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Productivity, Structural Change and Latin American Development

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Abstract

We calibrate a simple neoclassical growth model adapted to illustrate a process of structural transformation or industrialization to a group of nine South American countries. We show that low levels of agricultural productivity can substantially delay the process of industrialization which, together with low levels of non-agricultural productivity observed in recent decades, satisfactorily explains the significant differences in GDP per capita levels among the countries in our sample. Our results suggest that Argentina underwent the process of industrialization first followed by Uruguay, Chile, Brazil, Colombia, Ecuador, Peru, Paraguay and Bolivia. The model predicts that the ranking of these countries in terms of GDP per capita would follow this order until convergence occurs. The empirical evidence confirms the prediction of the model with the exceptions of Uruguay and Chile which caught up with Argentina in terms of GDP per capita levels in the late 1980s.

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1 Introduction

Trying to understand the origins of the large disparity in income per capita levels between rich and poor countries has been an enduring research question. While several factors explain different parts of the puzzle, there is widespread agreement that one of the prominent reasons for this disparity is that poor countries started the process of industrialization much later than their rich counterparts and that the industrialization process is slow (Lucas, 2000).

On this line of argument, Gollin, Parente, and Rogerson (2002, GPR hereafter), developed a model of structural transformation that explains why countries industrialize at different dates and why industrialization proceeds slowly. Using a basic neoclassical growth model modified to include both an agricultural and a non-agricultural sector, GPR (2002) argue that countries begin the process of industrialization only after being able to satisfy their basic agricultural needs (food). At this point, resources are freed up from the agricultural sector and moved to the non-agricultural sector as the industrialization process begins. Given that low agricultural productivity can significantly delay the point at which countries are able to satisfy their basic agricultural needs, low agricultural productivity can also delay the process of industrialization and result in the country falling behind the leaders in terms of income per capita. [1]

In order to study the effect of agricultural productivity, GPR (2002) set non-agricultural productivity, as well as the rate of technological progress in both the agricultural and non-agricultural sectors, constant and equal across the modeled economies. As a result, the modeled economies converge in the long run and each country proceeds to convergence at the same speed. The only difference resides, therefore, in the economies' agricultural productivity levels and the consequent date in which economies begin to industrialize. [2]

[1] Notice that GPR (2002) refer to "industrialization" as the process of moving resources from a basic or primary agricultural sector to any of the other sectors of the economy collectively referred to as the "non-agricultural sector." Thus, the non-agricultural sector is implicitly defined to include a wide range of activities such as manufacturing, mining, the provision of services, etc. Following GPR (2002), we refer to "industrialization" as the structural transformation that allows resources to flow from the agricultural sector to the non-agricultural sector, rather than the reorganization of the economy towards the manufacturing sector as is commonly understood by the Industrial Revolution process.

[2] GPR (2002) provide empirical evidence supporting their model using a panel of 62 developing countries and data from 1960-1990. They find a negative correlation between agricultural productivity and the share of employment in agriculture. They also find a positive correlation between increases in agricultural productivity and the flow of labor moving out of the agricultural sector.

We evaluate whether GPR's (2002) model of structural transformation fits the development experience of a set of nine South American countries (Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Peru, Paraguay and Uruguay) that share similar colonial institutions and cultural background. Using a simple calibration, we find that GPR's (2002) model provides a fairly accurate description of the observed income disparities of the countries in our sample.

In one of our first results, we estimate that Argentina exhibited the highest average agricultural productivity level during the twentieth century among the countries in our sample. GPR's (2002) model would predict, therefore, that Argentina should be the first country to start the process of industrialization. As a result, we would expect Argentina's income per capita to be higher than that of the rest of the countries until convergence occurs. Historical GDP per capita data shows that Argentina's GDP per capita has been, indeed, higher than that of most of the other countries in our sample until the last part of the twentieth century. As we will see below, Uruguay and Chile's GDP per capita caught up with that of Argentina (and, in the case of Chile's, largely surpassed it) starting in the late 1980s.

We also find that the predictions of the model in terms of how the countries in our sample rank according to GDP per capita levels is consistent with what the data suggests. We find that, after Argentina, Uruguay was the second country to start the process of industrialization followed by Chile, Brazil, Colombia, Ecuador, Peru, Paraguay and Bolivia. Following GPR's (2002) model we would expect countries to rank in terms of their GDP per capita levels in the same order until convergence occurs. We compare the model-generated GDP per capita values with actual data for the 2000-2010 period and find that, indeed, apart from the noted exceptions of Uruguay and Chile, countries ranked in terms of their observed GDP per capita values as the model predicted.

Our contribution is two-fold. First, to our knowledge, our paper is the first to calibrate GPR's (2002) model to a set of developing countries that share similar colonial institutions and cultural background. While data availability is always a restriction in this type of long-run exercises, we believe that GPR's (2002) model presents a simple and effective framework to understand long-run growth paths in South America. Second, as mentioned above, in GPR's (2002) model all countries are assumed to have the same non-agricultural productivity value implying that all countries eventually converge in terms of GDP per-capita. We subsequently relax this assumption to explain the observed large differences between modeled and observed GDP per capita values as of the

2000-2010 period.[3]

The importance of agriculture for the industrialization process has been long noted in the development literature (Johnston and Mellor, 1961; Johnston and Kilby, 1975; and Timmer 1988 and 2002). Before industrialization, almost all of the labor force is employed in agriculture. Once agricultural productivity rises enough to allow the production of subsistence levels of food, however, labor moves out from the agricultural sector an into the non-agricultural sector. Thus, the share of the agricultural sector in a country's GDP (and its level of employment) starts falling as labor migrates into other sectors (including extractive activities such as mining, manufacturing production and services).

Other related literature on this topic includes Caselli and Coleman (2001), who study the role of human capital accumulation as a factor that contributes to how quickly labor can move out of agriculture, and GPR (2004) who use a similar model to the one in their original paper but allow for a feedback effect from the non-agricultural to the agricultural sector. In a more recent paper, Restuccia, et al. (2008) also find that agricultural productivity is important for structural transformation. These authors focus, however, on the institutional barriers that prevent the adoption of agricultural technology and economy-wide productivity enhancer factors. These papers are part of a broader literature that includes agriculture in growth frameworks (Echeverria, 1997; Kongsamut et al., 2001; Glomm, 1992; Laitner, 2000; Hansen and Prescott, 2002; Tamura, 2002; Lucas, 2004; and Donovan, 2012).

The paper proceeds as follows. Section 2 describes the most important features of GPR's (2002) model, section 3 presents the calibration and quantitative evaluation, and section 4 concludes.

2 The Model

The basic structure of GPR's (2002) model is that of the one sector neoclassical growth model extended to include an explicit agricultural sector. In this framework, development is associated with industrialization which happens only when the country experiences a structural transformation that allows it to withdraw employment from the agricultural sector and move it into the non-agricultural sector. Asymptotically, agriculture's employment share shrinks to zero and the model becomes identical to the standard one-sector neoclassical

[3] There is no consensus about convergence among Latin American countries. According to Barrientos (2011), papers testing convergence in this region differ in their samples, periods, and methodologies making it difficult to summarize a preponderance of evidence for convergence.

growth model. To illustrate the mechanism behind the argument, we present here the basic features of the model.

2.1 Representative household

The economy is inhabited by an infinitely-lived household, endowed with a unit of time in each period, who maximizes lifetime utility as given by:

$$\sum_{t=0}^{\infty} \beta^t U(c_t, a_t) \tag{1}$$

where c_t is the non-agricultural good and a_t is the agricultural good.

GPR (2002) adopt a Stone-Geary variety for the functional form of the utility function in order to generate a structural transformation.

$$U(c_t, a_t) = \begin{cases} \log(c_t) + \overline{a} & \text{if } a_t \geq \overline{a} \\ a_t & \text{if } a_t < \overline{a} \end{cases} \tag{2}$$

This functional form allows the economy to withdraw labor from the agricultural sector once per capita output in this sector reaches the subsistence level of $\overline{a}$. There is nothing particularly special about the value of $\overline{a}$ and the results are not affected if it is either somewhat higher or lower. [4]

2.2 Nonagricultural sector

The non-agricultural sector includes all remaining sectors in the economy (i.e. manufacturing, mining, services, etc.). The non-agricultural sector produces aggregate output (Y_{nt}) by combining capital (K_{nt}) and labor (N_{nt}) using the following function:

$$Y_{nt} = A_n \left[K_{nt}^{\theta}((1+\gamma_n)^t N_{nt})^{1-\theta} + \alpha N_{nt} \right] \tag{3}$$

where A_n is the non-agricultural productivity assumed to be country-specific and determined by policies and institutions. The rate of exogenous technological change (γ_n) and α are assumed identical across countries. The production

[4] An expanded version of this model is found in GPR (2004) where the state of the non-agricultural sector can determine the labor allocated to agriculture.

function is standard except for αN_{nt} which is added to allow an economy with no initial physical capital to be able to accumulate it. In their calibration, GPR (2002) pick α to be a small number. The assumption of technological change being exogenous is quite reasonable from the developing country perspective.

