

GROWTH AND TECHNOLOGICAL CHANGE IN CUBA

Manuel Madrid-Aris¹

This empirical paper is purposely written to be simple and straight forward. It has two main goals. The first is to provide a descriptive analysis of the historical patterns of growth, international trade, factor accumulation and human capital in Cuba during the post-revolution period. The second is the estimation the rate of technical progress or total factor of productivity (TFP) in Cuba during the period 1963-1988, and to compare it with other world regions.

The literature dealing with economic growth, technological change and human capital is vast and growing at a fast rate. It is widely known that the importance of changes in TFP in explaining why some countries grow more rapidly than others, or why some specific industries of a country grow faster than others for a given period of time. But empirical estimations of TFP of centrally planned economies are rarely seen. This can be explained because of the lack of good and reliable data, which makes this type of research a lengthy if not unattainable task. As result of the lack of empirical studies relating growth and technological change, Cuba's economic growth still challenges economists. Hence, many questions could be asked, such as: Is the increased per capita income in Cuba a consequence of better educated labor force, which could have led to a high rate of technological change (TFP), or is it the result of increased investment resulting from Soviet subsidies? How much is the contribution of the different factors (la-

bor, capital, TFP) to total Cuban economic growth and to the growth of some specific sectors of the Cuban economy? Is Cuba's rate of technological change lower or higher than of capitalist economies? The research underlying this paper is directed to answer these questions.

The paper is organized as follows. The first section provides a brief overview of the Cuban economy, including some macroeconomics indicators, productive structure, international trade, and human capital indicators. The intent of this section is to give some background of Cuba's economy to have a better understanding of Cuba's initial economic conditions and its process of economic growth during the period 1960-1988. The second section contains a brief review of the literature dealing with economic growth, technological change and human capital. The third section is the core of the paper. It tries to explain growth and technological change in Cuba; technological change is estimated using the traditional methodology to estimate TFP (Solow, 1957). The contribution of factors to Cuban economic growth is also estimated. The fourth section contains an econometric estimation of the economy of scale of the Cuban economy and of some economic sectors (agriculture and industry). The fifth section compares Cuban technological change with other world regions. The last section contains some conclusions.

1. I would like to thank the many people in Cuba who helped me collect some of the data used in this research. The views expressed, opinions and conclusions reached in this paper are those of the author, and do not necessarily reflect those of the institutions with which the author is affiliated.

Table 1. Macroeconomic Indicators (in percent)

	Economic Growth	Per Capita Growth	Investment as a % of GMP	Soviet Subsidies as a % of GMP	Exports as a % of GMP	Imports as a % of GMP
1960-1964	1.9	-0.2	0.14	0.08	0.15	0.19
1965-1969	3.6	1.7	0.19	0.07	0.14	0.21
1970-1974	10.0	8.2	0.17	0.07	0.18	0.23
1975-1979	3.4	2.2	0.28	0.18	0.34	0.40
1980-1984	5.7	5.1	0.30	0.33	0.44	0.52
1985-1988	1.3	0.3	0.31	n.a.	0.40	0.60
AVERAGE	4.4	3.2	0.28		0.28	0.36

Source: Rodríguez (1990), Brundenius (1984), Mesa-Lago and Pérez-López (1985) and author's estimates; Soviet subsidies figures come from Central Intelligence Agency (1984, p. 40 and 1989, p. 39).

Note: Economic growth has been estimated with Gross Material Product (GMP), since statistics on the Gross Social Product (GSP) are not as accurate as GMP. See Mesa-Lago and Pérez-López (1985).

THE CUBAN ECONOMY: A BRIEF OVERVIEW

Cuba's economic history is directly linked to agricultural production and its international trade is mainly related to sugar production. The revolution has had to constantly struggle with the need to diversify the economy and build an industrial base against the need to increase sugar production in order to accumulate capital required to industrialize and diversify the economy. By 1959, 80% of Cuba's export revenues came from sugar. Although the Cuban revolution has tried to carry out plans for agricultural diversification, industrialization and export diversification, it has not accomplished enough in these areas given that the Cuban economy is still highly dependent on sugar as much as thirty years ago.

As will be shown below, the failure of the industrialization plans is reflected in the fact that the percentage of Cuba's total industrial production output as share of Gross Material Product (GMP)² has basically remained the same over a twenty-five year period. On the other hand, construction's share has increased steadily and agriculture's has decreased over the years.

Macroeconomic Indicators

Despite its smallness, dependence on sugar monoculture, lack of natural resources and energy resources, Cuba sustained a good economic growth during the period 1960-1988. Cuba was able to grow at a steady annual rate of 4.4% during this period. Statistics show that during the period 1960-1988, per capita income increased at an average annual rate of 3.2%. Cuba increased considerably the rate of investment, which went from 15% of the national product in 1960 to 30% in 1988 (Table 1). Huge amounts of resources were invested in agriculture and education.

