensity α_i are sector specific in this model.

Firms solve the following maximization problem

$$\max_{K_i, l_i} p_i y_i - w l_i - R K_i,$$

subject to (4). The cost that firms pay for renting capital is given by $R = r + \delta$, where δ stands for the depreciation rate of capital. The solution to this problem implies that inputs costs are equalized to their marginal values in each sector, that is

$$w = (1 - \alpha_i) p_i A_i^{1-\alpha_i} k_i^{\alpha_i} \quad (5)$$

and

$$R = \alpha_i p_i A_i^{1-\alpha_i} k_i^{\alpha_i-1}, \quad (6)$$

where $k_i = K_i/l_i$ is the capital per worker in each sector. Equal wages and rental rates across sectors are an implication of free mobility of labor and capital across sectors within the country.

Using equations (5) and (6), we can relate capital per worker in agriculture and services to that of manufactures

$$\begin{aligned} k_a &= \Omega_1 k_m, \\ k_s &= \Omega_2 k_m, \end{aligned} \quad (7)$$

where $\Omega_1 = \frac{\alpha_a(1-\alpha_m)}{\alpha_m(1-\alpha_a)}$ and $\Omega_2 = \frac{\alpha_s(1-\alpha_m)}{\alpha_m(1-\alpha_s)}$. Therefore, capital per worker is larger in more capital-intensive sectors.

Finally, from equations (5) and (7) we can obtain the following expressions for relative prices

$$p_a = \Omega_3 \frac{A_m^{1-\alpha_m}}{A_a^{1-\alpha_a}} k_m^{\alpha_m - \alpha_a} \quad (8)$$

and

$$p_s = \Omega_4 \frac{A_m^{1-\alpha_m}}{A_s^{1-\alpha_s}} k_m^{\alpha_m - \alpha_s}, \quad (9)$$

where $\Omega_3 = \left(\frac{\alpha_m}{\alpha_a}\right)^{\alpha_a} \left(\frac{1-\alpha_m}{1-\alpha_a}\right)^{1-\alpha_a}$ and $\Omega_4 = \left(\frac{\alpha_m}{\alpha_s}\right)^{\alpha_s} \left(\frac{1-\alpha_m}{1-\alpha_s}\right)^{1-\alpha_s}$. As equations (8) and (9) show, relative prices are determined by differences in productivity growth rates and differences in capital intensities as capital per worker accumulates.

3.3 Market Clearing and International Trade

Full utilization of resources and no population growth implies

$$l_a + l_m + l_s = L \equiv 1 \quad (10)$$

and

$$K_a + K_m + K_s = K,$$

that is, labor and capital demand in each sector equals total supply. Population is normalized to 1. Combining the previous two equations and (7) we obtain the inputs market-clearing condition

$$k_m = k(\Omega_5 l_a + 1 + \Omega_6 l_s)^{-1}, \quad (11)$$

where $k = K/L$ is the aggregate capital per worker, $\Omega_5 = (\Omega_1 - 1)$ and $\Omega_6 = (\Omega_2 - 1)$. Note that, aggregate capital per worker and sectoral capital per worker are not equalized as long as capital intensities differ across sectors.

We introduce international trade in the following goods market clearing conditions:

$$\begin{aligned} y_a &= c_a + x_a, \\ y_m &= c_m + \dot{k} + \delta k - x_m, \\ y_s &= c_s, \end{aligned} \quad (12)$$

where x_a stands for net agricultural exports and x_m for net manufacturing imports. Therefore, production of agricultural goods can be used for domestic consumption, exporting, or both. Manufactures can be produced domestically, imported, or both and they are used for domestic consumption, investing, and replacing depreciated capital. Services are non-tradeables.

We follow the insight provided in Stokey (2001) and Yang and Zhu (2013). That is, we assume that net agricultural exports are exogenously determined by foreign demand. In turn, net manufacturing imports adjust in every period to maintain balanced trade.⁷ As shown in section 2, balanced trade is not a far-fetched assumption in Paraguay. We introduce the balance trade condition as

$$p_a x_a = x_m = \tilde{c}_x, \quad (13)$$

⁷Stokey (2001) and Yang and Zhu (2013) take food imports as exogenous and assume balanced trade during the British industrial revolution. Stokey (2001) argues that Britain's comparative advantage in manufacturing goods during this period prompted international trade.

where \tilde{c}_x evolves exogenously. That is, we take the value of net agricultural exports observed in the data and equalize to the value of net manufacturing imports.

Finally, we can obtain an equation for aggregate output, $Y = p_a y_a + y_m + p_s y_s$, using expressions (4) and (5) as

$$Y = A_m^{1-\alpha_m} k_m^{\alpha_m} (\Omega_7 l_a + 1 + \Omega_8 l_s), \quad (14)$$

where $\Omega_7 = (1 - \alpha_m)/(1 - \alpha_a) - 1$ and $\Omega_8 = (1 - \alpha_m)/(1 - \alpha_s) - 1$.

3.4 Competitive Equilibrium

We consider the de-trended variables $c = c_m/A_m$, $z = k/A_m$ and $z_m = k_m/A_m$. Using equations (3) and (6) we obtain

$$\frac{\dot{c}}{c} = \alpha_m z_m^{\alpha_m - 1} - \delta - \rho - \gamma_m, \quad (15)$$

where z_m is given by equation (11) as

$$z_m = z(\Omega_5 l_a + 1 + \Omega_6 l_s)^{-1}. \quad (16)$$

Using equations (4), (10), (12), (13), and (14), we obtain the capital accumulation equation

$$\frac{\dot{z}}{z} = \frac{z_m^{\alpha_m}}{z} \left(1 - l_a - l_s + \tilde{x}(\Omega_7 l_a + 1 + \Omega_8 l_s) \right) - \frac{c}{z} - \delta - \gamma_m, \quad (17)$$

where $\tilde{x} = \tilde{c}_x/Y$ is the net agricultural exports to output ratio.⁸ Combining expressions (2), (4), (5), (9), and (12), we can obtain an equation describing the employment share in services

$$\Omega_9 l_s = \frac{\theta_s}{\theta_m} \frac{c}{z_m^{\alpha_m}} - \frac{\Omega_4 \tilde{c}_s}{A_m^{\alpha_s} A_s^{1-\alpha_s} z_m^{\alpha_s}}, \quad (18)$$

where $\Omega_9 = (1 - \alpha_m)/(1 - \alpha_s)$. Finally, combining expressions (1), (4), (5), (8), (12), (13), and (14), we obtain an equation for the employment share in agriculture

$$\Omega_{10} l_a = \frac{\theta_a}{\theta_m} \frac{c}{z_m^{\alpha_m}} + \frac{\Omega_3 \tilde{c}_a}{A_m^{\alpha_a} A_a^{1-\alpha_a} z_m^{\alpha_a}} + \tilde{x}(\Omega_7 l_a + 1 + \Omega_8 l_s), \quad (19)$$

where $\Omega_{10} = (1 - \alpha_m)/(1 - \alpha_a)$.