Output from the non-agricultural sector can be used for consumption or investment. Capital in this sector accumulates according to,

$$K_{nt+1} = (1 - \delta)K_{nt} + X_{nt} \tag{4}$$

where δ is the depreciation rate and X_{nt} is investment.

2.3 Agricultural sector

The agricultural sector produces output (Y_{at}) using only labor (N_{at}). There are two available technologies for producing the agricultural good: traditional and modern.[5] In the traditional technology, one unit of time produces $\overline{a}$ units of the agricultural good. GPR (2002) indicate that there are theoretical reasons to believe that a value close to $\overline{a}$ is appropriate. Models with endogenous fertility, for example, suggest that output per capita will be close to subsistence levels for economies that have not begun the process of industrialization (Galor and Weil, 2000; and Hansen and Prescott, 2002).

The modern agricultural technology is subject to exogenous technological change:

$$Y_{at} = A_a(1 + \gamma_a)^t N_{at} \tag{5}$$

where A_a (agricultural productivity) is assumed country-specific and determined by policies and institutions. It could also be thought of being affected by climate conditions and the quantity and quality of land per person. Technological innovations that are useful for a specific crop in a given climate may not be particularly relevant for other crops in other parts of the world. GPR (2002) assume that the rate of exogenous technological change, γ_a, is common across countries and output from this sector is only used for consumption. Therefore, the agriculture resource constraint is simply:

$$a_t \leq Y_{at}. \tag{6}$$

[5] As GPR (2002) point out, adding land as a factor of production would have no impact on the results.

2.4 The competitive equilibrium

Here we briefly describe the competitive equilibrium of this economy by focusing on how different values of agricultural productivity (A_a) affect the resulting dynamic allocations.

At the beginning, labor is allocated entirely to agriculture until:

$$A_a(1+\gamma_a)^t \geq \bar{a} \tag{7}$$

Once this is satisfied, agricultural production switches to the modern technology and labor starts to flow out of agriculture at the rate γ_a. Hence:

$$N_{at} = min\left\{\frac{\bar{a}}{A_a(1+\gamma_a)^t}, 1\right\} \tag{8}$$

and

$$N_{nt} = 1 - N_{at} \tag{9}$$

Given a labor allocation path, the household's optimization problem gives us the optimal path for investment. Households choose consumption of the non-agricultural good and capital to maximize the utility function (1) subject to the feasibility constraint, $c_t + X_{nt} = Y_{nt}$, the law of motion of capital (4), and the appropriate non-negativity constraints and constraints on K_{nt}.

The Euler equation for this optimization problem is given by,

$$\frac{A_n[K_{nt+1}^{\theta}((1+\gamma_n)^{t+1}N_{nt+1})^{1-\theta} + \alpha N_{nt+1}] - K_{nt+2} + (1-\delta)K_{nt+1}}{\beta A_n[{K_{nt}}^{\theta}((1+\gamma_n)^t N_{nt})^{1-\theta} + \alpha N_{nt}] - K_{nt+1} + (1-\delta)K_{nt}}$$
$$= A_n {K_{nt+1}}^{\theta-1}\theta((1+\gamma_n)^{t+1}N_{nt+1})^{1-\theta} + 1 - \delta \tag{10}$$

and the steady state capital level is:

$$K_n^{ss} = \left[\frac{(1/\beta - 1 + \delta)}{(A_n)\theta((1+\gamma_n)^{ss}N_n^{ss})^{1-\theta}}\right]^{1/(\theta-1)} \tag{11}$$

This solution is equivalent to the one obtained from transitional dynamics of the neoclassical growth model assuming a given time path of labor input N_{nt}.

Since technology in the agriculture sector grows at rate γ_a, N_{at} eventually approaches 0, and N_{nt} approaches 1. The model is asymptotically equivalent to the standard one-sector neoclassical growth model.

3 Quantitative Evaluation

Figure 1 presents Maddison's (2001) historical GDP per capita trajectories starting in 1900 for the countries in our sample. Clearly, Argentina's GDP per capita has been higher than that of the rest of the countries for most of the twentieth century with the exceptions of Uruguay and Chile's GDP per capita which caught up, or surpassed, that of Argentina starting in the late 1980s. [6]

[Figure 1 about here.]

Aside from the noted exceptions of Uruguay and Chile, the evidence in Figure 1 is consistent with the predictions of the model. As Table 1 below reports, our calibration suggests that Argentina's average agricultural productivity during the twentieth century was higher than that of the rest of the countries in the sample. Therefore, Argentina would have started the process of industrialization first and its GDP per capita would be expected to be higher than that of the rest of the countries until convergence occurs.

As reported by Mundlak, et al. (1989), at least until the 1930s, Argentina did present one of the largest agricultural productivity levels in the world. Two factors seem to have been important in this respect. The first had to do with the geographical advantage that having an extended coastline represented. Such advantage favored large inflows of European capital and labor as well as a favorable attitude towards openness and international trade. The second had to do with the early development of railways that allowed a large expansion of agricultural production and exports as the cost of moving products from the *pampas* to the ports significantly reduced. Between 1860 and 1930 the rich land of the *pampas* fuelled economic growth as exports per worker quadrupled and Argentina grew more rapidly than the United States, Canada, Australia and Brazil.

[6] Maddison's (2001) data is a PPP measure of GDP per capita expressed in 1990 Geary-Khamis dollars. To test the robustness of our results we also use a non-PPP measure of GDP per capita published by the United Nation's Economic Commission for Latin America (ECLAC). Appendix A shows GDP per capita series for the countries in our sample using ECLAC's data.

3.1 Data

Data on the labor share in agriculture (N_a) is the key requirement to calibrate the model. We use the series reported by Banks (2011) for the earlier periods and complement it with data from the Food and Agriculture Organization for the latter periods (starting in 1980). In the case of Chile, we also use Diaz, et al. (1998) which reports labor share data for this country since 1853. For most countries, the period for which data on N_a is available starts in 1946. For Argentina, Brazil and Colombia, however, data is available since 1919. As mentioned above, we also use Maddison's (2001) PPP GDP per capita and ECLAC's non-PPP GDP per capita data.

3.2 Calibration

Following GPR (2002), we first set A_n equal to 1 for all countries to focus on the effect of differences in A_a and the associated different industrialization dates. We relax this assumption later on to generate our second set of results.

The parameters related to the utility and production functions, as well as the law of motion of capital, take the same values used in GPR (2002). The discount factor β is chosen so that the asymptotic annual interest rate is 5 percent. The parameter α is set equal to 0.0001 as in GPR (2002). Following Parente and Prescott (1994, 1999), the capital share parameter θ is set equal to 0.5. The parameter γ_n is set to 0.013 which is the growth rate of output per capita in the United Kingdom over the last 100 years. Asymptotically, this parameter represents the growth of technological progress. Since Latin American countries generally do not develop technology but import it, $\gamma_n = 0.013$ would also be their long run growth rate. The depreciation rate δ takes a typical value for annual depreciation of 0.065.

The subsistence level parameter $\overline{a}$ and the rate of exogenous technological change in the agricultural sector, γ_a, are common across countries in the set. These two parameters can be found by building a system of equations using equation (8). Given that we have the largest data availability on N_a for Chile, we find these two parameters to match Chile's agricultural employment shares in 1890 and 1990. The system of equations is:

$$\frac{\overline{a}}{A_a(1+\gamma_a)^{1890}} = 0.4026 \tag{12}$$

$$\frac{\overline{a}}{A_a(1+\gamma_a)^{1990}} = 0.1868, \tag{13}$$

where 0.4026 and 0.1868 are the agricultural employment shares in Chile for 1890 and 1990, respectively.

Solving equations (12) and (13) we obtain $\overline{a} = 0.4057$ and $\gamma_a = 0.0077$. We use these values to calibrate the evolution of GDP per capita for every country in the set.

Once we obtain the values of $\overline{a}$ and γ_a, we can obtain the values for A_a by using equation (8) and N_a data available for each country and year. For each country, we use the average A_a over time. In other words, we calibrate A_a so that the model matches the path of agricultural labor share observed in the time series available.

