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Effects of Primary, Secondary and Tertiary Education on Economic Growth

Evidence from Guatemala

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Abstract: This paper investigates the impact of human capital on economic growth in Guatemala during 1951-2002 using an error-correction methodology. The results show a better-educated labor force having a positive and significant impact on economic growth. Consistent with micro studies for Guatemala, primary and secondary education are most important for productivity growth. These findings are robust while changing the conditioning set of the variables, controlling for data issues and endogeneity. Due to an environment of social and political conflict, however, total factor productivity has been slightly negative for the past decades, and there is evidence of a missing complementarity between the country's skills and its technology base. A growth-accounting framework is presented, which takes into account quality changes of physical capital, and differentiates by level of education. It shows that the human capital variables explain more than 50 percent of output growth. Of these, secondary schooling was the predominant determinant of growth.

Key words: Economic Growth, Education, Econometrics, Guatemala.

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"El crecimiento económico acelerado del país es necesario para la generación de empleos y su desarrollo social. El desarrollo social del país es, a su vez, indispensable para su crecimiento económico y una mejor inserción en la economía mundial. Al respecto, la elevación del nivel de vida, la salud de sus habitantes y la educación y capacitación constituyen las premisas para acceder al desarrollo sustentable en Guatemala."

Peace Accords, 1996

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1. Introduction

This study examines the contribution of human capital to economic growth in Guatemala over the past 50 years.[2] The interest is twofold. First, for the country itself there are very few studies that thoroughly analyze past growth patterns, and there are no studies that empirically appraise the direct impact of education on growth. In general, evidence on human capital and growth comes almost entirely from cross-country analysis. Single-country studies, however, may be more illuminating since they overcome the heterogeneity problem and take into account the unique historical information for each country. Indeed, the original motivation of studying economic growth focuses on the time-series dynamics of macroeconomic variables. Moreover, the cross-section focus may be inadequate if returns to education or the quality of education differ substantially across countries.

Second, this study focuses on the contribution of different levels of education to growth. This is an important aspect regarding the problems associated with measuring *average* years of schooling. Looking at education in a disaggregated way also proves more fruitful to the policy-maker since it indicates how resources should be divided between different education levels. Finally, the empirical analysis is based on an error-correction methodology, deals with endogeneity, and explores several data construction and robustness issues. All this may be relevant for future case studies as well.

This study, probably for the first time, constructs a reliable data set that accounts for the determinants of long-run growth in Guatemala. In terms of data availability, the country constitutes a most precarious case. Despite these caveats, however, satisfactory and coherent time series data were obtained. The results based on a production function augmented for human capital reveal that a better-educated labor force has a significant positive impact on long-run growth. Consistent with cross-country evidence, primary and secondary education appear to be most important for productivity growth, followed by tertiary schooling. These findings are in agreement with the micro evidence for Guatemala. Interestingly, the results also suggest that the effect of education in both micro and macro regressions is of similar magnitude.

[2] This paper was originally prepared as a background study for Guatemala's 2005 Country Economic Memorandum. I have benefited from discussions with Eduardo Somensatto, Felipe Jaramillo and Andy Mason (World Bank), Hermann Sautter, Stephan Klasen, Dierk Herzer, Michael Grimm and Julian Weisbrod (University of Goettingen) as well as Armando Morales (IMF) and Juan Alberto Fuentes (UNDP). Christian Dreger (Halle Institute for Economic Research), Paul Schreyer (OECD), Oda Schmalwasser (German Federal Statistical Office) and María Concepción Castro (SEGEPLAN) equally deserve many thanks. I particularly want to thank Silvia Villatoro and Estuardo Morán (Banco de Guatemala) for their great assistance in compiling part of the data. The results and opinions presented here are the author only. They do not necessarily reflect the points of view of the people above, and should not be attributed to the institutions the author is affiliated with.

This holds while changing the conditioning set of the variables, for example by considering trade openness. An interesting result is that *primary* schooling seems to be particularly affected by policies that promote competitiveness. This does *not* suggest, however, that other schooling levels are unimportant. Rather it seems that in Guatemala, during the past decades, a sufficient coverage *and* quality of primary education were the minimum requirement to adopt foreign technologies. Overall, the econometric results have been found robust, even after controlling for endogeneity as well as for alternative data sources.

Finally, a modified growth-accounting framework is presented which takes into account quality changes of physical capital and differentiates by the level of education. It shows that the human capital variables explain more than 50 percent of output growth. Of these, secondary schooling was the main determinant of growth. Due to an environment of social and political conflict, however, productivity growth was slightly negative over the past decades. In addition, given the increase of average education and a decay of the quality-adjusted physical capital at the same time, there is evidence of a missing complementarity between the country's skills and its technology base. Ultimately, the empirical findings point towards the importance of an institutional and political environment conducive to growth.

This study is organized into eight sections. The following section briefly assesses patterns of growth and some of the reasons that led to a low endowment of human capital. Section 3 discusses how to measure the contribution of human capital to growth over time. Furthermore, it provides an overview of relevant empirical findings. Section 4 is concerned with data compilation. Section 5 introduces the empirical methodology and presents the main results, disaggregated by education level. Section 6 tests the robustness of the results. The regressions include several variables that help to explain the country's growth performance, for example measures for the quality of capital, trade and governance. Based on these findings, section 7 accounts for the sources of growth. Section 8 concludes.

2. Patterns of Growth in Guatemala

To understand Guatemala's growth patterns, and hence the role of education, its turbulent political and social history must be taken into account. Average annual growth rates were about 3.9 percent between 1951 and 2002. According to Bailén (2001) this is in line with the neighbor countries.[3] Due to rapid population growth, however, *per capita* growth in Guatemala has averaged only about 1.3 percent per

[3] For example, growth has been lower than in Costa Rica (4.7 percent) but higher than in Honduras (3.7 percent), El Salvador (3.2 percent) and Nicaragua (2.1 percent).

year. A continuation of this growth rate implies that the average Guatemalan would need approximately 53 years to double his real income.

Historically, growth was not particularly pro-poor, i.e. favoring the rural or agricultural economy where the poor live. The elite domination and ethnic division failed to promote social and institutional development. Instead, growth in Guatemala's was accompanied by the exclusion of large parts of the society from wealth, and, as a consequence, accompanied by underlying social conflict. Poverty rates and inequality indicators are among the highest in the Latin American region. According to the World Bank (2003a) about 56 percent of Guatemala's population lives in poverty in 2000.

Box 1. Guatemala: Growth with Low Productivity and Poor Social Development

Relatively few studies focus on Guatemala's growth experience over a long time period. One of the most comprehensive assessments is a voluminous study by Gómez and Ordoñez (1991). They focus on structural adjustment issues for the early 1990s, but their conclusions are still of interest. In particular, they claim that productivity in Guatemala was low because of manifold structural problems, including a deficient financial intermediation system and 'resistance' to technological change. That is, Guatemala's international competitiveness was traditionally based on a low-skilled labor force with consequently poor social development and little incentives for firms to increase productivity. In addition, a culture of rent-seeking among entrepreneurs as well as public institutional and financial weakness prevented significant change.

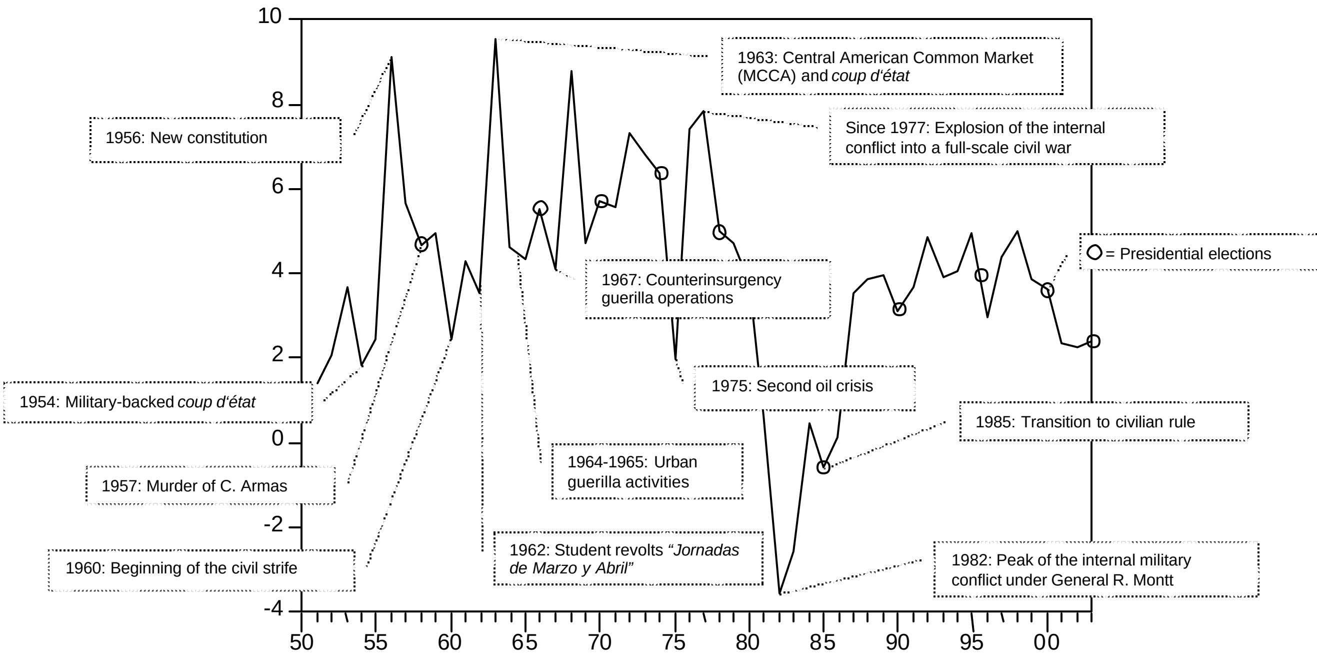
Guatemala's recent growth experience can be divided into three broad episodes. Figure 1 visualizes annual GDP growth from 1951-2003, where selected *parallel* historical events are given from Luján (2000).[4] Table 1 presents the average output growth rates of primary, industry and service sectors for the period 1951-2003. In addition, there are three sub-periods. The growth rates of the primary sectors in Guatemala, which employ the majority of the rural and poor people, lagged behind other sectors for the *entire* time period. By contrast, in particular for the last decades, the growing sectors where those of electricity, communications and banking. Until approximately 1975, Guatemala appears to have had a reasonable growth performance, followed by a remarkable slowdown for the later periods. However, this requires closer examination.

La 'edad de oro', 1951-1975. During the first period Guatemala maintained reasonable growth rates. Ever since the 1954 coup, military governments were repeatedly in power, sometimes through fraudulent elections, sometimes by *coup d'états*. In terms of its growth performance, this era is sometimes referred to as the 'golden period' but the denomination is *very* misleading. This is because the structural imbalances of the economy remained unchanged and ultimately gave rise to the explosion of civil strife. Annual growth was highly volatile? a fact most likely

[4] The correlations do not necessarily imply causality. Moreover, in many Latin American countries growth rates during the decades of the 1950s and 1960s were quite volatile as well.

associated with the dependence on agricultural export growth as well as political events. For example, in 1956 a new constitution was drawn up and in 1963 Guatemala was preparing to enter into the Central American Common Market (MCCA).[5] At first sight, Figure 1 suggests that the civil war's guerilla activities — starting around 1960 — appeared to have an impact only on short-run growth. However, the later growth accounting exercise suggests that, indeed, the trend growth of total factor productivity (TFP) was negatively affected by the civil strife from the beginning.

Figure 1. Guatemala: Economic Growth, Social Conflict and Politics, 1951-2003
(growth rates in percent)



Source: Author's elaboration based on data from Banco de Guatemala. Data for 2002 (2003) is preliminary (estimated). Historical events are taken from Luján (2000).

External shocks and the civil war, 1975-1985. A second period starts shortly after the deterioration of the terms of trade and the international oil crisis. In 1976 a major earthquake affected Guatemala. After 1977, social tension culminated in a full-scale civil war that reached genocidal proportions in the early 1980s. Consequently, growth declined dramatically. Apart from causing immense human sorrow, these events destroyed human life and physical capital. They also imposed high costs for long-run growth.

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5 An excellent review of the rise and fall of the Central American integration process for 1950-1999 can be found in de La Ossa (2000).

Recuperation and stagnation, 1985-2002. A third episode of growth begins approximately in 1985 when democracy was restored, albeit with civilian governments patronized by the generals. Although growth rates recovered, they have ever since followed a more or less stagnant pattern. A cornerstone in economic and social development in history was the signing of the Agreement of a 'Firm and Lasting Peace' in December 1996, the formal end to the civil war. Since the signing of the UN-sponsored Peace Accords, Guatemala has made progress by increasing investments in infrastructure and human capital. It has also made some efforts to improve public financial management, and in the area of tax revenues. However, UNDP (2003a) finds that the implementation of the Peace Accords has been uneven. Moreover, in particular during the past decades, Guatemala seems to be affected by electoral cycles. This issue has been investigated by López-Cálix (2002) who indeed finds weak empirical evidence supporting this hypothesis.

Box 2. Social Conflict and Guatemala's Growth Collapse

A key study for understanding the Guatemalan growth collapse after 1975 is Rodrik (1999). His core idea is that the effect of the external shocks on growth is increased within the context of 'social conflict' and weak institutions for 'conflict management.' The term social conflict refers to the depth of social inequality and ethic fragmentation. Conflict management refers to democratic institutions, an effective judiciary and a non-corrupt bureaucracy. All of these adjudicate distributional competition within a framework of rules and accepted procedures. However, as in the case of Guatemala, the economic costs of shocks can be magnified by the associated distributional conflicts. These are triggered because social divisions run deep and governmental as well as democratic institutions are weak. Consequently, the productivity of resource utilization can be diminished in a number of ways. For example, by delaying adjustments in fiscal policies and key relative prices, including the real exchange rate and real wages. In addition, these adjustments may generate uncertainty in the economic environment and paralyze the economy for years. Cross-country econometric evidence supports this hypothesis. Rodrik finds that countries experiencing the sharpest drops after 1975 were those with divided societies and weak institutions. This seems indeed to be the case for Guatemala, and is an important finding not only in retrospect but also for the future.

Finally, GDP growth has declined continually since 1999. The processes behind this decline are not exactly understood. It is uncertain whether this represents a decrease in Guatemala's trend growth or a prolonged cyclical downturn. However, it is not unreasonable to argue that this decline is partly associated with high levels of violence, kidnappings (including the central bank governor) and social unrest. In addition, Guatemala scores poorly on most governance indicators, particularly those for corruption, the rule of law and the justice system, and political stability. The culmination of these factors ultimately seems to damage the climate for growth and investment.[6]

[6] Larrain (2004) analyses these issues in more detail. Hypotheses for the recent growth slowdown can be found in World Bank (2003b). These include restrictive macroeconomic policies, unfavorable external developments, the ending of the economic model relying on traditional agro-exports, and several political factors. As of June 2000, Guatemala is listed as non-cooperative country in the OECD-backed 'Financial Action Task Force on Money Laundering.'

Somewhat paradoxical, over the past decades, Guatemala has experienced relative macroeconomic stability. Guatemala has a rather low level of external indebtedness, inflation has been held back, and after a process of (uncompleted) structural reforms the economy is now fairly open and with low levels of protection. Thus, contrary to other Latin American countries, macroeconomic mismanagement may presumably not be regarded as the main factor to understand Guatemala's modest performance in terms of per capita growth. Rather, other issues undermine Guatemala's long-run growth patterns.[7] In addition to the factors already mentioned, one is low human capital endowment.

Table 1. Guatemala: Sectoral Output Growth, 1951-2003 (in percent) [a/]

Sector	1951-03	1951-75	1976-85	1986-03
Primary	3.2	4.2	1.6	2.7
Agriculture, forestry, livestock and fishing	3.1	4.2	1.5	2.6
Mining and quarrying	8.1	3.3	16.9	9.5
Industry	4.3	5.6	2.8	3.2
Manufacturing	4.0	5.9	2.4	2.2
Construction	4.0	3.9	5.4	3.9
Gas, electricity and water	8.4	9.7	6.0	8.2
Services	4.2	5.0	2.5	3.9
Wholesale and trade	3.8	5.0	1.3	3.3
Transport, storage and communications	6.2	7.5	3.4	5.9
Banking	6.9	8.3	6.1	5.3
Public administration and defense	4.6	4.5	5.6	4.5
Other services	3.4	4.2	2.4	2.9
Total GDP growth	3.9	4.9	2.3	3.5

Source: Author's calculations based on data from Banco de Guatemala. a/ Information for 2002 (2003) is preliminary (estimated).