Table 1 shows that the highest rate of economic growth was achieved when the investment rate was decreasing. It is apparent that between 1960 and 1964 there were no increases in per capita income. On the other hand, during the period 1964-1988 income per capita increased at a considerable rate. Note that Soviet subsidies rose considerably through time, reaching a higher share of national product than investment for the period 1980-1984. In other words, it can be assumed that most of the Cuban investment during this period was realized by using Soviet subsidies. This clearly shows that the Cuban economy was losing saving capacity.

2. Cuba's national income accounting system is different from the Western concept of Gross National Product (GNP). Cuba uses the Soviet system of Global Social Product (GSP) and Gross Material Product (GMP), which is also called "gross product." For a detailed explanation of the Cuban national income accounting system, see Brundenius (1984, p. 19-40) and Mesa-Lago and Pérez-López (1985).

Table 2. Sectoral Shares and Sectoral GMP Growth Rate (in percent)

	Industry GMP as a % of GMP	Industry Output Rate of Growth	Agriculture GMP as a % of total GMP	Agriculture Output Rate of Growth
1963-1969	0.65	2.2	0.24	5.0
1970-1974	0.69	11.4	0.19	0.7
1975-1979	0.65	2.6	0.18	4.0
1980-1984	0.66	5.9	0.16	1.9
1985-1988	0.68	1.8	0.14	0.7
AVERAGE	0.67	4.7	0.19	2.7

Source: Rodríguez (1990) and *Anuario Estadístico de Cuba*, various issues.

Table 3. Structure of Cuban Exports (in percent)

	1957	1970	1975	1980	1987
Sugar	80.0	76.7	89.8	83.6	74.3
Tobacco	5.9	3.1	1.8	1.7	2.0
Minerals	5.7	16.7	4.7	4.8	6.6
Others	9.3	3.5	3.7	9.9	17.1
TOTAL	100.0	100.0	100.0	100.0	100.0

Source: Central Intelligence Agency (1984, 1989); Rodríguez (1990); and author's estimates.

Note: Other exports include fish, citrus, fruits, minerals, and rum.

Industrial and agricultural production are the main economic sectors in Cuba's economy, accounting for more than 80% of the total GMP or about 60% of Gross Social Product (GSP). Table 2 shows the share of total GMP and their rate of growth for the period 1963-1988: agriculture's share has been decreasing over time, while industry's share has remained constant over the last 25 years.

International Trade

Cuba's main exports are sugar and sugar derivatives (Table 3). These accounted, during the 1980's, for approximately 77% of total exports. Recently, mineral exports (mainly nickel) have replaced Cuba's second chief export, tobacco. Tobacco exports accounted for 10% of total exports in 1960, but for only 2% in 1987.

The concentration of international trade on sugar exports makes Cuba's economic output extremely vulnerable to world sugar prices, which have dramatically fluctuated over the years. During the revolution, some stability was attained by Russian guaranteed

Table 4. Structure of Cuban Imports (in percent)

	1965	1970	1975	1980	1986
Foodstuffs	25.2	20.0	19.0	17.1	10.4
Raw materials	2.9	4.7	3.9	4.3	4.0
Fuels and lubricants	9.8	8.7	10.0	20.5	33.5
Mach & transportation equipment	15.4	28.1	24.2	35.1	30.8
Others	46.7	38.5	42.9	23.1	21.3
TOTAL	100.0	100.0	100.0	100.0	100.0

Source: Central Intelligence Agency (1984, p. 33 and 1989, p.31).

fixed prices, which were often higher than world prices.

With respect to Cuba's imports, statistics show the degree of the nation's dependency on imports. This dependence is clearly evident in a continuous trade balance deficit for more than 32 years. This constant international trade deficit contributed to Cuba's reliance on Soviet financing. Following the so-called "end of the cold war," with the disintegration of the Soviet Union, Cuba no longer receives Russian financing for the trade deficits.

Note that Cuba's imports statistics are not very accurate because some of their strategic goods imports—such as weaponry—were supplied free of charge at least during 1962-1970. Foodstuffs were, on average, the most important imports between 1963-1975, accounting for about 20% (

4). Fuel imports increased considerably from 1960 to 1986, accounting for one third of total imports in recent years. Also note that the share of machinery and transportation equipment imports increased at a rate

of more than 4% a year during the last 20 years. Cuba's dependency on imported technology for machinery and transportation equipment is clear. Table 4 shows the failure of the Cuban industrialization program adopted as the main goal of the government after 1959.

Education and Human Capital

Investing in human capital is a concept widely used by economists, which basically describes the process of improvement of the quality of the labor force. Thus, human capital is referred to as the level of education of the labor force. Improvement of the quality of the labor force is basically accomplished by education and training. Since there is no accurate data concerning the rate of change of education of the Cuban labor force, for purposes of discussion in this paper, it is assumed that human capital changes at the same rate than the enrollment rate change.

Table 5 contains data of enrollment in Cuba between 1958 and 1985. With respect to education, Cuba considerably increased the rate of enrollment, thus increasing its human capital during this period. It is clear from Table 5 that human capital accumulation has been quite rapid. Hence it could be concluded that the Cuban government was successful in achieving a high rate of improvement of human capital.