Given an initial condition for the state variable z , a transversality condition and the exogenous process \tilde{x} , the dynamic equilibrium is defined as the sequence $\{c, z, z_m, l_a, l_m\}_{t=0}^{\infty}$ that solves the system of differential equations (15) to (19).

⁸We assume \tilde{x} converges to a fixed number.

3.5 Discussion

Equations (18) and (19) describe the evolution of employment in agriculture and services. To clarify the role of each driver of structural change, we redefine these equations in terms of aggregate output Y and total expenditure $E = p_a c_a + c_m + p_s c_s$. Using (1) and (2) we have that $c_m = \theta_m(E + p_s \tilde{c}_s - p_a \tilde{c}_a)$. Combining the definitions of E and Y with equations (1), (2), (4), (5), (12), and (13), we can restate employment shares as

$$\frac{\Omega_9 l_s}{(\Omega_7 l_a + 1 + \Omega_8 l_s)} = \theta_s \frac{E}{Y} - \frac{\theta_s p_a \tilde{c}_a + (1 - \theta_s) p_s \tilde{c}_s}{Y},$$

and

$$\frac{\Omega_{10} l_a}{(\Omega_7 l_a + 1 + \Omega_8 l_s)} = \theta_a \frac{E}{Y} + \frac{(1 - \theta_a) p_a \tilde{c}_a + \theta_a p_s \tilde{c}_s}{Y} + \frac{\tilde{c}_x}{Y},$$

where, as before

$$p_i = \Omega_i \left(\frac{A_m}{A_i} \right)^{1 - \alpha_i} z_m^{\alpha_m - \alpha_i},$$

for $i = a, s$.

In these equations employment shares are determined by the size of the value of minimum requirements ($p_a \tilde{c}_a, p_s \tilde{c}_s$) and trade (\tilde{c}_x) relative to output (Y). To simplify the model further, we assume no trade ($\tilde{c}_x = 0$) and equal productivity growth rates and capital intensities across sectors ($\gamma_a = \gamma_m = \gamma_s$ and $\alpha_a = \alpha_m = \alpha_s$). In this case, relative prices p_a and p_s are constant and employment shares are simplified to

$$l_s = \theta_s \frac{E}{Y} - \frac{\theta_s \bar{p}_a \tilde{c}_a + (1 - \theta_s) \bar{p}_s \tilde{c}_s}{Y},$$

and

$$l_a = \theta_a \frac{E}{Y} + \frac{(1 - \theta_a) \bar{p}_a \tilde{c}_a + \theta_a \bar{p}_s \tilde{c}_s}{Y},$$

Clearly, as output Y grows, the minimum requirements vanish. If $\theta_s \bar{p}_a \tilde{c}_a + (1 - \theta_s) \bar{p}_s \tilde{c}_s > 0$ and $(1 - \theta_a) \bar{p}_a \tilde{c}_a + \theta_a \bar{p}_s \tilde{c}_s > 0$, then employment in agriculture decreases while employment in services increases. In the limit, when minimum consumption requirements disappear, employment shares are determined by the weight of agricultural goods and manufactures in sectoral expenditure. This is exactly the mechanism described in Kongsamut et al. (2001) as the demand-side approach to structural change.

When productivity growth rates and capital intensities are different across sectors, supply-side mechanisms are active and operate through changing relative prices. Changes in relative productivities (A_m/A_i) and capital accumulation when capital intensities are not equal ($\alpha_m \neq \alpha_i$) alter the path of relative prices. This in turn affects the value of minimum requirements and, therefore, the allocation of labor.

Finally, with international trade the term \tilde{c}_x is positive. Two considerations are in order. First, in the limit, when minimum consumption requirements vanish as income grows and/or relative prices decline, employment in the agricultural sector remains large in order to satisfy foreign demand (as long as \tilde{c}_x/Y converges to a fixed number). Second, how fast employment in agriculture declines depends on the difference between net agricultural exports growth and the decline of minimum consumption requirements.

4 Quantitative Analysis

4.1 Calibration

We take the standard values of $\delta = 0.05$ and $\rho = 0.02$ from Barro and Sala-i-Martin (2003). For the capital intensity parameters, we use the values estimated by Valentinyi and Herrendorf (2008) for the United States economy. These values are $\alpha_a = 0.54$, $\alpha_m = 0.33$ and $\alpha_s = 0.34$. By doing so, we follow the intuition of Restuccia et al. (2008) and calibrate the technology parameters to an economy with less frictions.

We calibrate the utility weights θ_a , θ_m , and θ_s to match long run expenditure shares of developed countries.⁹ We set these parameters to match expenditure shares in the United States ($\theta_i = p_i c_i / E$) as reported in Herrendorf et al. (2013) for value added consumption shares. The values are $\theta_a = 0.02$, $\theta_m = 0.13$ and $\theta_s = 0.85$. The minimum consumption \tilde{c}_a and home-production \tilde{c}_s are in turn set to match employment shares in Paraguay in 1962. The calibrated values for \tilde{c}_a and \tilde{c}_s imply an income-elasticity of agricultural goods lower than services, which in turn has an income-elasticity lower than manufacturing goods.

We normalize the initial value of productivity $A_{m,0} = 1$, and set $A_{a,0}$ and $A_{s,0}$ to match relative prices p_a and p_s in 1962. The productivity parameters, γ_a and γ_s , are in turn set to match the evolution of the relative prices p_a and p_s , as described in Figure 5. Note that, to replicate the decline in both p_a and p_s , we need productivity growth rates and/or capital intensities in agriculture and services larger than in manufacturing. The productivity in manufactures, γ_m , is calibrated to match the long run average annual growth rate of the Paraguayan economy from 1962–2011 of 1.8%.

The initial value of the state variable (z) is set to 50% of its steady state. As Figure 6

⁹According to Gollin and Rogerson (2014) expenditure shares of rich countries provide information about preference parameters, since higher income implies non-homothetic terms close to zero.

indicates, capital per capita has seen a rise since 1962, especially around the time of the hydro-electrical power plant construction beginning in the 1970s in Paraguay. Therefore, we argue that initial capital per capita is not close to its steady state value.