The current human capital base is essentially a product of past agricultural growth and eminently anti-distributional policies. The World Bank (2003a) and UNDP (2002) document that insufficient cheap labor, in particular for coffee, was the main barrier for the expansion of export crops during earlier periods. Hence, in order to create a low-wage labor force, the campesino and indigenous society was excluded from education. The plantation economy that resulted provided little incentives to accumulate human capital. Historically, the low level of schooling is also an outcome

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7 During a very brief episode in the early 1990s, inflation increased and fiscal discipline eroded. More recently, the World Bank (2003b) presents arguments suggesting that short-run growth *may* be related to the cyclical stance of fiscal and monetary policies.

of a discriminatory education system. For the attentive observer, these issues are still felt today.

Table 2 shows that the country still performs poorly for indicators of education and health, and ranks highest among states in the region for child malnutrition, despite some improvements over time.[8] In addition, Guatemala spends less on education than any other country in the region. Based on household survey data comparing the education level of age cohorts, the Inter-American Development Bank (2001) finds that the educational gap between Guatemala and other Latin American countries is widening.

Table 2. Guatemala, Central and Latin America: Comparison of Human Capital Indicators, 1998-2002

Indicator	Guatemala	Nicaragua	Honduras	El Salvador	Costa Rica	Mexico	Latin America
Public spending on education (in percent of GDP) (average 1998-2000) [c/ d/]	1.7	5.0	4.0	2.3	5.7	4.4	N.D.
Average years of schooling (2000) [b/]	4.8	6.3	5.3	5.1	6.7	7.9	7.3
Net primary school enrollment (in percent) (2000-2001) [c/]	84	81	88	81	91	103	97
Net secondary school enrollment (in percent) (2000-2001) [c/]	26	36	N.D.	39	49	60	64
Adult illiteracy (in percent of total population) (2002) [a/]	30.1	32.9	23.8	20.3	4.2	8.3	10.5
Infant mortality (per 1000 births) (2001) [a/]	43	36	31	33	9	24	28
Life expectancy at birth (years) (2002) [a/]	65.5	68.7	66.1	70.1	77.6	73.6	70.7

Source: a/ World Bank (2003c). b/ Cohen and Soto (2001). c/ UNDP (2003b). d/ Notice that Guatemala's public spending in education has increased recently. UNDP (2003a) reports a figure of 2.6 percent in 2002. N.D. = no data available.

Historically, it may be that a certain degree of development and growth in Guatemala was attainable with a skilled elite and a large amount of unskilled workers. Since the economy has diversified over time and is now less dependent on agriculture than before (Segovia and Lardé 2002), the past exclusionary education policies may present an obstacle for future growth. On the micro level, there is evidence suggesting that insufficient human capital constitutes a constraint for production. For

[8] Anderson (2001) provides a brief synopsis of recent developments in the education sector.

example, a firm survey by Grupo de Servicios de Información (1999) indicates that for all firms the quality of skills ranks as the second most important constraint. For small firms, important for employment and income generation, the quality of skills is the main production constraint.

3. Measuring the Contribution of Education to Growth

The accumulation of human capital through education has long been acknowledged to be an important factor in the development process of a nation. Education is thought to be beneficial because it decreases inequality, improves the quality of life, and in particular it is a factor in rising the income level and facilitating economic growth. This section will concentrate on the latter effect and summarize some evidence on the relationship between education and growth.

3.1 Augmented Solow Model and Endogenous Growth

The existing literature contains a number of distinct conceptual rationales for the inclusion of human capital in models of economic growth. According to Sianesi and van Reenen (2003), the two main macro approaches are the augmented Solow model and the new growth theories.

Augmented Solow Model

One way to estimate the impact of education on growth is to adapt the Solow (1956) model. The augmented version extends the basic framework to allow human capital as an extra input to enter the production function. In particular Mankiw et al. (1992) show that traditional growth theory can accommodate human capital and provide a reasonable approximation for empirical analysis. At the economy-wide level, it may also take into account human capital externalities. Still, one of the key insights is that the factor accumulation affects the *level* of income, but per se is insufficient to achieve long-run *growth*. Long-run growth depends rather on growth in technological progress. Human capital accumulation may therefore have only a short-term impact on the rate of growth.

However, rates of accumulation are expected to have explanatory power for growth rates during the transition to an eventual equilibrium growth path. In particular, considering the case of Guatemala? presumably far away from a balanced growth process? consideration of transition could open up the possibility of assessing the macroeconomic role of education for economic growth within this framework. In addition, since the ‘short run’ in the context of growth theory is often thought of in terms of decades, these effects can be worthwhile policy objectives. Up to now, for the reasons clarified below, this approach has remained the workhorse of applied empirical research. The model is fairly flexible and allows for alternative specifications that can be adjusted to best match the available data.

Endogenous Growth Approach

Expanding these ideas, new growth theories emphasize the endogenous determination of technological progress, which is determined within the model. Thus, long-run growth can be affected by government policies instead of being driven by exogenous technological change. With respect to human capital, the endogenous growth approach argues that there should be an *additional* effect over and above the static effect on the level of output. Models that explain long-run growth by focusing on technological progress and research and development, such as Romer (1990a) and Grossman and Helpman (1991), argue that domestic technological progress results from the search for innovations. The discovery of an innovation, undertaken by profit-maximizing individuals, raises productivity and is ultimately the source of long-run growth. This kind of model attributes growth to the existing *stock* of human capital. A second category is the model of Lucas (1988). It broadens the concept of capital and suggests that human capital *accumulation* may be an engine of growth itself, due to spillover effects that negate diminishing returns in production.

In particular, with respect to developing countries, one way of characterizing the role of human capital is the consideration of technology transfer from innovating countries. Already Nelson and Phelps (1966) suggested that education facilitates the adoption and implementation of new technologies, which are continuously invented. For example, countries with lagging technological capacity may be most able to catch-up if they have a large stock of human capital. In this case, the level of human capital effects growth by facilitating improvements in productivity. Also Lucas (1990) conjectures that physical capital does not flow from rich to poor countries because of a relatively low stock of complementary human capital.

In a rather influential study, Benhabib and Spiegel (1994) propose an empirical growth model in which human capital externalities can be considered in subsequent advances in education and in new physical capital via technology import. Their results indeed suggest that human capital impacts growth through two mechanisms. On the one side, human capital seems to influence the rate of domestically produced innovation, as proposed in the endogenous growth model of Romer (1990a). On the other side, in the spirit of Nelson and Phelps (1966), they claim that the human capital stock affects the speed of adoption of technology from abroad. More recently, in a generalized version of their model of technology diffusion? that allows for a nonlinear specification of total factor productivity growth? Benhabib and Spiegel (2003) find that a minimum initial human capital level is necessary to exhibit catch-up in productivity relative to the leader nation.

However, Pritchett (2001) agues convincingly that the finding of *only* a level effect on growth is rather puzzling. First, in the framework of endogenous growth, spillover effects of knowledge should be *in addition* to rather *instead* of the production effects of human capital. In other words, finding only spillover effects may be inconsistent with the micro evidence on the returns to education. Second, as will be stressed in more detail in the next section, Jones (1995) criticism of endogenous growth models applies here. That is, growth rates cannot be made a function of non-stationary parameters unless cointegration between the variables is accepted.

3.2 Some Implications for Empirical Testing

Distinguishing between the role of education as a factor of production, and as a factor that facilitates technology absorption and the production of knowledge, is significant. Any policy measure which raises the level of human capital may only have a one-and-for-all effect in the first framework, but will increase the growth rate of the economy forever in the second one. In such cases, the estimated increase in productivity is not simply a phenomenon in the transitional period since an increase in the flow of education leads to a gradual increase in human capital stock. Implicit is the claim that by increasing the level of education the rate of economic growth will increase over time. Empirically, however, there is no consensus over which is the appropriate approach.

Observational Equivalence

A main problem for empirical testing at the macro level emerges from observational equivalence. This means that, despite a number of different ways of hypothesizing how human capital can affect growth, empirical analysis can yield similar predictions regarding the relationship between some human capital variables and some variables of income growth. In other words, apart from data uncertainty, the empirical research seeking to test these alternatives has been hampered by the use of relatively similar econometric specifications. Insofar, macro regressions do not readily allow testing one theory against another. Rather they tend to emphasize an expanded set of variables as suggested by the literature. Consequently, Romer (1990b) argues that the role of an endogenous growth framework is not to generate testable predictions, but rather to guide the process of data analysis.

The Jones Critique

A second criticism, especially relevant for the present study, is the seminal contribution of Jones (1995). Testing endogenous growth models in the context of time series implies establishing a relationship between a variable that is usually stationary? without drift? such as income growth, and a variable which is usually non-stationary, such as years of schooling. In other words, his results fundamentally call into question the implicit prediction of many endogenous growth models suggesting output growth should exhibit large permanent increases. Time series data over a very long time period for the United States and other OECD countries reveal that the growth rates of GDP per capita in these countries exhibit little persistent changes, and can be characterized by more or less constant mean.

This observation imposes a testable prediction. According to endogenous growth models permanent changes in certain policy variables, such as schooling, or the number of scientists and engineers engaged in research and development, should have *permanent* effects on the rate of economic growth. Empirically, however, neither in the United States nor in other OECD countries does economic growth seem to exhibit such an effect. Incidentally, albeit for different reasons than in the OECD countries, these stationarity properties seem to be equally true for schooling and income growth in the Guatemalan data, as demonstrated in the Augmented Dickey-Fuller (ADF) tests in the Appendix.

3.3 More Evidence on Education and Growth

Empirical studies usually take the form of regression analysis and typically look at many more explanatory variables than human capital. A large number of papers have found one or more variables that correlate with growth. In fact, their number is very large and the question arises which combinations of these variables are actually robust. In the context of the present study, some of these findings will be outlined next.

Weak Correlations

While there is strong theoretical support for a key role of human capital in growth, Sala-i-Martin (2002), Easterly (2001) and in particularly Pritchett (2001) argue that the empirical relationship between education and growth is weak.[9] However, more specifically, Temple (2001) points out that fragile correlation in cross-country data may be due to measurement error and influential exceptions. Also, some kinds of relationships are more robust that others. For example, what is less clear and weak is the relationship of educational *growth rates* on output growth, the role of different education levels, and differences in effects of female and male education on growth. By contrast, some measures of health seem to be positively correlated with growth. In addition to human capital, many other factors have been found to be important for growth. Following Barro (2001), these include institutions, such as free markets, secure property rights and the rule of law. Similarly, more open economies and countries with lower initial inequality appear to experience higher growth.

Conditional Convergence

One much debated prediction of neoclassical growth models is that of convergence. Poor countries should grow relatively faster than rich countries if countries are similar with respect to their structural parameters for preferences and technology. The cross-country studies by Mankiw et al. (1992), Barro and Sala-i-Martin (1995) and Barro (2001) find some evidence of convergence, albeit in a modified form. More

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9 Pritchett (2001) uses measures of the *growth* rate of human capital and finds a *negative* impact on output growth. Easterly (2001) argues that human capital accumulation is not a panacea. He emphasizes indirect ways that explain technological progress and factor accumulation by looking at the features of economies that facilitate them, such as government policies and structural issues.

specifically, among other things, convergence is found conditional upon a country's initial human capital stock. Therefore, a poor country on average may grow faster, but only if the poor country's human capital stock is above the amount initially expected at the level of per capita income.

Reverse Causality

Most of the evidence of some sort of relationship between education and growth is based on statistical *correlations*. From these correlations, it has been generally inferred that higher levels of education cause higher growth. One critique of these findings comes from Bils and Klenow (2000) who suggest reverse causation. Based on a calibrated micro-foundation model, they claim that faster growth induces people to stay longer in school. In other words, the channel from schooling to growth that is assumed to dominate in many models cannot explain all the observed correlation between education and growth. However, the reverse channel provides some explanation. Therefore, in an econometric framework, schooling should be treated as an endogenous input with respect to income. This implies making use of econometric methods for dealing with this problem.

Few Individual Case Studies

Recent research has mainly relied on cross-country regression analysis. However, the original motivation of studying economic growth focuses on the time-series dynamics of macroeconomic variables. In addition, the cross-section focus may be inadequate if rates of return to education or the quality of education differ substantially across countries. Unfortunately, with respect to human capital, there are very few studies that analyze a single country over a certain time period.

The exception is a study from Jenkins (1995) using time series data from 1971-1992 for the United Kingdom. Still, the limited size of her time series sample makes it difficult to draw firm conclusions that can be generalized. Also Pissarides (2000) summarizes single case studies for India, Egypt, Tanzania and Chile. Part of an OECD project, these studies were to provide a more thorough test of the relation between human capital and growth in a single country context. For the case of India, the study less plagued with methodological or data problems, the regressions show a significant contribution of human capital on industrial output growth. The estimate suggests that an increase in the average number of years of schooling by 1 year should raise output by about 30 percent.

Magnitude of the Education Effect

In the augmented Solow model, the role of education can be inferred from estimates of the regression coefficients. However, with reference to the empirical research reviewed in Sianesi and van Reenen (2003), there is no agreement on its magnitude. In principle, there would be positive empirical evidence in favor of a macroeconomic productivity effect of education if the elasticity of human capital resembles the share of human capital in factor income. As a measure of reference, one can calculate the share of human capital in labor income from back-of-the-envelope calculations.

For example, Mankiw et al. (1992) consider the minimum wage as the return to labor with no education. Historically, the minimum wage has been between 30 to 50 percent of average wage income in the United States. On this account, it would follow that the return to education equals about 50 to 70 percent in labor income, which is about 70 percent of total factor income. Obviously, the problem with this kind of calculation is that in developing countries the minimum wage is less enforced and less likely applicable.[10] Pritchett (2001) therefore uses an estimation based on the distribution of wages. Either of these calculations suggest that the human capital coefficient should be at least $^1/_3$.

Effects of Education Levels

Somewhat surprisingly, relatively few studies at the macro level address the question of level-specific education effects. The view that schooling does not have the same impact on economic growth at different education levels is based on the labor economics literature. Psacharopoulos and Patrinos (2002) provide a comprehensive review on the rates of return to education. International evidence suggests that returns vary according to the education level. Lower income countries tend to have higher returns to schooling. If education has economic externalities? such as expanding well-being and the technological possibilities of the economy? the true benefits of education may be better captured by the study of different education levels on economic growth. This is because the computation of rates of returns based on micro data can only measure the effects of education through individual's wages. However, this might not hold in macro analysis.

Within an endogenous growth framework one can also derive a distinct role for each education level. The intuition here is that primary education provides individuals with basic cognitive skills that enhance productivity in the production of final goods, but only post-primary education facilitates the absorption of new technologies, and enables individuals to contribute to the production of knowledge. Empirically, in the framework of the augmented Solow model, treating each education level as a separate input into production can quantify the role of primary, secondary and tertiary schooling. While the standard approach in the literature is to consider an aggregate measure of human capital, there are some exceptions that will be briefly reviewed now.

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[10] In Guatemala, the legal minimum wage currently amounts to approximately 3-5 U.S. dollars per day (UNDP 2003a). While the legal minimum wages are relatively high with respect to average wages, about $^1/_2$ of workers in Guatemala earn less than the legal minimum wage. This is because of weak enforcement and the fact that self-employed workers are not subject to the minimum wage regulation.

Barro and Sala-i-Martin (1995) regress the growth rate of GDP per capita for a large sample of countries on initial income and a set of control variables. Four measures of educational attainment are always present. These are average years of male secondary and higher schooling as well as average years of female secondary and higher schooling. The male education variables have a jointly significant impact on growth. The female variables enter sometimes with a negative sign. One possible interpretation, advocated by Barro, is that females are discriminated in the formal labor markets. Another explanation for this rather 'puzzling' finding could be simply due to collinearity of the education variables.[11] Other regressions include average years of female and male primary education. None of these variables are found to be significant. Barro (2001) has continued to investigate the relations between education and growth using the same methodology. An important finding here is that school *quality* is much more important to growth than its *quantity*. Overall, the studies do not make very clear the effect of education levels on growth given the negative contribution of secondary female schooling, and the insignificant result for primary education.

