Institute for Advanced Development Studies

03/2012

Productivity, Structural Change, and Latin American Development

by:

Carlos Gustavo Machicado, Felix Rioja, Antonio Saravia.

Development Research Working Paper Series

03/2012

March 2012

Productivity, Structural Change, and Latin American Development

Carlos Machicado [a], Felix Rioja [b], Antonio Saravia [c,*]

[a] *Institute for Advanced Development Studies*

[b] *Department of Economics, Georgia State University*

[c] *Deloitte Tax LLP*

Abstract

We calibrate a simple neoclassical model of structural transformation to a set of Latin American countries and show that slow growth in agricultural productivity can substantially delay the development process and result in significant differences in per capita incomes. Some of our results indicate that low agricultural productivity delayed the beginning of the industrialization process in Paraguay and Bolivia by about 100 years compared to the leader of the group, Chile. The development process can be accelerated, however, by increasing productivity in the non-agricultural sector. In fact, in the long run, it is non-agricultural productivity what determines the speed of convergence. Improvements in non-agricultural productivity between 20% to over 100% would be required for the other Latin American countries in our set to significantly close the income gap with Chile by the end of the century.

Key words: Economic Development, Latin America, Agriculture Productivity, Manufacturing Productivity
JEL Classification: O47, O57, E13

* Corresponding author.
Email addresses: cmachicado@inesad.edu.bo (Carlos Machicado), frioja@gsu.edu (Felix Rioja), asaravia@deloitte.com (Antonio Saravia).

Preprint submitted to INESAD *27 March 2012*

1 Introduction

Trying to understand the origins of the large disparity in income per capita 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 the aforementioned disparity is that poor countries started the process of industrialization much later than their rich counterparts, and that the industrialization process is slow (see, for example, Lucas (2000)).

On this line of argument, Gollin, Parente, and Rogerson (2002) (henceforth GPR (2002)) 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 (food) needs. Thereafter, resources are freed up for the non-agricultural sector and the process of industrialization begins. Hence, low agricultural productivity can significantly delay industrialization and result in the country falling behind the leaders in terms of income per capita. [1]

In this paper, we evaluate whether the GPR (2002) model of structural transformation fits the development experience of a set of Latin American countries (Bolivia, Brazil, Chile, Colombia, Ecuador, Peru and Paraguay) that share similar original institutions and cultural background. As we will see below, Chile started to industrialize much earlier than the rest of the countries in the set. Perhaps not surprisingly, therefore, Chile's income per capita has been 40 to 80% higher than that of the rest of the countries during the period covered by our analysis.

Our contribution is two-fold. First, to our knowledge, our paper is the first to calibrate the GPR (2002) model to a set of Latin American countries sharing similar original institutions and cultural background. While data availability is always a restriction in this type of long-run exercises, we believe that the GPR (2002) model presents a simple and effective framework to understand long-run growth paths in Latin America. Second, in GPR (2002) all countries are assumed to have the same non-agricultural total factor productivity (TFP) implying that all countries eventually converge in terms of income per-capita. We relax this assumption and allow for different TFPs in non-agricultural

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

production. Allowing for different TFPs in non-agricultural production yields insights on very long term differences in income per capita among the countries under study. Thus, while agricultural productivity determines the start date of industrialization, non-agricultural productivity determines how fast or slowly convergence proceeds in the future.

The importance of agriculture for the industrialization process has been long noted in the development literature as in Johnston and Mellor (1961), Johnston and Kilby (1975), and Timmer (1988, 2002). Before industrialization, almost all of the labor force works in agriculture. Once agricultural productivity rises enough to allow the production of subsistence levels of food, however, individuals move out from the agricultural to the non-agricultural sector. Thus, the share of the agricultural sector in a country's GDP (and its level of employment) starts falling as people move to urban settings into industrial activities 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 (2007) who use a similar model to the one in their original paper but allow for a feedback effect from the manufacturing to the agricultural sector. In a more recent paper, Restuccia, Yang and Zhu (2008) also find that agricultural productivity is important for structural transformation. They 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; for example, Echeverria (1997), Kongsamut et al. (2001), Glomm (1992), Laitner (2000), Hansen and Prescott (2002), and Lucas (2004).