Table 5. Students Enrolled by Level of Education (per 1,000 inhabitants)

	Primary	Secondary	Higher	Other	Total
1958	106.1	13.0	3.8	1.0	123.9
1980	163.6	120.0	15.6	28.5	327.9
1985	143.0	151.0	21.5	18.5	334.0

Source: Zimbalist and Brundenius (1989, p.168).

Improvements in the educational attainment of the labor force, as happened in Cuba, should contribute positively to output through efficiency gains, which should be reflected in the rate of technical change or TFP. Thus, the important issue to be examined in this paper about human capital is how human capital improvement contributed to Cuban economic growth. The two crucial questions regarding human capital that we will try to answer in the coming sec-

tions are: How much did the educational effort contribute to economic growth under a centrally planned economy? Is there any economic return from the investment directed to improve Cuban human capital during the period 1962-1988?

LITERATURE REVIEW

Many theories have been developed by economist over the years to explain economic growth and development. These usually try to pinpoint what are the determining factors that contribute to growth and development.

Old political economist such as Adam Smith and J.S. Mill considered education as an important factor for economic growth and development. But investment in human capital was for the most part ignored in discussions of economic growth until the mid-1950s. In the 1960s work by T.W. Schultz (1961, 1963), Denison (1962), Mincer (1958, 1962) and Becker (1964), began to focus more and more attention on the role of human capital in economic growth and technological change and to determine the returns from education and the proportion of the rate of growth of output due to investment in education.

In 1980, the World Bank showed renewed interest in the development of human capital (Wheeler, 1980). The results of Wheeler's comparison of 88 developing nations suggested that education, health and nutrition contributed to growth of output not only directly, but also indirectly, by increasing the rate of investment and by lowering the birth rate. Wheeler also found that, on the average, an increase in the literacy rate from 20 to 30% caused national income (GDP) to increase by 8 to 16%.

The finding that general investment has less effect on growth rates when it is not supported by educational investment has been confirmed by studies carried out by Jamison and Lau (1982) and Psacharopoulos (1984). An empirical study by Mankiw, Romer and Weil (1992), using an augmented version of the Solow model (1956)—adding accumulation of human and physical capital—also found that the presence of human capital accumulation increases the impact of physical capital accumulation. Decades earlier, Schultz (1963) had also expressed puzzlement over a

residual he was finding when measuring the increases in production over time and determined that the missing piece was the investment in human capital via education.

The neoclassical growth model was mainly defined by Solow (1956). His model focuses on capital accumulation and the quality of labor for economic growth. But, Solow's model had the shortcoming in that it did not explain the link between growth and technological change, which was seen as exogenous in his framework, which obviously could result from level of education of the work force among other factors.

The new endogenous growth theorists, starting with Paul Romer (1986) and Robert Lucas (1988), have tried to find the determinant factors that drive economic growth, such as human capital, new technologies, economies of scale, and international trade. Much empirical work has been carried out lately to find out what factors are important for economic growth. Barro (1991) studied 98 countries for the period 1960-1985, concluding that faster growth is associated with a higher rate of investment by either private or government sector, a lower share in GDP of government consumption spending, higher school enrollment rates, greater political stability, and lower fertility rates.

UNDERSTANDING CUBAN GROWTH AND TECHNOLOGICAL CHANGE

Capital, labor, human capital and technical progress are in general the four principal sources of growth of aggregate output. Based on extensive data collected for this study, the traditional methodology (Solow, 1957) will be applied to the Cuban case to have a better understanding of its economic growth.

Conceptual Points

Consider the traditional production function:

$$Y_t = F(K_t, L_t, t) \quad (1)$$

$$Y_t = A(t)G(K_t, L_t) \quad (1')$$

where Y_t , K_t , and L_t are the quantities of aggregate real output, physical capital and labor, respectively, at time t , and t is an index of chronological time. The

second equation (1') is the traditional neoclassical growth model, which is a specific case of the first one. Since A varies with time and independently of K and L , technological change is by assumption disembodied, where a Hicks neutral technological change is assumed. This is the basic Solow (1957) model.

The growth rate of output (GDP or GMP) can be expressed in the familiar equation of growth accounting by taking natural logarithms of both sides of equation (1) and differentiating it totally with respect to t :

$$\frac{d \ln Y_t}{dt} = \frac{\partial \ln F}{\partial \ln K}(K_t, L_t, t) \frac{d \ln K_t}{dt} + \frac{\partial \ln F}{\partial \ln L}(K_t, L_t, t) \frac{d \ln L_t}{dt} + \frac{\partial \ln F}{\partial t}(K_t, L_t, t) \quad (2)$$

Here $\frac{\partial \ln F}{\partial \ln K}$, $\frac{\partial \ln F}{\partial \ln L}$ are the elasticities of output with respect to capital and labor at time t and $\frac{\partial \ln F}{\partial t}$ is the instantaneous growth rate of output holding the inputs constants, or equivalent to the rate of technical progress, which is normally known as total factor productivity.

Note that the factor $A(t)$ of equation (1') represents the rate of technical progress, which may contain many elements such as: (1) capacity of people to create or to adopt new technologies; (2) capacity of the people to achieve a better way of combining means of production (Schumpeter's view); (3) the efficiency of incentives or markets to innovate; (4) several possible forms of cost reduction (Harberger, 1990); (5) the efficiency of energy use; and (6) catch-up growth.