Another paper that investigates the link between education levels and growth is Petrakis and Stamatakis (2002). In a cross-country regression with a relatively small sample size they consider three groups of countries: advanced, developed and less developed. The empirical results suggest that the link of education and growth varies with respect to a country's level of development. Primary education is more important in less developed countries, while higher education seems dominant in advanced countries. In fact, there is some similarity with Gemmel (1996) who also distinguishes between primary, secondary and tertiary schooling for these three groups of countries. He argues that the effects of human capital on growth are most apparent at the primary and secondary levels in developing countries, but at the tertiary level for OECD countries. Unfortunately, the findings in both studies do not allow one to assess with certainty the role of secondary education. In fact, it sometimes enters with a negative sign.

Finally, based on a framework similar to Benhabib and Spiegel, Papageorgiou (2003) is also concerned to empirically determine the contribution of primary and post-primary education on growth. In a cross-country regression he finds that primary education contributes mainly to the production of final output, whereas post-primary education contributes to the adoption and innovation of technology. When the data is divided into subsamples, the results are less encouraging. However, the implicit claim

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[11] Klasen (2002) argues that the education variables are generally correlated. Empirically, this makes it difficult to identify individual effects of female and male education. However, the negative effect for female secondary education disappears once regional dummy variables are incorporated into econometric models. This finding may be due to East Asia's large initial gender gaps in the 1960s, and the combination of low economic growth and comparatively lower gender gaps in Latin America.

is that for the poorest countries human capital acts mainly as input into final production and, to a lesser extent, as a facilitator for innovation. The relative contribution of human capital to innovation seems to increase with country wealth. Overall this is an interesting study. Nevertheless, the analysis ignores the Jones (1995) critique, and the conclusions are ultimately derived from a priori assumptions.

3.4 Summing-Up

Empirical results often do not allow for a clear-cut measurement of the macroeconomic role of education on growth, and theory seems to be much ahead of empirics. Cross-country evidence suggests that the relative importance of education level varies by the degree of a country's development. Results that come close to a priori expectation of the magnitude of human capital on growth seem to share three properties. First, a specification of the underlying regression that is based on a production function. Second, in particular regarding human capital, empirical data of reasonable quality. And finally, a functional form of the regression equation that tends to reduce econometric problems.

Attempts to measure empirically the impact of education on growth can be divided into two broad categories. The augmented Solow model originates the first class, while the second group is inspired by an endogenous growth approach. However, this is rather a conceptual framework for thinking about growth, which can be useful in the analysis of data, but does not generate a set of easily testable equations nor sharp quantitative predictions. In the light of observational equivalence and given the problems associated with testing endogenous growth models in a time series context, the following analysis will be based on a production function augmented for human capital. Nevertheless, some attention will be given to variables that proxy for trade openness and technological innovation, and their joint impact on education.

4. Data Compilation in a Post-Conflict Country

Guatemala is definitely deficient in easily accessible data. Thus, to identify the macroeconomic impact of education on economic growth, a primary task is to overcome information constraints. It is important to note that a significant fraction of the economic activity in Guatemala can be found in the informal sectors. Since this lack of documentation does not influence all factors equally, there remains a potential bias that cannot always be traced.

However, satisfactory and coherent results can be obtained. A sizable amount of information, although not easily accessible, can be compiled from disperse or bulky individual files. Even for local experts, this is a challenging task. The lack of a consistent compilation of data to allow a serious analysis of growth patterns hampers inter-temporal comparisons and, more generally, research of development patterns for the country. Given these constraints, so far, there is very limited empirical research on virtually any macroeconomic topic in Guatemala.

The following paragraphs describe the data needed for the analysis that follows. These are measures for the human and physical capital stock and the labor force, and quality indices for human and physical capital. Information other than that reported in this section is listed in the Appendix. The time series are mainly from Banco de Guatemala, and, in the case of educational statistics, from the Ministry of Education and the United Nations Educational, Scientific and Cultural Organization.

4.1 Human Capital Stock

The human capital stock of Guatemala is defined by average years of schooling evident in the labor force.[12] In line with most empirical analyses, this study assumes that years of schooling provides a reasonable approximation of the human capital stock, although it should be briefly stressed that the indicator is incomplete for several reasons.

(1) Education as proxy variable. Human capital is multifaceted and includes a complex set of human attributes. As a consequence, the genuine level of human capital is hard to measure in quantitative form. At best, average years of schooling can be regarded as a proxy for the component of the human capital stock obtained in schools. Therefore, in a later robustness test, life expectancy at birth will be included in the regressions. Life expectancy is commonly viewed as a companion indicator to educational capital that captures the effect of health.

(2) Quality changes. Average years of schooling measurements do not take into account quality changes within the education system. Quality changes may complicate comparison of schooling effects on growth over time as well as making comparisons with other countries difficult. Bratsberg and Terrel (2002), CIEN (2002) and the World Bank (1995c) argue that the quality of the education system in Guatemala is rather low, and may not have shown much improvement over time.

(3) Aggregation bias. Average years of schooling raise human capital by an equal amount regardless of whether a person is enrolled in a primary, secondary or tertiary school. This is an important point because by defining human capital by average years of schooling, one implicitly gives the same weight to any year of schooling acquired by a person. This completely disregards the findings of the microeconomic literature on wage differentials. For example, Psacharopoulos and Patrinos (2002) suggest that the rates of return to education could be decreasing with the acquisition

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[12] The use of labor force instead of total population data is due to problems regarding the Guatemalan population data for the 1980s. By contrast, the labor force proxy used here is assumed to take into account some of the effects of the civil war, i.e. migration and displacement.

of additional schooling. Therefore, in order to capture the impact of education on growth better, a more complete picture will be presented by analyzing the role of primary, secondary and tertiary schooling.

After making some modifications to account for the statistical circumstances in Guatemala, the following procedure for constructing estimates of the human capital stock is used, based on the attainment census method advocated by Barro and Lee (2001). The use of a perpetual inventory method that employs census and survey information on educational attainment as benchmark figure can be seen as a major advantage over previous methodologies. The benchmarks are taken from various national censuses and surveys, see Table 3. Guatemalan statistics report distributional attainment stratified by age and sex in five cases: no formal education, first cycle of primary, second cycle of primary, first cycle of secondary, second cycle of primary and tertiary education. The data has been summarized into 4 broad categories, that is, no school, some primary, some secondary and some tertiary education.

The procedure starts to construct current flows of adult population, which are added to the initial benchmark stocks of the labor force (taken for 1950 from the Barro and Lee 2001 data set). The formulas for the three levels of schooling for the labor force aged 15 and over are as follows:

(1) $$HN_{0,t} = HN_{0,t-1} \cdot (1-d_t) + L15_t \cdot (1-PRI_{t-1})$$

(2) $$HN_{1,t} = HN_{1,t-1} \cdot (1-d_t) + L15_t \cdot (PRI_{t-1} - SEC_t)$$

(3) $$HN_{2,t} = HN_{2,t-1} \cdot (1-d_t) + L15_t \cdot SEC_t - L20_t \cdot TER_t$$

(4) $$HN_{3,t} = HN_{3,t-1} \cdot (1-d_t) + L20_t \cdot TER_t$$

where

HN_j = number of the economically active population for whom j is the highest level of schooling attained (j=0 for no school, j=1 for primary, j=2 for secondary and j=3 for higher education)

PRI = enrollment ratio for primary education

SEC = enrollment ratio for secondary education

TER = enrollment ratio for tertiary education

L = number of the economically active population

L15 = number of persons aged 15

L20 = number of persons aged 20

$d_{h,t}$ = mortality rate of the human capital stock.

The mortality rate for the economically active population aged 15 and over is estimated from:

$$(5) \qquad d_{h,t} \approx \frac{L_{t-1} - (L_t - L15_t)}{L_{t-1}}$$

and assumes that the mortality rate (which also includes the exit of the economically active population due to retirement or inactivity) is independent of the level of schooling attained, which is not entirely correct. The term L_t–$L15_t$ describes the number of survivals from the previous period, which are subtracted from L_{t-1} in order to estimate the total number of missing persons. Equation (5) as such describes the proportion of the labor force which did not survive from the previous period. The formulas can be rearranged to create the final equations that were used to generate the attainment ratios, hr_j, for the four broad levels of schooling for the economically active population aged 15 and over:

$$(6) \qquad hr_{0,t} = \frac{HN_{0,t}}{L_t} = hr_{0,t-1} \cdot \left(1 - \frac{L15_t}{L_t}\right) + \frac{L15_t}{L_t} \cdot (1 - PRI_{t-1})$$

$$(7) \qquad hr_{1,t} = \frac{HN_{1,t}}{L_t} = hr_{1,t-1} \cdot \left(1 - \frac{L15_t}{L_t}\right) + \frac{L15_t}{L_t} \cdot (PRI_{t-1} - SEC_t)$$

$$(8) \qquad hr_{2,t} = \frac{HN_{2,t}}{L_t} = hr_{2,t-1} \cdot \left(1 - \frac{L15_t}{L_t}\right) + \frac{L15_t}{L_t} \cdot SEC_t - \frac{L20_t}{L_t} \cdot TER_t$$

$$(9) \qquad hr_{3,t} = \frac{HN_{3,t}}{L_t} = hr_{3,t-1} \cdot \left(1 - \frac{L15_t}{L_t}\right) + \frac{L20_t}{L_t} \cdot TER_t$$

The procedure requires school enrollment ratios that are crucial for exact calculations, but the proper accounting for Guatemala is not easy. Even though net enrollment ratios would be more precise for estimating the accumulation of human capital, gross enrollment ratios are used, as only this data is available. As reported in the Appendix, the ratios are taken from various yearbooks of the Guatemalan Ministry of Education (MINEDUC) for the 1990s, the United Nations Educational, Scientific and Cultural Organization (UNESCO) for earlier periods, and other sources available for Guatemala. The data for primary, secondary and tertiary enrollment ratios have been found consistent over time. Interpolation techniques were used to fill gaps in the data, but the use of this approach was kept to a minimum. The tertiary enrollment time series were more difficult to compile and required greater use of interpolated estimates.

In general, the estimated attainment data compares favorably with the census and survey information. The less accurate fit for 1981 is here believed to be due to large measurement errors or the possible manipulation of the census, which took place during the peak of the armed conflict in Guatemala. Consequently, this discrepancy was not smoothed over. Equally, data for 1998 differs slightly from the estimate. This is due to the fact that the survey largely oversamples the urban population of the economy in that year. Given the simplicity of the assumptions of the underlying model, however, the overall results have been found quite satisfactory.

Table 3. Guatemala: Education Level of Labor Force, 1950-2002 (in percent) [a/]

Year	Source	No school	Some Primary	Some Secondary	Some Tertiary
1950	SEGEPLAN (1978)	72.3	24.9	2.3	0.5
1964	SEGEPLAN (1978)	60.7	33.4	4.7	1.2
1973	SEGEPLAN (1978)	51.7	40.8	6.1	1.4
1981	CENSO (1981)	(37.7)	(48.7)	(10.9)	(2.7)
1989	ENS (1989)	38.9	47.7	11.4	2.1
1994	CENSO (1994)	35.4	47.8	14.1	2.7
1998	ENIGFAM (1998)	(30.8)	(50.3)	15.9	3.1
2000	ENCOVI (2000)	28.9	48.6	16.5	6.0
2002	ENEI 1 (04-05/2002)	26.9	49.3	19.3	4.5
2002	ENEI 2 (08-09/2002)	24.7	50.8	19.3	5.2
2002	ENEI 3 (10-11/2002)	25.0	48.7	21.0	5.3

Source: Compiled from census and survey data, ENCOVI and ENEI figures are from UNDP Guatemala. a/ Brackets indicate uncertain figures. Discrepancies are due to rounding.

In any case, simply employing gross enrollment ratios would overestimate the accumulation of human capital. Gross enrollment ratios are defined as the ratio of total enrollment in the respective schooling level to the population of the age group that is expected to be enrolled at that level. Thus, gross enrollment ratios can exceed 1 and therefore exaggerate the true amount of enrollment when students repeat, which is often the case in Guatemala.[13] In response to this problem and in order to benchmark the estimated educational attainment data with census and survey information, the gross enrollment ratios have been adjusted by a depreciation factor for the respective education level, as reported in Loening (2004).

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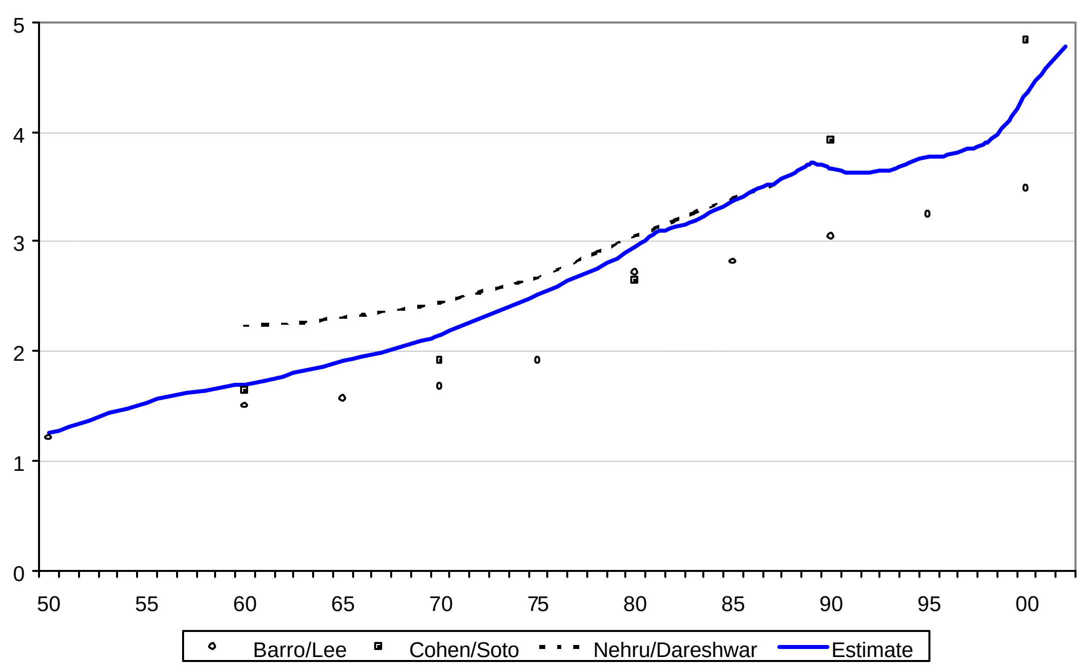
[13] The use of net enrollment ratios is hampered by large data gaps. Also, net enrollment ratios introduce large measurement errors if there are under- or over-aged children starting at each level of education, see Barro and Lee (2001). In Guatemala students who start late constitute a significant fraction of total enrollment—in particular for primary schooling.

Finally, the formula to construct the measure for the human capital stock combines the estimated attainment data with the information on the duration of each schooling level. It is given as:

(10) $$h_t = \sum_{j=1}^{3} hr_{j,t} \cdot d_{j,t}$$

where h_t stands for the average years of schooling, hr_j is the estimated attainment ratio of the labor force and d_j is the average number of years of education received in the respective schooling level j. Average education values have been calculated from the *Encuesta Nacional Socio-Demográfica* (ENS) from 1989 and are assumed to have remained constant over time. This may result in a slight overestimate of the human capital stock for the period prior to 1989 and underestimate the average years of schooling for later periods. However, data from more recent household surveys suggest that this assumption may not be a large source of error.

Figure 2. Guatemala: Average Years of Schooling in Labor Force, 1950-2002



Source: Author's calculations, as well as Barro and Lee (2001), Cohen and Soto (2001), and Nehru et al. (1995) education data.

How do these calculations compare to other sources? The correlation coefficients between the estimated average years of schooling here and those provided by Soto (2002), Barro and Lee (2001), and Nehru et al. (1995), using different techniques and data sources, all exceed 0.95 in the case of Guatemala. Figure 2 compares the results. The time series shown by the solid line harmonizes to a large extent with alternative estimates at different points of time. Unlike the Barro and Lee data set, there is no implausible jump for 1980. The Cohen and Soto (2002) estimate provides the closest approximation. Additionally, not shown by Figure 2, the average years of schooling estimates here come close to values obtained from census and survey data. For example, Psacharopoulos and Arriagada (1986) report that mean education in the labor force was in the order of 1.7 for 1964. Edwards (2002) reports a value of 4.3 years for 2000. According to the estimate here, average years of schooling was in the order of 1.9 years in 1964 and 4.4 years in 2000.

A closer look at Figure 2 yields two important descriptive outcomes. First, the data suggest that mean education evident in the labor force slightly declined during the early 1990s. This outcome is associated with the disastrous effect of the civil war on the country's human capital base. Those disadvantaged cohorts from the 1980s entered later into the labor force. Second, there has been substantial increase in the average years of schooling within the economically active population since 1998. This can be attributed to improvements within the education system and increased attention to education after the signing of the 1996 Peace Accords.

