RE1-04-010

Economic and Social Study Series

GROWTH IN URUGUAY: FACTOR ACCUMULATION OR PRODUCTIVITY GAINS?

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May 2004

REGION 1

Inter-American Development Bank

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Preface

This paper is part of the project "Explaining Economic Growth Performance" launched by the Global Development Network (GDN). The purpose of this project is to explain economic growth performances across seven regions - East Asia, South Asia, Latin America, Eastern Europe, Former Soviet Union, Middle East and North Africa, and Sub-Saharan Africa. Project support was provided by the GDN. Eduardo Fernández-Arias coordinated the preparation of the country papers for the Latin American region on behalf of the Latin American and Caribbean Economic Association (LACEA).

Introduction

During the last five decades the Uruguayan economy faced volatile macroeconomic conditions. Economic policies swung from highly controlled capital flows, exchange rates, and interest rates to the introduction of significant financial liberalization. Periods of high inflation alternated with recurrent efforts to stabilize price movements. The public sector oscillated between intervention (including price controls) and deregulation, and between imposing strong barriers to imports and unilateral reductions of trade barriers, including creation of the Mercosur common market with neighboring countries.

Uruguay's economy went seriously off-course during this period. From being one of the most developed nations in the world at midcentury in terms of per capita income and other social indicators, Uruguay approached the millennium as a member of a less-select club, the group of middle-income countries struggling to get by.

According to data from the Penn World Table, in 1955 Uruguay's annual gross domestic product (GDP) per capita was US$4,285 (in 1985 international prices). This was close to the figure for France (US$4,770 per capita), higher than that of Austria and Italy, and 44 percent of U.S. per capita GDP. In 1998, according to the same source, Uruguay's GDP per capita had grown to US$6,058 but fallen comparatively to 29 percent of the U.S. benchmark and about half the level of France, Austria, and Italy. Uruguay's rate of growth between 1955 and 1998 was one of the lowest among the 60 countries for which data is available.

Most of this poor growth performance can be attributed to Uruguay's economic stagnation in 1955–73, when average per capita GDP decreased at a cumulative rate of 0.2 percent annually. During this period government policy was highly interventionist, especially in external trade but also toward the financial sector as well as influencing key aspects of the domestic economy. The regime of controls ranged from setting wages and exchange rates to limitations on free-entry in certain markets.

This environment changed substantially during the next decade. And for the past quarter century, successive governments have pursued policies that promoted the development of a market-oriented economy. At first glance, those efforts were successful: GDP per capita growth averaged 1.7 percent in 1973–2000, significantly better than the performance of the previous 18 years. Yet the rate is still much lower than those of other developing countries that also introduced market-oriented reforms during the last two decades.

This paper will show that the upturn in economic growth since liberalization is due to improved resource allocation that, in turn, promoted an increase in human capital accumulation. No significant changes are observed in the pattern of physical capital accumulation or the evolution of Total Factor Productivity (TFP).

The analysis begins with an overview of recent economic policy in Uruguay, summarizing the characteristics of each period. A growth accounting exercise is then conducted to begin weighing which factors are crucial to understanding the country's pattern of growth. This exercise will show, as previously stated, that TFP played a minimal role. This evidence is complemented by analysis of a time series of key variables, which permits us to address the empirical regularities that must be explained to understand economic growth in Uruguay.

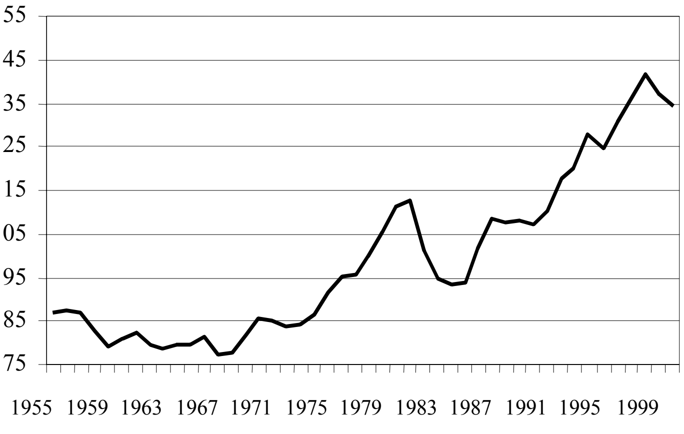
Next a model is formulated that is consistent with the stylized facts that have been documented. Given the absence of observed changes in TFP, the growth dynamic will not be driven by innovation and technological progress. Instead an "imbalance effect" along the lines of Barro and Sala-i-Martin (1995, Chapter 5) or Stokey (1996) is proposed, but in a model of a small open economy in which three goods are produced (two tradables and one nontraded) with the use of three factors of production: skilled and unskilled labor and physical capital. A change in commercial policy will modify the initial relative factor intensities, and the economy will face a transition to a new equilibrium during which output growth will be higher than in steady-state.
This model is then empirically implemented and tested. The importance of the more competitive environment that Uruguayan firms faced after the implementation of Mercosur in the 1990s is addressed, being reflected in a higher accumulation of human capital and a progressive reduction of the physical to human capital ratio during the decade. Conclusions follow.

Overview of Economic Policies

The evolution of per capita GDP in Uruguay clearly reflects the implementation of economic policies and their results. Figure 1 shows two distinct periods: the stagnation of 1955–73 and the resumption of growth from 1974 to the present.

As noted earlier, the first period was indelibly stamped by significant government intervention and high macroeconomic instability. After the Great Depression in 1930, Uruguay enacted, as did many other countries, a set of measures to control external commerce and equilibrate the balance of trade. Among the most notable measures were incremental tariffs and quotas and exchange rate controls. The ensuing reduction of imports helped local industry to develop, a tendency that was reinforced by the Second World War when international trade largely collapsed. The manufacturing sector experienced high growth rates during the 1940s, even after the end of the war, as

Figure 8.1. GDP per capita (Index 1978=100)



the government consolidated its “import substitution” strategy by continuing to insulate local industry from renewed competition from abroad.

However the ability of the Uruguayan economy to continue growing based on its domestic market was depleted by the end of the 1950s. At that moment, a new phenomenon appeared — surging inflation. In 1959 Congress passed a package of reforms to stabilize the economy by dismantling administrative controls on trade and exchange rate transactions. That plan finally collapsed in 1963, and was followed by a period of persistent fiscal deficits and recurrent exchange rate and balance-of-payments crises. Those external crises discouraged the government from following and extending the reforms of 1959. Indeed, the policy shifted to systematic introduction of new trade barriers and adoption of exchange rate controls.

Yet the combination of exchange rate crises and fiscal deficits fuelled inflation so that, at the edge of falling into hyperinflation, the government implemented a second stabilization plan in 1968–1972. The initial phase of this plan induced expansion of domestic consumption and the highest GDP growth rates since the early 1950s. But that was merely a business-cycle boom associated with the stabilization effort. Only in 1973, under pressure from the OPEC oil crisis and its negative impact on Uruguay’s trade balance, did the government finally embrace economic measures aimed at promoting export growth while simultaneously liberalizing most nontariff barriers to imports. The exchange rate policy was also changed, establishing the total convertibility of the capital account of the balance-of-payments. Fiscal reform, which included introduction of a value-added tax (VAT), helped to bring down the budget deficit and reduce the previous tax regime’s bias against exports.

The economic reforms of 1974–75 introduced a change in the trend of GDP, as Figure 1 clearly shows. GDP growth averaged 3.9 percent between 1973 and 1978, with a significant increment in net investment in construction and in machinery and equipment, as indicated in Figures 2 and 3. Exports also grew very rapidly in response to the new incentives, and tracked the growth of imports in 1973–78 (Figure 4).

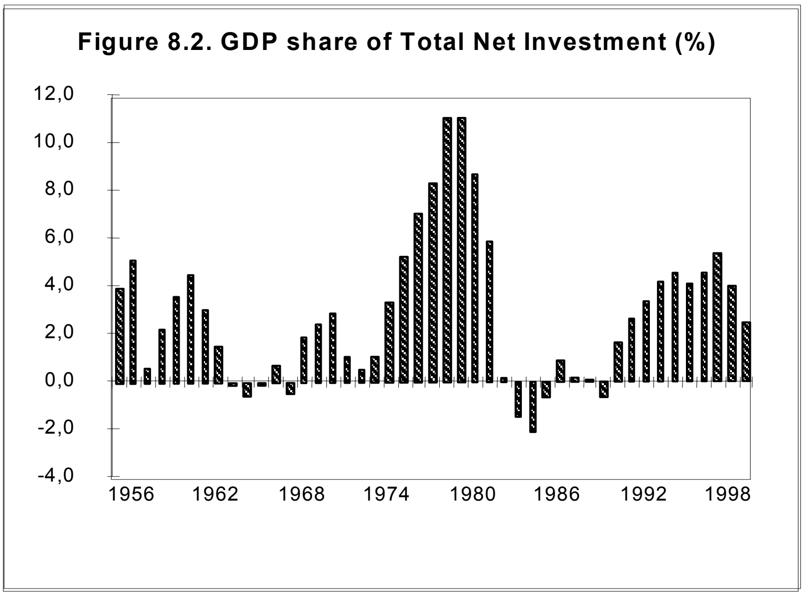


Figure 8.2. GDP share of Total Net Investment (%)
12,0
10,0
8,0
6,0
4,0
2,0
0,0
-2,0
-4,0
1956
1962
1968
1974
1980
1986
1992
1998