For the above mentioned facts, it is important to understand the determinants of TFP, especially when they are aggregated for the whole economy, and try to find an explanation to better understand this "black box" called $A(t)$. Endogenous analysis of TFP has been a widely used technique to find the determinants and quantifying the facts that that generates technological change, such as, education, foreign trade and economy of scales. In general, technological change is considered to be mainly embodied in the labor, thus, it is assumed that education is the main determinant of technological progress.

In the present research we will be applying a Cobb-Douglas function to estimate the total factor of pro-

ductivity for the entire Cuban economy and by sectors (agriculture and industry). Thus:

$$Y_t = A_t K_t^\alpha L_t^\beta \quad (3)$$

Equation (4) is the discrete approximation of the time derivative obtained after taking natural log and then differentiating equation 3:

$$\frac{\Delta Y}{Y} = \frac{\Delta A}{A} + \alpha \frac{\Delta K}{K} + \beta \frac{\Delta L}{L} \quad (4)$$

Where, $\frac{\Delta Y}{Y}$, $\frac{\Delta K}{K}$, $\frac{\Delta L}{L}$ are the rate of growth of output, capital and labor respectively in annual basis. The constants α and β are the elasticities of output with respect to capital and labor respectively. The factor $\frac{\Delta A}{A}$ represents the rate of technical progress or TFP.

Hence, we have to keep in mind that when equations (2) or (4) are used to measure technical progress over time, three basic assumptions are implicit. In general constant return to scale are considered, together with neutrality of technical progress³ and profit maximization with competitive output and factors markets.

As we know, not every quantity on the right side of equations (2) or (4) can be measured directly. In fact only the growth rate of output, capital and labor are directly measured. Hence, the elasticity of output with respect to labor and capital must be estimated. This forces us to assume perfect competition, which implies that firms will set return on capital equal to marginal product of the capital, which implies that the elasticity of output with respect to capital (α) can be measured as the capital income in total output (GDP or GMP). Thus, the elasticity of output with respect to labor is considered as the labor share in total aggregated output.

Another alternative to using equation (1) to measure technical progress is the direct econometric estimation of the aggregate production function. Such direct estimation, does not require any assumption beyond that of the functional form.

Estimating the Stock of Capital and Factor Shares

It is common practice to build the time series for capital stock based on perpetual inventories using investment time series. Others use the rate of growth in investment as a proxy for the rate of growth in capital.⁴ Since there are no estimates of the stock capital for the Cuban economy, a capital stock time series was constructed. The key assumption of the methodology used to estimate the stock of capital is that the capital-output ratio is constant for short period of time.⁵ Thus, the stock of capital is determined by:

$$K = \frac{I}{(\hat{Y} + \delta)} \quad (5)$$

Where \hat{Y}, δ are the rate of growth of output and the depreciation rate, respectively. This equation is used to estimate the stock of capital at the beginning of the period (1960). The following years stock of capital is basically the initial stock of capital plus gross investment minus depreciation. The stock of capital series was calibrated with the depreciation figures obtained from the Cuban national account statistics in conjunction with our estimates. The annual rate of depreciation considered for the whole economy and the industry sector was 4.5%, which corresponds to the average value of depreciation in similar income economies. Depreciation for agriculture was considered as 3.5%. Sensitivity analysis was conducted using a higher rate of depreciation (6%) to analyze how sensitive are the TFP estimates, without detecting much variation in the TFP obtained.

3. A function with neutral technical change takes the form $Y = A(t)f(K, L, t)$. In a specific case of a Cobb-Douglas, it would be expressed as $Y_t = A \cdot e^{\lambda t} K_t^\alpha L_t^\beta$.

4. Victor Elias (1993) argues that using investment rate of growth instead of capital rate of growth leads in most of the cases to a difference of less than 20% for the two estimates. In our case using investment rate of growth as a proxy for the rate of change of the stock of capital leads to results that differ by greater than 200%. I recommend the creation of the capital stock series, which leads to more accurate results.

5. For a further explanation and example of this methodology, see Harberger (1976, pp. 132-155).

The estimation of the factor shares of labor in total output was estimated from Cuba's national accounts.

Total Factor Productivity for the Cuban Economy

Using equation (4), the TFP in Table 6 were estimated for the Cuban economy. Table 6 shows that productivity changes have been decreasing through time, achieving negative values after 1980. On the other hand the rate of investment increased considerably from 1963 to 1988. This results are contrary to what any economist would expect. Empirical applications to capitalist economies shows that increases in investment and human capital and a lower rate of population growth leads to higher TFP. Hence, we would expect a higher TFP for Cuba, but we have found the opposite results.