For calibration purposes, we modify equation (13) as

$$\tilde{x} = \frac{\tilde{c}_x}{Y} = \frac{p_a x_a}{Y} = \frac{x_m}{Y}$$

that is, we continue to consider balanced trade but now assume that it is the value of net agricultural exports as a fraction of aggregate output that evolves exogenously. For the exogenous process \tilde{x} we consider the formulation

$$\tilde{x}_t = \tilde{x}_{fin} - \frac{\tilde{x}_{ini}}{e^{\mu_1 t}},$$

and we calibrate \tilde{x}_{ini} and \tilde{x}_{fin} to match an initial value of net agricultural exports of 6.1% of aggregate output and a final value of 18.2%.¹⁰ The parameter μ_1 controls the speed that takes \tilde{x}_t to reach its final value. We set it to match as closely as possible the data in Figure 3. Table 2 summarizes the parameter targets and values.

4.2 Results

We solve the transitional dynamics of the model numerically, using the algorithm provided in Trimborn et al. (2008). Using the parameter configuration in Table 2, the benchmark model is able to explain the employment trend in all sectors. That is, a decline of employment share in agriculture, a rise in services and an almost flat manufacturing employment. The resulting simulation is shown in Figure 7. The model simulates faster transition out of agriculture and is unable to replicate the kink observed after 2002, as would be expected. Furthermore, the model slightly underpredicts the employment share in services and overpredicts it in manufacturing after the mid-1990s, when employment in this sector declines in the data. However, the overall fit of the model appears to be good. Figure 8 shows the model's fit of relative prices and the exogenous process assumed for net agricultural exports.¹¹

We test the relevance of each mechanism of structural change by turning it off and leaving the rest active. To turn international trade off, we set $\tilde{x}_t = 0$ for every period

¹⁰Of which 13.7% corresponds to net agricultural exports while 4.5 % to electricity exports.

¹¹In the appendix, we simulate the model without considering electricity exports as part of net agricultural exports. We find no significant differences with respect to the results of this section.

and recalibrate the non-homothetic terms \tilde{c}_a and \tilde{c}_s to match initial employment shares in agriculture and services. Figure 9 summarizes the results. Several considerations are in order. First, employment in agriculture declines much faster without trade. By 2012, only 10% of the workforce remains in this sector, as opposed to 27.2% observed in the data and 23.7% in the benchmark model. Second, employment in manufacturing is predicted to increase considerably in this setting. Employment in this sector rises to 36%, considerably above the maximum of 20% observed in the data during the 1990s. Not surprisingly, given our choice of parameters, this behavior resembles the structural change pattern in a closed-economy such as the United States. Finally, the time path of employment in services is only slightly affected by the closed-economy assumption. Without trade, the model predicts a shift of employment from agriculture to manufacturing. This, however, is not observed in the data for Paraguay, as already discussed in Section 2.

4.3 Quantifying the Role of Agricultural Trade

Using the benchmark and counter-factual simulation, we can quantify the importance of international trade in explaining the pattern of structural change in Paraguay. For this purpose, we introduce the Labor Reallocation Index (LRI) which is defined by Swiecki (2013) as

$$LRI = 1 - \frac{|\Delta l_a^{simul} - \Delta l_a^{data}| + |\Delta l_m^{simul} - \Delta l_m^{data}| + |\Delta l_s^{simul} - \Delta l_s^{data}|}{|\Delta l_a^{data}| + |\Delta l_m^{data}| + |\Delta l_s^{data}|}$$

where Δl_i^{data} is the observed difference between employment in sector i between 1962 and 2012, and Δl_i^{simul} is the same for the simulated data. According to Swiecki (2013), the index can be interpreted as the fraction of observed changes in employment shares attributed to the model under consideration. When $LRI = 1$, the simulation perfectly captures the pattern of employment in all sectors. When $LRI = 0$, the model predicts no employment reallocation. Finally, if $LRI < 0$ the model predicts structural changes in a different direction to what is observed in the data (or predicts much larger changes). In addition, we define

$$LRI_i = 1 - \frac{|\Delta l_i^{simul} - \Delta l_i^{data}|}{|\Delta l_i^{data}|}$$

for each sector.

We compute the LRI to formally evaluate the contribution of trade in structural change. We complement this measure with the R-squared statistic. Table 3 summarizes the results. The benchmark model explains 84.7% of the changes observed in employment

shares between 1962 and 2012. When international trade is not considered, only 36.1% of the observed changes can be accounted for by the model. When the LRI_i is computed for each sector, the model including trade consistently over-performs the alternative model in all sectors. Evidence provided by the R-square statistic is less conclusive, but it seems to favor the open-economy model as well. In sum, we conclude from this exercise that trade is crucial to accurately describe the pattern of structural change in this country.

Finally, we test the contribution of the remaining structural change drivers. By construction, biased technical change and different capital intensities cannot explain changes in employment shares under homothetic preferences. In fact, when we shut down non-homothetic preferences, the model predicts structural change in the wrong direction ($LRI < 0$). If we set productivities and capital intensities equal across sectors, the model can only account for 73.1% of changes in employment, which is 11.6% below the benchmark model.

4.4 Transition to the Steady State

We simulate the full transition to the steady state and find that employment in agriculture declines to 14.5%. Comparing this value to what the model predicts in 2012 (23.7%), we could argue that 9.2% of the labor share allocated to agriculture is still employed to satisfy subsistence requirements in 2012. Most importantly, the model predicts that employment shifts directly into services, as employment in this sector increases by 8.4% as we approach the steady state.

It is important to emphasize this result, since the open-economy model predicts that the pattern of structural change in this type of economy is not going to be exactly as the one described by Kuznets (1973) for developed countries. Clearly, this lack of industrialization (the shift of employment to the manufacturing sector) depends on our assumption that net agricultural exports continue to account for 18.2% of total output, as we approach the steady state.

5 Conclusion

In this paper, we study the effect of agricultural trade on structural change. For this purpose, we calibrate a three-sector model of exogenous growth to match the structural

change pattern of Paraguay. This country experienced a significant increase in net agricultural exports as a percentage of aggregate output during the period 1962–2012. The conclusions are three-fold. First, international trade is crucial to account for structural change in this country. The model including trade explains 84.7% of the changes in employment shares during this period, while the model without trade can only account for 36.1% of the changes. Second, employment in agriculture remains large in order to satisfy foreign demand, even as the expenditure share of consumption in this sector declines. Third, in the long run employment shifts directly from agriculture into services, bypassing manufacturing.

The main implication of this exercise is that the pattern of structural change observed in current advanced countries can differ from that of a country, given sufficiently large net agricultural exports. As discussed in Section 2, it is important to note that there only a few countries with large net agricultural exports as a percentage of GDP. However, these results would apply to countries that promote comparative advantage in production of agricultural goods and trade expansion. As we have shown in this paper, such policies would result in a higher share of employment in agriculture at the expense of a lower employment share in manufacturing.