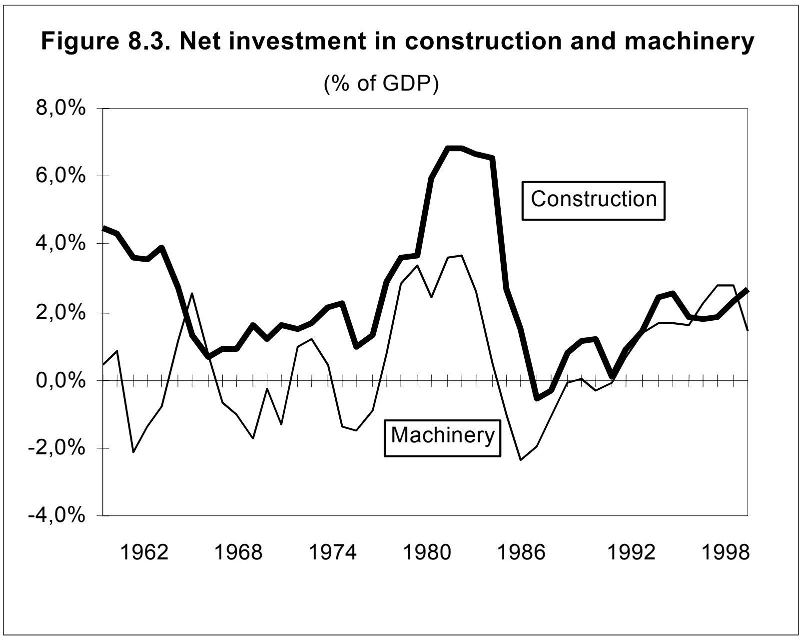
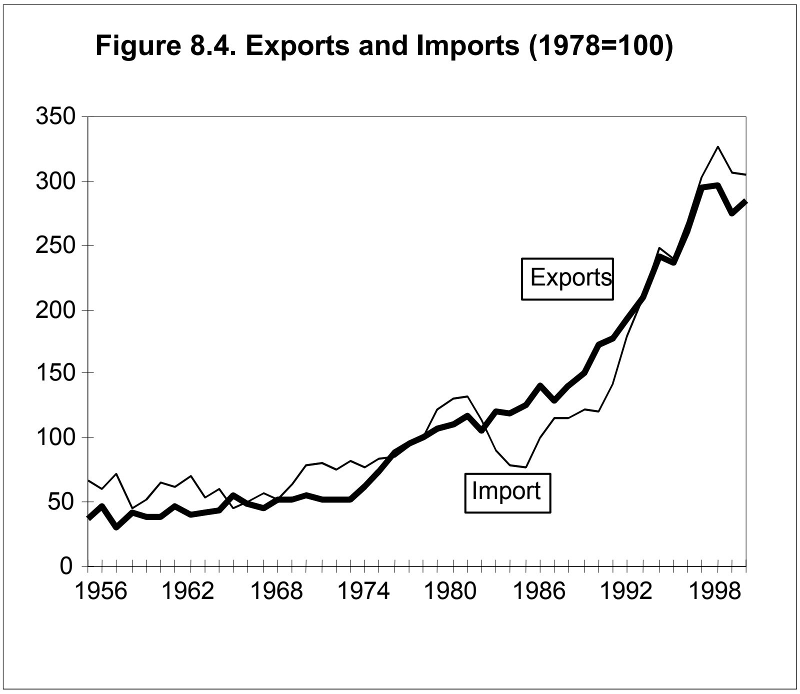
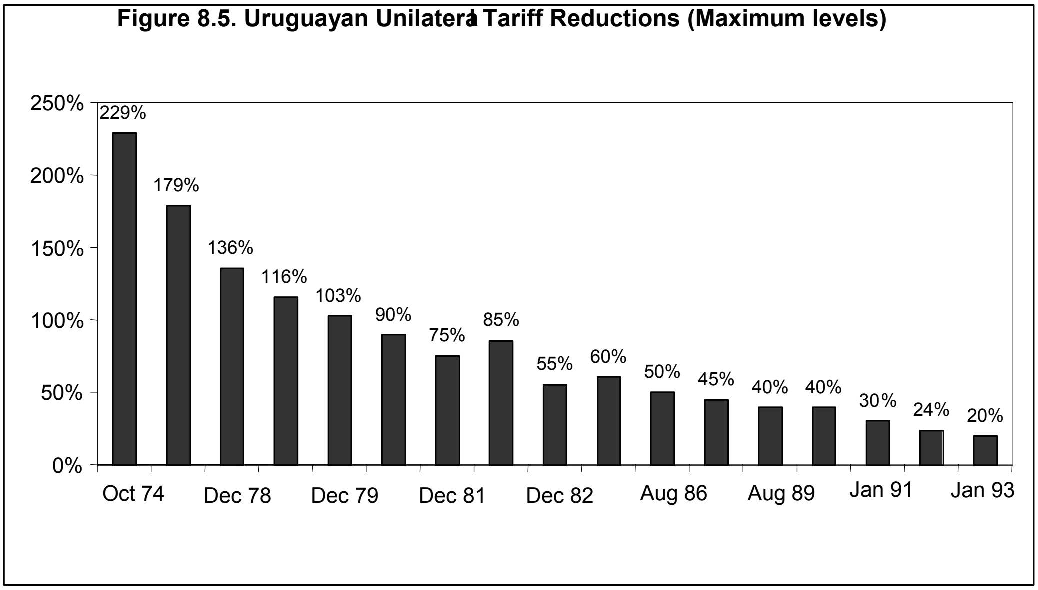


Figure 8.3. Net investment in construction and machinery
(% of GDP)
8,0%
6,0%
4,0%
2,0%
0,0%
-2,0%
-4,0%
Construction
Machinery
1962
1968
1974
1980
1986
1992
1998



Government priorities returned to the problem of inflation in the second half of the 1970s, and in 1978 a third effort was launched to stabilize the inflation rate. This program used the preannouncement of the exchange rate as the nominal anchor (the "Tablita") in an attempt to make domestic inflation gradually converge to the rate of international inflation. Macroeconomic inconsistencies in the plan, combined with the 1981 Argentine currency crisis and the onset of the international debt problem that interrupted the flow of capital to the region, brought the program to an end in 1982.



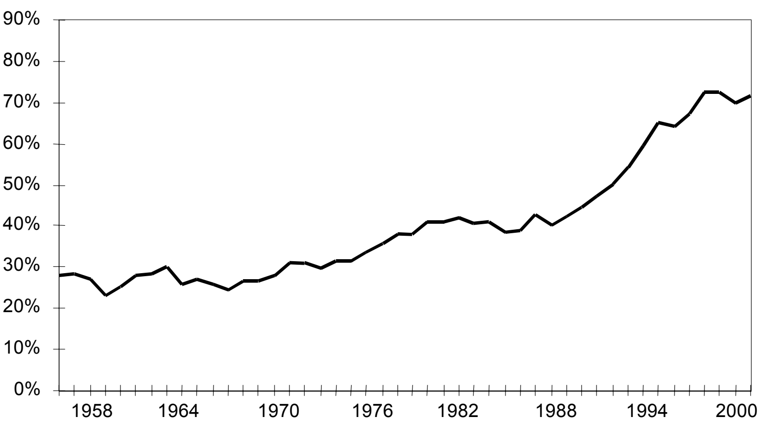
Exit from the Tablita Plan prompted a deep crisis in the local financial market. The adverse domestic and external environment plunged the Uruguayan economy into deep recession, perhaps the worst in its history. GDP per capita fell 17.2 percent between 1981 and 1984, falling to its pre-1976 level.

Since then, the Uruguayan business-cycle has been closely bound to the economic fortunes of its neighbors. In the mid-1970s, bilateral trade agreements were signed between Uruguay and Argentina and Brazil (agreements known as CAUCE and PEC respectively), and in 1985 they were widened in scope. These preferential trade agreements deepened the natural dependency of the Uruguayan economy on what happened regionally, and the culmination of that process was the Mercosur agreement, launched by the Asunción Treaty in 1991.

Regional influence on the domestic business-cycle is readily noticeable, particularly in relation to stabilization plans in Argentina and Brazil. The expansion of domestic demand in those countries after the implementation of the Austral and Cruzado plans was a crucial drag that helped pull Uruguay from economic recession in 1986–87. Again in 1991, Argentina's convertibility plan provided a strong push to its domestic demand that spilled over, in part, to Uruguay. Something similar happened in 1994 with the Plan Real in Brazil. On the other hand, when the Argentine and Brazilian economies suffered in 1995 after the Tequila effect and in 1999 after the Brazilian devaluation, Uruguay's economy also suffered.

Economic policies during the 1990s were oriented to consolidate the market-oriented reforms begun in the mid–1970s. Before implementation of Mercosur, Uruguay culminated the process of reducing tariffs that had begun in 1978, and eliminated most nontariff import barriers that had survived the initial abolition (Figure5). As a result of the unilateral reduction of trade barriers and the expansion of trade in Mercosur, the openness ratio of the Uruguayan economy has had a steady increment during the last 25 years (Figure 6).

Figure 8.6 Openness Ratio (Exports plus imports as a share of GDP)



There have also been attempts to promote public-sector reforms, introducing new regulatory frameworks that enable the private sector to participate in the financing and operation of public-sector projects in areas like telecommunications and energy. Similarly Social Security reform allowed private-sector firms to operate like pension funds.

Growth Decomposition and Time Series Data

Having summarized the economic history of Uruguay during the last five decades, it is time to analyze the determinants of economic growth. The previous analysis emphasized the behavioral change in the economy after reforms in the 1970s; now we turn to assessing the factors behind the growth performance.

First, a decomposition of the sources of growth will be made to help understand the degree to which variation in GDP per capita is linked to changes in factor accumulation or to productivity improvements from innovation and technological progress.

Second, a closer look will be taken at key variables. In particular, it will be useful to know which variables have effectively changed its behavior after the introduction of economic reforms.

Growth Accounting

Assume that the production function of the economy can be characterized as

$$Y_t = A_t F\left(L_t h_t, K_t\right) \tag{1}$$

where *Y* is aggregate output or GDP, *K* is physical capital, *L* is labor, *h* is a correction for workforce quality (which this paper always interprets as an index of human capital), and *A* is an index of productivity or technological change that evolves over time.

Totally differentiating this production function, the rate of growth is determined by

$$\hat{Y}_t = \hat{A}_t + \frac{\left(\frac{\partial F}{\partial Lh} L_t h_t\right)}{Y_t}\left(\hat{L}_t + \hat{h}_t\right) + \frac{\left(\frac{\partial F}{\partial K} K_t\right)}{Y_t}\hat{K}_t \,. \tag{2}$$

If factors of production are paid their marginal product, then the elasticities are

$$\frac{\left(\frac{\partial F}{\partial Lh} L_t h_t\right)}{Y_t}\,, \tag{3a}$$

$$\frac{\left(\frac{\partial F}{\partial K} K_t\right)}{Y_t}\,, \tag{3b}$$

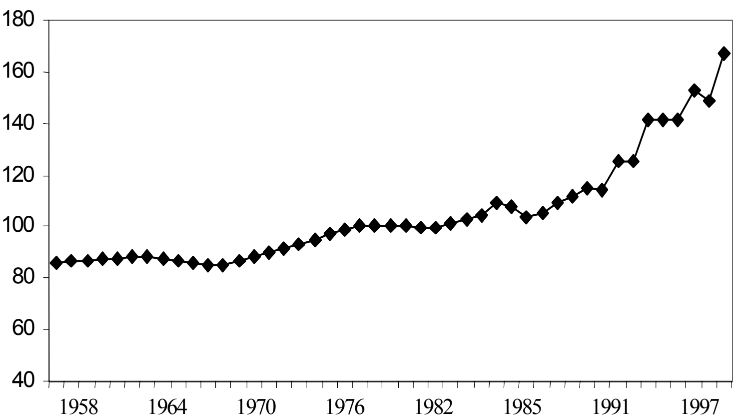
which represent the share of labor and capital in total product, respectively. Assuming constant returns to scale, then

$$\frac{\left(\frac{\partial F}{\partial Lh} L_t h_t\right)}{Y_t} + \frac{\left(\frac{\partial F}{\partial K} K_t\right)}{Y_t} = 1 . \tag{4}$$

Given the data on GDP growth, factor shares, the labor force, and estimations of physical and human capital, the changes in total factor productivity $\hat{A}_t$ are estimated as a residual. GDP growth and factor shares are taken from the national accounts. Labor force is defined as labor employed, with data coming from the National Institute of Statistics.

Elias (1996) was updated to construct the series for physical capital. The human capital series was constructed using the labor-income-based measure suggested by Mulligan and Sala-i-Martin (1995).[1] The evolution of this variable is shown in Figure 7.

Figure 8.7. Human Capital Index (1978 =100)



The results are presented in Table 1. Aggregate output growth averaged 1.8 percent yearly in the period under consideration. Prior to 1973, the average rate of growth was 0.7 percent, while during 1974–99 GDP growth averaged 2.6 percent. Growth during the Mercosur era — 3.5 percent a year — was especially notable.

[1] Mincer regressions of labor income on a constant, years of education, years of labor experience and its square, and a dummy for sex were run for each year from 1982 to 1999, using data from the Households Survey. The constant term represents the estimated labor income for the noneducated, inexperienced male and can be interpreted as the unskilled-worker wage. The human capital index is defined, for each year in the sample, as the ratio of the average labor income in the sample to the constant term in the regression. Prior to 1982, evolution of the human capital index was estimated through the years-of-schooling variable in the Barro-Lee dataset.