Table 6. TFP Estimates for the Cuban Economy

	TFP (%)	Output Rate of Growth (%)	Investment Rate of Growth (%)	Investment/GMP
1963-1970	1.0	4.4	3.2	0.18
1971-1980	0.8	5.9	18.3	0.26
1981-1988	-1.7	3.8	4.9	0.31
Average (63-88)	0.22	4.5	9.3	0.25

Table 7 shows that Cuban TFP contribution to economic growth is very low (only 3%). The contribution of investment to economic growth is very high (75%). Hence, Cuba's economic growth has been basically driven by increased investment, which is the result of the Soviet subsidies (Table 1). In other words, TFP results shows that Cuba was not able to take advantage of the investment in human capital to increase efficiency by cost reduction or productivity increase, specially during the 1980s.

Sectoral Total Factor of Productivity

To better understand the previous results, a sectoral analysis of TFP was conducted. The sectoral results obtained are shown below. Table 8 shows that agricultural TFP has been negative for the period 1963-1988. Hence, there was complete technological stagnation in the Cuban agricultural sector under the Cuban centrally planned economy. During this peri-

Table 7. Aggregated Sources of Growth and Factor Contribution to Growth

	Growth Rate (%)	Contribution to Output Growth	Factor Contribution (%)
Output (1963-1988)	4.5		
Source of Output Growth (1963-1988)			
Capital	5.8	3.3%	72%
Labor	2.0	1.1%	25%
TFP	0.2	0.1%	3%

od, agricultural output growth was basically driven by increased investment. Note that the investment rate in the agricultural sector was much higher than in the industrial sector and the whole economy. Again, the only possible explanation is that agricultural output was the result of increased investment. It could be concluded that the negative agricultural TFP led to the widely known actual level of underdevelopment in agriculture (low yields and low level of productivity).

In sum, the large amount of investment in the agricultural sector has been mainly wasted and Cuba's agricultural sector has been consuming the stock of capital, without any productivity achievement. It seems an irony, because Cuba's industrial development strategy was oriented toward getting resources from agriculture to develop an industrial base. But, reality shows that agriculture has been a big consumer of resources, without any positive result. While Cuba's main exports are based on agricultural products, agriculture was not able to achieve any positive level of technological change.

One possible explanation for this technological stagnation is the lack of markets and economic incentives, which are impossible to be implemented in a centrally planned economy. In sum, it is possible to conclude that Cuban centrally planned agricultural economic policies were totally inefficient in their attempt to force some technological change during the period 1963-1988. Again, it can be concluded that Cuba was not able to take advantage of the investment in human capital which could have led to an

Table 8. TFP Estimates for Agriculture

	TFP (%)	Agriculture Output Rate of Growth (%)	Agricultural Investment Rate of Growth (%)	Agricultural Investment as Share of Agricultural TMP
1963-1970	-1.9	3.8	8.0	0.28
1971-1980	-1.2	2.7	10.3	0.35
1981-1988	-2.4	1.7	5.6	0.48
Average (63-88)	-1.5	2.7	8.1	0.37

Table 9. TFP Estimates for Industry

	TFP (%)	Industry Output Rate of Growth (%)	Industry Investment Rate of Growth (%)	Industry Investment as share of Industry GMP
1963-1970	1.4	5.2	13.2	0.06
1971-1980	0.7	4.6	25.6	0.11
1981-1988	-0.4	4.3	6.0	0.19
Average (63-88)	0.6	4.7	15.0	0.12

increase in TFP and eventually to an increase in agricultural output.

Table 9 shows that TFP in the industrial sector was moderate for the period 1963-1980. But again, TFP was negative for the period 1981-1988. Looking at Table 2, it seems contradictory that at the same time imports of capital goods such as machinery and transportation equipment were increasing, TFP was decreasing. Table 9 shows that the ratio of investment over output in the industrial sector was very low compared with the agricultural sector. This clearly shows that the right amount of investment, avoiding over investment, makes people more productive, achieving higher rates of technological change. Again, during the 1980s Cuba was not able to take advantage of the investment in human capital which could have led to an increase in TFP.

The rates of growth of the different factors and their contribution to economic growth can be seen in Tables 10 and 11. Some could argue that the negative TFP during the 1970s and 1980s could be attributable to business cycles fluctuations. But in the case of Cuba this is not possible, since this period is considered as the golden era of the Revolution due to the high rate of economic growth achieved. Moreover, during this period, Cuba was receiving the largest amount of subsidies from the Soviet Union, which

isolated Cuba from world business cycles (see Table 1).

Looking the results in Table 11, it is difficult to explain why the massive investment in physical and human capital led to low TFP in the seventies and eighties. One explanation could be the very well known Latin American proverb "*escoba nueva barre bien*" (a new broom always cleans well). In other words, during the first years of Castro's regime, the vast majority of the population was excited about the revolution and communism. This initial excitement created high incentives for people to work hard and be productive and innovative, which could have led to the positive level of technological change observed during the 1960s. Then, as people tired of the regime, as the result of unfulfilled expectations and lack of gains from communism, they relaxed in their creativity and stopped working hard. Consequently, TFP decreased to negative levels.