Our findings indicate that the model provides an accurate description of the observed income disparities of the seven Latin American countries under study. We find, for example, that the beginning of the industrialization process in Paraguay and Bolivia lags by about 100 years compared to that of the leader of the group, Chile. Consistent with the model's implications, we find that Paraguay and Brazil presented much lower levels of agricultural productivity than Chile. We also find that the reduction in income differences (convergence) depends critically on productivity in the non-agricultural sector. Within this framework, improvements in non-agricultural productivity between 20% to over 100% would be required for the other countries to significantly close the income gap with Chile by the end of the century.

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

2 The Model

The basic structure of the GPR (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 growth model. To illustrate the mechanism behind the argument, we present here the basic features of the GPR (2002) 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 was either somewhat higher or lower. [2]

[2] 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.

2.2 Nonagricultural sector

GPR (2002) correctly called one of the sectors of this economy the "non-agricultural" sector, since it includes not only manufacturing but also services and remaining sectors. This sector produces output (Y_{mt}) by combining capital (K_{mt}) and labor (N_{mt}) using the following function:

$$Y_{mt} = A_m \left[K_{mt}^{\theta}((1+\gamma_m)^t N_{mt})^{1-\theta} + \alpha N_{mt} \right] \tag{3}$$

where A_m (TFP) is assumed country-specific and determined by policies and institutions. The rate of exogenous technological change (γ_m) and α are assumed identical across countries. The production function is standard except for αN_{mt} 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 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,

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

where δ is the depreciation rate and X_{mt} 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. [3] 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. [4]

The modern agricultural technology is subject to exogenous technological change:

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

[4] See Galor and Weil (2000) and Hansen and Prescott (2002).

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

where A_a (TFP) 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:

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

It is important to mention that the agricultural sector is a “basic” agricultural sector in the sense that its output only satisfy “basic food needs.” Thus, this agricultural sector needs to be clearly differentiated from industrial agriculture or agriculture for export which are not included in the model.

2.4 The competitive equilibrium

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

At the beginning labor is allocated entirely to agriculture until:

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

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:

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

and

$$N_{mt} = 1 - N_{at}$$

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, $c_t + X_{mt} = Y_{mt}$, the law of motion of capital (4), and the appropriate non-negativity constraints and constraints on K_{mt}.

The Euler equation for this optimization problem is given by,

$$\frac{A_m[Km_{t+1}{}^{\theta}((1+\gamma m)^{t+1}Nm_{t+1})^{1-\theta} + \alpha Nm_{t+1}] - Km_{t+2} + (1-\delta)Km_{t+1}}{\beta A_m[Km_t{}^{\theta}((1+\gamma m)^{t}Nm_{t})^{1-\theta} + \alpha Nm_{t}] - Km_{t+1} + (1-\delta)Km_{t}} = AmKm_{t+1}{}^{\theta-1}\theta((1+\gamma m)^{t+1}Nm_{t+1})^{1-\theta} + 1 - \delta$$

and the steady state capital level is:

$$Km_{ss} = \left[\frac{(1/\beta - 1 + \delta)}{(Am)\theta((1+\gamma m)^{ss}Nm_{ss})^{1-\theta}}\right]^{1/(\theta-1)} \tag{7}$$

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

3 Quantitative Evaluation

Before describing the data and the calibration, it is important to show the evolution of GDP per capita for the countries in our set. As one can clearly see in Figure 1, Chile's GDP per capita has been higher than that of the other countries since at least 1910. This difference has clearly accentuated starting in the early 1980's after Chile's open economy approach resulted in significant increases in TFP. It is also evident from the figure that, since the mid 1980's, our sample is divided into three distinct groups: the first one with Chile as the exclusive regional leader in terms of GDP per capita, the second one with Colombia and Brazil as countries presenting more modest growth rates but on an overall positive trend, and a third one with Bolivia, Peru, Ecuador and Paraguay with economies that seem to have been stagnated from the mid 1980s to 2000.

While our exercise refers to long-run paths of development and convergence, it is also interesting to comment on clear patterns arising during specific years.