Even so, as it can be appreciated from Figure 2, this increased attention to education only has compensated for the loss of educational capital caused by civil strife. Consequently, recent educational progress does not represent a major improvement regarding the long-run growth of the country's human capital base. In this context, it is worth recalling that educational attainment in Guatemala remains lowest compared to other Latin American countries.

4.2 Labor Force

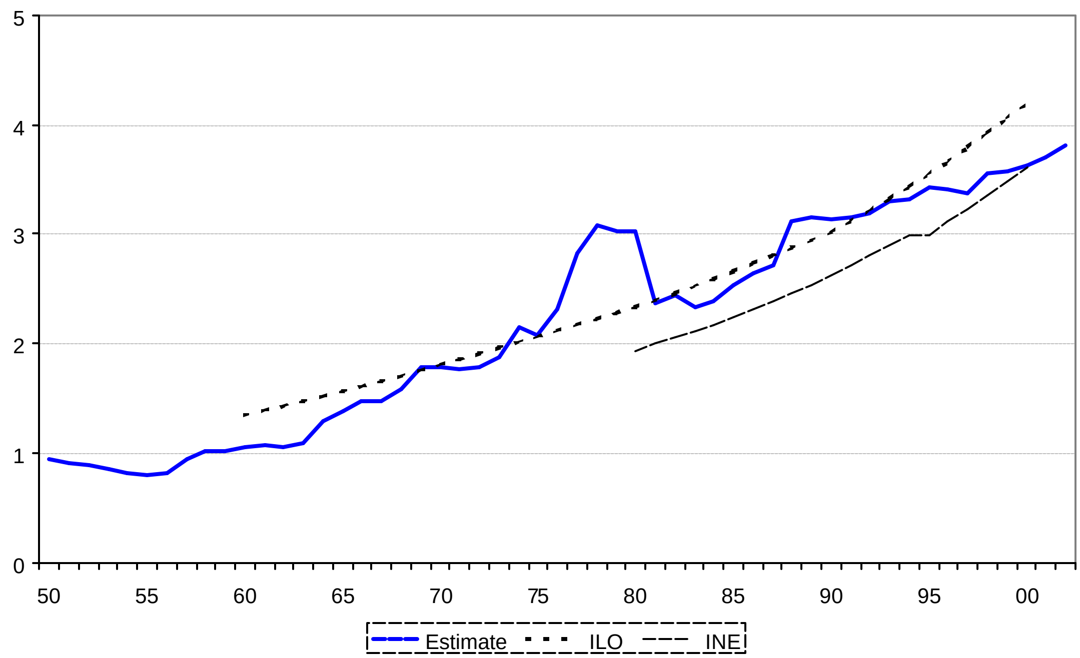
The measure of labor quantity here is the economically active population. For Guatemala there are several estimates. The National Statistic Institute (INE) provides calculations different from those of the Ministry of Work, both of which date back to 1980. Based on census and survey data, estimates for selected years have also been provided by the United Nations Development Programme (UNDP) for Guatemala. The labor force is usually defined as the working and job-seeking population, but the different calculations do not always reveal what underlies the specific assumptions and age definitions used for calculations. To develop a consistent time series of the economically active population, the International Labor Organisation (ILO) has used information on age specific labor force participation rates and population statistics. Unfortunately, for the reasons clarified below, these estimates are unreliable.

(1) Data discrepancies. First, there is no agreement either on the level or on the growth rates of the labor force. Virtually all data is different from each other. For example, UNDP (2003a) reports a total labor force estimate of about 2.84 million for 1989, as compared to 2.54 million from INE or 2.95 million from ILO. Second, as typical for estimates in other countries, labor force data should show some cyclical fluctuations as labor responds to higher output growth. Official estimates for Guatemala, however, are remarkably free of *any* fluctuations and follow a

monotonous trend. This suggests reliance on population statistics or use of interpolation techniques.

(2) Omission of the civil strife. Most importantly, these estimates do not take into account migration flows and the consequences of the civil war on the economically active population. Especially the last point devalues official estimates. According to the Commission for Historical Clarification (1999), the internal military conflict left an estimated 200,000 civilians dead and another 1 million displaced, for a total population of about 10 million. Such an immense impact of the civil strife should be reflected somewhere in the statistics? but it is not.

Figure 3. Guatemala: Labor Force, 1950-2002 (millions of workers)



Source: Author's calculations based on Banco de Guatemala (2003), INE and ILO data.

In the absence of reliable information about the economically active population from these sources, labor is here proxied by the number of private contributors to the Guatemalan Social Security System (IGSS). The reliance on the number of private contributors to the Social Security System in order to account adequately for the economically active population is also adopted in an IMF study for the case of El Salvador by Morales (1998), and for Guatemala by Prera (1999). The numbers representing the labor force are calculated by assuming that the social security contributors account for approximately 25 percent of the total labor force.[14] The participation rate has a negligible impact on the later calculations and is based on a historical mean value.

Although a broad approach may limit the precision of calculations, the regressions in sections 5 and 6 show that the variable has a high explanatory power on growth. Moreover, as can be seen from Figure 3, the estimated values give a more reasonable picture than the data from official sources. Notice that the *level* of the economically active population, but not its growth rate, is basically in line with ILO or INE calculations. In 1980s, when the civil war had already taken genocide proportions, the labor force dropped dramatically by about 660,000.[15] For recent years, the estimate for the economically active population derived from IGSS statistics comes close to INE data.

4.3 Physical Capital Stock

Internationally, the Perpetual Inventory Method (PIM) is a common way to estimate capital stock, but there are uncertainties associated with the calculation. In general, due to the lack of information about the initial capital stock, questionable validity of assumptions about the rate of depreciation, and lack of information about the utilization of capital, estimates should be taken with care. With these reservations in mind, the PIM was used to construct the physical capital stock for Guatemala. The following paragraphs present two distinct calculations, one with aggregated and another with disaggregated investment data.

Estimate with Aggregated Investment Data

The physical capital stock that is used throughout the subsequent analyses is computed using the PIM with aggregated investment data. The procedure argues that the stock of capital is the accumulation of the stream of past investments:

(11) $$K_t = K_{t-1} \cdot (1 - d_K) + I_t$$

where K is the capital stock, I gross fixed capital formation, d_K the annual depreciation rate of the capital stock, and t an index for time. The initial value of the capital-output ratio for 1950 is taken from the Nehru and Dhareshwar (1993) data

[14] UNDP (2003a) reports a participation rate of 24.5 percent (2002). Based on INE data, as reported by Global Info Group (1999), this compares to 27.6 percent (1995), 29.9 percent (1990) and 28.2 percent (1985).

[15] It should be emphasized that the reliance on IGSS data may understate the drop of the economically active population during the 1980s. This is because the working population in the informal and rural sectors—typically not captured by the social security system—was particularly affected by violence and displacement policies.

set.[16] Information about gross fixed capital formation was provided directly by the Economic Research Department of the Banco de Guatemala. The data is compiled using the somewhat dated 1953 UN System of National Accounts, which is currently under revision.[17] In line with other studies for Latin America, such as Loayza et al. (2002) and Morales (1998), the overall depreciation rate is assumed at 5 percent. This is still a rather high estimate when compared with more commonly used thumb values.

However, regarding the armed conflict, which has lasted for 36 years, and several periods of high violence in Guatemala, it was found useful to adopt a high depreciation rate in order to account for both capital *destruction* and *distraction* from productive use. For example, the latter may have resulted in unprofitable military spending, several forms of non-productive investments, or temporary spare capital because of infrastructure deficiencies. As to be shown in the following section, the results of the regression analyses are not sensitive to moderate adjustments in the depreciation rate. In terms of data availability over a long time period, and given the robustness to alternative assumptions about depreciation, the capital stock series with aggregated investment data is adopted in the later regression analyses.

Estimate with Disaggregated Investment Data

Based on the PIM, Morán and Valle (2002) present a second approach for Guatemala. In their model the capital stock is estimated for eight broad asset groups for 1971-2000. However, presumably because of too high depreciation rates for public and private construction, they seem to underestimate the genuine level of the capital stock.[18] Following their methodology but applying different depreciation rates and taking into account the initial benchmark estimate from Nehru and Dareshwar (1993), a second capital stock series has been calculated with disaggregated investment data for the period 1970-2002.

The initial values are obtained from a pre-estimate starting in 1950. The data gaps for the sectoral composition of the eight assets groups prior to 1970 are filled in by extrapolation techniques. These values, however, do *not* enter in the later regression or growth accounting exercise. They only provide reasonable initial values for the

[16] The potential error of the estimate of initial capital stock diminishes over time due to depreciation. Based on international data, Nehru and Dhareshwar (1993) offer an estimate of the capital stock for Guatemala that was taken as a benchmark.

[17] UNDP (2002) provides a brief summary of the associated empirical consequences and causes that prevented an actualization of the Guatemalan National Accounts.

[18] In addition, the following results of the quality index for the physical capital stock differ. This may be due to the possibility of an oversight in the logarithmic transformation by Morán and Valle (2002), as was pointed out in a personal communication with Estuardo Morán, Banco de Guatemala, October 15, 2003.

disaggregated capital stock. Table 4 presents the assumed average life service lines for each of these assets groups. The average service life for a given class of asset is considered to be identical for all kinds of economic activities. The service lives are arrived at by considering the nature of these asset groups, consulting experts, and a careful review of the average service lives used by other countries, as reported in OECD (2001b).

Based on average service life estimates, geometric depreciation rates are applied. With geometric depreciation, the market value in constant prices is assumed to decline at a constant rate within each period. The implicit depreciation factor for each asset group is set at a value that ensures that the initial value will have been reduced to 10 percent of the original value by the time it reaches the end of its expected service life. The main drawback of geometric depreciation is that it will never exhaust the full value of an asset. That is, the depreciated value of the asset falls asymptotically, approaching, but never reaching, zero. While the infinity problem is somewhat troublesome, geometric depreciation has the practical advantage of being suited better for benchmark estimates, such as in the present study.

Table 4. Guatemala: Asset Classes and Average Service Lives

Asset Class	Average Service Life (Years)	
	Private Sector	Public Sector
Construction	50	50
Machinery and Equipment	...	15
Imported Capital Goods	15	...
Domestically Produced Capital Goods	10	...
Cultivated Assets and Major Improvements to Land	6	...
Other Assets	10	...

Source: Based on OECD (2001b) and expert consultation.

4.4 Quality Indices of Capital and Labor

Based on the previous calculations, quality indices can be elaborated. The quality index of the labor force will only be used in the later growth accounting exercise since it already reflects improvements in human capital. However, the estimate for the quality of capital enters into the regressions. The following paragraphs are concerned with the construction of the indices for the quality of capital and labor, respectively, and a brief comparison over both indices for 1970-2002. The capital and labor quality indices yield interesting outcomes.

Quality of Capital

One can calculate a quality index of capital by using the disaggregated capital stock data. The estimate follows the methodology advocated by Laurits et al. (1980) and

Roldós (1997). For the case of Guatemala, this means that changes in the index of quality of capital, *zq*, are computed as a weighted average of investment of the four broad asset groups. These are (1) public and private construction, (2) imported capital goods and investment in machinery and equipment, (3) domestically produced capital goods, and (4) cultivated assets and major improvements to land. The formula used is:

(12) $$\Delta \log zq_t = \sum_{i=1}^{4} v_{i,t} \cdot (\Delta \log K_{i,t-1}) - (\Delta \log K_{t-1})$$

where K_i is the respective capital stock and the weights v_i are the relative capital rental rates. The index reflects changes in the composition of capital. If *all* components of the capital stock are growing at the same rate, quality remains unchanged. If *components* of the capital stock with higher capital rents are growing more rapidly, quality increases. Since data on the rental rates v_i is not readily available for Guatemala, estimates of these are, following Roldós (1997), based on the arbitrage relation:

(13) $$v_{i,t} = (1 + r_t) \cdot P_{i,t} - (1 - d_{Z,i}) \cdot P_{i,t+1}$$

where P_i is a price index, $d_{Z,i}$ the depreciation rate, and r_t is the economy-wide real interest rate. The price indices for the respective asset groups are taken from the Morán and Valle (2002) database. In order to take into account the volatility of the real exchange rate, which affects directly the relative price of the four types of capital, and to correct for measurement bias, the final series are smoothed by a 3-year moving average.

Quality of Labor

To quantify labor quality, an index *hq* is computed as a weighted average of labor within different levels of education. This formulation is consistent with the growth accounting literature that makes adjustments for education. It allows a more accurate indication of the contribution of labor to production. The index *hq* is defined as follows:

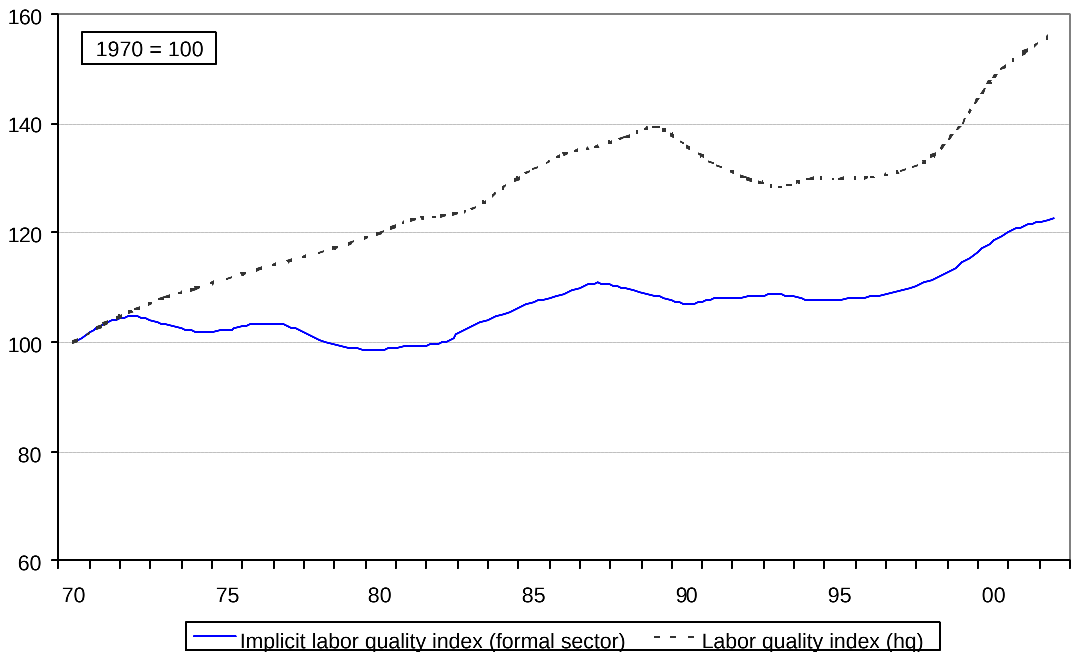
(14) $$hq_t = \sum_{j=1}^{3} w_j \cdot (L_{j,t} / L_t)$$

where L_j is the labor force with education level *j* (primary, secondary and tertiary) and w_j are the weights for the respective schooling level. The weights measure how the productivity effect of schooling varies with the level of education and are taken from the later regression analysis (Table 6). Interestingly, they correspond approximately with the private returns to schooling at each education level, as presented by Psacharopoulos and Patrinos (2002) for Guatemala.

Following OECD (2001a) another possibility to compute an implicit labor quality index would be to assume direct relations between skills and occupations, to rank occupations by their skill intensity and then use information on the occupational distribution of labor over time. In this case, skilled labor and less skilled labor have to be weighted by their respective relative labor productivity to account for differences in skills. For the case of Guatemala, similar to equation (14), this can be done by weighting labor inputs of different industries with the share that each type of labor occupies in total labor compensation.

However, it should be kept in mind that this kind of implicit differentiation of labor is a rather incomplete substitute for labor quality. It can only take into account some of the quality changes of labor input and does not allow the sources of the change to be identified. Moreover, the eight industry categories available from Banco de Guatemala (2003) statistics only apply to the *formal* sector. As such, they ignore approximately 75 percent of the population working in the informal and rural economy. Placing less emphasis on educational improvements in *primary* schooling—the working population of the IGSS is typically better educated than the population in the informal and rural sectors—the implicit labor quality index is biased downwards.[19]

Figure 4. Guatemala: Comparison of Labor Quality Indices, 1970-2002 (in percent, relative to base year 1970)



Source: Author's calculations based on Banco de Guatemala (2003) data (implicit labor quality index), and human capital stock estimate for labor quality index (*hq*).