ECONOMETRIC ESTIMATION OF ECONOMY OF SCALE

It could be possible that Cuba's economy does not show constant return to scale (CRTS) as a whole. To verify the assumption of CRTS, in this section a Cobb-Douglas production function will be estimated econometrically to test the hypothesis of constant re-

Table 10. Rates of Growth of Factors

Years	Rate of Growth (%)								
	Overall Economy (%)			Agriculture (%)			Industry (%)		
	Labor	Capital	TFP	Labor	Capital	TFP	Labor	Capital	TFP
1963-1970	1.2	4.5	1.0	1.3	8.8	-1.9	1.2	5.1	1.4
1971-1980	2.1	6.8	0.80	0.7	6.9	-1.2	2.3	5.5	0.7
1981-1988	2.6	6.1	-1.7	0.7	5.6	-2.4	3.9	4.1	-0.4
Average (63-87)	2.0	5.8	0.2	1.1	6.7	-1.5	2.5	4.9	0.6

Table 11. Contribution of Factors to Economic Growth

Years	Contribution of Factors (as % of total economic growth)								
	Overall Economy (%)			Agriculture (%)			Industry (%)		
	Labor	Capital	TFP	Labor	Capital	TFP	Labor	Capital	TFP
1963-1970	18	67	15	16	107	-23	16	66	18
1971-1980	22	70	8	11	108	-19	27	65	8
1981-1988	37	87	-24	18	144	-62	51	54	-5
Average (63-87)	25	72	3	17	106	-23	31	61	8

turn to scale considered previously and to verify the elasticities of labor and capital to real output. Thus:

$$Y_t = A \cdot K_t^\alpha \cdot L_t^\beta \quad (6)$$

applying natural logs to equation (6), we obtain the linear equation:

$$\ln Y_t = \ln A + \alpha \ln K_t + \beta \ln L_t + \varepsilon \quad (7)$$

Estimating equation (7) with time series data for the period 1962-1988, yields the results in Table 12. Note that econometric estimation of equation (6) could lead to a multicollinearity problem (see Boskin and Lau, 1992; Harberger, 1996). Our data was tested for multicollinearity, without finding any problem. Null hypothesis tests for CRTS were conducted, which led us to accept the hypothesis of existence of CRTS for the industrial sector and the Cuban economy as a whole.

Results from Table 12 show that the elasticity of capital (0.52) and of labor (0.54) to output for the overall economy are close to the average value of factor share to total output considered in the previous section, which average 0.51 and 0.49. In sum, it can be concluded that the results previously obtained by us-

Table 12. Regressions Results (1962-1988)

	Ln A	α	β	$\alpha+\beta$	N	R ²
Y _t -Agriculture	2.56	0.37	0.11	0.48	27	0.94
Y _t - Industry	-2.64	0.71	0.38	1.09	27	0.98
Y _t -Cuban Economy	-3.89	0.52	0.54	1.06	27	0.97

ing the indirect method are good estimates of TFP for the Cuban economy.

CUBA'S TECHNOLOGICAL CHANGE COMPARED TO OTHER REGIONS

Table 13 provides a comparative historical analysis of Cuba's rate of technical progress during this period with respect to other regions. Estimates in Table 13 show that on average during the period 1963-1988, Cuba performed much worse than most of the capitalist economies.⁶ In sum, it seems that under a centrally planned economy, the rate of technological change (TFP) is significantly lower than in capitalist economies.

CONCLUSIONS

Some general conclusions can be drawn from the above analysis. First, that the Cuban economy as a whole, as well as the industrial sector, exhibited con-

Table 13. GDP Growth and Contribution of Factors to Economic Growth

Countries	GDP (%)			TFP Contribution to Growth (%)			GMP(%) TFP(%)	
	1950-73	1973-80	1980-89	1950-73	1973-80	1980-89	1963-1988	1963-1988
Cuba							4.4	3 (0.2)
Chile	3.42	3.39	2.9	51 (1.75)	44 (1.48)	26 (0.74)		
Latin America	5.79	5.20	1.34	42 (2.43)	23 (1.20)	-97 (-1.30)		
Asia	7.73	7.51	7.64	51 (3.93)	31 (2.31)	54 (4.09)		
Advanced	5.34	2.23	2.56	69 (3.26)	47 (0.93)	47 (1.20)		

Source: Hofman (1993, pp. 128-130.)

Note: Figures in parenthesis represent the value of TFP.

stant return to scale during the period 1962-1988. Second, that the Cuban agricultural sector exhibited decreasing return to scale during the same period. Third, that TFP for the Cuban economy has been decreasing through time, turning negative during the 1980s. Fourth, that the average rate of change in technical progress (TFP) of the Cuban economy over the period 1963-1988 is very low (0.2%), this value being much lower than for most capitalist economies that were growing at rates similar to Cuba's. Fifth, that the agricultural sector showed a very high negative rate of technical change; thus, there was a complete technological stagnation in this sector.

With respect to the agricultural sector it can be concluded that: (1) Cuban centrally planned economic policies were totally inefficient in promoting technological change in agriculture; (2) human resources were used in an inefficient manner; and (3) there was over investment in agriculture, which possibly led to an even lower TFP. Our results show that Cuban government agricultural planning has been very poor and inefficient, a finding that has been validated by other studies (e.g., Mesa-Lago, 1981, pp. 24-25). According to Mesa-Lago, this poor planning is the result lack of manpower, its lack of knowledge and expertise, and the lack of maintenance controls; for example, because of lack of maintenance controls, equipment breakdowns depleted the locomotive fleet by 50% (Mesa-Lago, 1981, p. 26). Obviously all

these facts are reflected in the negative TFP estimated in the present study.