For example, one can, clearly observe in Figure 1 the effect on Chile's economy (and to a lesser extent on the other economies) of the Great Depression in the early 1930s. It is also interesting to notice the overall regional acceleration during the late 1970s followed by a recession during the early 1980's. [5]

3.1 Data

Time series on labor share in agriculture (N_a) is one of the key data requirements to calibrate the model. Data for this variable have been collected from Banks (2011), for the early periods, and from the Food and Agriculture Organization (FAO) for the latter periods. For Chile, we also used the data set compiled by Diaz et al. (1998). GDP per capita for the different countries has been obtained from Maddison (2001) and is expressed in 1990 Geary-Khamis dollars. In one of our simulations we employ estimations for the non-agriculture TFP parameter A_m from Paus, Reinhardt, and Robinson (2003). [6]

3.2 Calibration

The parameters $\overline{a}$ and γ_a are set to match Chile's agricultural employment shares in 1890 and 1990. To do this we solve the following system of equations,

$$\frac{\overline{a}}{(1+\gamma_a)^{1890}} = 0.4026 \tag{8}$$

$$\frac{\overline{a}}{(1+\gamma_a)^{1990}} = 0.1868, \tag{9}$$

where 0.4026 and 0.1868 are the agricultural employment shares in Chile for 1890 and 1990, respectively. Solving equations (8) and (9) we obtain $\overline{a} = 0.4057$ and $\gamma_a = 0.0077$. Based on these values, Chile's average A_a for 1853-2007 is 0.92. As our numeraire, however, we set A_a equal to 1. Initially, we

[5] 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 so it is hard to summarize a preponderance of evidence for convergence.

[6] At this point it is also important to mention that Argentina, Uruguay and Venezuela are not included in our sample because these economies based their development path in industrialized agricultural and farming sectors. Given that GPR (2002) is a simple analytical model which does not account for industrialized agricultural sectors, we leave this important feature for future research.

also assume $A_m = 1$ for all the countries and focus on the effect of differences in A_a.

The rest of the parameters take the same values used in GPR (2002). The parameter α is set equal to 0.0001. Following Parente and Prescott (1994, 2000), the capital share parameter θ is set equal to 0.5. The depreciation rate δ takes a typical value for annual depreciation of 0.065. The parameter γ_m 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, $\gamma_m = 0.013$ would also be their long run growth rate. The discount factor β is chosen so that the asymptotic annual interest rate is 5 percent.

3.3 Results

The first task is to obtain the values for A_a (agricultural productivity) for each year (whenever data on N_a is available) for each country. To do this we simply replace the values for $\overline{a}$ and γ_a previously found in the following equation:

$$\frac{\overline{a}}{(1+\gamma_a)^t N_{at}} = A_{at} \tag{10}$$

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.

Table 1 presents the initial results. The agricultural TFP (A_a) values reported in the second column are relative values with respect to Chile's A_a which is normalized to 1. In the fourth column we report the year in which industrialization begins. Industrialization is defined to begin the first year in which $N_a < 1$ and N_m is greater than zero.

Several interesting implications follow from Table 1. First, a country with a lower agricultural TFP begins its industrialization process later. Chile, with the highest A_a, began its industrialization in 1772. On the other hand, Bolivia, with the lowest A_a, began its industrialization in 1891. Brazil and Colombia began to shift labor from the agriculture sector into the non-agriculture sector in 1836 and 1844, respectively.

Second, given that we are assuming that A_m is equal to 1, all income differences asymptotically vanish, i.e , per capita incomes converge. The last column of Table 1 shows the year in which output per capita for each of the selected countries converges to the 90 percent level of Chile's income per capita.

As the model predicts, the country with the highest A_a after Chile, which is Brazil, would be the first to converge to Chile's income per capita. Brazil would catch up with Chile in the year 2043. Paraguay that started to industrialize in 1863 would catch up with Chile in 2098. Notice that all of the selected countries take more than 200 years to reach its steady-state relative output levels. As GPR (2002) state, this transition is much slower than what occurs in the one-sector neoclassical growth model. The reason for this difference is that, in our model, labor moves only slowly into the non-agricultural sector.