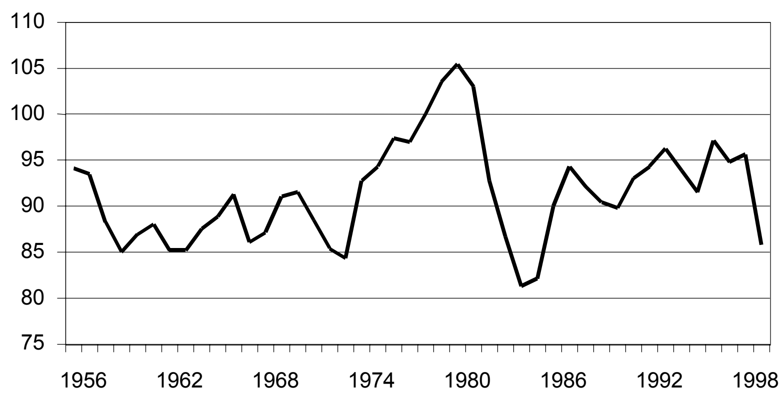
Table 8.1. Sources of growth in the Uruguayan economy (1957 -99)

Period	GDP growth	Incidence of labor Employment	Quality	Total	Incidence of Capital	Total Factor Productivity
Change (%)						
1957 - 1999	1.8	0.5	0.9	1.4	1.1	-0.69
1957 - 1973	0.7	0.6	0.4	1.0	0.8	-1.07
1974 - 1999	2.6	0.5	1.1	1.6	1,4	-0.45
1974 - 1990	2.1	0.4	0.5	0.9	0.9	0.28
1991 - 1999	3.5	0.7	2.5	3.2	2.2	-1.86
Contribution to GDP growth (%)						
1957 - 1999	100	29.3	46.6	76.3	61.6	-37.8
1957 - 1973	100	88.5	52.7	141.7	104.4	-146.2
1974 - 1999	100	18.3	44.6	63.3	54.2	-17.5
1974 - 1990	100	18.5	25.2	43.9	42.4	13.7
1991 - 1999	100	18.7	71.6	91.1	61.7	-52.8

Sources: Author's calculations

During the low growth of 1957–73, almost all the increment in production was explained by employment since GDP per worker remained constant during the period. Increments in the quality of labor, measured as an index of human capital, explained nearly 50 percent of GDP growth during the entire period. In the 1990s this human capital concept explained more than two-thirds of output growth. Its lower incidence occurred during 1974–90, when its contribution to output growth was 25 percent.

Figure 8.8. Total Factor Productivity Index (1978 = 100)



Accumulation of capital also played an important role in output growth. Its higher rates of growth were achieved in the 1990s, when human capital accumulation grew even faster.

An unexpected result is that, except in 1974–90, TFP showed negative rates of growth in almost all subperiods (and an average decrease of 0.7 percent annually across the whole period). Figure 8 shows the computed series for TFP. It reveals no changes in trend or level for the entire period, a result confirmed in the time series analysis.

The growth accounting exercise suggests that factor accumulation was the dominant contributor to economic growth. The rate of growth in factor accumulation seems related to the major changes in the economic environment during the past five decades: the set of economic reforms in the middle 1970s and the implementation of Mercosur in the 1990s. A closer look at the series involved will shed additional light on this analysis.

Time Series Evidence

An important way of assessing impact from economic policies on growth is to determine if changes in variables under government control provoke a change in the *level* or in the *differences* of aggregate output. The first result is usually found in comparative static analyses of changes in trade policy, factor endowments, or other shocks. In this case, the change in policy affects the level of output and its transitory rate of growth. Finally, however, the rate of growth returns to the initial values. This is also the conclusion of neoclassical growth models, in which a change in the variables that determine a steady state induces an increment of the level of output per worker in the long run, but no change in the steady-state rate of growth.

Typically in endogenous growth models, a change in a policy variable permanently affects the rate of growth or the difference of the series. This section will address what outcome, given the characteristics of the series under analysis, could be expected to happen in Uruguay after economic reforms.

Table 8.2 Augmented Dicky - Fuller Test Results

Variable	Differences	Constant	Trend	ADF t-test	Lags
GDP per worker	0			1.2633	0
	1	0.00764 (1.0896)		–5.5308 ***	0
Human capital index	0	–0.2119 (–0.6457)	0.0080 (0.8156)	0.6132	1
	1			–0.3183	4
Machinery and equipment per worker	0			0.5114	1
	1			–4,0815 ***	0
Private fixed capital	0			0.1350	0
	1	0.0008 (0.1343)		–6.1171 ***	0
Public construction	0			2.1708	0
	1	0.0118 (1.7547)		–5,3357 ***	0
Total factor productivity	0	1.6321 (3.4179)		–3.4226 **	1

**Significant at 5% level.
*** Significant at 1% level.

The evolution of the TFP level in Figure 8 suggests no change in the mean of this variable during the period under analysis. But this also seems to be so for the net investment variables in Figures 2 and 3. If these variables were indeed stationary around some mean, then the change in policies would have modified the level of the physical capital, but with no long-run changes for the variable's rate of change.

To address this issue, unit root tests for the variables of interest were performed. Table 2 shows the augmented Dickey-Fuller tests of the form:

$$\Delta Y_t = \beta_0 + \beta_1 t + (\alpha - 1)Y_{t-1} + \sum_{i=1}^{k} \Delta Y_{t-i} \,. \qquad (5)$$

With the exception of TFP and the index of human capital, all the series in levels under analysis have unit roots. The index for TFP is stationary around a nonzero mean, while the index of human capital looks, at least, integrated of order of two.

In particular, GDP in levels is integrated at order one, and so its differences (or GDP growth) is a stationary series around a mean. This implies that the output growth mean is not significantly different before and after the 1970s reforms. Those reforms induced an increment in the output level but not in the steady-state growth rate.

A similar conclusion can be deduced with respect to the various measures of physical capital. The stock of total fixed private capital is integrated at order one, but its differences, the net investment in those items, is stationary. So it can be concluded that the reforms did not affect the equilibrium investment rate, but increased it temporarily while the steady-state value of the capital stock was obtained.

Table 8. 3. Perron Tests for Structural Breaks

Variable	Differences	Model	Perron t-test	Lags
GDP per worker	0	AO	–3.196	0
Human capital index	0	AO	–3.759**	0
	1	IO	9.472***	0
Machinery and equipment per worker	0	AO	–2.479	1
Private fixed capital	0	AO	–3.395	0

Note: Model AO refers to the "additive outlier model" of Perron, in which there is change in slope but no change in the intercept. IO refers to the ive outlier" model, in which there is a change in the intercept but no change in
** Significant at the 5%
*** Significant at the 1%

The series for human capital deserves close attention. It is the only variable of all those considered, except TFP, whose rate of change is not stationary. To check if the nonstationariness of changes in human capital results from a structural time break, the Perron test unit roots under structural breaks was performed. The results are presented in Table 3.

After analysis of data unreported here, the only significant structural change found in the index-of-human-capital series was in 1991, following introduction of

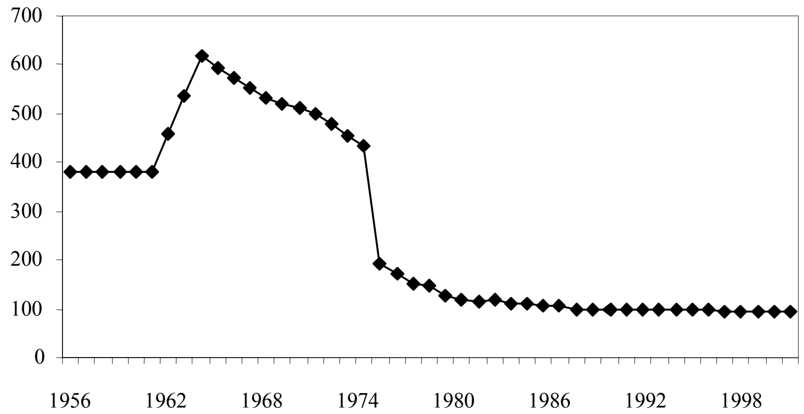
Mercosur. When a change in trend is introduced to capture the effect of a deterministic movement in the series, the null hypothesis of a unit root in the series in levels is not rejected at a 5 percent significance level. But the trend change from 1991 is significant enough to make the differenced series stationary when that change is taken into account.

Finally, with the exception of the TFP series, which is stationary in levels, all the analyzed series are integrated at order one, and so their first differences are stationary. In the case of the index of human capital, the stationariness of the series in differences is obtained after a correction is made for a jump of the series in differences (a change in trend in the series in levels) since 1991.

Given this series behavior, the increment in the output growth rate after episodes of liberalization, like the reforms of the mid-1970s or later implementation of Mercosur, is a transitory phenomenon that tends to be reversed unless new shocks occur.

These variables tell a story consistent with the traditional neoclassical growth model, with a steady-state and an invariant growth rate despite changes introduced in the model's parameters. Evolution of the human and physical capital can be interpreted as the response of one factor to a favorable change in relative prices. If more- skilled workers are attracted to sectors in expansion, whether due to better relative prices or technology improvements, a transformation from unskilled to skilled workers through better education will occur, and the equilibrium ratio between capital and labor will be modified. In the case of Uruguay, the time series evidence supports the hypothesis that the more competitive environment after introduction of Mercosur in the 1990s changed the relative demand of factors since sectors that produced commodities with high intensities of unskilled workers and physical capital begin to slow down. This change in demand would be reflected in the wage differential between skilled and unskilled workers, attracting a higher proportion of well-educated people.

Figure 8.9. Index of Nominal Protection



Since the ratio between skilled workers and the other factors is low in comparison with equilibrium values, the return to human capital will be higher (as is happening in Uruguay) and will decrease as the economy approaches equilibrium. During that transition, as capital and labor are reallocated to the sectors with higher productivity, the aggregate product will also rise.

Analyzing the extent to which changes in factor demand is related to the new economic environment facing the Uruguayan economy after the 1970s requires a measure for the policy variables characterizing the liberalization process. An index of nominal protection for the period under analysis was constructed, and the results are presented in Figure 9.[2]

The index of nominal protection gives an indicator of the evolution of the relative price of importables during the period under consideration. But in an economy with three goods (exportable, importable, and nontradable) another important relative price is the real exchange rate, defined as the relative price of tradables to nontradables.

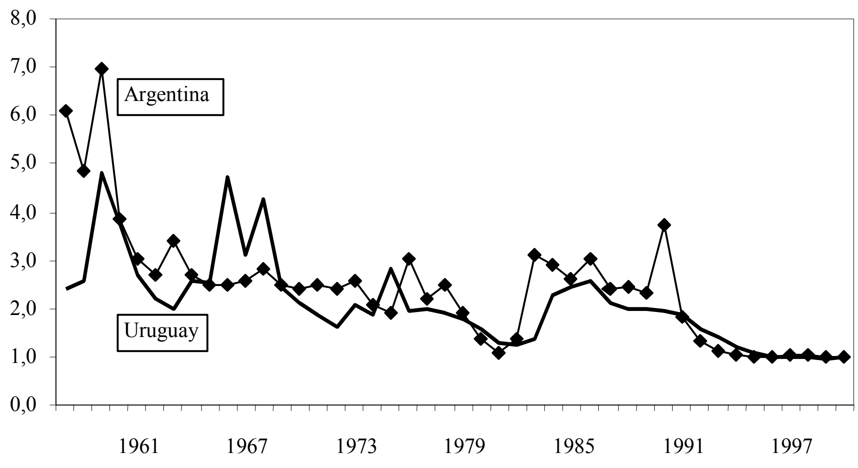
In the case of Uruguay, the real exchange rate supplies the channel through which regional macroeconomic shocks, especially those from Argentina, affect the Uruguayan business-cycle. Figure 10 clearly shows the strong relationship between the real exchange rate of Argentina and Uruguay, which was formally addressed through a cointegration analysis not reported in this paper. Since the domestic markets of both countries are highly integrated due to intense cross-border movement of people (for tourism, business, or family ties), most goods and services usually considered to be nontradables face competition from close substitutes in the other country. This explains the tendency of both countries' real exchange rates to move together over the long run.