With respect to the industrial sector, it can be concluded that the change in TFP has also been decreasing, but in this case the average value for the period of 1962-1988 is positive (0.6). The gains in productivity during the 1960s could be considered reasonable, but again TFP is negative during the 1980s. It seems ironic that the largest lack of capital was in this sector, which was able to achieve a moderate level of technological change during the period 1962-1988.

These research results clearly show that Cuba's growth during 1963-1988 was basically the result of capital accumulation rather than from productivity gains. Moreover, considering the large amount of Soviet subsidies given to Cuba during the 1970s and 1980s, at first glance one might conclude that Soviet dependency created inefficiency, because during this period of lack of capital (lower level of investment), technical progress was higher. Cuba's experience is contrary to capitalist economies, where an increase of physical and human capital create increases in technological change. Cuba's special case could be partially explained by the lack of economic incentives to innovate and by a centrally planned investment policy which was totally inefficient in allocating resources.

The main conclusion from this empirical analysis is that Cuba's development strategy has been a com-

6. Similar results were found by Poznanski (1985) when comparing the technological performance of the Soviet bloc countries with respect to the U.S. and Western Europe. See Poznanski (1985) for plausible explanations for the poor technological performance of centrally planned economies.

plete failure. The progress in Cuba was much like Russian growth in the past—it was obtained by massive, often wasteful, capital accumulation rather than by productivity growth. In other words, the Cuban centrally planned development strategy has consumed large sums of the capital received through Soviet subsidies; these subsidies have been mostly wasted, without any improvement in technological change. Hence, it could be concluded that the main problem with a centrally planned economy is the lack of the right economic incentives and price systems. The lack of these elements do not allow for technical progress, leaving centrally planned economies behind those of capitalist countries.

It can also be concluded that most of the investment in education has not had any economic return, especially those investments in human capital related to agricultural activities. In other words, a large amount of money has been wasted in the creation of human

capital which has not been very productive under the Cuban centrally planned system.

TFP estimates for Cuba compared to other countries (Table 13) show that if Cuba maintains a centrally planned economy, it will have a very difficult time catching up with the rest of the world. To correct this path, Cuba should consider some policies that make use of the markets and economic incentives to encourage technological change.

Many important topics were not considered in this paper, such as the role of the public sector through its actions and its expenditures in the process of technological change. Finally, additional research is needed linking Cuba's international trade and public policy with technological change, in order to arrive at a better understanding and quantification of the determinants of the low level of Cuban technological change and their effects.

REFERENCES

- Barro, Robert, J. "Economic Growth in a Cross Section of Countries," *Quarterly Journal of Economics* (May 1991), 407-444.
- Barro, R., and X. Sali-i-Martin. "Convergence Across States and Regions," *Brookings Papers on Economic Activity* (1991).
- Becker, G.S. *Human Capital*. New York: Columbia University Press, 1964.
- Boskin, B., and L. Lawrence. "Capital, Technology and Economic Growth." In Landau, Ralph, Nathan Rosenberg and David Mowery, *Technology and the Wealth of the Nations*. Stanford: Stanford University Press, 1992.
- Brundenius, Claes. *Revolutionary Cuba: The Challenge of Economic Growth With Equity*. Boulder: Westview Press, 1984.
- Central Intelligence Agency. *The Cuban Economy: A Statistical Review*. Washington, 1984, 1989.
- Denison, E. "United States Economic Growth," *Journal of Business*, 35 (1992), 357-394.
- Denison, E. *Trends in American Economic Growth, 1929-1982*. Washington: Brookings Institution, 1985.
- Domínguez, Jorge. *Cuba: Order and Revolution*. Cambridge: The Belknap Press of the Harvard University Press, 1978.
- Elias, Victor. "The Role of Total Productivity in Economic Growth." In Special Issue on Economic Growth, Universidad de Chile, Departamento de Economía, Santiago, Chile, 1993.
- Fischer, Stanley. "Growth, Macroeconomics and Development." In Olivier Blanchard and Stanley Fischer, eds., *Macroeconomics Annual 1991*. Cambridge: MIT Press, 1991, 329-379.