How well does the model match the data? Figures 2 to 8 plot model generated data and actual data for each of the countries. For each country, these figures show the evolution over time of the agricultural labor share and of GDP per capita.[7] Despite the model's simplicity, we observe that the data generated by the model matches fairly well the experience over the last 100 years for the countries in our set. There are periods for a couple of countries where the match is not as close. For example, according to the model Brazil should not have experienced the jump in GDP per capita during the 1950s and 1960s and Bolivia should have grown at higher rates than it actually did. The reason for these mismatches is that the model is not capable to reproduce periods of very high or low growth, i.e. periods in which the changes in TFP are large, because we are assuming a constant TFP in the non-agricultural sector. For instance, Bolivia experienced high rates of growth during the 1970s explained by a boost in aggregate TFP, but then during the 1980s it experienced a large recession with negative rates of growth explained by a large decrease in aggregate TFP. Nevertheless, from a quantitative perspective, the model supports the long-standing idea that low agricultural productivity is a major determinant of development.

Figure 9 shows the time path in which all the other countries catch up with Chile (get to 90 percent of its GDP per capita) assuming $A_m = 1$. Therefore, this exercise focuses exclusively on the role of the industrialization date. A country that begins its industrialization later will start its development later and therefore will take more time to attain higher levels of GDP per capita and close the gap with the leader. This is certainly the case of Bolivia, which started last and is the poorest country in the group.

[7] In Figures 2 to 8, "GDPpc relative to 1950" is the country's GDP per capita in year t divided by GDP per capita in 1950. There is nothing special about 1950; it is chosen just as a frame of reference. Relative income is computed using 1995 prices from the benchmark economy. To compute the prices we use the marginal productivity of labor of the agricultural and nonagricultural sectors, we equalize both to the 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.

Table 2 shows each country's relative income with respect to Chile's during the 1990-2000 period. As expected, notice that, when comparing the second column with the third one (model generated data using the original assumption of $A_m = 1$), the model does not accurately replicate the data. For example, the actual data show that Brazil's GDP per capita was 62 percent of that of Chile during the 1990-2000 period but the model predicts that number to be 85 percent. However, when using estimations of A_m, i.e. the manufacturing productivity estimated values reported by Paus, Reinhardt, and Robinson (2003), the model predicts Brazil's GDP per capita to be 61 percent of that of Chile. Unfortunately, Paus, Reinhardt, and Robinson (2003) report estimates for A_m only for Brazil, Colombia, and Peru. As reported in the table, using such estimates of A_m for these three countries results in a very close match of the modeled GDP per capita (relative to Chile) to the actual data. For the countries for which there were no available estimates of A_m, i.e. Ecuador, Paraguay and Bolivia, we estimated the values of A_m that would have generated the best fit to the actual data. These values are reported starred in the last column of Table 2.

Finally, a typical question in the growth literature, particularly when the interest resides in absolute convergence, is: How long would it take a country to close its GDP per capita gap with the leader? Here we modify the question slightly and ask: By how much would the non-agricultural TFP (A_m) need to increase in each country in order to "catch up" in GDP per capita terms with Chile by the end of this century? Our definition of "catch up" for this exercise is reaching 90% of Chile's GDP per capita. In other words we simulate the value of A_m that would allow each country to catch up with Chile in 2100. The results are reported in Table 3. Brazil, which is the country closer in GDP per capita to Chile, would need $A_m = 0.98$ to catch up. That represents a required 18.23 percent increase in non-agricultural productivity. The required increase in A_m would be 16.42 percent in Colombia and much larger in the rest of the countries.

4 Concluding Remarks

In this paper, we evaluate whether the GPR (2002) model of structural transformation fits the development experience of a set of Latin American countries (Bolivia, Brazil, Chile, Colombia, Ecuador, Peru and Paraguay) that share similar original institutions and cultural background. We examine whether the model is able to characterize the long-run development pattern of an initially similar group of developing countries in which some started the industrialization process earlier than others. To our knowledge this paper is the first in calibrating the GPR (2002) model to several developing countries. Our findings indicate that the model provides an accurate description of the observed income disparities of the countries in our sample. The model generates series of output per capita very similar to the actual data series of Maddison (2001).