The value of A_a is crucial to model the evolution of GDP per capita in each country. Having obtained A_a, we can use equation (8) again to obtain the modeled values for N_a. We can then use equation (9) to obtain the modeled values for N_n. Modeled time series for N_a and N_n allow us to find modeled time series for K_n, Y_n and, ultimately, $Y = Y_a + pY_n$, where p is the relative price of the non-agricultural good while setting the price of the agricultural good as the numeraire.[7]

3.3 Results

3.3.1 GDP per capita and the Agricultural Labor Share

Below we present a set of figures that compare model-generated values with actual data. For each country, the figure on the left shows the observed data and the modeled-generated time series of N_a. The figure on the right shows the observed data and model-generated time series of GDP per capita using data from Maddison (2001) (Appendix B shows the equivalent figures using ECLAC's data).[8] As the figures show, despite its simplicity, the model is able to match the long run trajectory of N_a for the countries in our sample quite closely. The model is also able to closely match the long run trajectory of GDP per capita for most countries in the sample.

[7] To compute p we set the marginal productivity of labor in the agricultural and nonagricultural sectors to real wages and normalize the price of the agricultural good to 1. As labor can move freely between sectors, we obtain the price of the nonagricultural good as the ratio of marginal productivities of labor. Without loss of generality, we obtain p by using marginal productivities of labor for Chile as of 1995.

[8] Following GPR (2002), the figures show both modeled and observed GDP per capita series relative to a base year. We use 1950 as the base year for each country in our sample.

[Figure 2 about here.]

[Figure 3 about here.]

[Figure 4 about here.]

[Figure 5 about here.]

[Figure 6 about here.]

[Figure 7 about here.]

[Figure 8 about here.]

[Figure 9 about here.]

[Figure 10 about here.]

In Figure 2, notice that the model-generated trajectory of GDP per capita tracks the actual data for Argentina quite well up to the mid-1970s. Starting in the mid-1970s, however, Argentina's actual GDP per capita falls below the model-generated trajectory. Indeed, Argentina's actual GDP per capita fell more than 20 percent between 1975 and 1990 (Maddison, 2001).

Several economic and political factors contributed to Argentina's GDP per capita falling behind its modeled path in the last decades (Thorp, 1998). In terms of GPR's (2002) model, such sustained departure from the modeled path may be interpreted as a decrease in non-agricultural productivity due to the significant institutional and macroeconomic deterioration that started in the late 1970s.[9] The resulting uncertain environment led to a productive decline in most sectors of the economy. In the particular case of the manufacturing sector, the accumulation of large budget deficits had a severe effect on production as most of the industries were strongly promoted and protected by import substitution policies. The decline was so large that manufacturing production in the early 1990s was similar to its level in the 1940s (Kosacoff, 2011).

Contrary to the Argentinian case, notice that the observed GDP per capita series for Chile in Figure 5 lies well above the model-generated trajectory starting in the early 1990s. Several factors contributed to Chile's economic boom. In terms of GPR's (2002) model, these factors may be reflecting an

[9] Argentina experienced large budget deficits and severe hyperinflation starting in the 1970s. Indeed, Argentina's inflation reached an average of 300 percent per year from 1975 to 1991 (Argentina's National Institute of Statistics). Furthermore, in the late 1990s and early 2000s, the country faced a severe financial crisis that generated a complete collapse of the financial sector and resulted in the country defaulting on its international obligations in January of 2002.

increase in non-agricultural productivity. According to Reinhardt et al. (2006), for example, the steady increase in GDP per capita can be largely attributed to an increase in mining export volumes fueled by higher copper prices brought on by a boom in electronics. [10] Additionally, Reinhardt et al. (2006) point out that Chile also experienced strong growth in exports of unprocessed and processed *modern* agricultural products including forestry and fishing. [11] Importantly as well, Chile started to adopt strong institutions that promoted free trade and foreign direct investment during the early 1980s. The country continued to adopt such institutions during the 1990s and 2000s increasing productivity in all sectors of the economy.

The case of Brazil is similar to Chile's. The observed GDP per capita series lies above the model-generated trajectory starting in the late 1970s. During this period, there was a gradual process of transitioning from military regimes to democracy denoted "abertura." With the establishment of democracy in the 1980s, Brazil also increased its openness to foreign investment and trade that has continued steadily into the present. In terms of GRP's (2002) model, these policies seem to have encouraged increases in non-agricultural productivity. As one of our results below suggests, Brazil's non-agricultural productivity can be calculated to be 11 percent higher than what the model originally estimates as of the 2000-2010 period.

The model matches the data fairly well for the rest of the countries shown in Figures 2 through 10 with the exception of Bolivia. Bolivia's observed GDP per capita (Figure 3) is notably below the model-generated trajectory. This result is likely due to the fact that Bolivia underwent very turbulent political and economic years during the second half of the 20th century which may have negatively affected its non-agricultural productivity. In fact, Bolivia suffered various coup d'etats during this period which involved drastic swings in political and economic institutions.

3.3.2 Agricultural Productivity and the Beginning of Industrialization

Table 1 presents the average agricultural productivity values and the years in which industrialization begins for each country in the sample. Formally, industrialization is defined to begin the first year in which $N_a < 1$ and, therefore, $N_n > 0$.

As expected, Argentina, the country with the highest A_a, started the process

[10] Copper accounts for approximately 40 percent of Chile's exports (World Bank (2012)).
[11] Modern agriculture should be clearly distinguished from what GPR's (2002) model labels as the "agricultural sector" which consists of a basic sector that does not produce beyond subsistence levels of food.

of industrialization first. According to our calibration, we estimate that this happened in 1718. According to the account of historian Rock (1987), under the Spanish colonial regime, the territory that Argentina occupies today produced leather and hides as well as mined silver that exported to Europe. At the same time, however, there was a flourishing production of handicrafts and construction in the city of Buenos Aires. This evidence indicates that industrialization as defined in GPR (2002) started to gain momentum in the early part of the 1700s in colonial Argentina. At the other extreme, we estimate that Bolivia, the country with the lowest A_a, did not start the process of industrialization until 1891.

[Table 1 about here.]

Recall as well that, given that we are assuming that A_n is equal to 1 for all countries, all income differences vanish asymptotically (i.e. GDP per capita values converge). The last column of Table 1 shows the year in which GDP per capita for each of the countries reaches 90 percent of that of Argentina (i.e. converges with the leader's GDP per capita). As the model predicts, the country with the highest A_a after Argentina, Uruguay, is the first to converge. In fact, given, that Uruguay's A_a is very close to that of Argentina, Uruguay's modeled GDP per capita is never below 90 percent of Argentina's GDP per capita. This result can be clearly observed in Figure 11 below which shows the modeled trajectory of GDP per capita levels for each country in the sample. In essence, Uruguay converged with Argentina right from the start of its industrialization process.

[Figure 11 about here.]

Table 1 and Figure 11 also indicate that Chile's modeled GDP per capita is the second one to converge to that of Argentina; Brazil, Colombia, Ecuador, Peru, Paraguay and Bolivia follow in that order. Notice that the model appropriately captures the intuition that motivated this paper that one of the reasons for large income disparities is that poor countries started the process of industrialization much later than their rich counterparts and that the industrialization process is slow. According to our calibration, for example, Brazil, which started the process of industrialization 112 years after Argentina, will only converge with the modeled Argentina's GDP per capita in 2080. Moreover, Paraguay and Bolivia, which started the process of industrialization 143 and 173 years after Argentina, will only converge with Argentina in 2128 and 2170, respectively.[12]

[12] Theoretically, these results are derived from the fact that, in GPR's (2002) model, the transition is much slower than the transition that occurs in the one-sector neoclassical growth model because labor moves only slowly into the non-agricultural sector.

[Table 2 about here.]

Table 2 shows the comparison of actual and model-generated GDP per capita for each country relative to that of Argentina for the 2000-2010 period. We show both Maddison's (2001) data as well as ECLAC's. Given that GPR's (2002) model is, in essence, a model of long-run economic growth, we would not expect the modeled values to perfectly match relative GDP per capita values as of a particular period of time. Importantly, however, the model predicts fairly accurately the order in which the countries in the sample should rank in terms of GDP per capita as of the 2000-2010 period. Indeed, consistent with the model's hypothesis, the empirical evidence shows that countries that began the process of industrialization earlier present higher GDP per capita values than the ones that industrialized at a later date.

3.3.3 Non-agricultural Productivity

While the differences between the modeled and observed GDP per capita values during the last decade, as shown in Table 2, can be obviously reflecting short-run type of effects or business cycles, they may also be reflecting deeper structural or long-run type of effects such as different values for A_n than originally assumed.