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Appendix

Simulation excluding electricity exports

When electricity exports are excluded from net agricultural exports, we can no longer assume that equation (13) holds. Therefore, we introduce the additional exogenous process

$$p_a x_a = \tilde{c} a_x,$$

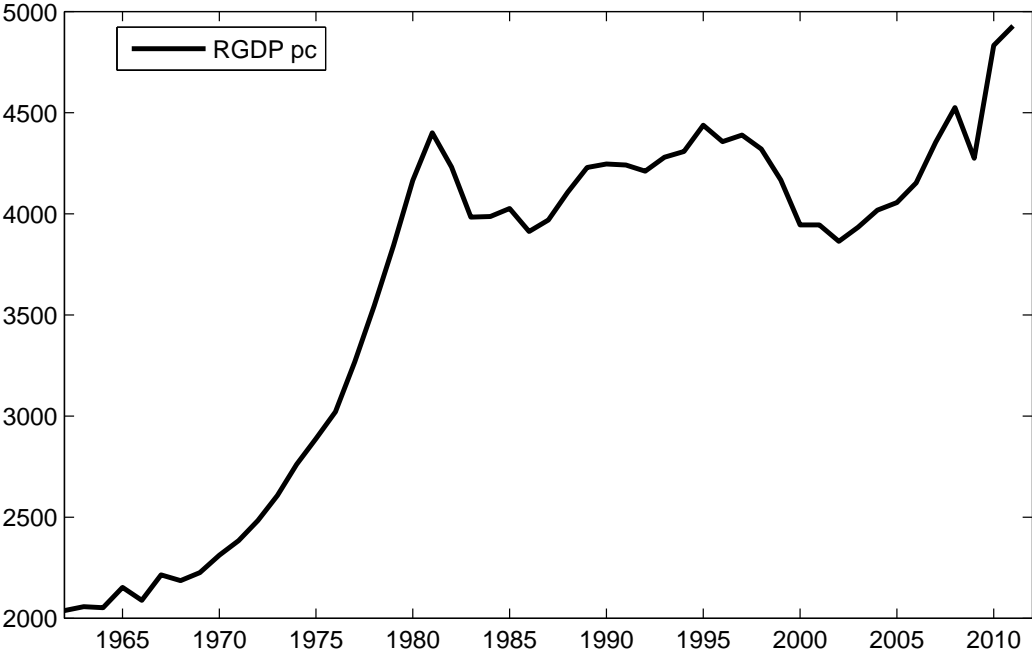
where $\tilde{c} a_x$ is set to match an initial level of net agricultural exports of 6.1 % of GDP in 1962 and 13.7 % of GDP in 2012. We modify, equation (19) as

$$\Omega_{10} l_a = \frac{\theta_a}{\theta_m} \frac{c}{z_m^{\alpha_m}} + \frac{\Omega_3 \tilde{c} a_x}{A_m^{\alpha_a} A_a^{1-\alpha_a} z_m^{\alpha_a}} + \frac{\tilde{c} a_x}{A_m z_m^{\alpha_m}}.$$

Introducing this modification to the model results in the following simulated values (for 2012): $l_a = 0.2012$, $l_m = 0.2063$ and $l_s = 0.5924$. These values are not far from the benchmark model's prediction ($l_a^{bench} = 0.2367$, $l_m^{bench} = 0.2088$ and $l_s^{bench} = 0.5545$).

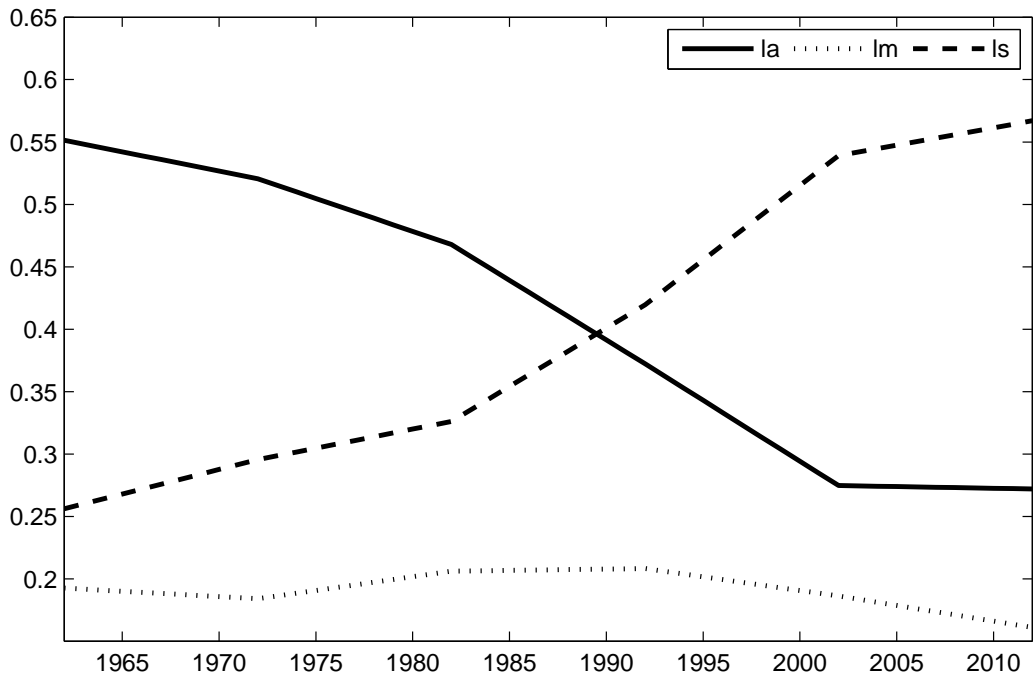
Appendix: Figures and Tables

Figure 1: Real GDP Per Capita at Constant 2005 National Prices (in 2005 US\$)



Source: Penn World Tables 8.1.