We find that low agricultural productivity delayed the beginning of the process of industrialization in some cases, like Paraguay and Bolivia, by about 100 years compared to the leader of the group, Chile. We also find that the reduction in income differences (convergence) depends critically on productivity in the non-agricultural sector. Improvements in non-agricultural productivity in the range of 16% to over 100% would be required for the other countries to significantly close the income gap with Chile by the end of the century.

Future work will 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.

5 References

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

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

Caselli, F. and W.J. Coleman II, 2001. The US structural transformation and regional convergence: a reinterpretation. *Journal of Political Economy* 109 (3), 584–616.

Caselli, F. 2005. Accounting for Cross-Country Income Differences. Chapter 9 in Handbook of Economic Growth, P. Aghion and S. Durlauf, editors. Elsevier.

Díaz José, Rolf Lüders y Gert Wagner.1998. Economía Chilena 1810-1995: Evolución Cuantitativa del Producto Total y Sectorial, Documento de Trabajo No. 186, PUC-Chile.

Echevarria, C., 1997. Changes in sectoral composition associated with economic growth. *International Economic Review* 38 (2), 431–452.

Galor, Oded. 1996. Convergence? Inferences from theoretical models. *The Economic Journal*, Vol. 106, No. 437, pp. 1056-1069.

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

Glomm, G., 1992. A model of growth and migration. *Canadian Journal of Economics* 42 (4), 901–922.

Gollin, D. 2002. Getting Income Shares Right. *Journal of Political Economy*, Vol. 110 (2), pp. 458-474..

Gollin, Douglas, Stephen Parente, and Richard Rogerson. 2002. The Role of Agriculture in Development, *AEA Papers and Proceedings* Vol. 92, No.2, pp: 160-164.

Gollin, Douglas, Stephen Parente, and Richard Rogerson. 2004. Farmwork, Homework, and International Productivity Differences. *Review of Economic Dynamics*, Vol. 7, pp. 827-850.

Gollin, Douglas, Stephen Parente, and Richard Rogerson. 2007. The Food Problem and the Evolution of International Income Levels. *Journal of Monetary Economics*, Vol. 54 (4), pp. 1230-1255.

Hansen, G., Prescott, E.C., 2002. Malthus to Solow. *American Economic Review* 92 (4), 1205–1217.

Johnston, Bruce F. and John W. Mellor. 1961. The role of agriculture in economic development. *American Economic Review* 51(4): 566-93.

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

Kongsamut, P., Rebelo, S., Xie, D., 2001. Beyond balanced growth. *Review of Economic Studies* 68 (4), 869–882.

Laitner, J., 2000. Structural change and economic growth. *Review of Economic Studies* 67 (July), 545–561.

Lucas Jr., R.E., 2000. Some Macroeconomics for the 21st Century. *The Journal of Economic Perspectives*, Vol. 14, No. 1. (Winter), pp. 159-168.

Lucas Jr., R.E., 2004. Life earnings and rural–urban Migration. *Journal of Political Economy* 112 (1, part 2), S29–S59.

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

Paus, Eva., Nola Reinhardt, and Michael Robinson. 2003. Trade Liberalization and Productivity Growth in Latin American Manufacturing, 1970-98. *Policy Reform*, Vol 6(1), pp. 1-15.

Restuccia, Diego, Dennis T. Yang and Xiaodong Zhu. "Agriculture and Aggregate Productivity: A Quantitative Cross-Country Analysis," *Journal of Monetary Economics*, Volume 55 (2), March 2008, pp. 234-50.

Tamura, Robert. 2002. Human capital and the switch from agriculture to industry, *Journal of Economic, Dynamics and Control*, 27, pp. 207-242.

Timmer, C. Peter. 1988. The agricultural transformation. Chapter 8 in Handbook of Development Economics, Vol. I, ed. H. Chenery and T.N. Srinivasan. Amsterdam: Elsevier Science Publishers.

Timmer, C. Peter. 2002. Agriculture and economic development. Chapter 29 in Handbook of Agricultural Economics, Vol. 2A: Agriculture and Its External Linkages, ed. Bruce L. Gardner and Gordon C. Rausser. Amsterdam: Elsevier Science Publishers.