For Uruguay, Brazil and Colombia the modeled and observed GDP per capita values are relatively close. For these countries, GDP per capita is approximately where the model would predict it to be during the 2000-2010 period given the calibrated A_a's and associated years in which industrialization begins. In terms of the model, therefore, the differences between modeled and observed GDP per capita values for these countries may only be reflecting short-run type of effects.

On the other hand, for countries like Chile, Ecuador, Peru, Paraguay and Bolivia, observed and modeled GDP per capita values present larger differences. Within this group, Chile can be thought of as an *over-achiever* as its GDP per capita relative to Argentina's shown in Table 2 is 47 to 64 percent larger than the model would have predicted. The opposite is true for the other countries in our sample, particularly for Paraguay and Bolivia for which their GDP per capita under-performed in relation to the model by approximately 50 to 63 percent and 50 to 64 percent, respectively. Such large differences could be reflecting long-run type of effects. In terms of the model, those effects will be reflected in different A_n values.

[Table 3 about here.]

In Table 3 we ask, what A_n value would be consistent with the observed values of GDP per capita for each country relative to that of Argentina during the 2000-2010 period using Maddison's (2001) data. As expected, A_n values are not very different from 1, our original assumption, for Uruguay, Brazil and Colombia. For Chile, Ecuador, Peru, Paraguay and Bolivia, on the other hand, the required A_n departs from 1 to a larger extent. The cases of Chile, Paraguay and Bolivia are particularly significant. To account for the observed value of Chile's average GDP per capita relative to that of Argentina during the 2000-2010 period, the value of A_n would need to have been 1.24 (24 percent higher than the original assumption). In the case of Chile, a larger A_n is likely correlated to higher copper prices and an overall and sustained improvement of the country's institutions, openness, and macroeconomic stability that the country experienced over the last two or three decades. The complete opposite story can be told for the cases of Paraguay and Bolivia. To account for the observed value of Paraguay and Bolivia's average GDP per capita relative to that of Argentina during the 2000-2010 period, the value of A_n would need to have been 0.62 and 0.61, respectively (38 and 39 percent lower than the original assumption). These large differences can also be interpreted as structural or long-run type of effects. In the case of these two countries, a lower A_n is likely related to the adoption of inefficient institutions, political instability and investment uncertainty over the last two or three decades.

[Table 4 about here.]

Table 4 presents the same exercise as Table 3 but using ECLAC's data. The results are fairly consistent with those of Table 3. Notice, however, that to account for the observed value of Brazil's average GDP per capita relative to that of Argentina during the 2000-2010 period, the value of A_n using ECLAC's data would need to have been 1.11 (11 percent higher than the original assumption and 20 percent higher than the value found for Brazil in Table 3). This means that the model would predict for Brazil to converge with Argentina in 1962. Also, notice that, using ECLAC's data, Chile's over-performance is larger and results in an A_n 32 percent larger than the original assumption. Paraguay and Bolivia's under-performance is also larger and results in A_n's 52 and 58 percent lower than the original assumption, respectively.

4 Concluding Remarks

We evaluate whether GPR's (2002) model of structural transformation fits the development experience of a set of South American countries (Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Peru, Paraguay and Uruguay) that share similar colonial institutions and cultural background. We performed this exercise by calibrating the country's agricultural productivity levels and inferring from these values the years in which each country started its industrialization or structural transformation process. Our findings indicate that the model provides a fairly accurate description of the observed development path and disparities among the countries in our sample.

To focus on the effect of agricultural productivity we first set non-agricultural productivity constant and equal to 1 for all countries. Our first result indicates that Argentina is the country with the highest average agricultural productivity level during the twentieth century and, therefore, the country predicted to have started the industrialization process first among the countries in our sample. The model predicts, therefore, Argentina's income per capita to be higher than that of the rest of the countries until convergence occurs. This is, indeed, what the observed data trajectories of GDP per capita show. With the notable exceptions of Uruguay and Chile, Argentina's GDP per capita has been higher than that of the rest of the countries for most of the twentieth century. In fact, apart from the noted exceptions, as of the 2000-2010 period, countries are ranked, in terms of GDP per capita, in the order in which they started the industrialization process as predicted by model. This is an important result of the model and our calibration exercise.

Finally, when comparing the modeled and observed GDP per capita values relative to that of Argentina as of the the 2000-2010 period, we notice that, for some countries, the differences can be sizable. We examine one potential source that could account for such differences: non-agricultural productivity levels. We calibrate non-agricultural productivity levels to generate the observed income differences in the 2000-2010 period. Using these values we update the prediction of when convergence for each country (defined as reaching at least 90% of Argentina's GDP per capita) has or will occur. We find that for some of the laggard countries, ceteris paribus, convergence could be still over a century away. The reason for this extremely slow convergence process is that productivity levels in both sectors in laggard countries are significantly below the leading countries.

Future research will extend the model to study the effect of institutional changes in agriculture (e.g., agrarian reforms) that may increase or decrease agricultural productivity and, therefore, the long-run path of development. We would then be able to ask what the long-run effect of an agrarian reform, or similar historical institutional change, was in terms of GDP per capita for a particular economy.

5 References

Banks, Arthur, *Cross-National Time-Series Data Archive*, Jerusalem: Databanks International, http://www.databanksinternational.com, 2011.

Barrientos, Paola, "Convergence Clubs in Latin America: A Historical Approach," Unpublished manuscript, School of Economics and Management, University of Arhus, Denmark, 2011.

Caselli, Francesco and Wilbur Coleman II, "The US Structural Transformation and Regional Convergence: A Reinterpretation," *Journal of Political Economy* 109 (3) (2001): 584–616.

Díaz, José, Rolf Lüders and Gert Wagner, "Economía Chilena 1810-1995: Evolución Cuantitativa del Producto Total y Sectorial," Working Paper No. 186, Pontificia Universidad Católica, Chile, 1998.

Donovan, Kevin, "Agricultural Risk, Intermediate Inputs and Cross-Country Productivity Differences," Working Paper, Arizona State University, 2012.

— and David Weil, "Population, Technology, and Growth: From Malthusian Stagnation to the Demographic Transition and Beyond," *American Economic Review* 90 (4) (2000): 806–828.

Glomm, Gerhard, "A Model of Growth and Migration," *Canadian Journal of Economics* 42 (4) (1992): 901–922.

Gollin, Douglas, Stephen Parente and Richard Rogerson, "The Role of Agriculture in Development," *AEA Papers and Proceedings* 92 (2) (2002): 160–164.

—, — and —, "Farm Work, Home Work, and International Productivity Differences," *Review of Economic Dynamics* 7 (4) (2004): 827–850.

Hansen, Gary and Edward Prescott, "Malthus to Solow," *American Economic Review* 92 (4) (2002): 1205–1217.

Johnston, Bruce and John Mellor, "The Role of Agriculture in Economic Development," *American Economic Review* 51(4) (1961): 566–93.

—, and Peter Kilby, *Agriculture and Structural Transformation: Economic Strategies in Late-Developing Countries*, New York: Oxford University Press, 1975.

Kongsamut, Piyabha, Sergio Rebelo and Danyang Xie, "Beyond Balanced Growth," *The Review of Economic Studies* 68 (4) (2001): 869–882.

Kosacoff, Bernardo, "The Argentine Industry: A Thwarted Restructuring Process," in Banco BICE/Universidad Nacional de Quilmes, *Producción y Trabajo en la Argentina, Memoria Fotográfica 1860–1960*, Buenos Aires: BICE/UNQ, 2011.

Laitner, John, "Structural Change and Economic Growth," *Review of Eco-*

nomic Studies 67 (2000): 545–561.

Lucas, Robert, "Some Macroeconomics for the 21st Century," *The Journal of Economic Perspectives* 14 (1) (2000): 159–168.

—, "Life Earnings and Rural–Urban Migration," *Journal of Political Economy* 112 (1, part 2) (2004): S29–S59.

Maddison, Angus, *The World Economy: A Millennial Perspective*, OECD: 2001.

Mundlak, Yair, Domingo Cavallo and Roberto Domenech, "Agriculture and economic growth in Argentina, 1913–84," Research Report 76, International Food Policy Research Institute, 1989.

Parente, Stephen and Edward Prescott, "Barriers to Technology Adoption and Development," *Journal of Political Economy* 102 (1994): 298–321.

— and —, "Monopoly Rights: A Barrier to Riches," *American Economic Review* 89 (1999): 1216–1233.

Reinhardt, Nola, Wilson Peres and Nelson Correa, "Structural Change in the Chilean Economy: The Sectoral Impact of Economic Reforms, 1970-2000," in Patricio Aroca and Geoffrey Hewings (eds.), *Structure and Structural Change in the Chilean Economy*, New York: Palgrave-McMillan, 2006.