- Grossman, G. and H. El Hanan. *Innovations and Growth in the Global Economy*. Cambridge: MIT Press, 1993.
- Harberger, A.. *Project Evaluation*. Chicago: University of Chicago Press, 1976.
- Harberger, A. *Reflections on the Growth Process*, UCLA manuscript, 1990.
- Harberger, A. *Reflections on Economic Growth in Asia and the Pacific*, UCLA manuscript, August 1996.
- Hofman, Andre. "Chile's Economic Performance in the 20th Century: A Comparative Perspective." In Special Issue on Economic Growth, Universidad de Chile, Departamento de Economía, Santiago, Chile, 1993.
- Jiménez, Georgina. *Hablemos de Educación: Recopilación de Artículos, Comentarios y Reportajes sobre Educación*. La Habana: Editorial Pueblo y Educación, 1985.
- Jorgenson, Dale W. and Z. Griliches. "Issues in Growth Accounting: A Reply to F. Denison," *Survey of Current Business*, 52:5, Part II (1972), 65-94.
- Jorgenson, Dale W., Frank M. Gollop, and Barbara M. Fraumeni. *Productivity and U.S. Economic Growth*. Cambridge: Harvard University Press, 1987.
- Kim, J.I., and Lawrence Lau. "Economic Growth of the East Asian Newly Industrializing Countries," *Journal of the Japanese and International Economies* (1995), 235-271.
- Krugman, Paul. "The Myth of Asia's Miracle," *Foreign Affairs* (Nov/Dec 1994), 62-78.
- Landau, Ralph, Nathan Rosemberg and David Mowery. *Technology and the Wealth of the Nations*. Stanford: Stanford University Press, 1992.
- Lau, L. and Jong-Il Kim. *The Sources of Economic Growth of the Newly Industrializing Countries on the Pacific Rim*. Stanford University: Center for Economic Policy Research #295, 1992.
- Levine, R. and D. Renelt. "A Sensitivity Analysis of Cross-Country Growth Regressions," *American Economic Review*, 82:4 (September 1992), 942-963.
- Lucas, Robert. "On the Mechanics of Economic Development," *Journal of Monetary Economics* 22 (1988), 3-42.
- Mankiw, G., D. Romer, and D. Weil. "A Contribution to the Empirics of Economic Growth," *Quarterly Journal of Economics* 57:2 (May 1992), 407-43.
- Mesa-Lago, C. *The Economy of Socialist Cuba: A Two Decade Appraisal*. Albuquerque: University of New Mexico Press, 1981.
- Mesa-Lago, C. "Cuba's Economic Counter-Reform: Causes, Policies and Effects. In *Cuba After Thirty Years: Rectification and the Revolution*, ed. by Richard Gillespie. London: Frank Cass Company Ltd., 1990.
- Mesa-Lago, C. and J. Pérez-López. *A Study of Cuba's Material Product System, Its Conversion to the System of National Accounts, and Estimation of Gross Domestic Product per Capita and Growth Rates*. World Bank Staff Working Papers No. 770. Washington: World Bank, 1985.
- Mincer, Jacob. "Investment in Human Capital and Personal Income Distribution," *Journal of Political Economy* (August 1958).
- Mincer, Jacob. "On-the-job Training: Costs, Returns and Some Implications," *Journal of Political Economy* 70:5 (October 1962).
- Pérez-López, Jorge. *Measuring Cuban Economic Performance*. Austin: University of Texas Press, 1987.
- Psacharopoulos, G. *Returns on Education*. San Francisco: Jossy Bass-Elsevier, 1973.
- Psacharopoulos, G. "The Contribution of Education to Economic Growth." In *International Comparisons of Productivity and Causes of Slowdown*, edited by J.W. Kendrick. Cambridge: Ballinger Press, 1984.

- Rodríguez, José Luis. *Estrategia del Desarrollo de Cuba*. La Habana: Editorial de Ciencias Sociales, 1990.
- Romer, Paul. "Human Capital and Growth: Theory and Evidence." NBER Working Paper #3173, 1989.
- Romer, Paul. "Endogenous Technical Change," *Journal of Political Economy* 98 (1990), 71-102.
- Schultz, T. W. "Investing in Human Capital," *American Economic Review* (March 1961).
- Schultz, T. W. *The Economic Value of Education*. New York: Columbia University Press, 1963.
- Schultz, T. W. "Education Investment and Return." In *Handbook of Development Economics*, Chapter 13, H. Chenery and T.N. Srinivasan, eds. New York: North Holland, 1988.
- Solow, Robert M. "A Contribution to the Theory of Economic Growth," *Quarterly Journal of Economics*, 70 (1956), 65-94.
- Solow, Robert M. "Technical Change and the Aggregate Production Function," *Review of Economics and Statistics*, 39 (1957), 312-320.
- Solow, Robert M. "Investment and Technical Progress." In *Mathematical Methods in the Social Sciences*, Kenneth J. Arrow, Samuel Karbin and Patrick Suppes, eds. Stanford: Stanford University Press, 1960.
- Wheeler, D. "Human Resource Development and Economic Growth in LDC's: A Simulation Model," World Bank Staff Working Paper No 407. Washington: World Bank, 1980.
- Young, A. "A Tale of Two Cities: Factor Accumulation and Technical Change in Hong Kong and Singapore." In *Macroeconomics Annual 1992*. Cambridge: MIT Press, 1992.
- Young, A. "The Tyranny of Numbers: Confronting the Statistical Realities of the East Asian Growth Experience," *Quarterly Journal of Economics* (August 1995), 641-680.
- Zimbalist, Andrew and Claes Brundenius. *The Cuban Economy: Measurement and Analysis of Socialist Performance*. Baltimore: The Johns Hopkins University Press, 1989.