Table 1
Agricultural TFP and year of industrialization

Country	A_a	A_m	Year of Ind	Catch up year (90% of Chile's income per capita)
Chile	1	1	1772	
Brazil	0.6095	1	1836	2043
Colombia	0.5737	1	1844	2061
Ecuador	0.536	1	1853	2080
Peru	0.5227	1	1856	2086
Paraguay	0.4987	1	1863	2098
Bolivia	0.4024	1	1891	2146

Table 2
Relative income (with respect to Chile) during the 1990-2000 period

Country	Data	Model (using $A_m = 1$)	Model (using PRR (2003)'s A_m)	A_m estimated by PRR (2003)
Brazil	**0.6187**	0.8507	**0.6141**	0.8289
Colombia	**0.6762**	0.8267	**0.6231**	0.8503
Ecuador	**0.3779**	0.7977	**0.3766**	0.63*
Peru	**0.3694**	0.7865	**0.345**	0.5975
Paraguay	**0.4175**	0.7647	**0.415**	0.69*
Bolivia	**0.224**	0.6502	**0.2119**	0.45*

* Own estimation

Table 3
Percentage change of non-agricultural TFP required to catch up with Chile in 2100

Country	A_a	Current A_m	Required A_m	Difference
Brazil	0.6095	0.8289	0.98	18.23%
Colombia	0.5737	0.8503	0.99	16.42%
Ecuador	0.536	0.63	0.993	57.62%
Peru	0.5227	0.5975	0.994	66.34%
Paraguay	0.4987	0.69	1	44.93%
Bolivia	0.4024	0.45	1.03	128.89%