Restuccia, Diego, Dennis Yang and Xiaodong Zhu, "Agriculture and Aggregate Productivity: A Quantitative Cross-Country Analysis," *Journal of Monetary Economics* 55 (2) (2008): 234–250.

Rock, David, *Argentina, 1516–1987. From Spanish Colonization to Alfonsín*, Berkeley: University of California Press, 1987.

Tamura, Robert, "Human Capital and the Switch from Agriculture to Industry," *Journal of Economic, Dynamics and Control*, 27 (2002): 207–242.

Timmer, Peter, "The Agricultural Transformation," in Hollis Chenery and T.N. Srinivasan (eds.), *Handbook of Development Economics* Edition 1, Amsterdam: Elsevier Science Publishers, 1988.

—, "Agriculture and Economic Development," in Bruce Gardner and Gordon Rausser (eds.), *Handbook of Agricultural Economics* Vol. 2A, Amsterdam: Elsevier Science Publishers, 2002.

Thorp, Rosemary, *Progress, Poverty, and Exclusion: An Economic History of Latin America in the 20th Century*, Washington, DC: Inter-american Development Bank, 1998.

Appendix A

[Figure 12 about here.]

Appendix B

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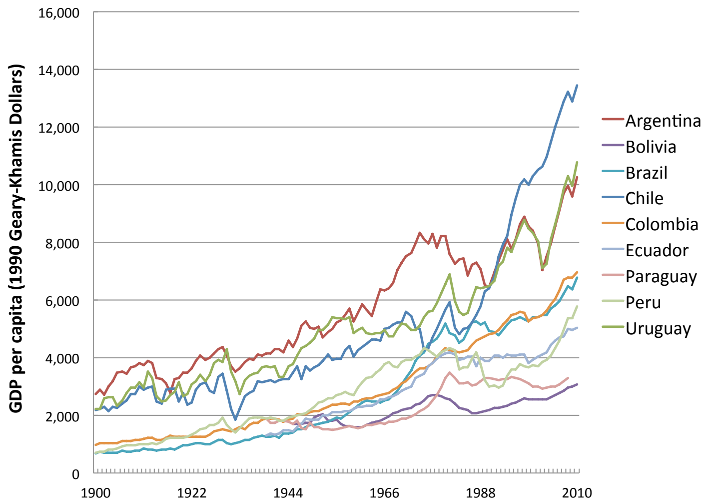
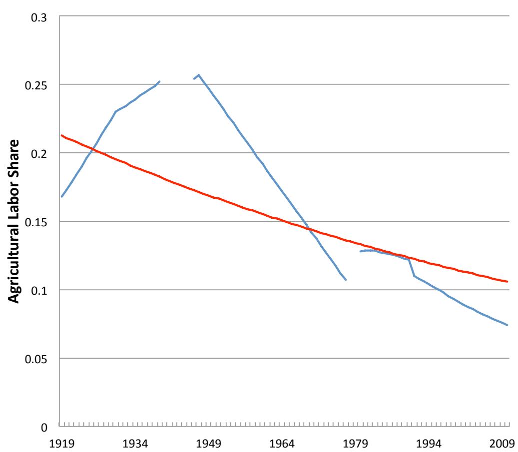