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[19] This is because primary school enrollment has increased substantially over time (see Table 3).

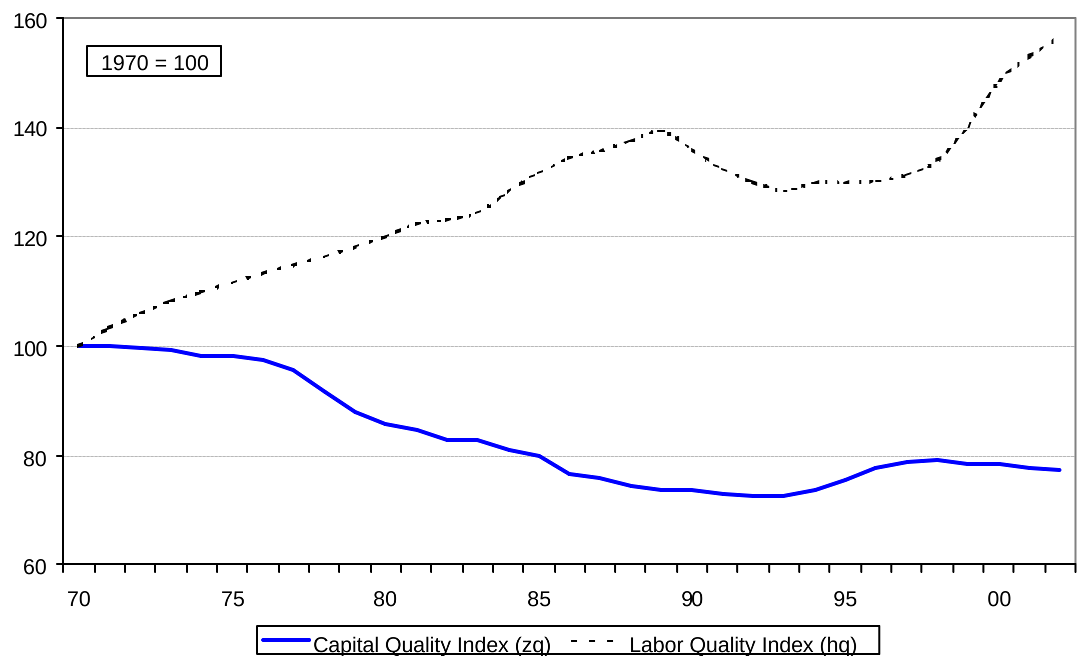
Nevertheless, for illustrative purposes, Figure 4 compares both indices. What is striking is the apparent similarity between both measures of labor quality despite completely different sources of data. This suggests that the time series properties of the human capital stock and its respective weights may be of reasonable quality.

Comparison of Both Indices

Finally, Figure 5 compares the estimated indices of the quality of labor, *hq*, and capital, *zq*. The descriptive analysis yields three important outcomes. First, the index of labor quality presents a clear upward trend, reflecting improvements in educational capital and a shift to more skilled jobs. However, as a consequence of the civil strife, labor quality slightly declined during the early 1990s but begins to increase again after 1998.

Second, the quality of capital has decreased over time. In particular after 1977, the data suggests that capital quality declined dramatically. In the mid 1990s, the advent of the Peace Accords led to an improvement, followed, however, by a stagnant pattern. In any case, for the period under observation, the quality of Guatemala's capital stock declined by about 20 percent. The exact reasons underlying the deterioration are unclear and require further research. Prominent explanations are the destructive impact of the internal military conflict, and a negative investment climate due to an unstable policy environment and lack of good governance.

Figure 5. Guatemala: Indices of Capital and Labor Quality, 1970-2002 (in percent, relative to base year 1970) [a/]



Source: Author's calculations. a/ Changes in capital quality reflect the fact that investment with comparatively higher rental rates (imported capital goods as well as machinery and equipment) decreased during the civil war but eventually climbed up again.

Third, a comparison of both indices shows an apparent gap between the evolution of the quality of capital and the quality of labor. This could imply that the deterioration of quality of capital is associated with, among other factors, the decreased output growth during the last decades. In other words, there is a missing complementarity between the country's skills and its technology base. The next section will take a closer look at the empirical determinants of growth in Guatemala.

5. Empirical Evidence for Guatemala

This section presents the main empirical evidence regarding the relationship between education and growth in Guatemala. Section 5.1 introduces the empirical methodology. Section 5.2 reports the findings for average years of schooling and growth. Given the apparent shortcoming of aggregate measurements of human capital, section 5.3 examines separately the effects of primary, secondary and tertiary schooling on growth. Finally, section 5.4 compares the returns to education at the macro level with the microeconomic evidence.

5.1 Methodology

The empirical methodology for the following sections is based on the human capital augmented growth model of Mankiw et al. (1992). This model considers human capital as an independent factor of production. It can be represented in a Cobb-Douglas production function with constant returns to scale:

(15) $$Y_t = A_t \cdot K_t^{a} \cdot H_t^{\beta} \cdot L_t^{(1-a-b)}$$

where Y represents output and A is the level of technology or total factor productivity.[20] K, H and L are physical capital, human capital and labor. Multicollinearity between capital and labor is avoided by standardizing output and the capital stock by labor units, which also impose the restriction that the scale elasticity of the production factors is equal to unity. Converted into a logarithmic expression, the production function can be estimated in its structural form:

(16) $$\log y_t = \log A_t + \boldsymbol{a} \cdot \log k_t + \boldsymbol{b} \cdot \log h_t + u_t$$

where the lower case variables $y = Y/L$ and $k = K/L$ are output and physical capital in intensive terms, and $h = H/L$ stands for average human capital. At first glance, the

[20] Further research may focus on a specification less restrictive than a standard Cobb-Douglas production function to allow a higher degree of precision for the determination of the technical coefficients. For example, factor shares are not necessarily constant, and the elasticity of substitution can be less than 1. A potentially interesting avenue is Jones (2004). He presents a production function that exhibits a short-run elasticity of substitution between capital and labor that is less than 1, and a long-run elasticity that equals to 1.

formula already appears suitable for estimation. However, some problems arise since it is well known that most macroeconomic time series contain unit roots and that the regression of one non-stationary series on another is likely to yield spurious results. As reported in the Appendix, the data for Guatemala is no exception. The estimation bias can be removed by transforming the time series to stationarity. This can be done by first differencing. In any case, this will create its own problems, notably because of the risk of losing valuable information on the long-run relationships of the variables.

One approach to dealing with this dilemma is to employ an error-correction model which combines long-run information with a short-run adjustment mechanism. This methodology has been used successfully in alternative growth studies. Examples of this are Nehru and Dareshwar (1994), Morales (1998), and Bassanini and Scarpetta (2001). The error-correction model can be estimated in different ways. Banerjee et al. (1993) show that the generalized one-step error-correction model is a transformation of an autoregressive distributed lag model. As such, it can be used to estimate relationships among non-stationary processes. Based on Hendry's (1995) concept of general-to-specific modeling, the error-correction model of the human capital augmented production function for Guatemala can be specified as follows:

(17) $$\Delta \log y_t = g_1 \cdot \Delta \log k_t + g_2 \cdot \Delta \log k_{t-1} - g_3 \cdot (\log y_{t-1} - a \cdot \log k_{t-1} - b \cdot \log h_{t-1} - \log A_{t-1}) + u_t$$

For Guatemala, in line with much empirical cross-country research, the short-run effects of schooling on growth have been found insignificant and are as such excluded from the regressions. This suggests that only the *level* of human capital has a long-run effect on economic *growth*. As it stands, the equation can be estimated by ordinary least squares (OLS) or instrumental variables (IV) techniques, but the coefficients cannot be formed without knowledge of a and b. However, one can estimate the re-parameterized form:

(18) $$\Delta \log y_t = c + g_1 \cdot \Delta \log k_t + g_2 \cdot \Delta \log k_{t-1} + g_3 \cdot \log y_{t-1} + g_4 \cdot \log k_{t-1} + g_5 \cdot \log h_{t-1} + \sum_j d_j \cdot dummy_{j,t} + u_t$$

Estimates of the parameter γ_3 can now be used to calculate the required elasticities a and b. The loading coefficient g_3 contains additional information because it can be interpreted as a measure of the speed of adjustment in which the system moves towards its equilibrium on the average. In addition, Banerjee et al. (1998) argue that in a single equation framework a significant coefficient serves as a test for cointegration. Notice that the technology parameter, A, is allowed to change overtime as a function of different variables, Z:

(19) $$\log A_t = f(Z_t)$$

where in its simplest formulation the technology level is proxied by a constant term, *c*, and a series of dummy variables. In a later section, proxy variables with respect to growth of trade openness, bad governance, time trends and other variables will be included in the equation. The majority of the following regressions include three dummies. First, a 1963 impulse dummy captures a positive one-off effect stemming from expectations regarding the Central American Common Market (MCCA). Second, a 1982 impulse dummy takes into account a negative one-off effect stemming from the peak of internal war. Third, a 1977 step dummy which models a structural change in the long-run relationship of the variables. A Chow breakpoint test does not reject the null hypothesis of no structural change during that year (p = 0.000).

In fact, the 1977 dummy is always negative, very significant, and most likely corrects for the deviations resulting from the civil strife. Interestingly, this finding is consistent with the quality index of the capital stock series showing a decreasing trend since 1977.[21]

5.2 Average Years of Schooling and Growth

Table 5 shows the results for the average years of schooling specification. The adjusted R^2 of the error-correction model is rather high and indicates a good data fit. Test statistics do not indicate any serial correlation or misspecification at conventional levels. The residuals have been found to be normally distributed and to follow stationary patterns. If not mentioned otherwise, these properties apply equally to subsequent regressions. The loading coefficient is highly significant and suggests a moderate speed of adjustment towards the long-run growth path, equal to about 25 percent of the deviations per year. After any specific shock to the economy it would, on the average, take approximately 10 years to reach the level of output consistent with long-run growth (with differences to be less than 10 percent). In the subsequent regressions, however, the magnitude of the coefficient? but not its significance? was found to be fragile with respect to the econometric specification. The asymptotic critical values of the t-ratio for the coefficient are taken from Banerjee et al. (1998). The significance level suggests a cointegrating relationship of the variables.[22]

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[21] Evidently, the Guatemalan time series are full of distortions, for example the 1976 earthquake and major political events. However, a sparse inclusion of dummy variables is the preferred econometric formulation. Other settings will be described in the following sections. It is important to emphasize that the basic results are not sensitive to the dummy variables. That is, the omission of the impulse dummies (1963 and 1982) does have little impact on the qualitative results. However, it is important to model the structural break.

[22] Notice equally that the human capital parameters are highly significant and compare favorably with the critical values provided by Pesaran et al. (2001). This is reassuring given the small sample size of 50 observations and the consequently low power of the ADF tests, where the stationarity properties of the repressors may not be known with certainty.

Table 5. Production Function for Guatemala: Average Years of Schooling Specification, 1951-2002

	Dependent variable: Percent change of GDP/worker	
	OLS	IV [a/]
Explanatory variables	(1)	(2)
Constant	-0.077** (-4.74)	-0.077** (-3.76)
Percent change of capital/worker	0.871** (30.2)	0.774** (5.74)
Percent change of capital/worker [-1]	0.120** (3.28)	0.169* (2.58)
log GDP/worker [-1] [b/]	-0.241** (-5.87)	-0.269** (-5.28)
log capital/worker [-1]	0.107** (3.76)	0.099* (2.29)
log average years of schooling [-1]	0.084** (5.00)	0.090** (4.54)
Step dummy 1977	-0.041** (-4.47)	-0.039** (-3.38)
Impulse dummy 1963	0.057** (4.69)	0.056** (4.15)
Impulse dummy 1982	-0.077** (-4.88)	-0.087** (-4.09)
Long-run elasticity of capital	0.444	0.366
Long-run elasticity of schooling	0.351	0.334
Adjusted R^2	0.964	0.956
F-statistic	170.5	40.67
Durbin Watson [c/]	2.003	2.112
S.E. of regression	0.012	0.013
N	51	50

a/ Lags of the independent variables are used as instruments. b/ Asymptotic critical values of the t-ratio are from Banerjee et al. (1998). c/ A Breusch-Godfrey test finds no evidence for the presence of first, second and third order correlation in the residuals.

t-statistics in parenthesis. ** Significant at 1%, * significant at 5%.

Source: Author's calculations.

The results are satisfactory considering the distortions caused by the internal military conflict and the simplicity of the assumptions used to construct the time series in the context of data uncertainties. At first sight, this seems astonishing. However, the good performance of the model may be due to the small size of the economy, and that the overall data uncertainties are not as severe as is commonly believed.

The most striking result is that human capital, as measured by average years of schooling, has a highly significant, positive and strong impact on long-run growth. Column 1 reports the implicit long-run coefficients estimated by OLS.[23] Since education levels are likely to respond to growing employment opportunities and increased income, column 2 shows the regression results when IV techniques are applied. In this case, lags of the explanatory variables are used as instruments. Compared to the OLS estimate, the quality of the results does not vary much with the IV estimation. The estimating parameters are in both cases significantly different from zero and the regressions, as test statistics indicate, show a satisfactory performance. However, the absolute value of the human capital coefficient is slightly reduced.

By contrast, the implicit elasticity of the capital coefficient is sharply reduced. The endogeneity problem, thus, does not distort the estimate but has an impact on the magnitude of the coefficients. In the IV specification, the estimated long-run effect of a 1 percent increase of average schooling on GDP per unit of labor is 0.33 percent. As such, it is roughly consistent with a priori expectations on the magnitude of the factor share of human capital. The results in terms of the human capital augmented Cobb-Douglas production function are approximately as follows:

(20) $$Y_t = A_t \cdot K_t^{1/3} \cdot H_t^{1/3} \cdot L_t^{1/3}$$

where the reported parameter values will serve as the base in a later growth accounting exercise. Notice that despite different methodologies the capital elasticity is broadly in line with empirical analyses which estimate a Cobb-Douglas production function for Guatemala (see Box 3). The capital elasticity, however, was found to be sensitive regarding the setting of the dummy variables. By contrast, the human capital coefficient was robust. These issues will be explored in more detail in the following analyses.

Finally, there are two additional findings of interest. First, even in the IV estimate, physical capital accumulation has a rather high impact on short-run growth. This suggests that measures to stimulate investment, for example by improving the investment climate, are likely to have an immediate impact on short-run growth.

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23 The long-run coefficients can be obtained by dividing the estimated parameter through the value of the loading coefficient, for example 0.084/0.241˜0.351. Discrepancies are due to rounding.

Second, the interception is significantly negative. Since the constant is expected to proxy for technology, a negative parameter in the sense of 'technological regress' is hard to understand. However, a loose interpretation for this finding would be that during the past 50 years, on average, the economy was not particularly efficient. One reason for that might be the conflictive political and social environment of Guatemala.

Box 3. Empirical Growth Studies for Guatemala: A Review

There are no studies for Guatemala that empirically assess the direct impact of education on economic growth over time. However, some standard growth accounting regressions exist that partially confirm the findings of the present study.

Prera (1999) and the World Bank (1996) came up with rough capital share estimates of about 0.4 and 0.6, respectively, while estimating a Cobb-Douglas production function. The World Bank provides neither a detailed methodology nor its data sources. The study from Prera faces several constraints regarding these issues. Particularly the fact that he ignores the existence of unit roots within the time series context and the low significance of the estimated parameters places doubt on the reliability of the results. Morán and Valle (2002) face the same problems. In addition, their parameter estimates must be considered carefully because of a short time period. The capital share is estimated about 0.3. Segovia and Lardé (2002) find a similar capital share using a first differences specification. Although the methodologies and data sources differ, the results partially suggest that the capital share for Guatemala is in agreement with empirical studies for other developing countries. According to Bosworth et al. (1996), capital shares are typically considered to be in the order of 0.3-0.4.

Some growth accounting studies for Guatemala also exist. Results differ and no firm conclusions can be drawn. The main discrepancies stem from the assumed or estimated factor shares, distinct time periods and, in particular, from data issues. Most studies rely on international data sets. They make no adjustments for the quality of inputs and are not concerned too much about data problems in the light of the civil strife. In general, studies tend to find that the role of total factor productivity growth was moderate and decreasing for recent periods. (with the exception of Bailén 2001, see for example Bosworth et al. 1996, Edwards 2000, Gregorio 1992, Loayza et al. 2002, Morán and Valle 2002, Nehru and Dhareshwar 1994, Segovia and Lardé 2002, Prera 1999, and World Bank 1996).