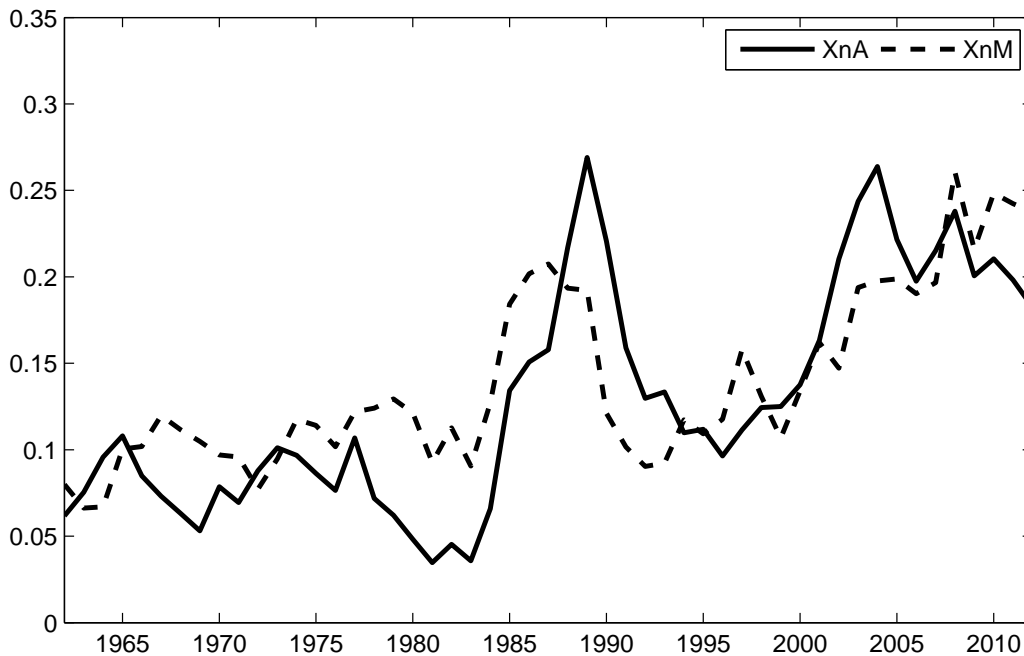
Figure 2: Employment Shares



Data for years 1962, 1972, 1982, 1992, 2002 taken from Census. Data for year 2012 taken from household surveys. We use a linear interpolation to fill the years in between.

Source: National Statistical Agency of Paraguay (<http://www.dgeec.gov.py/>).

Figure 3: Net Agricultural Exports and Net Manufacturing Imports (% of GDP)



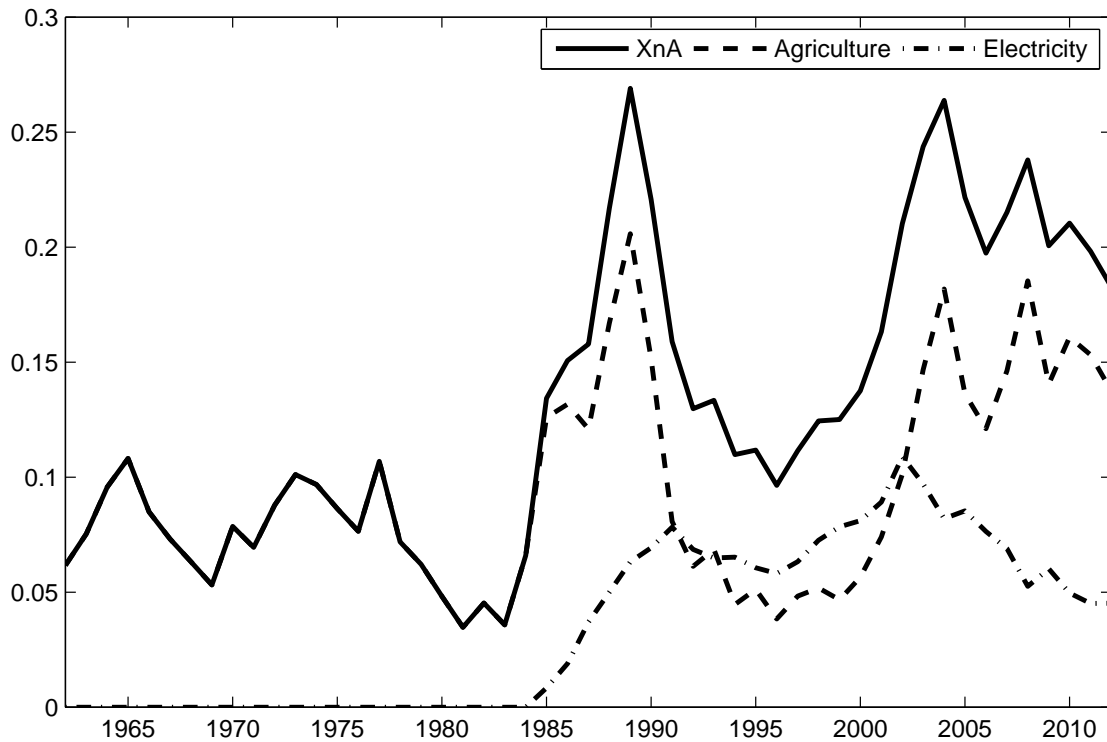
XnA: Net agricultural exports as % of GDP. It includes: exports minus imports of products in SITC Rev. 1 sections 0, 1, 2, 4, division 35 (electricity) minus division 27 and 28 from Comtrade. We add Other exports taken from CBP to account for non-registered trade. We impute 50% of SITC division 35 as electricity exports, which we consider as the effective inflow of cash from electricity exports (the remaining 50% is destined for debt payments and other expenses).

XnM: Net manufacturing imports as % of GDP. It includes: exports minus imports of products in SITC Rev. 1 sections 3, 5, 6, 7, 8, divisions 27, 28 and 68 minus division 35. We add Other imports taken from the CBP to account for non-registered trade and we subtract re-exports taken from the CBP from manufacturing imports.

GDP is taken from the CBP.

Source: UN Comtrade Database and Central Bank of Paraguay (CBP).

Figure 4: Net Agricultural Exports and Electricity (% of GDP)



XnA: Net agricultural exports as % of GDP. It includes: exports minus imports of products in SITC Rev. 1 sections 0, 1, 2, 4, division 35 (electricity) minus division 27 and 28 from Comtrade. We add Other exports taken from CBP to account for non-registered trade. We impute 50% of SITC division 35 as electricity exports, which we consider as the effective inflow of cash from electricity exports (the remaining 50% is destined for debt payments and other expenses).