Figure 1. *GDP per capita 1900 - 2000 (Maddison (2001))*



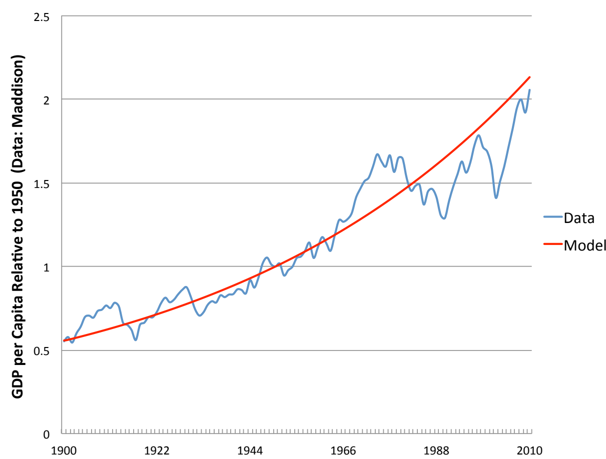


Figure 2. *Argentina: Agricultural Labor Share and GDP Per Capita (1950=1)*

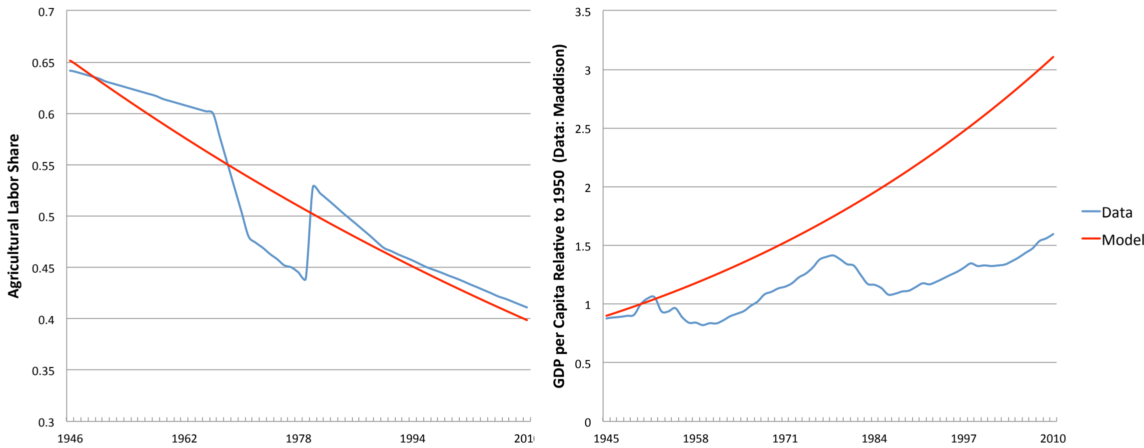


Figure 3. *Bolivia: Agricultural Labor Share and GDP Per Capita (1950=1)*

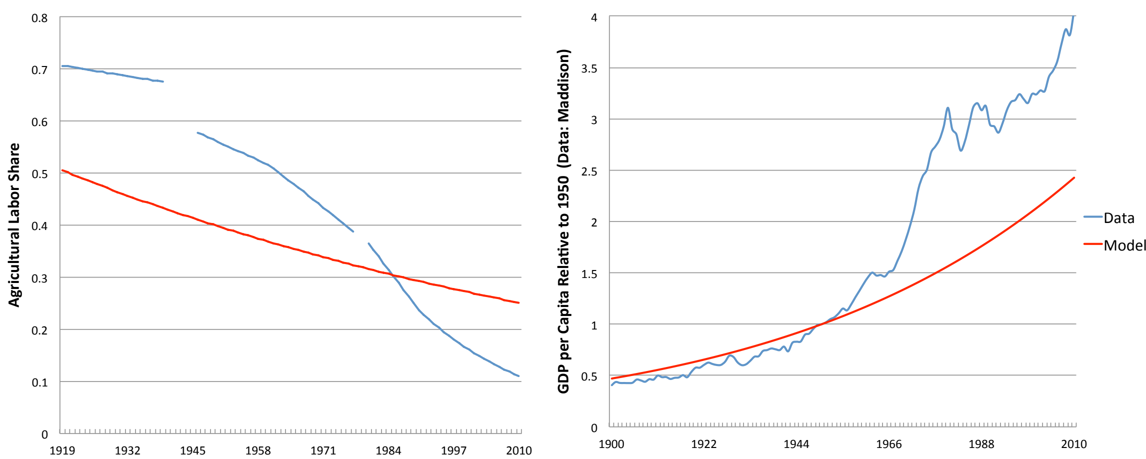


Figure 4. *Brazil: Agricultural Labor Share and GDP Per Capita (1950=1)*

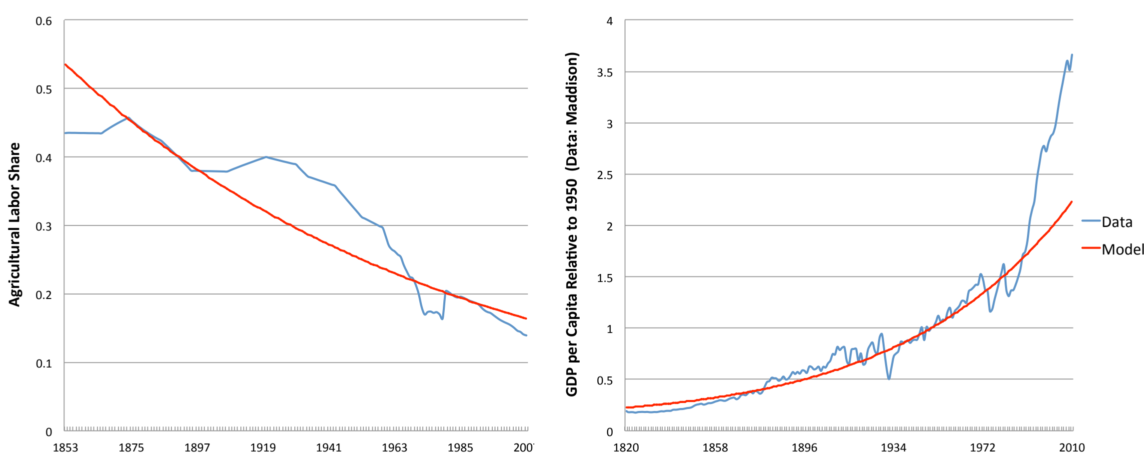


Figure 5. *Chile: Agricultural Labor Share and GDP Per Capita (1950=1)*

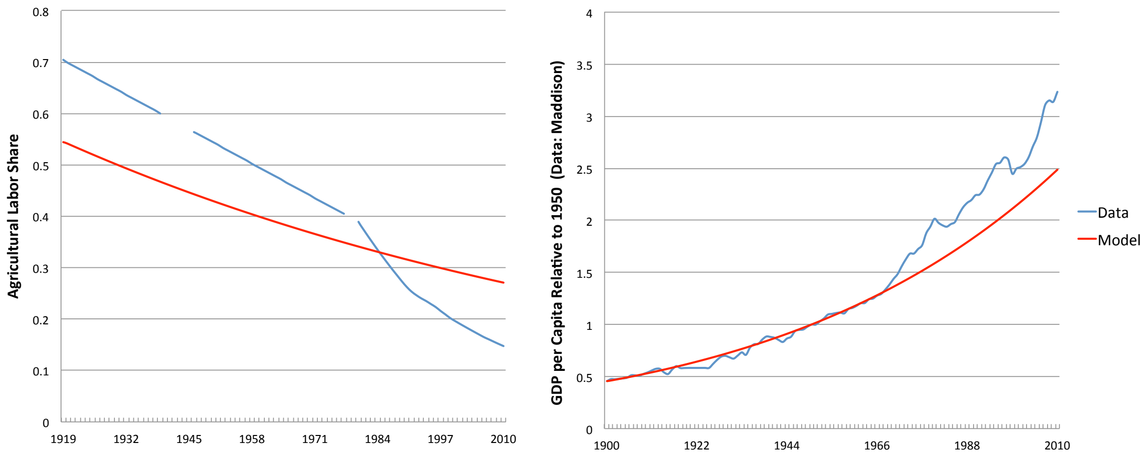


Figure 6. *Colombia: Agricultural Labor Share and GDP Per Capita (1950=1)*

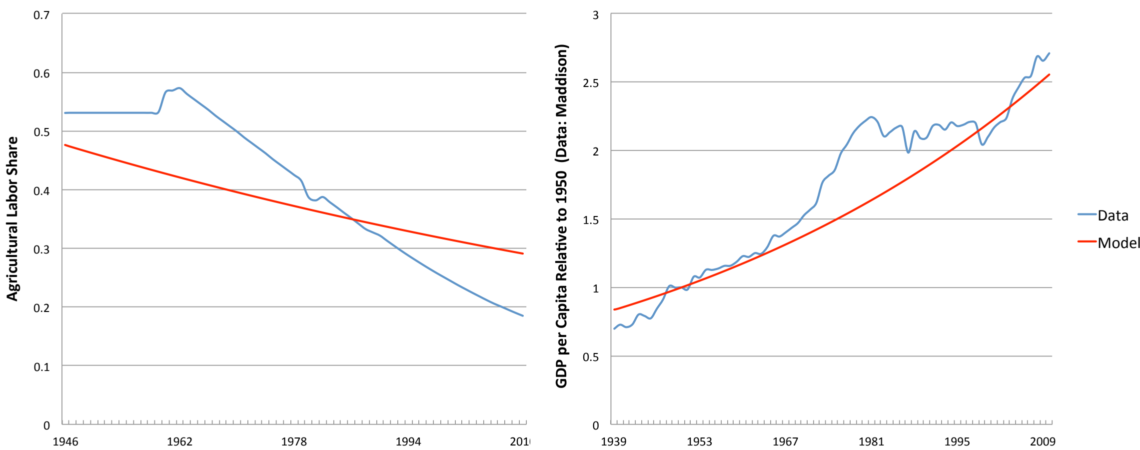


Figure 7. *Ecuador: Agricultural Labor Share and GDP Per Capita (1950=1)*

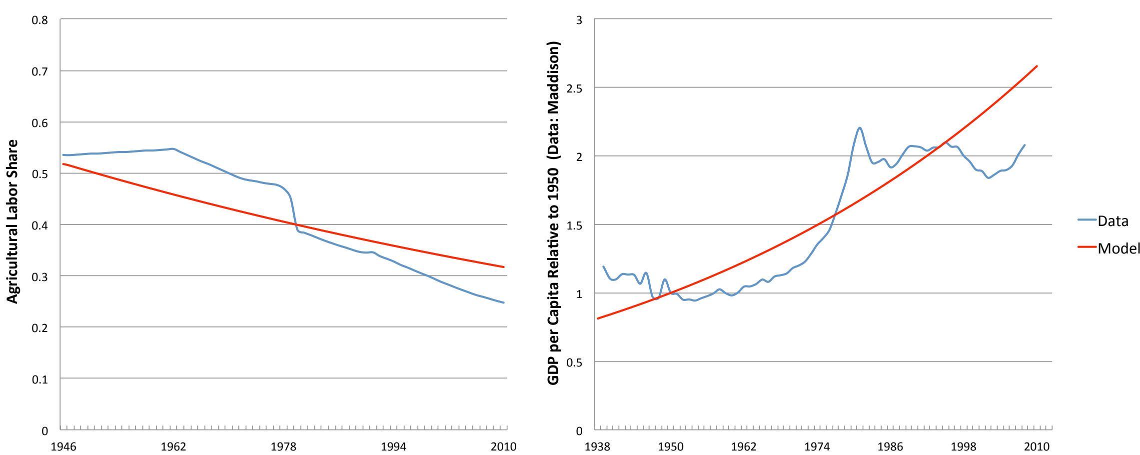


Figure 8. *Paraguay: Agricultural Labor Share and GDP Per Capita (1950=1)*

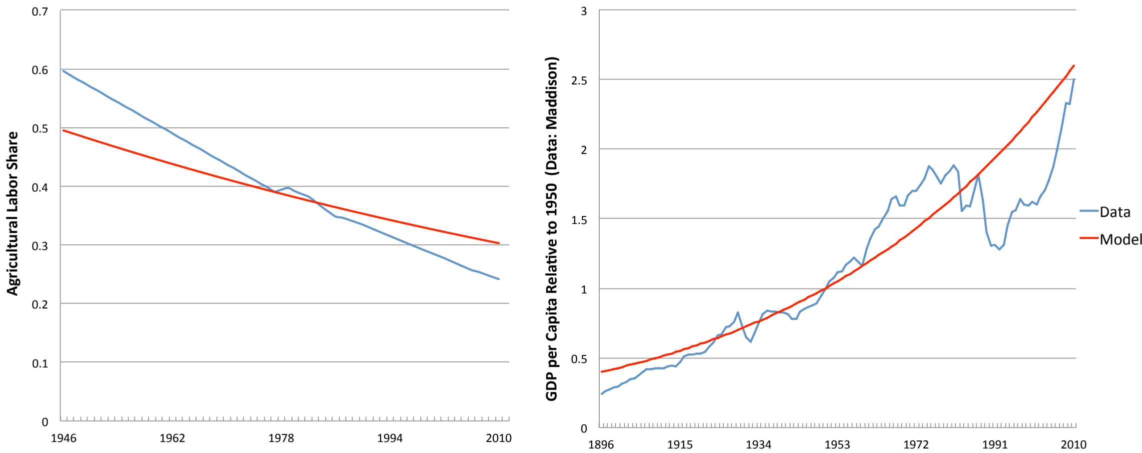


Figure 9. *Peru: Agricultural Labor Share and GDP Per Capita (1950=1)*