[2] For 1988–2000, the indexes of prices of imported products calculated by the Instituto Nacional de Estadística (INE) provide an excellent measure. This office calculates two indexes of imported product prices: one for CIF (Cost, Insurance, and Freight) prices and one for prices in terms of the importer deposit. Both indexes are calculated for the same basket of goods, so the ratio of the index of prices at deposit to the index of prices CIF gives the evolution of the costs incurred to nationalize the merchandise, including tariffs. This permits one to avoid the problem of representing trade policy through the nominal tariff during the 1990s, when almost 50 percent of Uruguay's international trade had preferential tariff treatment due to Mercosur.

The evolution of tariffs better describes Uruguayan commercial policies prior to the 1990s. After the trade reform in the late 1970s, there are good measures of average nominal protection (which includes tariffs and other nontariff policy instruments), extensively documented in Rama (1982), CINVE (1987), Macadar (1988), and De Brun and Michelin (1993). For the period before trade liberalization, measures of nominal protection are more difficult to obtain because of the multiplicity of nontariff trade barriers like quotas, import prohibitions, multiple exchange rate mechanisms, and exchange rate controls, among others. Favaro and Spiller (1990) estimated protection for that period based on the ratios of import to export prices for a sample of goods, which were used to compute a trade policy index.

After obtaining measures of nominal protection in the period under consideration, the index of tariff policy was calculated by adding 1 to the nominal protection percent in year XX and assigning the value 100 to the year 1988.

Figure 8.10. Real Exchange Rate: Uruguay and Argentina



The appreciation of the real-exchange-rate in Argentina after the Convertibility Plan of 1991 induced a relative increment of the price of non-tradables in Uruguay during the last decade. This change in relative prices was added to the one generated by the trade liberalization process, which under certain conditions of factors demand can result in the shift of the human to physical capital ratio observed in the last ten years and a temporary acceleration of the rate of growth during the transition. The next section develops a model that reasonably encompasses these stylized facts. After that, the model is tested empirically to assess if it can capture adequately the dynamics of the variables related with economic growth.

The Model

Consider a small open economy for which both the world price of traded goods and the world interest rate are taken as given. The economy produces three types of goods and services: traded goods (exportable and importable) are produced for consumption, investment in human and physical capital, or export; while nontraded goods are produced for domestic consumption and formation of human capital.

Three factors of production are used to produce those goods and services: skilled labor S, unskilled labor U, and physical capital K. Total labor force L, given by

$$L_t = S_t + U_t, \tag{6}$$

grows at the exogenous rate n. As in Stokey (1996), the distinction between skilled and unskilled workers tries to capture two kinds of productive services provided by labor, i.e., physical and mental effort.

Consumption and Human Capital Formation

Households are the direct owners of physical capital, which they rent to firms at a rate *r*, equal to the world interest rate. They can also receive loans from foreign residents with no restrictions to foreign debt besides the intertemporal budget constraint. Then, net assets per capita in this economy are represented by

$$a_t = k_t - d_t \,, \tag{7}$$

where *d* is net debt to foreigners (in per capita terms) and

$$k_t = \frac{K_t}{L_t} \,. \tag{8}$$

They also supply labor inelastically, but they choose the resources dedicated to human capital formation and, in this way, the amount of skilled and unskilled labor available.

The household's problem, given the initial endowments of assets and human capital and given the paths for factor and final product prices, is to choose paths for investment in physical and human capital, total expenditure and its allocation among the different goods and services, to maximize discounted utility:

$$U_0 = \int_0^{\infty} e^{-(\rho-n)t} \log u\left(c_{N,t}, c_{X,t}, c_{M,t}\right) dt \tag{9}$$

$$\text{s.t. } \dot{a}_t = W_{U,t} + z_t\left(W_{S,t} - W_{U,t}\right) + (r-n)a_t - \varepsilon_t + v_t - i_{z,t}$$

where ρ is the rate of time preference; skilled and unskilled wages are W_j, $j = S,U$; per capita consumption of nontradables, exportables, and importables are c_i, $i = N, X, M$; government transfers is represented by *v*, financed through the commercial policy

$$z = \frac{S}{L};$$

and i_z is nominal expenditure in human capital formation.

Let us assume that the world interest rate is $r = \rho$, one that would apply in steady state if the economy were closed. The representative household can borrow and lend at world interest rate *r*, so its investment and consumption decisions can be analyzed separately, which occurs in three stages. First, the path for human capital formation is determined to maximize the present discounted value of its labor income flow, net of investment costs. Second, given the optimal supply of skilled and unskilled labor, the path of aggregate expenditure on consumption goods is chosen to maximize lifetime utility. Third, given the prices of final goods, expenditure is allocated among nontradable, exportable, and importable goods.

Investment in human capital and the consumption path

The optimal path of expenditure in human capital formation is the one that maximizes V_0, given z_0, v, W_S and W_U, so that

$$V_0 = \int_0^{\infty} e^{-(r-n)t}\left[W_{U,t} + z\left(W_{S,t} - W_{U,t}\right) + v_t - i_{z,t}\right] dt \tag{10}$$

$$\text{s.t. } \dot{z}_t = Bi_{z,t}^{\phi} - \eta z_t$$

where $B > 0$, $0 < \eta < 1$ (depreciation rate), and $0 < \phi < 1$ are constants. The law of motion for z indicates the rate at which labor is transformed from unskilled to skilled. As in Stokey (1996), the parameter ϕ represents the adjustment cost.

We can analyze this optimization problem by setting up the current-value Hamiltonian:

$$J = e^{-(r-n)t}\left[W_U + z\left(W_S - W_U\right) + v_t - i_z + q\left(Bi_z^{\phi} - \eta z\right)\right] \tag{11}$$

where q is the current-value shadow price of the proportion of skilled workers in the total labor force. The first-order conditions of this optimization problem give the following laws of motion for human capital and its shadow price:

$$\dot{z} = \left[B\left(\phi q\right)^{\phi}\right]^{\frac{1}{1-\phi}} - \eta z, \tag{12a}$$

$$\dot{q} = \left(r - n + \eta\right)q - \left(W_S - W_U\right). \tag{12b}$$

The steady-state values of z, i_z, and q satisfy

$$\tilde{z} = \frac{1}{\eta}\left[B(\phi\tilde{q})^{\phi}\right]^{\frac{1}{1-\phi}}, \tag{13a}$$

$$\tilde{i}_z = \left[B\phi\tilde{q}\right]^{\frac{1}{1-\phi}}, \tag{13b}$$

$$\tilde{q} = \frac{W_S - W_U}{r - n + \eta}. \tag{13c}$$

The phase diagram of this system (available from the author upon request) shows that the only stable path goes through the $\dot{q} = 0$ locus, so the shadow price of human capital remains constant during the transition to a steady-state. Its means that if there is a change in relative wages, the shadow price q will jump on impact to its new steady-state value, and then z will increase or decrease gradually to its new equilibrium.

We can now proceed to the determination of the optimal consumption path. Define the consumption index as

$$c=\left[\alpha^{\alpha}\beta^{\beta}\left(1-\alpha-\beta\right)^{1-\alpha-\beta}\right]^{-1}c_N^{\alpha}c_X^{\beta}c_M^{1-\alpha-\beta} \tag{14}$$

and the instantaneous utility function as $u\left(c_N, c_X, c_M\right)=c$. If we replace $u\left(c_N, c_X, c_M\right)$ by the indirect utility given by

$$v\left(P_N, P_X, P_M; \varepsilon\right)=\frac{\varepsilon}{P}, \tag{15}$$

where P is the perfect price index $P=P_N^{\alpha}P_X^{\beta}P_M^{1-\alpha-\beta}$, the optimization problem (9) can be expressed as

$$U_0=\int_0^{\infty} e^{-(\rho-n)t}\left(\log\varepsilon-\log P\right)dt \tag{16}$$

$$\text{s.t. } \dot{a}_t=W_{U,t}+z_t\left(W_{S,t}-W_{U,t}\right)+(r-n)a_t-\varepsilon_t+v_t-i_{z,t}$$

where a_0 and the path of z, $i_{z,t}$, P_i, $i=N,X,M$, W_S and W_U are taken as given. The first-order conditions of this problem determine that the optimal path for spending satisfy

$$\frac{\dot{\varepsilon}}{\varepsilon}=r-\rho. \tag{17}$$

Given the assumption that $r=\rho$, the solution to this problem is a constant consumption spending, whose level is determined by integrating the differential equation in (16), assuming a non-Ponzi game condition, and using the optimal value of V_0 found in the first stage:

$$\tilde{\varepsilon}=(r-n)\left(V_0+a_0\right). \tag{18}$$

Allocation of consumption

Having obtained the optimal path for per capita spending, the constant level $\tilde{\varepsilon}$ in (18), the allocation of consumption to nontradable, exportable, and importable goods can be determined by maximizing the instantaneous utility function

$$u(\cdots)=\left[\alpha^{\alpha}\beta^{\beta}\left(1-\alpha-\beta\right)^{1-\alpha-\beta}\right]^{-1}c_N^{\alpha}c_X^{\beta}c_M^{1-\alpha-\beta} \tag{19}$$

$$\text{s.t. } P_Nc_N+P_Xc_X+P_Mc_M=\tilde{\varepsilon}.$$

The first-order conditions of this problem determine the sectoral demands, as follows:

$$c_N = \alpha \frac{\tilde{\varepsilon}}{P_N} , \tag{20a}$$

$$c_X = \beta \frac{\tilde{\varepsilon}}{P_X} , \tag{20b}$$

$$c_M = \left(1 - \alpha - \beta\right) \frac{\tilde{\varepsilon}}{P_M} . \tag{20c}$$

Finally, define the index of consumption of the tradables composite and the perfect price index for tradable goods as

$$c_T = \left[\frac{\beta^{\frac{\beta}{1-\alpha}} \left(1 - \alpha - \beta\right)^{\frac{1-\alpha-\beta}{1-\alpha}}}{1 - \alpha} \right]^{-1} c_X^{\frac{\beta}{1-\alpha}} c_M^{\frac{1-\alpha-\beta}{1-\alpha}} , \tag{21a}$$

$$P_T = P_X^{\frac{\beta}{1-\alpha}} P_M^{\frac{1-\alpha-\beta}{1-\alpha}} . \tag{21b}$$

Production and Equilibrium

The sector that produces nontraded goods employs skilled labor as the only input; while the exportable good is produced combining skilled labor and physical capital, and the importable good is produced combining unskilled labor and physical capital. As in Baldwin and Seghezza (1996), physical capital formation requires the tradable composite c_T, while human capital formation requires the aggregate composite *c*. That is, spending in physical capital combines the use of the exportable and importable good in proportions

$$\frac{\beta}{1-\alpha} \text{ and } \frac{1-\alpha-\beta}{1-\alpha}$$

respectively, while spending in human capital combines the three products in proportions α for nontraded goods, β for exportables, and $1-\alpha-\beta$ for importables.