Fig. 1. GDP per capita 1900 - 2000

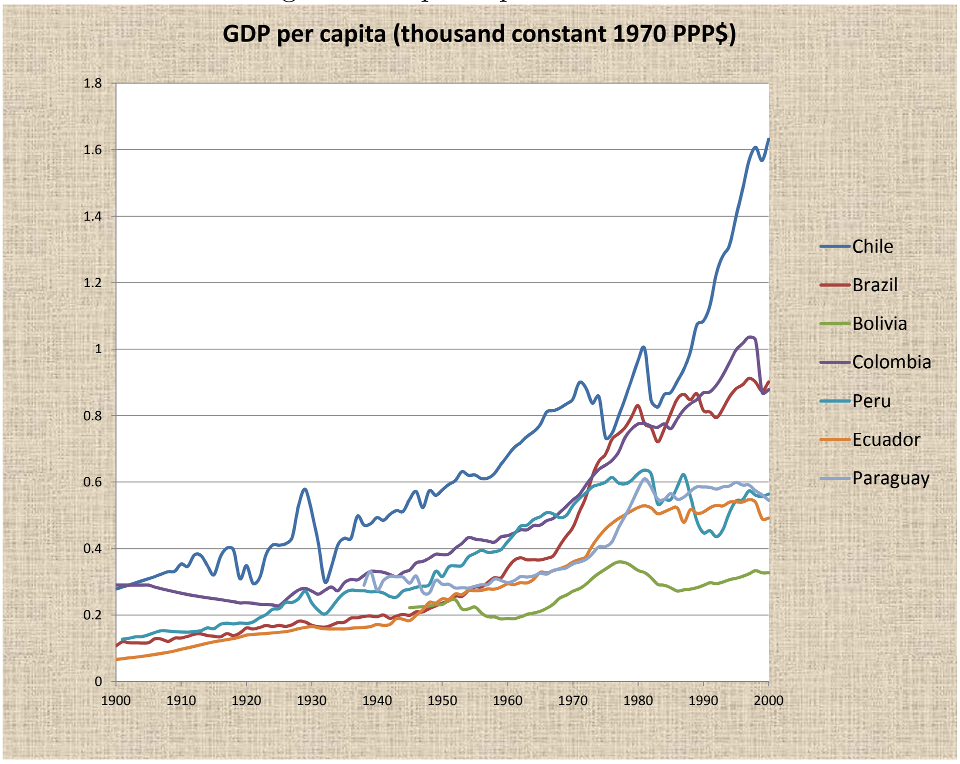

Fig. 2. Brazil

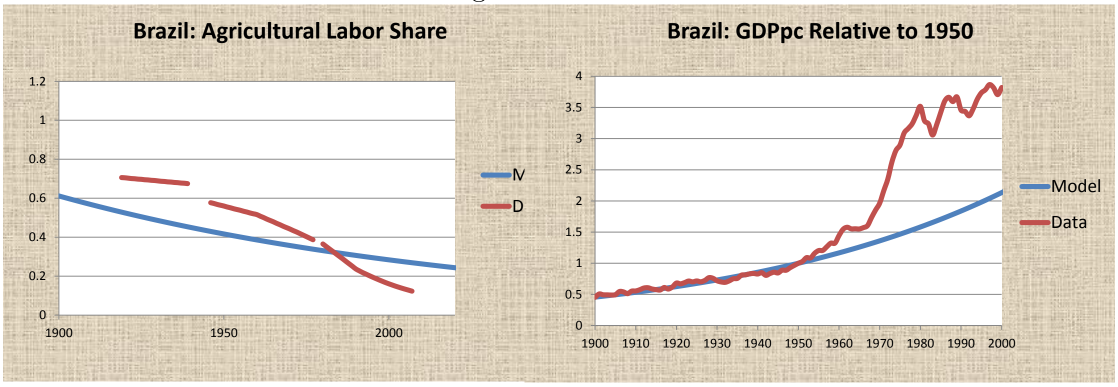

Fig. 3. Bolivia

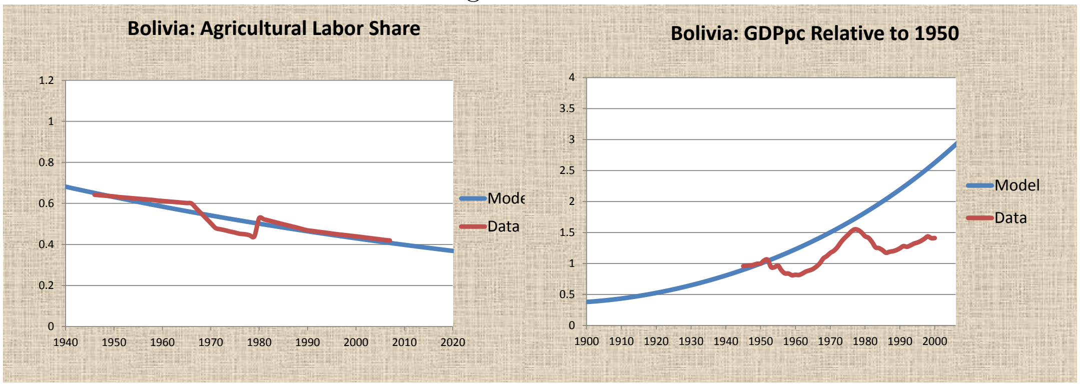

Fig. 4. Colombia