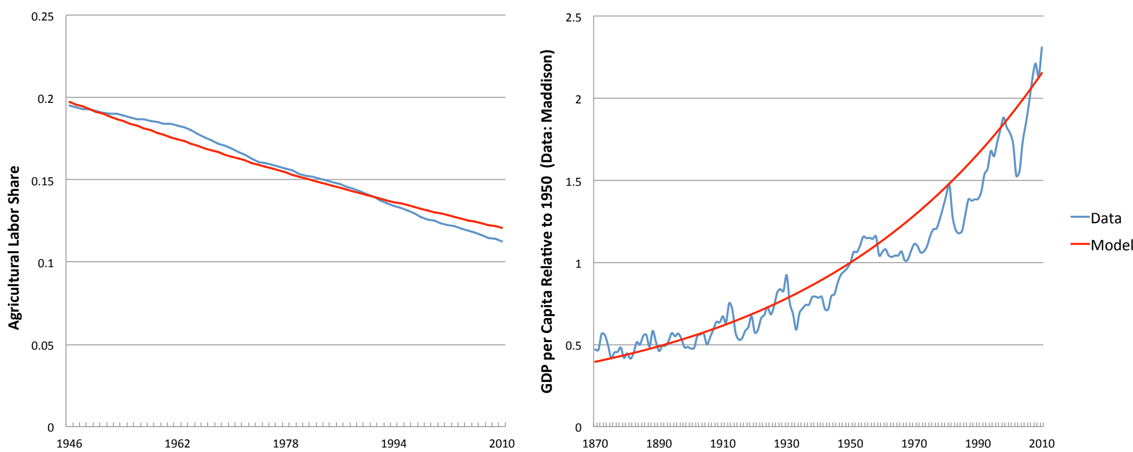


Figure 10. *Uruguay: Agricultural Labor Share and GDP Per Capita (1950=1)*

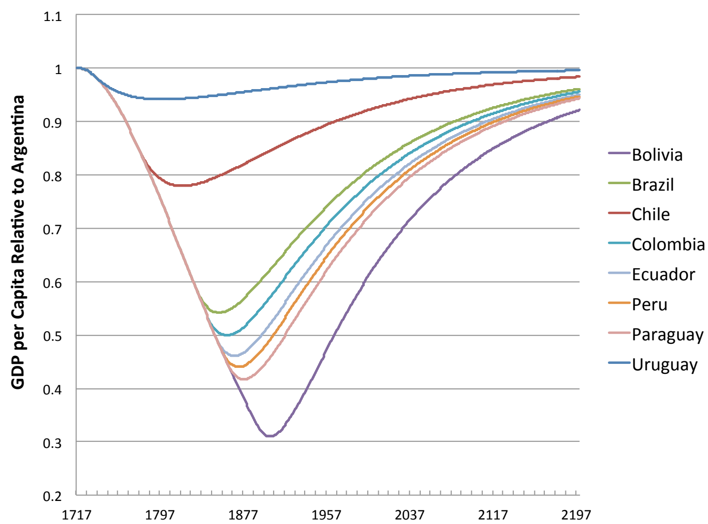


Figure 11. *Modeled GDP per capita Relative to Argentina*

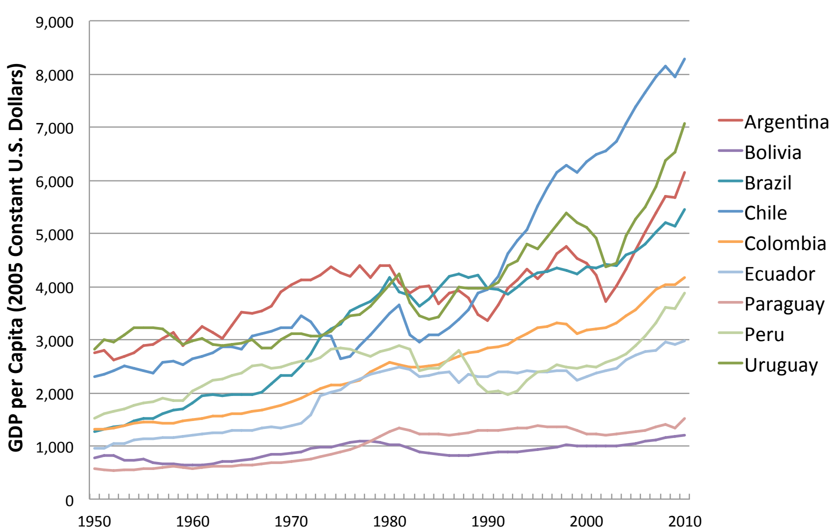


Figure 12. *GDP per capita 1900 - 2000 (ECLAC)*

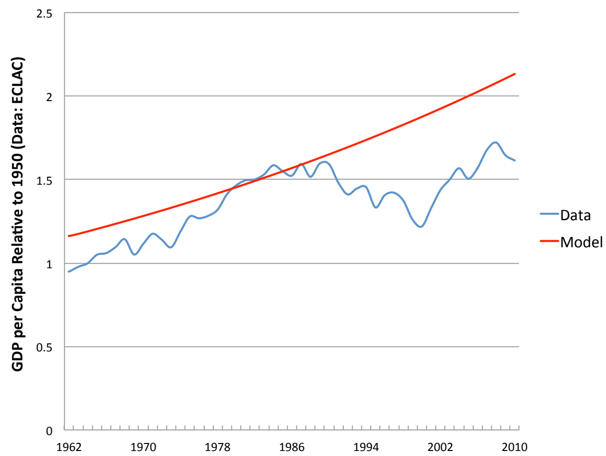


Figure 13. *Argentina: Modeled and Observed GDP per capita (1950-1) (Data: ECLAC)*

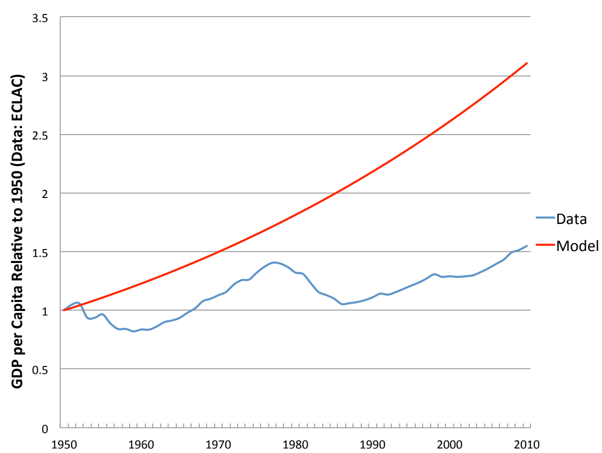


Figure 14. *Bolivia: Modeled and Observed GDP per capita (1950-1) (Data: ECLAC)*

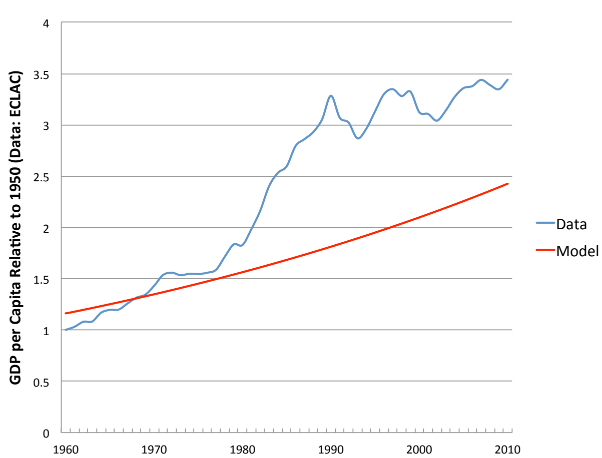


Figure 15. *Brazil: Modeled and Observed GDP per capita (1950-1) (Data: ECLAC)*

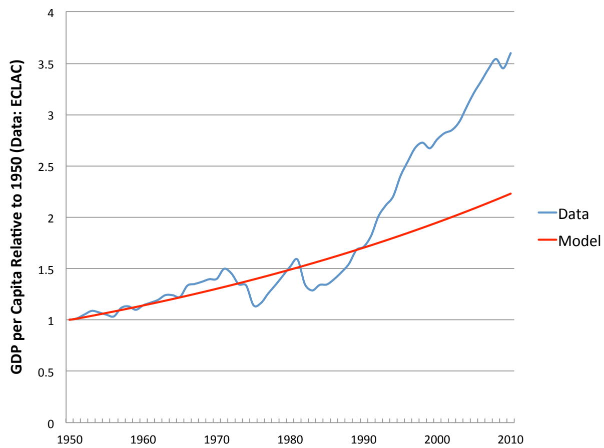


Figure 16. *Chile: Modeled and Observed GDP per capita (1950-1) (Data: ECLAC)*

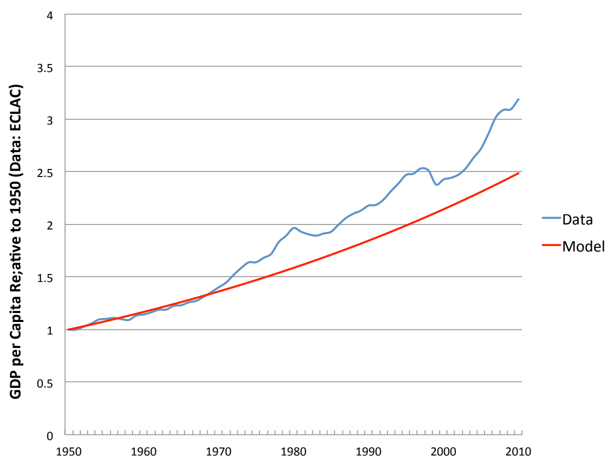


Figure 17. *Colombia: Modeled and Observed GDP per capita (1950-1) (Data: ECLAC)*