This specification seeks to capture the general fact that nontraded goods like services are, in general, relatively intensive in human capital while manufactured goods (usually traded goods) are more capital intensive. Each of the two sectors manufacturing tradable goods makes intensive use of a different type of labor, which will be reflected in this economy's pattern of trade. To highlight the role played by cross-sectoral differences in factor intensities on the pattern of trade, the differences are made as extreme as possible, and each tradable sector employs only one labor type. Changes in the relative price of the traded goods will influence the formation of human capital.

All markets are competitive. All goods and services are produced with constant returns to scale technologies. The production functions for the nontradable, exportable, and importable goods, respectively, are

$$Y_N = A_N S_N , \tag{22a}$$

$$Y_X = A_X K_X^{\gamma} S_X^{\gamma}, \tag{22b}$$
$$Y_M = A_M K_M^{\gamma} U_M^{\gamma}, \tag{22c}$$

where Y_i, $i = N, X, M$ represent physical quantities of production in each sector, A_i, $i = N, X, M$ are constants, and $U_M = U$, $S_X + S_N = S$, and $K_X + K_M = K$. There is no technological change in this economy since our main interest is to capture the effect on growth dynamics of a change in resource allocation.

Given the world interest rate *r*, the depreciation rate of physical capital δ, the world prices of the tradable goods P_i, $i = N, X, M$, and the skilled and unskilled wages W_j, $j = S, U$, the first-order conditions for the allocation of resources in the three sectors are the following:

$$P_N A_N = W_S, \tag{23a}$$
$$P_X A_X \gamma \left(\frac{z_X}{k_X}\right)^{1-\gamma} = P_T(r + \delta), \tag{23b}$$
$$P_X A_X (1-\gamma)\left(\frac{k_X}{z_X}\right)^{\gamma} = W_S, \tag{23c}$$
$$P_M A_M \gamma \left(\frac{1-z}{k_M}\right)^{1-\gamma} = P_T(r + \delta), \tag{23d}$$
$$P_M A_M (1-\gamma)\left(\frac{k_M}{1-z}\right)^{\gamma} = W_U. \tag{23e}$$

In equations (23c) and (23e) the price of a unit of physical capital is the tradable composite index. All stocks are expressed in per capita terms, so

$$z_X = \frac{S_X}{L}, \tag{24a}$$
$$z_N = \frac{S_N}{L}, \tag{24b}$$
$$1 - z = \frac{U}{L}, \tag{24c}$$
$$z_X + z_N = z, \tag{24d}$$
$$k_X = \frac{K_X}{L}, \tag{24e}$$
$$k_M = \frac{K_M}{L} \text{ y } k_X + k_N = k = \frac{K}{L}. \tag{24f}$$

The first-order conditions for optimal factors demand (23), the sectoral production functions (23) and the aggregate demand functions for final goods derived from (20) determine the nontraded-good equilibrium price P_N; nominal skilled and unskilled wages W_j, $j = S, U$; sectoral allocation of skilled labor z_i, $i = N, X$ and unskilled labor $1 - z$; and sectoral allocation of physical capital k_i, $i = X, M$; given

world prices of traded goods P_i, $i = X, M$ and the expenditure path in consumption goods $\widetilde{E} = \widetilde{\varepsilon} L$.

Equilibrium in the market of nontraded goods requires the following condition:

$$P_N Y_N = P_N C_N + \alpha I_Z \tag{25}$$

where $C_N = c_N L$ and $I_Z = i_z L$. Using equation (20a) and the production function (22a), the aggregate demand of labor in the nontradable sector is obtained:

$$S_N = \alpha \frac{E + I_Z}{A_N}, \tag{26}$$

or in per capita terms,

$$\widetilde{z}_N = \alpha \frac{\widetilde{\varepsilon} + \widetilde{i}_z}{A_N} \tag{27}$$

where $\widetilde{\varepsilon}$ and $\widetilde{i}_z$ come from (18) and (13b) respectively.

Wage equations for skilled and unskilled labor result from first-order conditions (23b–e). Combining equations (23b–c), the skilled wage is obtained:

$$\widetilde{W}_S = P_X \left[\gamma^{\gamma} (1-\gamma)^{1-\gamma} A_X \left(\frac{P_X}{P_M} \right)^{\frac{(1-\alpha-\beta)\gamma}{1-\alpha}} \left(\frac{1}{r+\delta} \right)^{\gamma} \right]^{\frac{1}{1-\gamma}} \tag{28}$$

The unskilled wage equation is obtained in a similar way from conditions (23d–e):

$$\widetilde{W}_U = P_M \left[\gamma^{\gamma} (1-\gamma)^{1-\gamma} A_M \left(\frac{P_M}{P_X} \right)^{\frac{\beta\gamma}{1-\alpha}} \left(\frac{1}{r+\delta} \right)^{\gamma} \right]^{\frac{1}{1-\gamma}}. \tag{29}$$

The equilibrium ratio $\dfrac{\widetilde{W}_S}{\widetilde{W}_U}$ results from dividing (28) and (29) and equals:

$$\frac{\widetilde{W}_S}{\widetilde{W}_U} = \left(\frac{A_X P_X}{A_M P_M} \right)^{\frac{1}{1-\gamma}}. \tag{30}$$

From equation (23a), the price of the nontraded good is immediately obtained using the result for the skilled wage in (28):

$$\widetilde{P}_N = \frac{\widetilde{W}_S}{A_N}. \tag{31}$$

Equilibrium ratios of capital to labor in the exportable and the importable sectors can be expressed, using equations (23c), (23e), (28), (29), and (30), as

$$\left(\frac{\tilde{k}_X}{\tilde{z}_X}\right) = \left(\frac{1}{A_X(1-\gamma)}\frac{\tilde{W}_S}{P_X}\right)^{\frac{1}{\gamma}}, \tag{32a}$$

$$\left(\frac{\tilde{k}_M}{1-\tilde{z}}\right) = \left(\frac{1}{A_M(1-\gamma)}\frac{\tilde{W}_U}{P_M}\right)^{\frac{1}{\gamma}}. \tag{32b}$$

From conditions (23b) and (23d), the following relation between relative factor intensities result, taking into account the value of

$\dfrac{\tilde{W}_S}{\tilde{W}_U}$ in (30):

$$\left(\frac{\tilde{k}_X}{\tilde{z}_X}\right) = \frac{\tilde{W}_S}{\tilde{W}_U}\left(\frac{\tilde{k}_M}{1-\tilde{z}}\right). \tag{33}$$

Therefore if we assume that skilled wages must be higher than unskilled wages, then the exportable sector will have a higher capital-to-labor ratio than the importable sector.

Effects of Changes in Trade Policy

The model analyzed here has the well-known properties of neoclassical growth models in which the economy converges to a steady state with zero per capita growth. The interest here is to analyze the economic dynamic after a change in the predetermined variables, due for example to a trade policy modification that affects the relative price of the exportable to the importable good

$\dfrac{P_X}{P_M}$,

where if we represent with an asterisk the variables at international prices and if τ is the import tariff, then

$$P_X = P_X^* \text{ and } P_M = P_M^*(1+\tau). \tag{34}$$

We will assume that $\hat{P}_X - \hat{P}_M$ is positive, for example because of a reduction in trade barriers. A "^" over a variable denotes the rate of change of that variable, that is

$$\hat{X} = \frac{dX}{X}.$$

Changes in relative prices

The impact of a change in the relative price of the exportable good on factor retributions, taken the world interest rate as given, resembles the well-known results of the Stolper-Samuelson theorem. The relative change of the skilled wage in terms of exportables and the unskilled wage in terms of importables can be expressed as:

$$\hat{W}_S - \hat{P}_X = \frac{(1-\alpha-\beta)}{1-\alpha}\frac{\gamma}{1-\gamma}\left(\hat{P}_X - \hat{P}_M\right) > 0, \tag{35a}$$

$$\hat{W}_U - \hat{P}_M = -\frac{\beta}{1-\alpha}\frac{\gamma}{1-\gamma}\left(\hat{P}_X - \hat{P}_M\right) < 0. \tag{35b}$$

As in the Stolper-Samuelson theorem, if

$$\hat{P}_M = -\frac{d\tau}{(1+\tau)} < 0 \tag{36}$$

because the government reduces the import tariff, keeping P_X constant, then it can be shown from (35a) and (35b) that $\hat{W}_X > \hat{P}_X > \hat{P}_M > \hat{W}_U$, with $\hat{W}_U < 0$.

It will be useful to find an expression for the rate of change of the ratio of skilled wages to unskilled wages:

$$\frac{\widetilde{W}_S}{\widetilde{W}_U}.$$

From (35a) and (35b) the following expression is obtained:

$$\hat{W}_S - \hat{W}_U = \frac{\hat{P}_X - \hat{P}_M}{1-\gamma} > 0. \tag{37}$$

Since $0 < \gamma < 1$, the change in the ratio of wages due to a change in final goods prices is magnified, and $\hat{W}_S - \hat{W}_U > \hat{P}_X - \hat{P}_M$.

The change in the price of the nontraded good follows from equation (31) and is equal to the rate of change of skilled wages:

$$\hat{P}_N = \hat{W}_S. \tag{38}$$

Changes in skilled labor and its allocation

Having determined the effect of trade policy on wages and the prices of domestic goods, its impact on factor demand can be analyzed. Beginning with the effect of a change in the relative price of exportables on human capital accumulation, equations (13a) and (13c) give the following expression for the rate of change in the participation of skilled workers in the total labor force *z*:

$$\hat{z} = \frac{\phi}{1-\phi}\frac{dW_S - dW_U}{W_S - W_U} = \frac{\phi}{1-\phi}\left[\hat{W}_S + \frac{W_U}{W_S - W_U}\left(\hat{W}_S - \hat{W}_U\right)\right] > 0 \qquad (39)$$

as long as $\hat{W}_S > 0$ and $\hat{W}_S - \hat{W}_U > 0$ according to equations (35a) and (37) and the assumption that $W_S > \hat{W}_U$.

Even though the positive impact of the relative increment in the price of the exportable good on human capital accumulation comes directly from the assumptions made about the production functions, the allocation of more-skilled workers to production of the nontraded and the exportable good is more intriguing. As can be seen from equation (27), the participation of skilled workers in the nontradable sector $\tilde{z}_N$ depends on the equilibrium values of expenditure per capita $\tilde{\varepsilon}$ and investment in human capital $\tilde{i}_z$. The latter is obtained from (13b), and depends on the shadow price *q* that jumps to its new steady-state value after a change in relative prices and remains constant thereafter. So $\tilde{i}_z$ will also jump to its new steady-state value and remain constant during the transition.