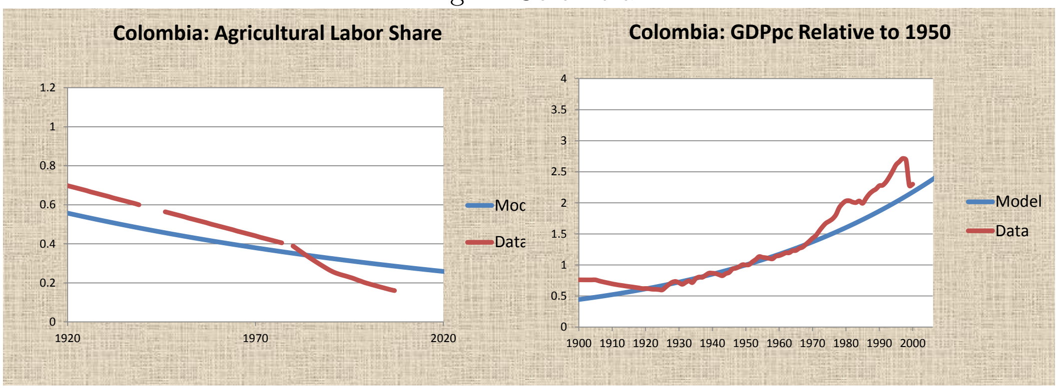

Fig. 5. Peru

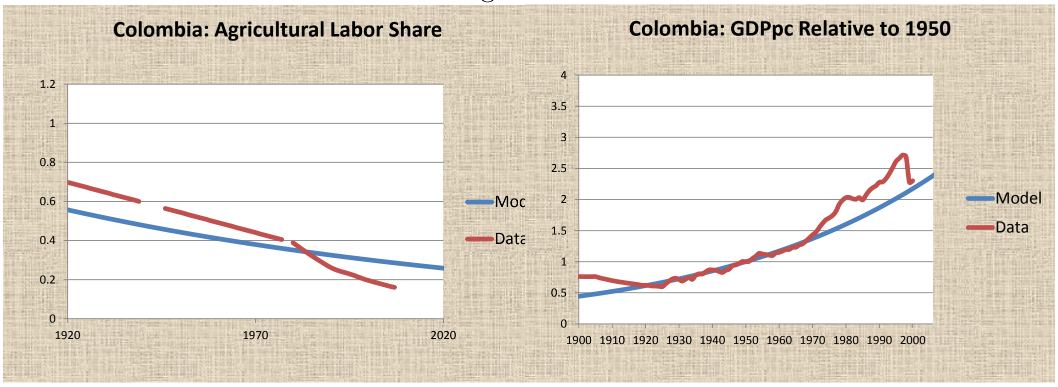

Fig. 6. Ecuador

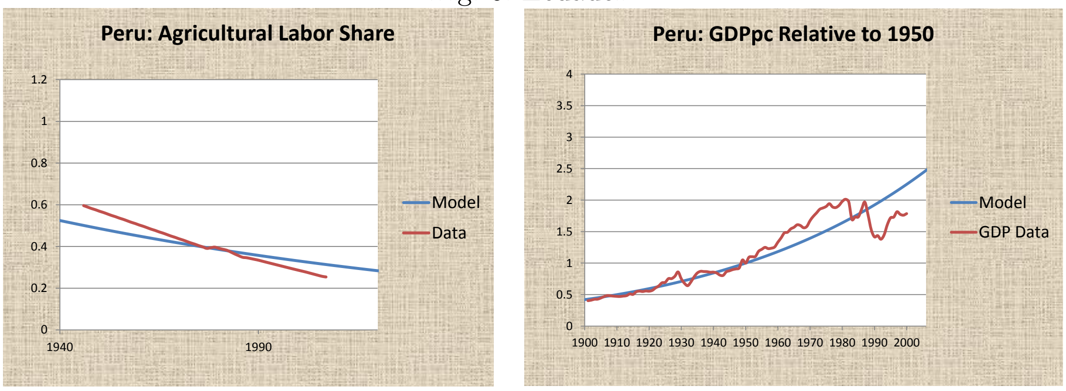

Fig. 7. Paraguay

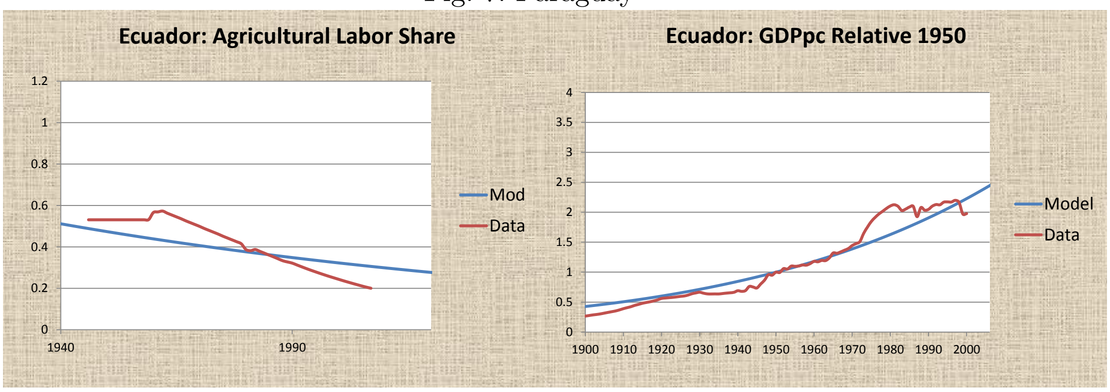

Fig. 8. Catch up process