Particularly interesting is the work of Sakellariou (1995) who claims to use the Lucas (1988) model of endogenous growth. While analyzing microdata from the 1989 household survey, Sakellariou tests external effects of education on wage differentials. Unfortunately, the study suffers from a limited number of industry categories and human capital variables. Consequently, the regressions turn out to be statistically insignificant and strong conclusions cannot be drawn. However, Sakellariou goes as far as finding that the analysis does not reject the hypothesis that external effects of human capital investment could be present in Guatemala.

5.3 Schooling and Growth by Education Level

Using education data by levels may be preferable for a number of reasons. In particular, the growth impact of different forms of educational capital may vary. Columns 1-6 in Table 6 present the results of the production function augmented for human capital. The education level of the labor force enters separately into the estimation. The share of the labor force with primary, secondary and tertiary education is used here as the relevant unit. It may be argued that *average years of schooling* by level of education should be used instead of labor force *participation*. In any case, with the given data, this would not change the results. Ideally, one would also include primary, secondary and tertiary education into the same equation in order to assess their joint impact on growth. However, due to strong collinearity, the estimation only supports the inclusion of one education level.[24] As can be appreciated from the test statistics the regressions perform quite well. Notice that the estimate for primary education includes a time trend starting in 1985, the year of Guatemala's transition to civilian rule. The inclusion of the trend variable was motivated to avoid serial correlation in the residuals, but does not have an impact on the magnitude of coefficients.

Table 6 presents both OLS and IV estimates. The endogeneity problem seems to be more pronounced for primary education, and in particular for physical capital. However, the qualitative results do not vary substantially. In all specifications the schooling variables are highly significant and positively correlated with growth. Interestingly, the significance levels increase with secondary and tertiary education. Regarding the long-run elasticities, the accumulation of primary schooling appears to be most important for growth, followed by secondary and tertiary education. This finding should *not* be interpreted as implying that other levels are unimportant. This is particularly true given the tight connections between the various forms of educational capital and the retrospective character of the empirics. Nevertheless, the evidence is in line with the limited cross-country studies on this topic. Recall that Gemmel (1996), Petrakis and Stamatakis (2002) and Papageorgiou (2003) plausibly suggest that the importance of post-primary education increases with the level of development. Similarly, de Ferranti et al. (2002) argue that in countries classified as adopters, such as Guatemala, policies should first focus on a critical threshold level of primary schooling, coupled with open trade policies. The intuition is here that different stages of technological transition require distinct policy priorities. A sufficient coverage *and* quality of primary education are regarded as the minimum prerequisite to adopt technologies. By contrast, in countries where basic skill requirements are fulfilled and firms are making significant adaptations or innovations, the creation of more specialized skills ought to be the priority. In addition, the results here partially confirm the earlier micro-level evidence for Guatemala.[25]

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[24] In principle, the inclusion of a time trend for 1999 and an interaction term for secondary and tertiary schooling would allow incorporating all three levels of education at a time. Tentatively, such an exercise yields similar qualitative results on the impact of each level of education on growth—albeit primary schooling becomes insignificant. In addition, due to the multicollinearity problem, this specification was found to be rather sensitive and performs less well than the results displayed in Table 6.

[25] For Guatemala, Psacharopoulos and others have extensively investigated the returns to schooling, sometimes by level of education. Such exercises are summarized in Psacharopoulos and Patrinos (2002), Haeussler (1993) and World Bank (1995). The studies generally report high private returns to primary schooling, but are merely based on ENS (1989) or earlier data, and typically do not care about sample selection bias.

Table 6. Guatemala: Effect of Schooling on Growth by Level of Education, 1951-2002

	Dependent variable: Percent change of GDP/worker					
	j = primary		j = secondary		j = tertiary	
	OLS	IV	OLS	IV	OLS	IV
Explanatory variables	(1)	(2)	(3)	(4)	(5)	(6)
Constant	0.087**	0.082**	0.127**	0.140**	0.096**	0.141**
	(3.43)	(2.83)	(4.20)	(3.60)	(3.78)	(4.43)
Percent change of capital/worker	0.871**	0.766**	0.875**	0.757**	0.872**	0.785**
	(28.8)	(5.14)	(29.5)	(5.12)	(28.6)	(6.02)
Percent change of capital/worker [-1]	0.113**	0.157*	0.128**	0.181*	0.083*	0.143*
	(2.94)	(2.42)	(3.33)	(2.51)	(2.21)	(2.32)
log GDP/worker [-1] a/	-0.242**	-0.264**	-0.213**	-0.234**	-0.224**	-0.327**
	(-5.51)	(-4.88)	(-5.43)	(-4.64)	(-5.20)	(-6.00)
log capital/worker [-1]	0.107**	0.088	0.091**	0.074	0.120**	0.155**
	(3.47)	(1.65)	(3.22)	(1.61)	(3.72)	(3.63)
log participation of education level$_j$ in labor force [-1]	0.103**	0.092**	0.049**	0.052**	0.023**	0.033**
	(3.89)	(2.79)	(4.59)	(3.92)	(4.27)	(5.20)
Trend 1985	0.002**	0.002**	...	...	...	...
	(3.38)	(3.15)				
Long-run elasticity of capital	0.445	0.333	0.426	0.319	0.538	0.474
Long-run elasticity of schooling in education level$_j$	0.426	0.349	0.230	0.220	0.104	0.101
Adjusted R^2	0.962	0.953	0.962	0.948	0.960	0.962
F-statistic	141.8	35.85	159.9	33.56	152.6	49.02
Durbin Watson b/	1.756	1.978	1.944	2.055	1.790	2.205
S.E. of regression	0.012	0.014	0.012	0.014	0.012	0.012
N	51	50	51	50	51	50

Note: The regressions include a 1977 step dummy and impulse dummies for 1963 and 1982, significant at 1%. a/ Asymptotic critical values of the t-ratio are from Banerjee et al. (1998). b/ A Breusch-Godfrey test finds no evidence for the presence of first, second and third order correlation in the residuals.

t-statistics in parenthesis. ** Significant at 1%, * significant at 5%.

Source: Author's calculations.

Finally, it is interesting to observe the changes of the physical capital coefficients by level of education. In the IV specification for primary and secondary schooling, capital only enters as weakly significant. By contrast, the coefficient for physical capital becomes very significant and alters its long-run elasticity if tertiary education is entered into the estimate.

To the extent that this effect does not merely reflect statistical arbitrariness, a possible interpretation would be that the productivity of physical capital is affected by tertiary schooling. These findings support the conjecture of Romer (1990b) that the level of scientific education should be correlated with the rate of growth and the share of output devoted to investment in physical capital. It should be kept in mind, however, that the reliability of tertiary education data is comparatively poor in Guatemala. Moreover, according to Anderson (2001), low quality and internal inefficiency plague university education. Hence, some care should be taken before drawing too strong conclusions from the observed changes.

5.4 Mincerian Human Capital Specification

An important question is how the effect of schooling at the macro level compares with the microeconomic evidence. The macro returns could be higher because of externalities from education. For example, if post-primary schooling leads to technological progress that is not captured in the private returns to education, or if education produces externalities in the form of the reduction of crime, more informed political decisions, better health and so on. To reconcile the macro effect of schooling with the micro level, Cohen and Soto (2001) estimate the following production function:

(21) $$Y_t = A_t \cdot K_t^{a} \cdot HM_t^{(1-a)}$$

where Y is output, A total factor productivity, K physical capital, and HM human capital. As first suggested by Bils and Klenow (2000), the micro evidence derived from a log-linear Mincer (1974) formulation can be used to specify the aggregate human capital stock as follows:

(22) $$HM_t = e^{y \cdot h_t} \cdot L_t \;\Leftrightarrow\; hm_t = e^{y \cdot h_t}$$

where hm_t is the human capital per worker, h_t is average years of schooling and y corresponds to the returns to education. This Mincerian approach has become popular in the literature since the work of Bils and Klenow.[26] The specification is a straightforward way of incorporating human capital into the production function in a

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[26] The working paper version was circulated prior to 2000. A caveat here is the missing role of experience.

manner that is consistent with the standard semi-logarithmic formulation for estimating returns to schooling at the micro level.

Nevertheless, Temple (2001) argues that the parameter y may not be interpreted as the social returns to schooling because it does not incorporate the opportunity costs of the resources used in educational provision. Still, it remains of considerable interest since an empirical estimate provides a way of either confirming or rejecting the importance of education suggested by micro studies.

For the Guatemalan case, the econometric specification is similar to the previous equations. The production function is first converted into a logarithmic expression:

$$\text{(23)} \qquad \log y_t = \log A_t + a \cdot \log k_t + (1-a) \cdot y \cdot h_t$$

Then, the production function is transformed into an error-correction formulation, which allows the long-run schooling parameter to be identified:

$$\text{(24)} \qquad \Delta \log y_t = g_1 \cdot \Delta \log k_t + g_2 \cdot \Delta \log k_{t-1}$$
$$- g_3 \cdot (\log y_{t-1} - a \cdot \log k_{t-1} - (1-a) \cdot y \cdot h_{t-1} - \log A_{t-1}) + u_t$$

Finally, the error-correction model is re-parameterized and includes a series of dummy variables:

$$\text{(25)} \qquad \Delta \log y_t = c + g_1 \cdot \Delta \log k_t + g_2 \cdot \Delta \log k_{t-1}$$
$$+ g_3 \cdot \log y_{t-1} + g_4 \cdot \log k_{t-1} + g_5 \cdot h_{t-1} + \sum_j d_j \cdot dummy_{j,t} + u_t$$

Notice that the implicit return to schooling can be calculated with knowledge of a and g_3. In principle, this approach would also allow the productivity effect of schooling to be differentiated by education level, as mentioned by Wößmann (2003). Unfortunately, the results here were found unstable for disaggregated education data. This is presumably due to the missing logarithmic transformation of the schooling variables.

Insofar, the specification provides an attractive way for comparing macro and micro evidence on the returns to schooling, but in a time series context tends to produce fragile parameter estimates. Nevertheless, when using aggregated data on human capital the regressions perform quite satisfactorily. Table 7 presents the results. Controlling for endogeneity does not distort the empirics. In the IV specification 1

Table 7. Production Function for Guatemala: Mincerian Human Capital Specification, 1951-2002

	Dependent variable: Percent change of GDP/worker	
	OLS	IV [a/]
Explanatory variables	(1)	(2)
Constant	-0.068** (-4.28)	-0.072** (-3.78)
Percent change of capital/worker	0.865** (28.7)	0.752** (6.05)
Percent change of capital/worker [-1]	0.104** (2.77)	0.163* (2.56)
log GDP/worker [-1] [b/]	-0.200** (-5.35)	-0.240** (-4.94)
log capital/worker [-1]	0.069* (2.56)	0.058 (1.45)
Average years of schooling [-1]	0.029** (4.56)	0.034** (4.28)
Step dummy 1977	-0.035** (-3.97)	-0.035** (-3.40)
Impulse dummy 1963	0.058** (4.63)	0.058** (4.11)
Impulse dummy 1982	-0.070** (-4.24)	-0.080** (-3.85)
Long-run elasticity of capital	0.343	0.240
Effect of 1 additional year of average schooling	0.219	0.184
Adjusted R^2	0.962	0.953
F-statistic	159.2	41.08
Durbin Watson [c/]	1.858	2.133
S.E. of regression	0.012	0.014
N	51	50

a/ Lags of the independent variables are used as instruments. b/ Asymptotic critical values of the t-ratio are from Banerjee et al. (1998). c/ A Breusch-Godfrey test finds no evidence for the presence of first, second and third order correlation in the residuals.

t-statistics in parenthesis. ** Significant at 1%, * significant at 5%.

Source: Author's calculations.

additional year of schooling increases income per worker by approximately 18.4 percent.[27] This number suggests that the macro return to schooling in Guatemala is rather high, but it compares favorably with earlier microeconomic evidence. For example, the World Bank (1995) reports a private return to schooling of 14.9 percent for Guatemala.[28] There is evidence for much lower returns in the informal sectors and for decreasing patterns over time, but the magnitude of the coefficient is echoed in Funkhouser (1997). An estimate from Haeussler (1993) based on 1989 survey and Ministry of Education data suggests that, depending on the schooling level and underlying assumptions, the social return to schooling lies in a band between 13-19 percent. Finally, these results also confirm the cross-country evidence from Cohen and Soto (2001). They essentially find that in macro and micro regressions the effect of education on income is of similar magnitude.

6. Robustness Check and Additional Explanatory Variables

This section seeks to answer some basic questions. How much confidence should be placed on the previous results? Evidently, given certain data restrictions and distortions caused by the civil war, a key issue is if the previous findings can be used to derive firm policy conclusions. In addition, another important aspect is considered: does the conditioning information set cause the schooling coefficients to change?

In order to answer these questions, the following paragraphs are organized as follows. Section 6.1 tests the stability of the variables. By comparing the results with alternative sources, section 6.2 includes time trends, and analyzes the reliability of the human and physical capital stock data. Section 6.3, the bulk of the analysis, includes additional variables explaining growth. An overview of the alternative data is presented in Figure 7. Additional variables are the quality of capital, trade openness, terms of trade, and imported capital goods. This section also examines the effect of life expectancy as a companion indicator for human capital. In addition the role of military expenditures is analyzed, which, among others things, may serve as a proxy for bad governance in Guatemala. Section 6.4 closes with a brief summary of the findings.

6.1 Stability of Coefficients

Given the distortions of the economy by the civil strife and other events, it is imperative to evaluate the stability of the coefficients. For example, comparing data

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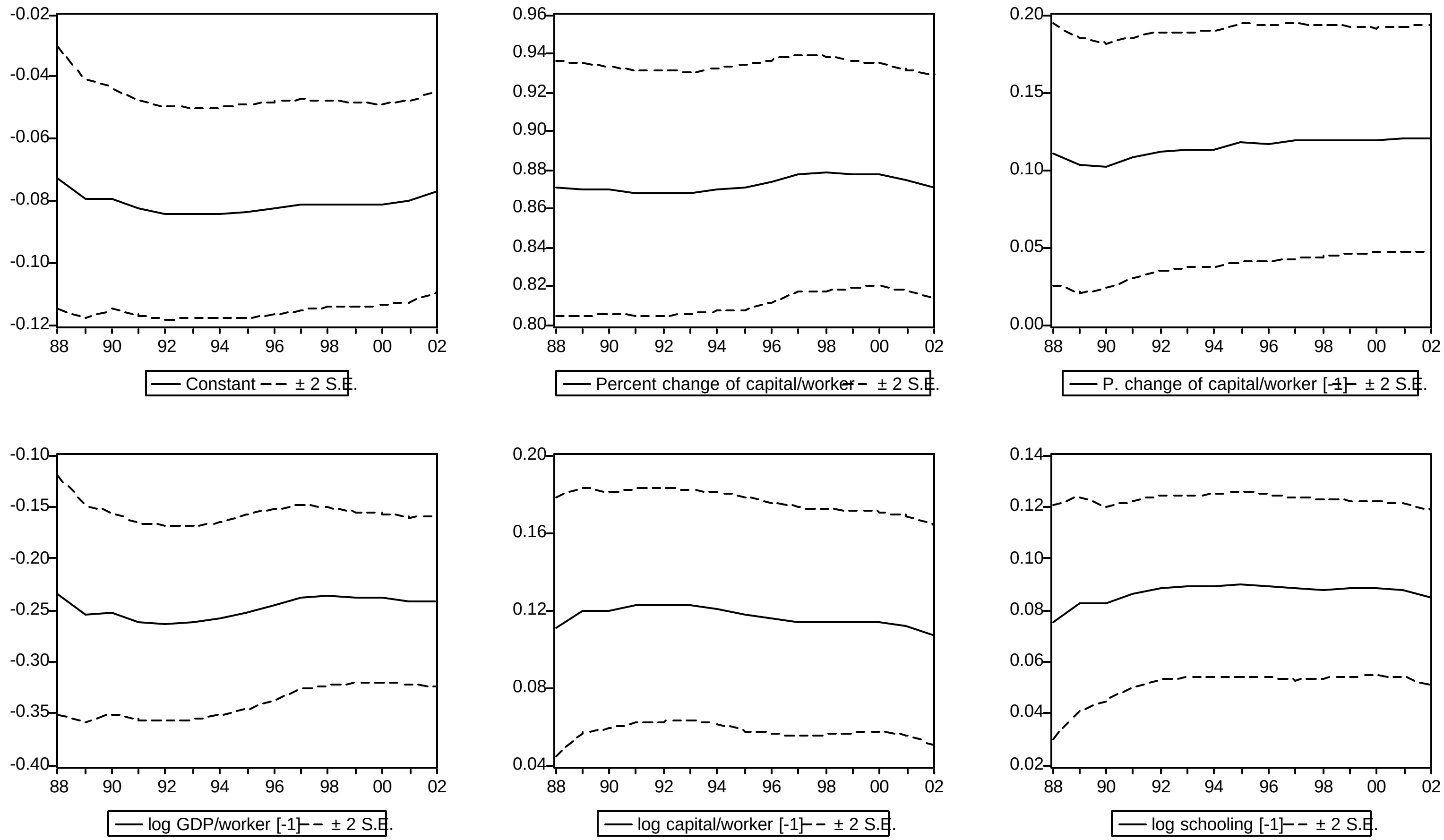
27 According to the Table, the implicit return to schooling can be calculated as follows: (0.034/0.240)/(1-0.240)˜0.184. Discrepancies are due to rounding.