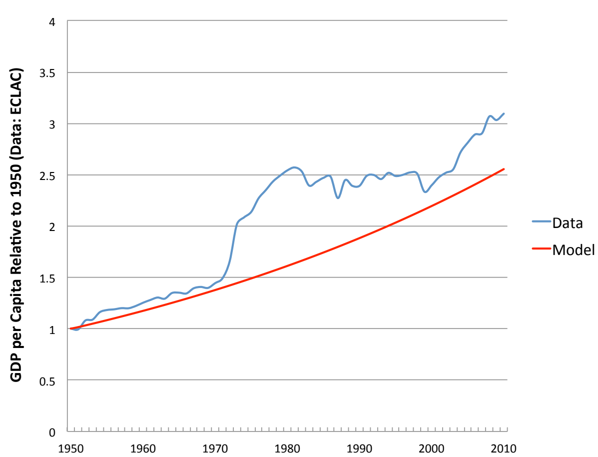


Figure 18. *Ecuador: Modeled and Observed GDP per capita (1950-1) (Data: ECLAC)*

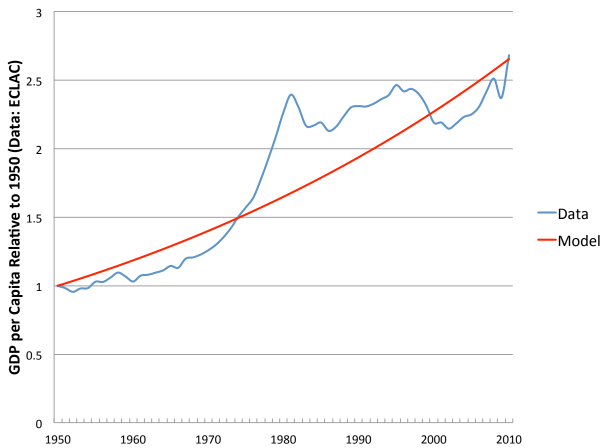


Figure 19. *Paraguay: Modeled and Observed GDP per capita (1950-1) (Data: ECLAC)*

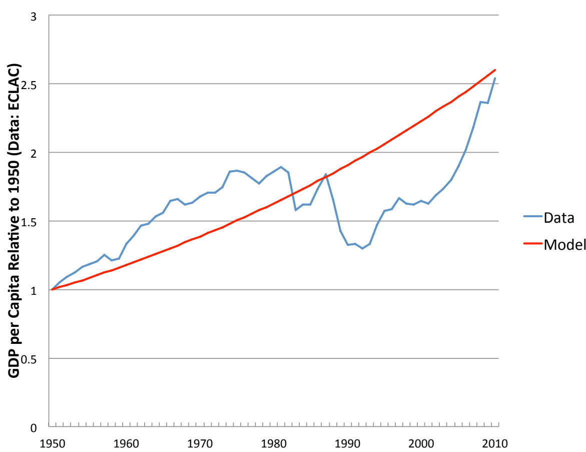


Figure 20. *Peru: Modeled and Observed GDP per capita (1950-1) (Data: ECLAC)*

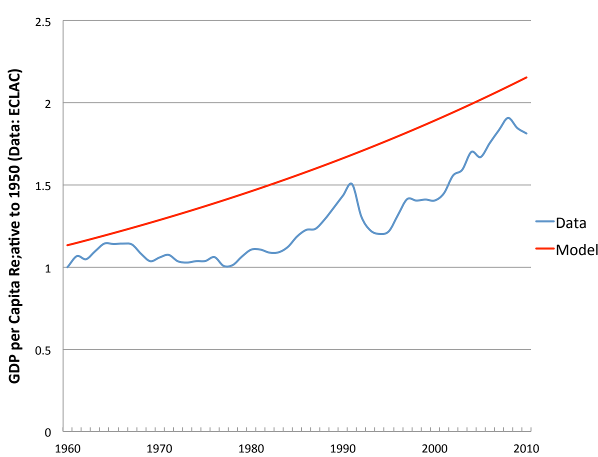


Figure 21. *Uruguay: Modeled and Observed GDP per capita (1950-1) (Data: ECLAC)*

Table 1
Agricultural Productivity, Beginning of Industrialization and Convergence

	A_a	A_n	Beginning of Industrialization	Year in which country's GDP per capita reaches 90% of Argentina's GDP per capita
Argentina	1.51	1	1718	
Uruguay	1.33	1	1735	1735
Chile	0.97	1	1776	1966
Brazil	0.64	1	1830	2080
Colombia	0.59	1	1840	2097
Ecuador	0.55	1	1850	2111
Peru	0.53	1	1855	2119
Paraguay	0.51	1	1861	2128
Bolivia	0.40	1	1891	2170

Using the agricultural productivity level (A_a) yielded by the model (equations 12 and 13) and the assumption of equal non-agricultural productivity (A_n), this table shows the year when industrialization began in each country as well as the year when each country's GDP per capita reaches 90% of Argentina's GDP per capita.

Table 2

GDP Per Capita Relative to the Leader

	Model	Data: Maddison	Data: ECLAC
Uruguay	98.15%	101.35%	113.39%
Chile	92.61%	136.67%	152.75%
Brazil	82.01%	68.14%	99.50%
Colombia	79.51%	70.27%	75.43%
Ecuador	76.99%	52.01%	55.61%
Peru	75.50%	51.55%	62.44%
Paraguay	73.72%	36.26%	27.27%
Bolivia	63.34%	31.56%	22.47%

This table shows the model-generated average GDP per capita between 2000 and 2010 for each country relative to that of Argentina and compares it to the one observed in the data.

Table 3
Non-Agricultural Productivity, Beginning of Industrialization and Convergence (Data: Maddison)

	Aa	An	Beginning of Industrialization	Year in which country's GDP per capita reaches 90% of Argentina's GDP per capita
Argentina	1.51	1.00	1718	
Uruguay	1.33	1.02	1735	1792
Chile	0.97	1.24	1776	1825
Brazil	0.64	0.89	1830	>2200
Colombia	0.59	0.92	1840	> 2200
Ecuador	0.55	0.78	1850	> 2200
Peru	0.53	0.78	1855	>2200
Paraguay	0.51	0.62	1861	> 2200
Bolivia	0.40	0.61	1891	> 2200

Using the agricultural productivity level (A_a) yielded by the model, this table shows the calibrated the non-agricultural productivity level (A_n) that generates the observed difference in GDP per capita with Argentina in 2000-2010 using Maddison's data. Given these two productivity levels, the table shows the year in which each country would converge with Argentina (reach 90% of Argentina's GDP per capita).

Table 4

Non-Agricultural Productivity, Beginning of Industrialization and Convergence (Data: ECLAC)

	Aa	*An*	Beginning of Industrialization	Year in which country's GDP per capita reaches 90% of Argentina's GDP per capita
Argentina	1.51	1.00	1718	
Uruguay	1.33	1.09	1735	1766
Chile	0.97	1.32	1776	1811
Brazil	0.64	1.11	1830	1962
Colombia	0.59	0.96	1840	>2200
Ecuador	0.55	0.80	1850	>2200
Peru	0.53	0.88	1855	>2200
Paraguay	0.51	0.48	1861	>2200
Bolivia	0.40	0.42	1891	>2200

Using the agricultural productivity level (A_a) yielded by the model, this table shows the calibrated non-agricultural productivity level (A_n) that generates the observed difference in GDP per capita with Argentina in 2000-2010 using ECLAC's data. Given these two productivity levels, the table shows the year in which each country would converge with Argentina (reach 90% of Argentina's GDP per capita).