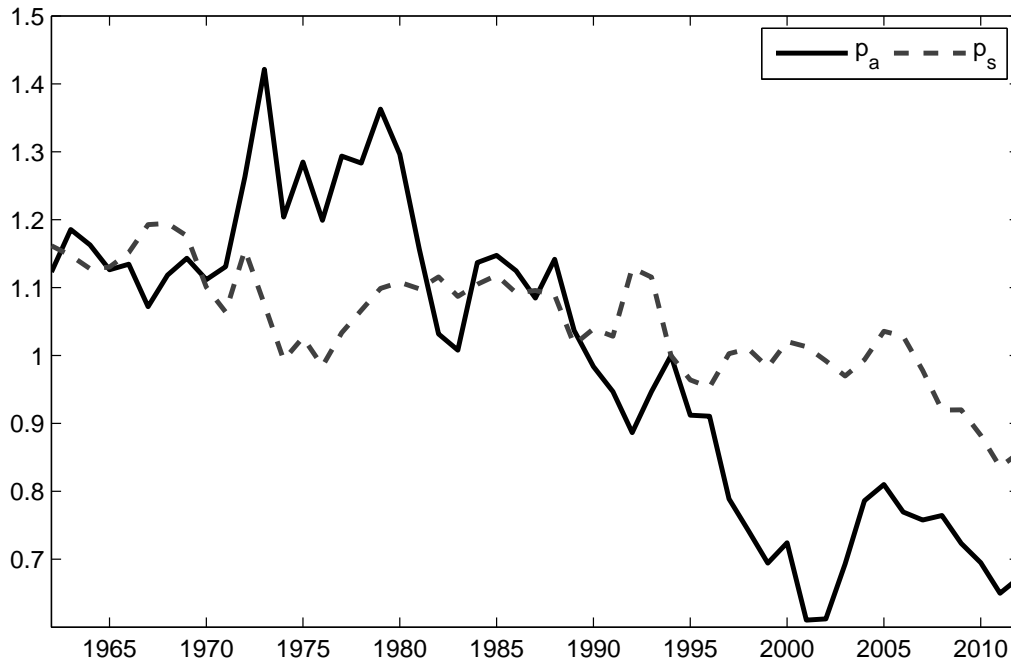
Agriculture: XnA - SITC Rev. 1 division 35 (electricity) as % of GDP.

Electricity: 50% of SITC division 35 as electricity exports.

GDP is taken from the CBP.

Source: UN Comtrade Database and Central Bank of Paraguay (CBP).

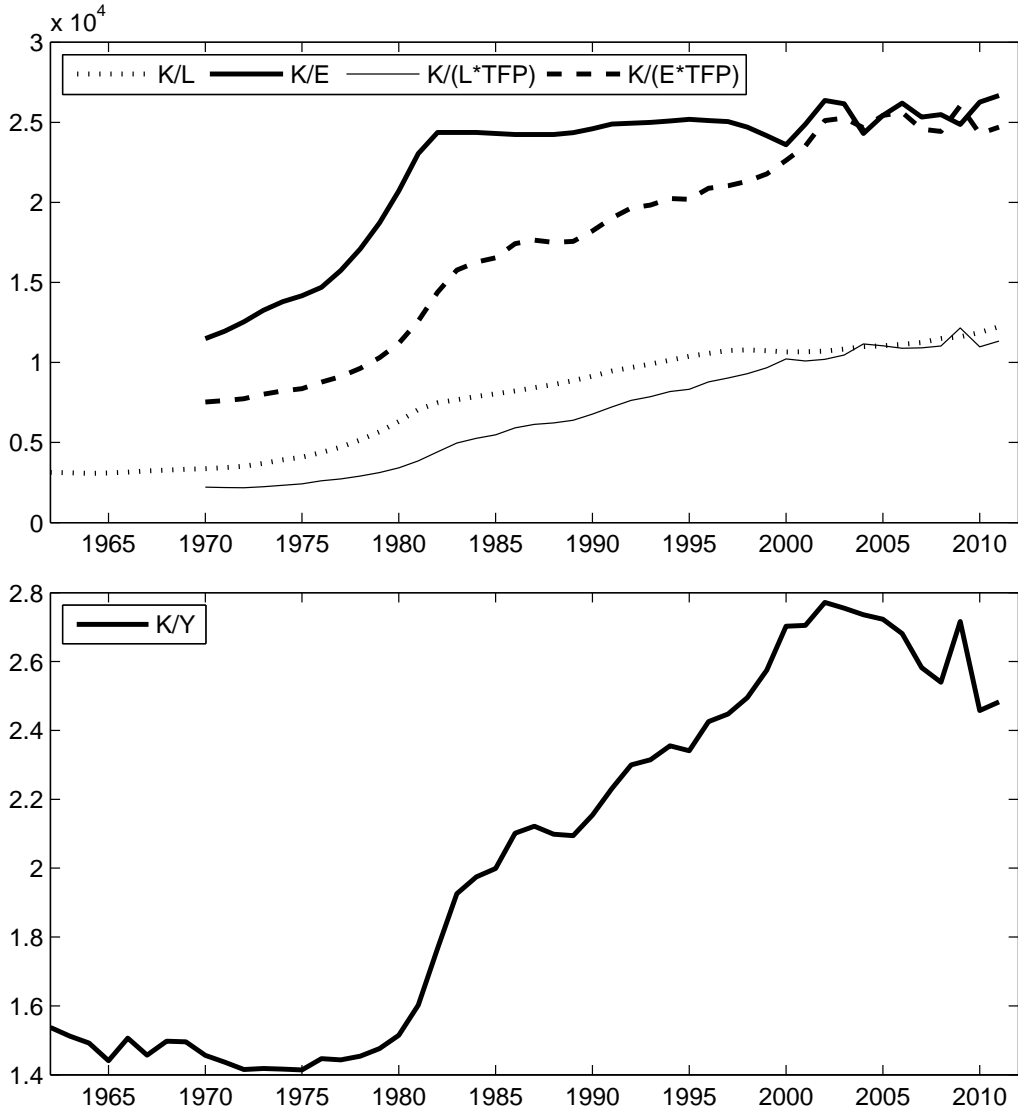
Figure 5: Relative Prices



p_a and p_s : relative price of agriculture and services in units of manufacturing goods. The relative price is calculated dividing value added in current prices by value added in constant prices in each sector, and then taking the ratio.

Source: Central Bank of Paraguay(CBP).