28 Based on ENCOVI (2000) survey data the World Bank (2003a) reports an overall rate of return of 6 percent.

Figure 6. Parameter Stability: Recursive Coefficients — Production Function with Average Years of Schooling Specification, 1988-2002



Note: Based on the OLS estimate presented in Table 5, column 1.

from different points of time could cause coefficients to show dramatic jumps. In this case, it would be almost impossible to interpret the magnitude and sign of the coefficients. In order to test for instability, this section evaluates parameter stability using recursive least squares. This allows a year-by-year comparison of the coefficients since ever larger subsets of the time series data are used in the regression.

With reference to the production function augmented for human capital, Figure 6 visualizes the recursive coefficients of the regression (Table 5) estimated by OLS. Also shown are the standard error bands around the coefficients. The coefficients do not display significant variations when more data is added to the equation. This is in particular true for the schooling parameter and indicates stability. In the light of permanent shocks to the Guatemalan economy, it is reassuring to note that the coefficient plots do not show significant jumps since the error-correction specification here is capable of digesting these disruptive events. Due to space limitations Figure 6 does not include the recursive coefficients for the 3 dummy variables, although they have been found to be equally stable. Parameter stability was found satisfactory as well using a Mincerian human capital specification (Table 7) or employing disaggregated data on educational attainment (Table 6).

6.2 Alternative Data Sources

The estimates in this study ultimately rely on constructed time series. Consequently it is possible to ask: May the earlier results be related to arbitrary improvements during the stage of data construction? In order to pre-empt any suggestions of data mining, in particular with reference to the human and physical capital stock, this section discusses the use of alternative data sources. The benchmark for the subsequent variations in the data is the production function augmented for human capital (see Table 5).

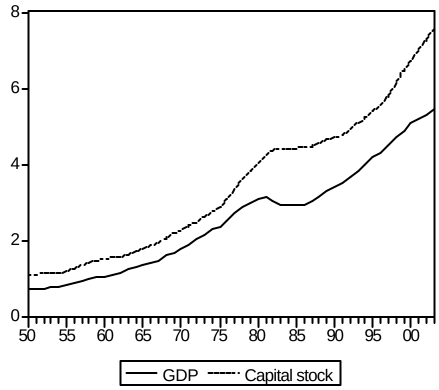
The results of the sensitive tests are reported in Table 8. In general, the following regressions do not perform as well as the earlier estimates but still satisfactorily pass conventional tests. A Breusch-Godfrey serial correlation test suggests the possibility that the estimates (only in column 1 and 4) might present mild evidence ($p<0.15$) of first order serial correlation. Since the indication was weak and would make little impact, no correction for it was attempted. In addition, the nature of the following exercise does not necessitate absolute precision but rather enriches the earlier findings. The following results suggest in general that the findings are not sensitive to the conditioning data set but rather strengthen the final conclusions about the importance of human capital.

Inclusion of Time Trends

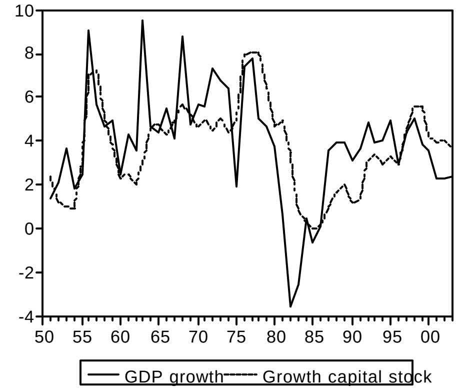
Column 1 of Table 8 presents the original estimate for average years of schooling (Table 5), and also includes two time trends in order to account for the possibility of missing explanatory variables. The inclusion of the trend variables was motivated by

Figure 7. Guatemala: Additional Explanatory Variables of Growth, 1950-2002

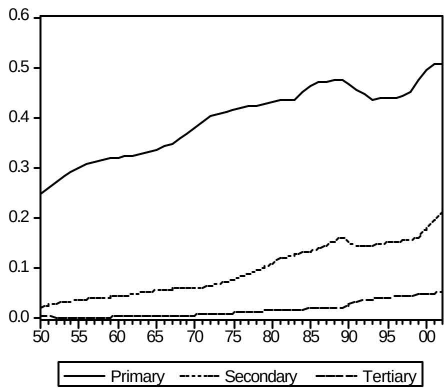
(a) GDP and Capital Stock (5 percent depreciation), Billions of 1958 Quetzals



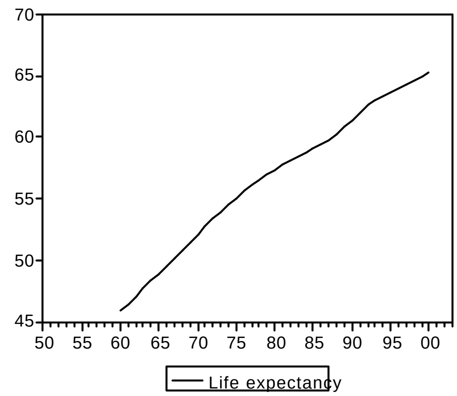
(b) Annual Growth of GDP and Capital Stock (in percent)



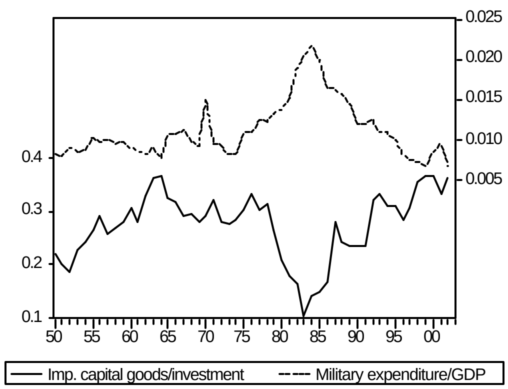
(c) Participation of Primary, Secondary and Tertiary Education in Labor Force (share)



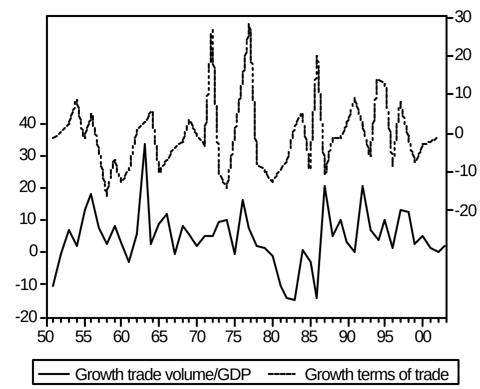
(d) Life Expectancy at Birth (y ears)



(e) Imported Capital Goods/Investment and Military Expenditure/GDP (shares)



(f) Annual Growth of Terms of Trade and Trade Openness (in percent)



Data sources: See Appendix.

a look at the residual plot of the earlier estimates. They show moderate variations during these time periods, in particular since 1999.

The inclusion of the trend variables does not have a substantial impact on the significance level of the long-run elasticities, albeit the magnitude of the coefficients is moderately affected. While the schooling coefficient decreases minimally, the physical capital coefficient is augmented. The time trend for 1985 is significantly positive but there is a negative trend since 1999. Interestingly, both time periods are related to political events. 1985 is the transition year to civilian rule. 1999 is the election year of the Alfonso Portillo government, where compromised representatives of the former military nomenclature are suspected of wielding political power.

To the extent that this association is correct, a loose interpretation would suggest that in Guatemala the strengthening (weakening) of civilian rule has a significant positive (negative) impact on long-run growth. While at first sight this interpretation appears plausible, however, it is obvious that other factors are important as well. Moreover, the growth-enhancing channel of democratic rights might be operating indirectly on some independent variables, such as educational attainment. This complicates the analysis. Hence, further research is needed to strengthen this hypothesis.

Alternative Capital Stock Data

Column 2 of Table 8 includes capital stock data with a 4 percent depreciation rate rather than the 5 percent thumb value assumed throughout this study. The data with 4 percent depreciation is essentially identical to the Nehru and Dareshwar (1993) capital stock series, despite some minor discrepancies? when compared with data from Banco de Guatemala? on investment. Assuming 4 percent depreciation of the capital stock has little impact on the results, although in the IV specification the significance of the capital coefficient is weakened. This suggests that a 4 percent depreciation is rather on the low side.

Column 3 includes the capital stock estimate built with disaggregated investment data originally constructed to compute the quality index for capital. This series is robustly correlated with growth. The long-run elasticities for physical and human capital are slightly higher than with the standard estimate of the capital stock. Due to the limited number of observations the regression could only be run by OLS. Thus, the coefficients are likely to be upwardly biased. Altogether, varying the assumptions about the depreciation rate moderately changes capital elasticities but does not change very much the role of human capital on growth.

Alternative Schooling Data

The most interesting sensitive test concerns the validity of the conclusions on the importance of human capital to growth. Column 4 uses interpolated education data from Barro and Lee (2001). Column 5 includes the interpolated time series from Cohen and Soto (2001) into the regressions. In both estimates human capital, as measured by average years of schooling, is robustly correlated with growth.

Table 8. Guatemala: Robustness of Results—Alternative Data Sources

	Dependent variable: Percent change of GDP/worker					
	Includes time trends starting in 1985 and 1999	4 percent depreciation of capital stock	Disaggregated capital stock estimate [b/]	Barro and Lee (2001) education data [c/]	Cohen and Soto (2001) education data [c/]	Population 15-64 instead of labor force data
	IV 1951-02	IV 1951-02	OLS 1971-02	IV 1951-00	IV 1961-02	OLS 1951-02
Explanatory variables	(1)	(2)	(3)	(4)	(5)	(6)
Constant	-0.071** (-4.05)	-0.075** (-3.46)	-0.042* (-2.57)	-0.073** (-4.31)	-0.061** (-4.43)	-0.013 (0.66)
Percent change of capital/worker	0.865** (8.44)	0.780** (5.59)	0.827** (33.0)	0.730** (10.3)	0.847** (9.18)	0.507* (2.44)
Percent change of capital/worker [-1]	0.119* (2.41)	0.168* (2.54)	0.167** (4.37)	0.160** (3.28)	0.138** (3.16)	...
log GDP/worker [-1] [a/]	-0.259** (-6.14)	-0.243** (-4.88)	-0.333** (-7.06)	-0.279** (-5.45)	-0.272** (-5.40)	0.040 (0.72)
log capital/worker [-1]	0.113** (3.19)	0.078 (1.63)	0.180** (5.47)	0.080* (2.40)	0.108* (2.10)	-0.127* (-2.02)
log average years of schooling [-1]	0.074** (4.54)	0.083** (4.58)	0.130** (6.65)	0.133** (4.86)	0.072** (5.53)	0.026 (1.53)
Trend 1985	0.002** (2.83)	...	...	...	...	...
Trend 1999	-0.008* (-2.50)	...	-0.008** (-3.63)	...	...	...
Long-run elasticity of capital	0.436	0.322	0.541	0.288	0.399	N.A.
Long-run elasticity of schooling	0.287	0.344	0.392	0.476	0.266	N.A.
Adjusted R^2	0.972	0.958	0.982	0.955	0.975	0.648
F-statistic	57.55	43.28	180.4	59.61	67.88	14.92
Durbin Watson	2.440	2.162	2.174	2.441	2.151	1.879
S.E. of regression	0.011	0.013	0.009	0.013	0.010	0.014
N	50	50	31	49	40	51

Note: The regressions include a step dummy for 1977 and impulse dummies for 1963 and 1982 significant at 1%. a/ Asymptotic critical values of the t-ratio are from Banerjee et al. (1998). b/ Includes 1976 and 1982 impulse dummies significant at 1%. c/ Data is interpolated.

t-statistics in parenthesis. ** Significant at 1%, * significant at 5%.

Source: Author's calculations.

Table 9. Guatemala: Effect of Schooling on Growth by Level of Education Considering Quality of Capital and Trade Openness, 1971-2002

	Dependent variable: Percent change of GDP/worker					
	j = primary		j = secondary		j = tertiary	
	OLS c/	OLS c/ d/	OLS c/	OLS c/ d/	OLS c/	OLS c/ e/
Explanatory variables	(1)	(2)	(3)	(4)	(5)	(6)
Constant	-0.048+ (-1.93)	-0.065** (-3.19)	0.042** (4.07)	0.031** (3.33)	0.125** (3.19)	0.112** (4.08)
Percent change of quality-adjusted capital/ worker	0.833** (26.5)	0.862** (31.9)	0.791** (25.9)	0.838** (29.2)	0.832** (25.8)	0.868** (36.4)
Percent change of quality-adjusted capital/ worker [-1]	0.158** (3.20)	0.182** (4.50)	0.153** (3.11)	0.162** (3.97)	0.106* (2.63)	0.050 (1.64)
log GDP/worker [-1] a/	-0.342** (-5.32)	-0.266** (-7.48)	-0.322** (-5.37)	-0.332** (-6.56)	-0.694* (-4.89)	-0.571** (-5.64)
log quality-adjusted capital/worker [-1]	0.181** (3.19)	0.106** (3.81)	0.119** (2.95)	0.141** (3.91)	0.352** (4.08)	0.283** (4.58)
log participation of education level$_j$ in labor force [-1]	0.094+ (1.72)	0.163** (4.28)	0.075** (3.90)	0.063** (3.84)	0.071** (3.03)	0.056** (3.39)
Step dummy 1977	...	...	-0.034** (-2.88)	-0.024* (-2.38)	-0.049** (-3.92)	-0.051** (-5.62)
Step dummy 1984	...	...	...	...	0.032** (4.11)	0.030** (5.44)
Step dummy 1986	0.026* (2.37)	...	...	...	...	...
Percent change of trade volume/GDP	...	0.141** (4.20)	...	0.117** (3.20)	...	0.017 (0.68)
Long-run elasticity of capital	0.529	0.401	0.370	0.424	0.507	0.496
Long-run elasticity of schooling in education level$_j$	0.274	0.614	0.233	0.188	0.103	0.098
Adjusted R^2	0.972	0.982	0.970	0.980	0.976	0.988
F-statistic	132.7	180.0	124.3	148.1	150.9	232.1
Durbin Watson b/	2.023	2.007	2.028	1.787	1.961	1.979
S.E. of regression	0.011	0.009	0.011	0.009	0.010	0.007
N	31	31	31	31	31	31

a/ Asymptotic critical values of the t-ratio are from Banerjee et al. (1998). b/ A Breusch-Godfrey test finds no evidence for the presence of first, second and third order correlation in the residuals. c/ Includes impulse dummies for 1976 and 1982 significant at 5%. d/ Includes 1986 impulse dummy significant at 1%. e/ Includes impulse dummies for 1975 and 1996 significant at 5%.

t-statistics in parenthesis. ** Significant at 1%, * significant at 5%, +significant at 10%.

Source: Author's calculations.

In addition, the parameter estimate yields a long-run elasticity in the range of 0.29-0.39. This magnitude is similar to the benchmark results obtained in the earlier estimate. Given the interpolated nature of these sources, a too strong interpretation of the associated changes makes little sense. Insofar, the sign and significance of the variables are more important than their magnitude. All in all, employing alternative data on human capital confirms the earlier conclusions about the importance of education on growth.

Population Instead of Labor Force Estimate

The regression in column 6 employs population data (15-64 years) instead of the labor force. Alternatively ILO labor force estimates could be used. The time series properties, however, are almost identical, and population statistics refer to a longer time period. In any case, the results are rather disappointing. That is, the significance of the coefficients and the overall fit of the model are poor. In order to ameliorate the estimate, the lag structure of the short-run capital coefficients was modified.