But $\tilde{\varepsilon}$ results from (18) and its change depends on the derivative of the integral (10). The present discounted value of the labor income stream plus transfers Ψ_0 is defined as follows:

$$\Psi_0 = \int_0^{\infty} e^{-(r-n)t}\left[W_{U,t} + z\left(W_{S,t} - W_{U,t}\right) + v_t\right]dt \,. \qquad (40)$$

If $\tilde{i}_z$ remains constant during the transition to the new steady state, the integral (10) can be expressed as

$$V_0 = \Psi_0 - \frac{\tilde{i}_z}{r-n} \,. \qquad (41)$$

The nominal expenditure per capita in consumption goods given by (18) is now

$$\tilde{\varepsilon} = (r-n)\left(\Psi_0 + a_0\right) - \tilde{i}_z \,, \qquad (42)$$

and the equilibrium value of the proportion of skilled workers allocated to the nontradable good sector is

$$\tilde{z}_N = \alpha\frac{(r-n)\left(\Psi_0 + a_0\right)}{A_N} \,. \qquad (43)$$

The problem is now to find the derivative of the integral (40) to a change in wages, due to an increment in the relative price of the exportable good. Define the "average" wage as

$$W_t = W_{U,t} + z\left(W_{S,t} - W_{U,t}\right), \text{ and let} \tag{44}$$

$$d\Psi_0 = \int_0^\infty e^{-(r-n)t}\left(dW_t + dv_t\right)dt$$

where dv_t is the change in transfers that corresponds to the change in government revenues when the import tariff is modified. If $dW_t > 0$ and $dv_t > 0$ for all $t \in [0,\infty]$, then $d\Psi_0 > 0$ unambiguously and $\tilde{z}_N$ will increase. In the following discussion, it will be assumed that tariffs are high enough to promote an increase in revenues on impact, immediately after the reduction in tariffs levels. During the transition as *z* increases, production of importables will decrease and imports will grow, and so $dv_t > 0$ for all $t \in [0,\infty]$. We will now consider the effect on *dW*.

On impact at time 0, *z* remains constant and so

$$dW_0 = dW_U + z\left(dW_S - dW_U\right). \tag{45}$$

Given that $dW_S - dW_U > 0$ from (37) and (39), this expression will always be positive if $dW_U > 0$. But we will consider the stringent condition $dW_U < 0$ for the extreme case in which $\hat{P}_X = 0$ and $\hat{P}_M < 0$. This would be the case for a reduction in import tariffs, without affecting the price received by the producers of the exportable good. Define the unskilled wage component proportion in the average wage and the skilled premium as

$$m_U = \frac{W_U}{W}, \tag{46a}$$

$$m_S = 1 - m_U = \frac{z\left(W_S - W_U\right)}{W}, \tag{46b}$$

respectively. Then

$$\frac{dW_0}{W_0} = m_U \hat{W}_U + m_S \frac{dW_S - dW_U}{W_S - W_U}. \tag{47}$$

Remembering from equation (39) that

$$\frac{dW_S - dW_U}{W_S - W_U} = \hat{W}_S + \frac{W_U}{W_S - W_U}\left(\hat{W}_S - \hat{W}_U\right) > 0$$

and using equations (35a–b) under the hypotheses $\hat{P}_X = 0$ and $\hat{P}_M < 0$, $\frac{dW_0}{W_0}$ will be positive if

$$\frac{m_S}{1-m_S} > \frac{1-\gamma\frac{1-\alpha-\beta}{1-\alpha}}{\frac{W_U}{W_S-W_U}+\gamma\frac{1-\alpha-\beta}{1-\alpha}} . \tag{48}$$

The right-hand expression depends on the value of

$$\gamma\frac{1-\alpha-\beta}{1-\alpha} .$$

Its presence in this equation comes from the assumption that investment in physical capital is a composite of the tradable goods, being

$$\frac{1-\alpha-\beta}{1-\alpha}$$

the participation of the importable good in the formation of investment. As most of the investment in physical capital comes from the importable good, the right-hand side of (48) will decrease and less participation of the skilled labor premium in the average wage will be required to verify the equation.

After the initial impact, during the time interval $t \in (0,\infty]$, z will be growing along the stable saddle path. As the skilled and unskilled wages remain constant after the initial change, $dW_t > 0 \;\; \forall t \in (0,\infty]$ from the initial value W_0. The change from the initial steady-state value of W to the new one is given by

$$\frac{d\widetilde{W}}{\widetilde{W}} = m_U\hat{W}_U + m_S\frac{d\widetilde{W}_S - d\widetilde{W}_U}{\widetilde{W}_S-\widetilde{W}_U} + m_S\frac{\phi}{1-\phi}\frac{d\widetilde{W}_S - d\widetilde{W}_U}{\widetilde{W}_S-\widetilde{W}_U} \tag{49}$$

where the last term is obtained from the expression for $\hat{z}$ in (39). The condition for $\frac{d\widetilde{W}}{\widetilde{W}} > 0$ is given by

$$\frac{m_S}{(1-m_S)(1-\phi)} > \frac{1-\gamma\frac{1-\alpha-\beta}{1-\alpha}}{\frac{W_U}{W_S-W_U}+\gamma\frac{1-\alpha-\beta}{1-\alpha}} . \tag{50}$$

Condition (50) is less restrictive than (48); so if the latter is met, the former will be also.

If the initial value of m_S is high enough to satisfy condition (48), the entire path of W_t will be above the initial steady-state values, the sign of the derivative of Ψ_0 will

be unambiguously positive, and the participation of skilled labor allocated in the nontradable good sector z_N will rise. If the initial value of m_S is not high enough to meet condition (50), the path of W_t will be below the initial equilibrium values for all $t \in [0, \infty]$, and the derivative of the integral (40) will be unambiguously negative. In this case, participation of the nontraded good in the allocation of skilled labor will decrease despite the increase in *z*. If m_S satisfies condition (50) but not (48), the path of W_t will be below the initial equilibrium values for some interval $t \in [0, T]$ with *T* finite, and above the values when $t \in [T, \infty]$. In this case, the sign of the derivative of Ψ_0 will be ambiguous and so will happen with z_N.

Another question is also raised. Assuming that m_S satisfies the condition for an increase in Ψ_0 and z_N, one wonders if the rate of change in z_N is higher, equal to, or lower than *z* since the result will affect the relative allocation of skilled workers among the nontraded and exportable goods sectors. Again, the condition for a rate of change of W_0 higher than $\hat{z}$ is, using the result in (39),

$$\frac{m_S(1-\phi)-\phi}{(1-m_S)(1-\phi)} > \frac{1-\gamma\dfrac{1-\alpha-\beta}{1-\alpha}}{\dfrac{W_U}{W_S-W_U}+\gamma\dfrac{1-\alpha-\beta}{1-\alpha}} . \tag{51}$$

This condition requires much larger values of m_S to be satisfied than in (48). If this condition is met,

$$\frac{dW_0}{W_0} > \hat{z}$$

on impact; and as W_t continues growing for $t \in (0, \infty]$, the rate of growth of Ψ_0 and of z_N will exceed $\hat{z}$, promoting a reallocation of skilled workers toward the nontraded-good sector.

Consider finally the condition to be met to allow for

$$\frac{d\widetilde{W}}{\widetilde{W}} > \hat{z} .$$

Proceeding in an analogous form as previously, we obtain the following:

$$\frac{m_S-\phi}{(1-m_S)(1-\phi)} > \frac{1-\gamma\dfrac{1-\alpha-\beta}{1-\alpha}}{\dfrac{W_U}{W_S-W_U}+\gamma\dfrac{1-\alpha-\beta}{1-\alpha}} . \tag{52}$$

As can be easily seen, (52) is less restrictive than (51), but not (48). If this condition is satisfied, the values of W_t in the new steady state will show an increment

with respect to the initial steady state of $\hat{z}$ or more. But since the path for W_t has lower rates of growth than $\hat{z}$ during some interval in the transition, it is not certain that Ψ_0 and z_N will grow more than $\hat{z}$ between the new and the old steady state.

Given reasonable values for the parameters involved, conditions (51) and (52) are unlikely to be met, but values for m_S that satisfy (50) and even (48) fall into reasonable ranges. Then, it will be assumed that $0 < \hat{z}_N < \hat{z}$. This implies that $\hat{z}_X$, the rate of change of the participation of skilled workers in the exportable-good sector with respect to the total labor force, is higher than $\hat{z}$.

Since a closed-form solution to the rate of change of z_N cannot be derived, the following representation will be adopted to simplify the calculations:

$$\hat{z}_X = \hat{z} + \theta_X > 0, \tag{53a}$$
$$\hat{z}_N = \hat{z} - \theta_N > 0, \tag{53b}$$
$$\theta_X, \theta_N > 0.$$

Changes in physical capital

The effects of trade policy on physical capital demand and its allocation among the tradable goods can be derived differentiating equations (32a) and (32b). Using the results in (35) and (53) the following relations are obtained:

$$\hat{k}_X = \hat{z} + \theta_X + \frac{1}{1-\gamma}\frac{1-\alpha-\beta}{1-\alpha}\left(\hat{P}_X - \hat{P}_M\right) > 0, \tag{54a}$$
$$\hat{k}_M = -\frac{z}{1-z}\hat{z} - \frac{1}{1-\gamma}\frac{\beta}{1-\alpha}\left(\hat{P}_X - \hat{P}_M\right) < 0. \tag{54b}$$

To obtain the change in aggregate physical capital, $k = k_X + k_M$, we obtain the following relation:

$$\hat{k} = \frac{k_X}{k}\hat{k}_X + \frac{k_M}{k}\hat{k}_M = \frac{k_X}{k}\left(\hat{k}_X - \hat{k}_M\right) + \hat{k}_M \ . \tag{55}$$

Using (54a) and (54b), $\hat{k}$ is given by

$$\hat{k} = \left(\frac{k_X}{k} - z\right)\frac{\hat{z}}{1-z} + \left(\frac{k_X}{k} - \frac{\beta}{1-\alpha}\right)\frac{\hat{P}_X - \hat{P}_M}{1-\gamma} + \frac{k_x}{k}\theta_X. \tag{56}$$

As equations (54a–b) show, physical capital is expanding in the exportable-good sector and is contracting in the importable-good sector. The net effect is positive if the exportable-good sector is capital intensive, and its demand of capital in terms of total physical capital has been higher than the participation of skilled workers over the total labor force, and higher than the participation of the exportable good in the product of tradables.

Sectoral and aggregate growth

Differentiating the sectoral outputs in equations (22a–c), using the results obtained previously on factor demands, gives the following:

$$\hat{y}_N = \hat{z}_N = \hat{z} - \theta_N > 0, \tag{57a}$$

$$\hat{y}_X = \gamma \hat{k}_X + (1-\gamma)(\hat{z} + \theta_X) > 0, \tag{57b}$$

$$\hat{y}_M = \gamma \hat{k}_M - (1-\gamma)\frac{z}{1-z}\hat{z} < 0, \tag{57c}$$

where $\hat{y}_i$, $i = N, X, M$ is $\hat{y}_i = \dfrac{dy_i}{y_i}$; and y_i, $i = N, X, M$ is $y_i = \dfrac{Y_i}{L}$.

To find an expression for the aggregate product in this economy, weighting factors must be determined to assemble the rates of changes in sectoral products. Initially it is assumed that not only is the trade balance in equilibrium, but all sectoral outputs equal their respective demand, as in a closed economy. This permits equalized sectoral participations in aggregate product with the same parameters of consumption.