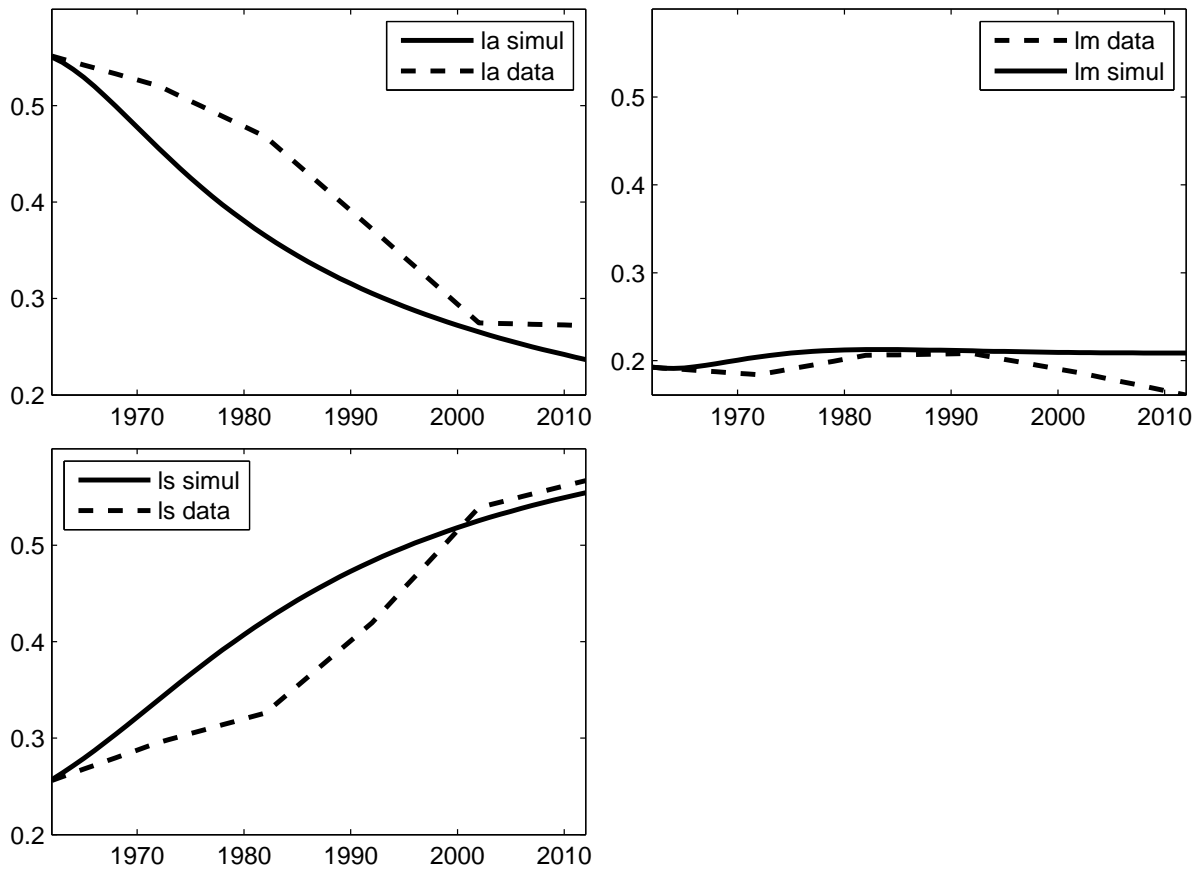
Figure 6: Capital Stock



K: Capital stock at constant 2005 national prices (in mil. 2005US\$), L: Population (in millions), E: Number of persons engaged (in millions), TFP: Total factor productivity at constant national prices (2005=1) and Y: RealGDP at constant 2005 national prices (in mil. 2005US\$).

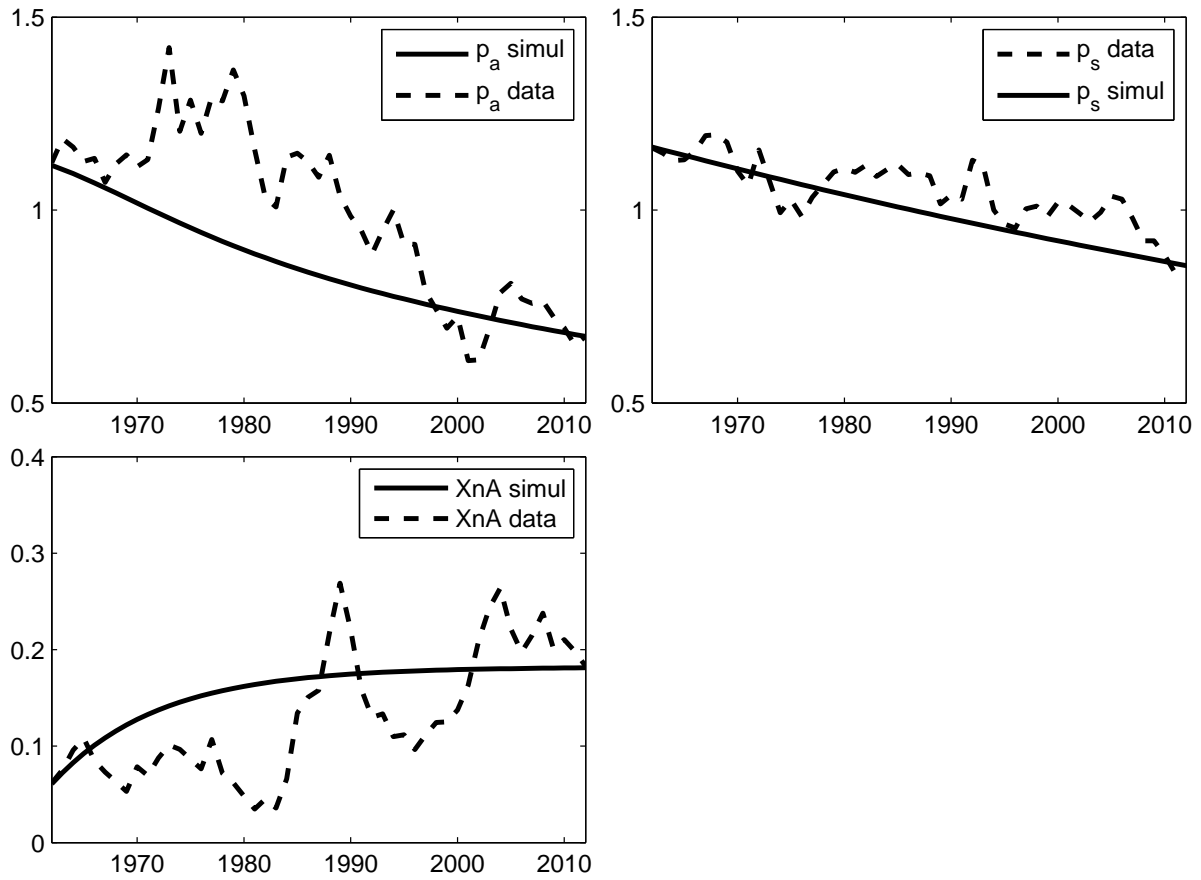
Source: Pen World Tables 8.1.

Figure 7: Employment Shares: Data vs Benchmark Model



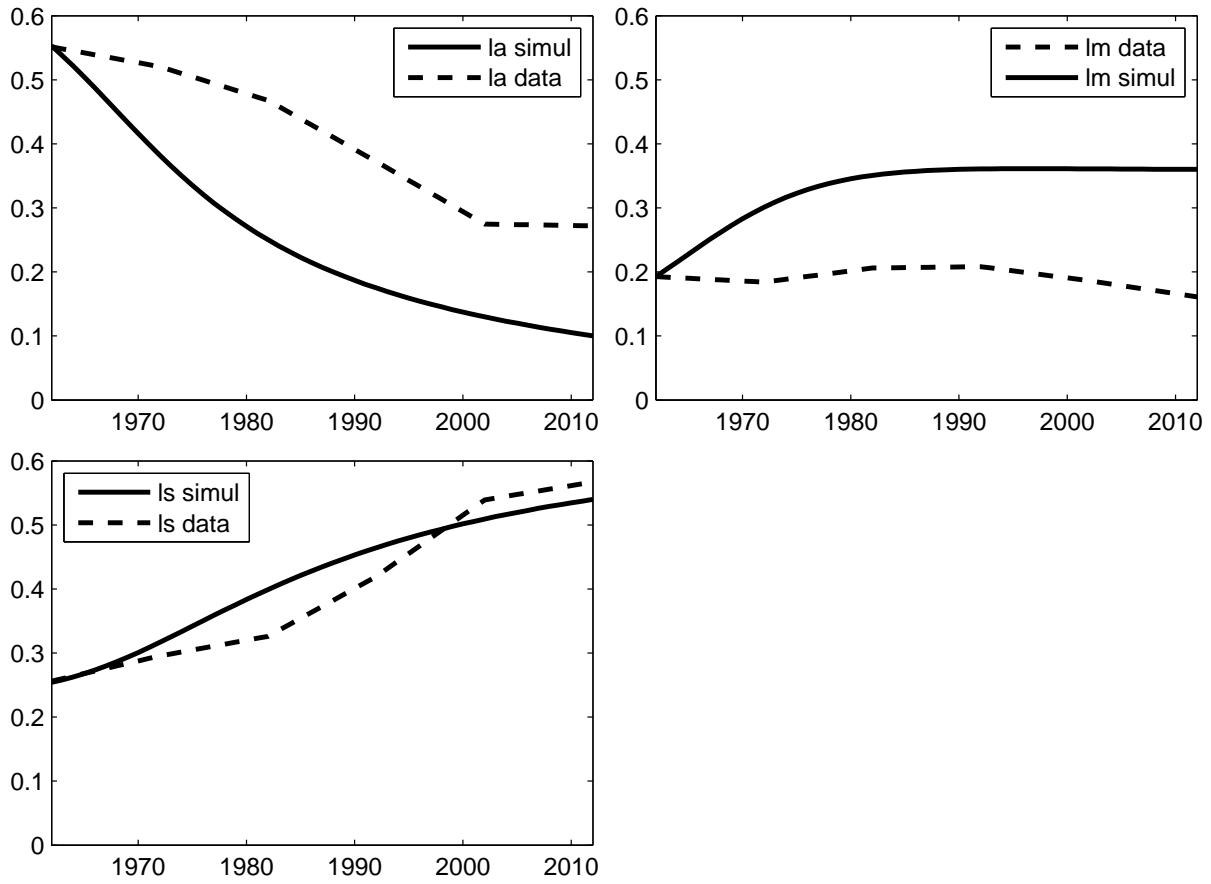
Continuous lines: model; dashed lines: data.

Figure 8: Relative Prices and Net Agricultural Exports: Data vs Model



Continuous lines: model; dashed lines: data.

Figure 9: Employment Shares: Data vs No Trade Model



Continuous lines: model; dashed lines: data.

Table 1: Net Agricultural Exports by Country

Country	NAE 2012	NAE 2012/NAE 1970
Argentina	6.4	1.740
Belize	5.2	0.709
Cote d'Ivoire	13.4	0.810
Guyana	5.5	0.766
Honduras	5.3	0.443
Malawi	10.0	1.726
New Zealand	9.2	0.674
Nicaragua	10.2	1.073
Paraguay	13.2	2.059
Thailand	5.2	0.934
Ukraine	6.1	-
Uruguay	9.2	1.729

NAE: Net agricultural exports as % of GDP. Agriculture includes all crops and livestock products. NAE 2012/NAE 1970: Ratio of NAE in 2012 with respect to 1970. A value larger than one indicates a rise of NAE.

Source: United Nations Food and Agricultural Organization (FAO).

Table 2: Calibration

Parameter	Target	Value
δ	Barro and Sala-i-Martin 2008	0.05
ρ	Barro and Sala-i-Martin 2008	0.02
α_a	Valentinyi and Herrendorf (2008)	0.54
α_m	Valentinyi and Herrendorf (2008)	0.33
α_s	Valentinyi and Herrendorf (2008)	0.34
γ_m	Long-run aggregate growth rate of 1.8%	0.0180
γ_a	Time-path of p_a	0.0315
γ_s	Time-path of p_s	0.0270
$A_{m,0}$	Normalized to 1	1
$A_{a,0}$	Initial value of p_a	0.2
$A_{s,0}$	Initial value of p_s	0.761
$z_{t=0}$	$0.5 * z_{ss}$	$0.5 * z_{ss}$
\bar{x}_{ini}	Agricultural exports in 1962 (% of GDP)	0.121
\bar{x}_{fin}	Agricultural exports in 2012 (% of GDP)	0.182
μ_1	Agricultural exports from 1962 to 2012 (% of GDP)	0.1
θ_a	Herrendorf, Rogerson and Valentinyi (2013)	0.02
θ_s	Herrendorf, Rogerson and Valentinyi (2013)	0.85
\tilde{c}_a	Agricultural labor shares at $t = 1962$	0.875
\tilde{c}_s	Services labor share at $t = 1962$	-0.160

Table 3: Evaluation

Variable	Model	LRI	R2
l_a	Benchmark	0.8775	0.9046
l_m	Benchmark	-0.5093	0.0797
l_s	Benchmark	0.9570	0.8845
Total	Benchmark	0.8469	-
l_a	No trade	0.3784	0.8552
l_m	No trade	-5.3029	0.0088
l_s	No trade	0.9192	0.9079
Total	No trade	0.3607	-
l_a	Homothetic preferences	-0.3308	0.6487
l_m	Homothetic preferences	-4.4926	0.0000
l_s	Homothetic preferences	0.3613	0.6210
Total	Homothetic preferences	-0.1958	-
l_a	Equal α 's and γ 's	0.7001	0.9758
l_m	Equal α 's and γ 's	0.3074	0.0451
l_s	Equal α 's and γ 's	0.8008	0.8899
Total	Equal α 's and γ 's	0.7306	-