Total demand for the exportable good is given by using (20b) and the assumptions made about the origin of expenses in physical and human capital:

$$P_X C_X + \frac{\beta}{1-\alpha} I_K + \beta I_Z = \alpha(E + I_Z). \tag{58}$$

Assumption that the trade balance is in equilibrium implies that

$$YN = E + I_K + I_Z \tag{59}$$

where *YN* is the nominal aggregate product. Define the initial investment ratios as

$$\kappa_\kappa = \frac{I_K}{YN}, \text{ and let} \tag{60a}$$

$$\Lambda_X = \beta\left(1 + \frac{\alpha}{1-\alpha}\kappa_K\right). \tag{60b}$$

The aggregate demand for the exportable good is

$$P_X C_X + \frac{\beta}{1-\alpha} I_K + \beta I_Z = \Lambda_X YN. \tag{61a}$$

Proceeding in analogous form in the importable sector, we get

$$P_M C_M + \frac{1-\alpha-\beta}{1-\alpha} I_K + (1-\alpha-\beta) I_Z = \Lambda_M YN, \tag{61b}$$

where $\Lambda_M = (1-\alpha-\beta)\left(1+\frac{\alpha}{1-\alpha}\kappa_K\right)$. Finally, total demand for the nontraded good is

$$P_N C_N + \alpha I_Z = (1 - \Lambda_X - \Lambda_M) YN. \tag{61c}$$

Equilibrium in the three markets (which implies no trade at the initial equilibrium) requires that the value of production must be equal to total expenditure in each type of good. Given equations (61a–c), the conditions for equilibrium are

$$P_X Y_X = \Lambda_X YN, \tag{62a}$$
$$P_M Y_M = \Lambda_M YN, \tag{62b}$$
$$P_N Y_N = (1-\Lambda_X - \Lambda_M) YN. \tag{62c}$$

From the equilibrium equations (62a–c), expressing all the product variables in per capita terms (dividing all magnitudes by total labor force L), the implicit price indexes for the different products are obtained: where

$yn = \frac{YN}{L}$, then

$$P_X = \Lambda_X \frac{yn}{y_X}, \tag{63a}$$

$$P_M = \Lambda_M \frac{yn}{y_M}, \tag{63b}$$

$$P_N = (1-\Lambda_X - \Lambda_M)\frac{yn}{y_N}. \tag{63c}$$

Define the "real" aggregate product as the nominal product divided by the aggregate perfect price index $P = P_N^{\alpha} P_X^{\beta} P_M^{1-\alpha-\beta}$, that is

$$Y = \frac{YN}{P} = \frac{YN}{P_N^{\alpha} P_X^{\beta} P_M^{1-\alpha-\beta}}, \tag{64a}$$

or in per capita terms,

$$y = \frac{yn}{P_N^{\alpha} P_X^{\beta} P_M^{1-\alpha-\beta}}. \tag{64b}$$

Substituting the price indexes (63a–c) in (64b), the following expression for the aggregate "real" product results:

$$
\begin{aligned}
y &= \frac{yn}{\left[\left(1-\Lambda_X-\Lambda_M\right)\dfrac{yn}{y_N}\right]^{\alpha}\left(\Lambda_X\dfrac{yn}{y_X}\right)^{\beta}\left(\Lambda_M\dfrac{yn}{y_M}\right)^{1-\alpha-\beta}} \\
&= \frac{y_N^{\alpha}y_X^{\beta}y_M^{1-\alpha-\beta}}{\left(1-\Lambda_X-\Lambda_M\right)^{\alpha}\Lambda_X^{\beta}\Lambda_M^{1-\alpha-\beta}}
\end{aligned}
\quad . \tag{65}
$$

Totally differentiating equation (65), the rate of growth of aggregate product is given by

$$
\hat{y} = \alpha\hat{y}_N + \beta\hat{y}_X + \left(1-\alpha-\beta\right)\hat{y}_M \,. \tag{66}
$$

Substituting equations (57a–c) in (66) and using the expressions for factor accumulation in (39) and (54a–b), an expression for the growth rate of this economy is found:

$$
\hat{y} = \frac{\phi}{1-\phi}\left(\frac{\alpha+\beta}{z}-1\right)\frac{z}{1-z}\frac{dW_S-dW_U}{W_S-W_U} - \alpha\theta_N + \beta\theta_X \,. \tag{67}
$$

Ignoring the effect of the term "$-\alpha\theta_N + \beta\theta_X$," which measures the impact on aggregate growth of the change in the allocation of skilled labor for the nontraded and the exportable good, the change in trade policy analyzed in this section will have positive impact on aggregate output if the participation of the sectors that use skilled labor (nontraded and exportable, given by $\alpha+\beta$), is high with respect to the ratio of skilled labor to the total labor force.

It can be seen from equations (54a–b) that two effects impact the allocation of physical capital among sectors. One is the "equilibrium capital-labor-ratio" effect, which drives the demand for physical capital via changes in labor use. The other is a substitution effect that modifies that capital-labor ratio via changes in relative prices. This substitution effect increases the demand for physical capital in the exportable sector and reduces it in the importable sector. In the derivation of equation (67), those movements are compensated because the assumptions made about the relative participations of all sectors in output imply that the incidence in aggregate growth of expansion in the exportable sector due to higher demand for physical capital (sparked in turn by a change in relative prices) is exactly matched by the incidence of contraction in the importable sector due to analogous reasons.

Consequently the only effect that influences aggregate growth is the change in labor composition. As a higher percentage of the total labor force is skilled, output of the nontraded and the exportable good will expand while output of the importable good contracts. The net effect is an increment in aggregate output if the incidence of the sectors that are increasing production, $\alpha+\beta$, is high enough to overcome reduced production of the importable good.

The condition $\dfrac{\alpha+\beta}{z} > 1$ for positive aggregate output growth implies that the participation of sectors that are expanding in total output is higher than the participation

of their labor resource inputs from the total labor force. This is consistent with the conclusion that can be drawn from (33), that is, the relative higher capital intensity of the exportable compared to the importable good.

Estimation

Implementation of the System

The model to be estimated is the production function (65), after substituting the sectoral outputs by the production functions (22a–c) and the dynamic equations for *z* and *k*, (39) and (56). Beginning from the production function, the following is obtained:

$$y = \frac{A_N^{\alpha} A_X^{\beta} A_M^{1-\alpha-\beta}}{\left(1 - \Lambda_X - \Lambda_M\right)^{\alpha} \Lambda_X^{\beta} \Lambda_M^{1-\alpha-\beta}} \left[\left(\frac{z_n}{z}\right)^{\alpha} \left(1 - \frac{z_n}{z}\right)^{\gamma\beta} \right] z^{\alpha+\beta\gamma} \left(1 - z\right)^{\gamma(1-\alpha-\beta)} k_X^{(1-\gamma)\beta} k_M^{(1-\gamma)(1-\alpha-\beta)}$$

(68)

The weighted average of the skilled and unskilled labor in various sectors is expressed by

$$\left[\left(\frac{z_n}{z}\right)^{\alpha} \left(1 - \frac{z_n}{z}\right)^{\gamma\beta} \right] z^{\alpha+\beta\gamma} \left(1 - z\right)^{\gamma(1-\alpha-\beta)} .$$

Assuming the initial participations as given, as are the investment ratios in Λ_X, Λ_M, the production function can be presented in an estimable form as

$$\begin{aligned}
&y = Mh^{1-\sigma} k^{\sigma} \\
&M = \frac{A_N^{\alpha} A_X^{\beta} A_M^{1-\alpha-\beta}}{\left(1 - \Lambda_X - \Lambda_M\right)^{\alpha} \Lambda_X^{\beta} \Lambda_M^{1-\alpha-\beta}} \left[\left(\frac{z_n}{z}\right)^{\alpha} \left(1 - \frac{z_n}{z}\right)^{\gamma\beta} \right] \\
&h^{1-\sigma} = z^{\alpha+\beta\gamma} \left(1 - z\right)^{\gamma(1-\alpha-\beta)} \\
&k^{\sigma} = k_X^{(1-\gamma)\beta} k_M^{(1-\gamma)(1-\alpha-\beta)} \\
&\sigma = (1-\alpha)(1-\gamma)
\end{aligned} \tag{69}$$

where *h* is an index of skilled to unskilled workers and *M* will be assumed constant. Finally, in logarithmic form,

$$\ln y_t = \ln M + (1 - \sigma) \ln h_t + \sigma \ln k_t . \tag{70}$$

To transform this equation into a dynamic version, one must take into account, as analysis earlier in the paper revealed, that TFP, which is the residual of an expression

like (70), is stationary. But since the aggregate output, the index of human capital, and all measures of physical capital are nonstationary, there must be a cointegration relationship in (70) that transforms variables I(1) into I(0). We will interpret the cointegration relation precisely as the production function.

But if a cointegration relationship exists between *y*, *h*, and *k*, the dynamic version of (70) is not just its first differences. Suppose the following partial adjustment mechanism for the equilibrium relationship (70), where the constant term is dropped for simplicity:

$$\ln y_t = a \ln y_{t-1} + b_0 \ln h_t + b_1 \ln h_{t-1} + c_0 \ln k_t + c_1 \ln k_{t-1}\,. \tag{71}$$

Deducing $\ln y_{t-1}$ from each side and making the appropriate adjustments in the other variables, we get:

$$\Delta \ln y_t = b_0 \Delta \ln h_t + c_0 \Delta \ln k_t - (1-a)\left(\ln y_{t-1} - \frac{b_0 + b_1}{1-a} \ln h_{t-1} - \frac{c_0 + c_1}{1-a} \ln k_{t-1} \right) \tag{72}$$

The term in brackets on the right-hand side is the residual of a regression of $\ln y$ on the factors of production, that is, the lagged-once residual of the production function.

To conclude, the estimable version of equation (70) is

$$\Delta \ln y_t = b_0 \Delta \ln h_t + c_0 \Delta \ln k_t - (1-a)\big(\ln y_{t-1} - (1-\sigma)\ln h_{t-1} - \sigma \ln k_{t-1}\big) + u_t\,. \tag{73}$$

Since a linear relationship between the rates of growth of *z* and *h* can be obtained from (69), the equation (39) can be expressed as

$$\Delta \ln h_t = d_1 \Delta \ln h_{t-1} + e_0 \Omega_t + v_t \tag{74}$$

where Ω_t represents exogenous variables that drive the dynamics of *h*. These variables may well include the error-correction mechanism in (73). Finally, the estimable version of (56) is

$$\Delta \ln k_t = f_1 \Delta \ln k_{t-1} + g_0 \Delta \ln h_t + g_1 \Delta \ln h_{t-1} + m_0 \Phi_t + w_t \tag{75}$$

where Φ_t represents exogenous variables that determine *k*. The system (73–5) permits one to estimate *z*, *h* and *k* simultaneously. To avoid problems of simultaneity bias, an Instrumental Variable (IV) estimation procedure was implemented.

Instrumental Variable Estimation

In the first stage, the production function (70) was estimated in levels to test for the stationariness of its residuals and the appropriateness of the error-correction mechanism in (73). The dependent variable is the GDP per capita (in logs, LPBIPC). Besides the index of human capital (LICAPHUM) and private-sector fixed capital (LCAPPRFIJPC) as explanatory variables, public-sector infrastructure (LCONSTPUBPC) was also included in the production function as a predetermined variable. The equation was estimated subject to the restriction that the sum of the parameters must add to one.

Table 4. Dependent variable: GDP per capita (in logs)

Dependent Variable LPBIPC – Estimation by Least Squares			
Annual Data From 1956:01 To 1999:01			
Usable Observations 44			
R^2		0.86	
Mean of Dependent Variable		3.46	
Std. Error of Dependent Variable		0.15	
Std. Error of Estimate		0.06	
Sum of Squared Residuals		0.15	
Durbin-Watson Statistic		0.53	
Q(11-0)		50.82	
Significance Level of Q		0.00	
Variable	Coeff	Std Error	T-Stat
1. Constant	-0.672	0.11	-5.98
2. LICAPHUM	0.550	0.08	6.88
3. LCAPPRFIJPC	0.271	0.05	5.51
4. LCONSTPUBPC	0.178	0.06	3.09

To estimate the system (73–5) a policy variable must be defined to get the impact of trade policy changes on the dynamics of factor accumulation and growth. The openness ratio showed in Figure 6 cannot be used as a proxy for the commercial policy since it may be endogenous to the variables that must be determined, like human and physical capital accumulation. An index of commercial policy therefore was defined by two steps: (1) regressing the openness ratio (GRADAP) on the index of nominal protection presented in Figure 9 (LPROTEC), a dummy for the Mercosur period (DUMMERC), and the real exchange rate (LURUTCR), and (2) combining the index of nominal protection and the Mercosur dummy using the coefficients obtained in the first step to construct a commercial policy index. The regression obtained in the first step is the following:

Table 5. Dependent Variable: Openness Ratio

Dependent Variable GRADAP – Estimation by Least Squares			
Annual Data From 1956:01 To 1999:01			
Usable Observations 44			
R^2		0.95	
Mean of Dependent Variable		0.39	
Std. Error of Dependent Variable		0.14	
Std. Error of Estimate		0.03	
Sum of Squared Residuals		0.04	
Regression F(3,40)		257.91	
Significance Level of F		0.00	
Durbin-Watson Statistic		1.16	
Q(11-0)		24.71	
Significance Level of Q		0.01	
Variable	Coeff	Std Error	T-Stat
1. Constant	1.086	0.08	13.17
2. DUMMERC	0.198	0.02	10.16
3. LPROTEC	-0.086	0.01	-10.57
4. LURUTCR	-0.048	0.02	-3.15

The presence of a unit root in the residuals of this equation is rejected. The index of commercial policy is then defined as

COMPOL = 1.085910342 + 0.197609409*DUMMERC – 0.086494762*LPROTEC. (76)

The system (73–5) was estimated using IV. The variable RESPBI represents the residuals of the production function in levels. The equation for the change in the product per capita is:

Table 6. Dependent Variable: Change in GDP per capita

Dependent Variable DLPBIPC – Estimation by Instrumental Variables			
Annual Data From 1960:01 To 1999:01			
Usable Observations 40			
R^2	0.71		
Mean of Dependent Variable	0.01		
Std. Error of Dependent Variable	0.04		
Std. Error of Estimate	0.03		
Sum of Squared Residuals	0.02		
Durbin-Watson Statistic	1.96		
Q(10-0)	6.29		
Significance Level of Q	0.79		
Variable	Coeff	Std Error	T-Stat
1. Constant	-0.009	0.01	-1.33
2. RESPBI {1}	-0.475	0.10	-4.73
3. DLPBIPC {1}	0.722	0.14	5.27
4. DLICAPHUM	-0.313	0.15	-2.06
5. DLICAPHUM {2}	0.398	0.16	2.52
6. DLCAPPRFIJPC	0.842	0.14	5.90
7. DLCAPPRFIJPC {1}	-1.107	0.28	-3.99
8. DLCONSTPUBPC {1}	0.778	0.24	3.20
9. DLCONSTPUBPC {2}	0.175	0.12	1.45
10. DLCONSTPUBPC {3}	-0.211	0.12	1.79

Table 7. Dependent Variable: Private Fixed Capital

Dependent Variable DLCAPPRFIJPC – Estimation by Instrumental Variables			
Annual Data From 1960:01 To 1999:01			
Usable Observations 40			
R^2	0.88		
Mean of Dependent Variable	0.00		
Std. Error of Dependent Variable	0.04		
Std. Error of Estimate	0.01		
Sum of Squared Residuals	0.01		
Durbin-Watson Statistic	1.95		
Q(10-0)	7.89		
Significance Level of Q	0.64		
Variable	Coeff	Std Error	T-Stat
1. Constant	-0.002	0.01	-0.94
2.DLCAPPRFIJPC {1}	0.689	0.12	5.53
3. DLCONSTPUBPC	0.878	0.05	16.58
4. DLCONSTPUBPC {1}	-0.683	0.11	-6.24

As can be seen, this variable is also exogenous with respect to the other dependent variables, human capital, and growth. It is interesting to note the significance of public-sector construction as an explanatory variable for the dynamics of private-sector investment.

As suggested by the model, the stylized facts, and the unit root tests discussed previously, both the introduction of Mercosur and Uruguay's unilateral liberalization efforts may have influenced the evolution of human capital. Thus the commercial policy variable (in differences, DCOMPOL) was introduced as an explanatory variable of the increment in human capital, together with other contemporary and lagged endogenous variables of the system.

Table 8. Dependent Variable : Change in Human Capital Index

Dependent Variable DLICAPHUM – Estimation by Instrumental Variables			
Annual Data From 1960:01 To 1999:01			
Usable Observations 40			
R^2	0.75		
Mean of Dependent Variable	0.02		
Std. Error of Dependent Variable	0.03		
Std. Error of Estimate	0.02		
Sum of Squared Residuals	0.01		
Durbin-Watson Statistic	1.88		
Q(10-0)	8.92		
Significance Level of Q	0.54		
Variable	Coeff	Std Error	T-Stat
1. Constant	0.013	0.01	2.30
2. DLPBIPC	-0.333	0.22	-1.52
3. DLPBIPC {1}	0.279	0.15	1.88
4. DLPBIPC {2}	-0.369	0.13	-2.82
5. DLPBIPC {3}	0.317	0.13	2.43
6. DLICAPHUM {1}	-0.168	0.17	-0.95
7. DLICAPHUM {2}	0.354	0.19	1.82
8. DLICAPPRFIJPC	0.603	0.27	2.25
9. DLICAPPRFIJPC {1}	-0.364	0.16	-2.27
10. DLICAPPRFIJPC {2}	0.387	0.14	2.82
11. DLICAPPRFIJPC {3}	-0.531	0.13	-4.09
12. DLCONSTPUBPC	-0.336	0.26	-1.29
13. DCOMPOL	0.417	0.12	3.38
14. DCOMPOL {1}	0.020	0.14	0.14
15. DCOMPOL {2}	0.523	0.13	3.91
16. DCOMPOL {3}	-0.199	0.15	-1.29

Figure 8.11a. Log of GDP per capita

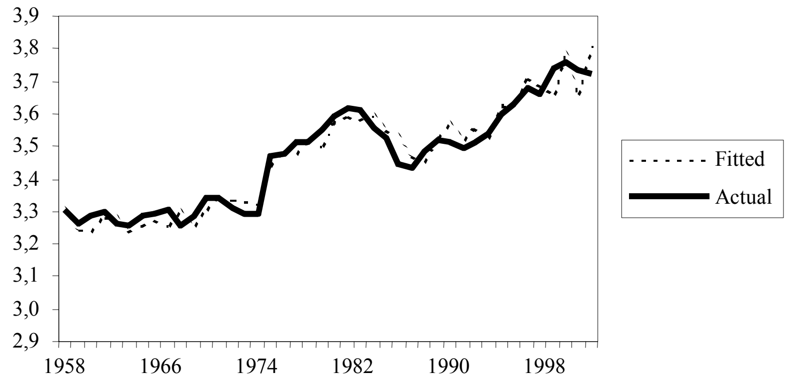
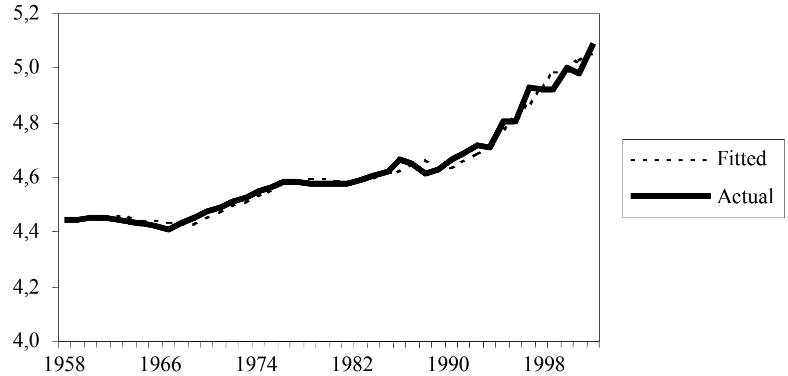


Figure 8.11.b. Log of human capital index



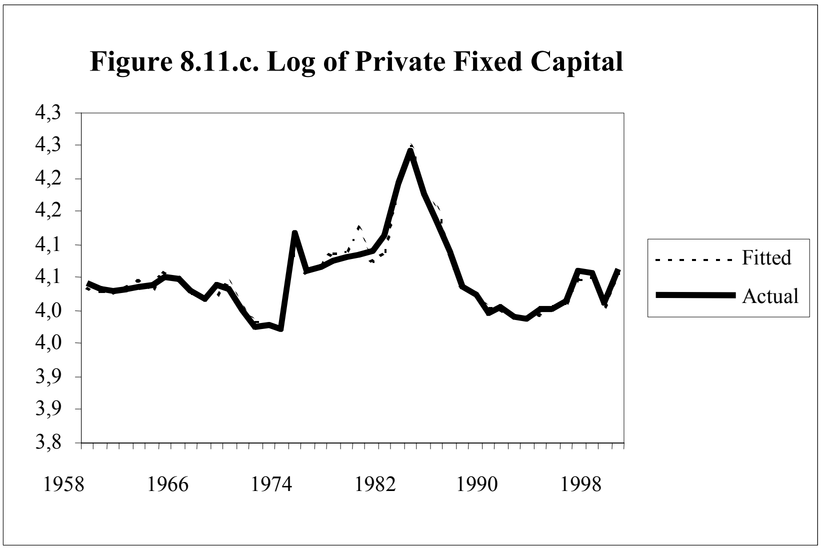


Figure 8.11.c. Log of Private Fixed Capital
4,3
4,3
4,2
4,2
4,1
4,1
4,0
4,0
3,9
3,9
3,8
1958
1966
1974
1982
1990
1998
Fitted
Actual

Conclusions

This paper studied the dynamics of economic growth in Uruguay during the last five decades. The most relevant empirical regularities to be explained are:

- The actual acceleration of economic growth, measured as the rate of variation of GDP per capita, after the economic reforms toward a market-oriented economy began to be implemented;
- The high contribution of human capital accumulation to the growth of GDP per worker over the entire period under consideration, but especially in the decade of the 1990s;
- The absence of change in TFP, which most of the time was actually negative according to growth accounting calculations; and
- The stability of net investment in physical capital before and after implementation of the reforms, notwithstanding some periods of temporary acceleration.

A model that explains most of these facts was formulated, and an estimation of its empirical consequences was performed. Essentially the behavior of the Uruguayan economy fits into the characteristics of a neoclassical model of economic growth, in which policy changes have transitory impacts on investment and growth until the economy reaches a new steady state with higher output per capita but the same prior equilibrium rate.

The model suggests that policy changes did help develop sectors whose use of skilled labor was relatively intensive. According to the model, and it is confirmed by the facts, if the economy receives a shock that favors the relative redistribution of skilled work, then the wage differential will rise, promoting the formation of human capital.

The model predicts a transitory higher growth rate of final output above the initial equilibrium, with the growth rate decreasing as the economy approaches its new steady state, clearly a neoclassical result.

The model estimated, which structure the theoretical model formulated, represents quite well the dynamics of growth and factors accumulation during the period under study. One can clearly conclude from the empirical evidence that economic growth in Uruguay has been supported by the accumulation of physical and human capital, with little or no contribution from changes in TFP.

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