Human capital still enters positively but is only weakly significant. A puzzling finding is that long-run capital accumulation has now a negative impact on growth, which is a counterintuitive and implausible result. Overall, given the absence of fluctuations and considering the civil war, Guatemalan population data seems to be a poor proxy for labor as well.

6.3 Additional Explanatory Variables

When the conditioning set of data in the regressions is modified, it is interesting to observe changes in the explanatory variables, such as schooling. For example, the production elasticities of human or physical capital could be larger than their factor shares because of presumed externalities. The benchmarks of the following analyzes are the results in section 5. When possible, the following paragraphs differentiate for the effect of primary, secondary and tertiary schooling.

Quality-Adjustment Capital

Column 2 of Table 10 shows an OLS estimate for the period 1971-2002 when the capital stock is adjusted for quality. For comparative purposes, column 1 presents the same regression but without such an adjustment. Following de Ferranti et al. (2002) the intuition behind this exercise is that embodied technological change could have a positive impact on the returns to education, in particular for post-primary schooling. However, in the case of Guatemala, the overall effect seems to be the opposite. An increase in the long-run elasticity for physical capital and a decrease of the importance of education on growth is found.

To interpret this puzzling finding recall that the index of capital quality actually measures a decay by about 20 percent. In contrast, human capital and hence labor quality, have increased substantially over time. This may point in the direction of a missing capital-skill complementarity in Guatemala, which would tend to reduce the returns to education. Interestingly, this effect impacts mainly on primary education. If one compares the respective elasticities of Table 6 (columns 1, 3 and 5) and Table 9 (columns 1, 3 and 5) the econometric results suggest that introducing quality adjustments for capital have little effect on secondary and tertiary education. Nevertheless, given the limited sample size of only 31 observations a word of caution is required here. These findings should be strengthened by additional research.

Trade Openness

Growth is often thought to be enhanced by trade openness. Apart from comparative–advantage arguments, it is argued that openness expands potential markets, facilitates the diffusion of technological innovations, improves managerial practices and promotes domestic competition, all of which increase efficiency. Considering the small size of the Guatemalan economy trade openness is of particular interest. For case of Latin America, Loayza et al. (2002) present evidence suggesting a significant relationship between trade openness and growth.

Column 3 of Table 10 suggests that the growth rate of trade openness is positively and significantly related to Guatemalan GDP growth. By contrast, the elasticities for physical and average human capital do not show significant variations. This finding changes, however, if disaggregated data on educational attainment is entered into the estimate. Table 9 reveals that the inclusion of the growth rate of trade openness alters the coefficient for primary education, while secondary and tertiary schooling remain more or less unchanged (columns 2, 4 and 6). The parameters for post-primary schooling are of a similar magnitude as those in the earlier estimate which did not consider trade openness (Table 6, columns 1, 3 and 5). Interestingly, in both cases, the coefficients for post-primary schooling are of almost identical magnitude, which is also an indication of robustness. The fact that trade affects only primary education may suggest that, over the past decades, general education and basic technical skills have been the key determinants for the diffusion of technological innovations. Or, more generally, the people with primary education seem to benefit particularly from the effects of trade openness.

Somewhat surprisingly, the econometric evidence reveals that trade openness, as measured by the trade volume over GDP, exhibits a short-run effect on growth. The long-run coefficient was found insignificant and as such excluded from the model. A possible interpretation of this finding points in the direction of Rodríguez and Rodrik (2000). They cast doubt on the robustness with respect to measurement concepts and specifications of the bulk of the empirical evidence on this topic. Instead, they suggest exploring alternative causal interpretations. For example, an additional indirect channel might be that more-open economies adopt better policies and institutions that explain part of the effects of openness on growth. Following this interpretation, hitherto, trade openness in Guatemala has not been associated with political change (see also Box 1).

Column 3 indicates that improvement in the terms of trade, that is, a higher growth of the ratio of export prices to import prices, seem to enhance short-run economic growth. In line with the effect of trade openness, the long-run coefficient was found insignificant. However, the positive impact of terms of trade growth must be regarded with some caution. This is essentially because its significance was found fragile considering the conditioning set of variables that enter into the regression.

Foreign Capital Goods

International trade may have an additional impact on growth through the imports of foreign capital goods. Lee (1995) emphasizes that developing countries can increase the efficiency of capital accumulation and thereby the rate of growth by importing relatively cheap foreign capital goods from higher income countries. Taking into account this potential avenue of trade on growth, the ratio of capital imports to total investment is used as a proxy variable for the efficiency of capital accumulation. The regression of column 4 in Table 10 indicates that the composition of investment is indeed an important determinant for long-run growth in Guatemala. The implied elasticity suggests that a 1 percent increase in the ratio of capital imports to total investment increases output by about 0.10 percent. This supports the idea of Lee that more use of imported capital goods increases the efficiency of capital accumulation. Therefore, any trade distortion that restricts the importation of capital goods damages the economy in the long run. Such distortions also include disincentives for trade, such as a climate that discourages investment. Thus, continuing political instability and a climate of violence dampens the prospective for growth not only for the present, but also for future.

Notice that the inclusion of the variable alters the coefficients for capital accumulation but has little impact on the elasticity of average years of schooling. Unfortunately, measuring the impact of foreign capital goods on schooling by level of education was hampered by implausibly high, albeit positive, parameter estimates for schooling. Tentatively, such an exercise reveals an altering of the coefficients for primary education but has little impact on secondary and tertiary schooling. This clearly supports the earlier finding of the effect of trade openness on growth by level of education.

Life Expectancy

Given the incomplete nature of education to proxy for human capital, a look at the effect of the health status yields important insights. Column 5 includes life expectancy at birth into the regression. The schooling variable is removed due to collinearity. The health variable is highly significant and has a very strong impact on long-run growth. The estimate suggests that a 1 percent increase in life expectancy would increase output by about 1.04 percent. Barro (2001) suggests that the variable has such a strong impact on growth because it may proxy for features other than health, such as social capital, better work habits and a higher level of skill. The elasticities could be biased due to the reliance on interpolated data sources.

Nevertheless, the results support the view that human capital policies in Guatemala should place a strong emphasis on the health status of the population. This finding is equally echoed by the World Bank (2003a) that places Guatemala among the worst performers in terms of health outcome in Latin America, and particular poor in child nutrition.

Military Expenditures and Governance

Given the strong influence of military rule in Guatemala's recent history, it is finally imperative to discuss the role of military expenditure on growth.[29] This issue is particularly important since in the light of Guatemala's low tax burden military expenditures will necessarily be met at the expense of other government services, such as education and health. Military spending shows the priority given to other fiscal functions by the government and serves as an indicator of the military's power as a lobby. As such, *Guatemalan* military expenditures may also indicate political corruption and other aspects of bad government.

However, a number of channels by which military spending can influence growth have been identified. According to Deger and Sen (1995), the defense sector can take skilled labor away from civilian production, but it can also train workers. It could crowd out resources for investment and impact negatively on the efficiency of resource allocation, but also provide positive externalities for the civilian sector, such as infrastructure development. It can stipulate civil strife, but also generate an increase in national security and strengthen property rights. Thus, the role of military expenditure is ambiguous and the direction of the overall effect remains an empirical question.

Given the historical and political context of Guatemala, however, it is hard to believe that military expenditure plays a positive role on economic growth. According to the Commission for Historical Clarification (1999) an overwhelming number of violent actions during the civil war was attributed to members of the army. In addition, forced displacement and mandatory civil defense patrols (*Patrullas de Autodefensa Civil*? PACs) diverted a significant share of the economically active population from productive activities. Guatemalan defense spending reached its height during the peak of the civil war and declined in the advent of the peace process. They eventually began to rise again in 2000. Even without econometric analysis, a look at Figure 7e reveals that output growth is essentially opposite to the ratio of military expenditure to GDP. Moreover, the negative correlation of the share of foreign capital goods to investment suggests that a higher ratio of military expenditure to GDP is associated with a decrease in the efficiency of capital accumulation. When military

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[29] As a share of GDP, military expenditure in Guatemala is not excessively high, ranging from 0.7 up to 2 percent. However, its share of government expenditures is quite significant. According to Scheetz (2000) it has varied from approximately 14 up to 31 percent (in the 1980s) in terms of total resources controlled by the Treasury.

Table 10. Guatemala: Additional Explanatory Variables to Growth

	Dependent variable: Percent change of GDP/worker					
	Without quality adjustment for capital [b/]	With quality adjustment for capital [b/]	Terms of trade and trade openness [b/]	Capital imports/ investment [c/]	Life expectancy instead of schooling [d/]	Military spending/ GDP
	OLS 1971-02	OLS 1971-02	OLS 1951-02	IV 1951-02	IV 1961-00	IV 1951-02
Explanatory variables	(1)	(2)	(3)	(4)	(5)	(6)
Constant	-0.080** (-4.62)	-0.120** (-3.66)	-0.073** (-5.49)	-0.070** (-3.69)	-1.266** (-5.16)	-0.215** (-3.85)
Percent change of capital/worker	0.818** (28.1)	0.793** (27.6)	0.891** (35.7)	0.929** (8.84)	0.784** (9.96)	0.846** (8.31)
Percent change of capital/worker [-1]	0.170** (3.92)	0.171** (3.61)	0.115** (3.56)	0.118* (2.20)	0.134** (2.95)	0.140** (2.81)
log GDP/worker [-1] [a/]	-0.230** (-5.40)	-0.408** (-5.83)	-0.227** (-6.76)	-0.316** (-5.96)	-0.307** (-5.34)	-0.316** (-6.38)
log capital/worker [-1]	0.070* (2.13)	0.167** (3.77)	0.095** (4.10)	0.206** (4.24)	0.135** (2.81)	0.159** (4.35)
log average years of schooling [-1]	0.105** (4.94)	0.149** (4.46)	0.086** (6.00)	0.092** (5.19)	...	0.102** (6.20)
log life expectancy [-1]	...	...	...	...	0.316** (5.09)	...
log military expenditure/GDP [-1]	...	...	...	...	...	-0.024* (-2.42)
Imported capital goods/investment [-1]	...	...	...	0.032** (2.73)	...	...
Percent change of trade volume/GDP	...	...	0.089** (3.57)	...	...	...
Percent change of terms of trade	...	...	0.037* (2.39)	...	...	...
Long-run elasticity of capital	0.306	0.409	0.420	0.653	0.439	0.501
Long-run elasticity of schooling	0.458	0.365	0.378	0.289	N.A.	0.323
Adjusted R^2	0.976	0.974	0.977	0.965	0.969	0.972
F-statistic	158.2	140.3	191.7	45.82	61.45	57.49
Durbin Watson [e/]	1.785	2.013	2.303	2.308	2.208	2.365
S.E. of regression	0.010	0.011	0.009	0.012	0.011	0.010
N	31	31	51	50	39	50

Note: The regressions include a step dummy for 1977 and impulse dummies for 1963 and 1982 significant at 1%. a/ Asymptotic critical values of the t-ratio are from Banerjee et al. (1998). b/ Includes a 1976 impulse dummy significant at 1%. c/ Includes a time trend starting in 1999 significant at 5%. d/ Data is interpolated. e/ A Breusch-Godfrey test finds no evidence for the presence of serial correlation in the residuals.

t-statistics in parenthesis. ** Significant at 1%, * significant at 5%.

Source: Author's calculations.

expenditures are included into the regression, column 6 of Table 10 reveals a significant negative impact on long-run growth. The implicit elasticity suggests that a 1 percent increase in the defense burden decreases output by approximately 0.08 percent. Considering the negative correlation with imported capital goods (r = –0.69) and the effects of the internal war, however, the true magnitude of military expenditures on long-run growth may be underestimated.

6.4 Summing-Up

For the case of Guatemala, sensitive tests reveal that the relationship of human capital and growth proves stable. Parameter stability of the coefficients is acceptable and employing alternative data in fact strengthens the findings. An important aspect is that the health status of the country exhibits a strong impact on long-run growth. In the light of Guatemala's recent history, it does not come as a big surprise that military expenditure has hampered growth. One important point here is that it crowds out investment. By contrast, imported foreign capital goods exhibit a significant impact on long-run growth via an increase in the efficiency of capital accumulation. In agreement with the previous section, primary schooling has the strongest impact on productivity growth, and is particularly affected by adjustments for the quality of capital and the growth of trade openness.

7. Sources of Growth

The following paragraphs apply a modified growth-accounting framework to explore some basic facts of economic growth in Guatemala. Growth accounting can be very informative by providing a consistent decomposition of economic growth among its proximate sources. As such, growth accounting is a useful framework to explain a country's growth experience and may provide a basis for medium-term recommendations. The section is divided into four parts. Section 7.1 briefly describes the methodological framework. To facilitate comparisons section 7.2 presents alternative measures of the sources of growth for Guatemala. After giving the results of a traditional Solow (1957) decomposition, indices for the quality of inputs are considered. Section 7.3 extends the basic growth accounting framework to disaggregate by level of education. Finally, section 7.4 compares the results with international evidence.

7.1 Growth Accounting Framework

Growth accounting is a technique that seeks to identify the sources of economic growth. The standard aggregate production function that generates the growth accounting equation is:

$$(26) \quad Y_t = A_t \cdot K_t^{a} \cdot L_t^{(1-a)}$$

where Y, K and L represent output, physical capital stock and labor input, respectively. The term A is total factor productivity (TFP) and reflects the relative efficiency of the inputs to produce a given amount of output. The production function is assumed to have constant returns to scale and the markets are assumed to be competitive. In this framework, the growth rate of output can be represented as:

$$(27) \qquad \frac{\Delta Y_t}{Y_{t-1}} = \frac{\Delta A_t}{A_{t-1}} + a \cdot \frac{\Delta K_t}{K_{t-1}} + (1-a)\cdot\frac{\Delta L_t}{L_{t-1}}$$

where output growth is divided into components attributable to changes in the factors of production. TFP growth is a residual that represents the component of growth that is not explained by increases in the factors of production, but rather by productivity gains. The production function elasticities can give estimates of factor shares that are used to weigh the relative contribution of the inputs growth rates and to obtain straightforward estimates of the residual. Based on the results of the earlier regressions, the capital share, a , is taken to be equal to $^1/_3$. According to Bosworth et al. (1996) the econometric results are quite consistent with the evidence for other developing countries. Reliable estimates typically yield capital shares in the range of 0.3-0.4.

Estimates of Solow residuals are sensitive to the precision of the estimated factor shares, measurement errors, and adjustments for utilization and quality. For the case of Guatemala, as will be apparent in the next section, it is crucial to explicitly account for the quality of inputs.[30] Within the basic framework, changes in the quality of labor and physical capital are picked up in TFP. As such, TFP growth is overstated and the contribution of inputs is understated. In order to explicitly account for changes in the quality of inputs, the standard sources of growth equation is extended:

$$(28) \qquad \frac{\Delta Y_t}{Y_{t-1}} = \frac{\Delta A_t}{A_{t-1}} + a \cdot \left(\frac{\Delta K_t}{K_{t-1}} + \frac{\Delta zq_t}{zq_{t-1}}\right) + (1-a)\cdot\left(\frac{\Delta L_t}{L_{t-1}} + \frac{\Delta hq_t}{hq_{t-1}}\right)$$

where zq_t and hq_t are quality indices of capital and labor, respectively.

Another important consideration, not captured by the basic framework, is to account for the contribution by level of education. Barro (1998) describes extensions of the basic growth accounting framework to allow for disaggregation across different factor types. Incorporating primary, secondary and tertiary education into the production function augmented for human capital gives:

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30 Accounting for the degree of utilization of factor inputs is equally important. A common proxy is to use the unemployment rate. However, in the case of Guatemala with its extremely poor data on unemployment, such an adjustment is more likely to introduce measurement error than to correct for it.

(29) $$\frac{\Delta Y_t}{Y_{t-1}} = \frac{\Delta A_t}{A_{t-1}} + a \cdot \left(\frac{\Delta K_t}{K_{t-1}} \right) + \sum_{i=1}^{3} b_i \cdot \left(\frac{\Delta H_{i,t}}{H_{i,t-1}} \right) + (1 - a - \sum_{i=1}^{3} b_i) \cdot \left(\frac{\Delta L_t}{L_{t-1}} \right)$$

where H_i indexes for primary, secondary and tertiary schooling. The capital share for physical capital is $^1/_3$. Likewise, the shares for human capital, b_i, are taken from the earlier regression estimates disaggregated by level of education. To ensure comparability with the aggregate case, however, the coefficients are scaled so as to preserve the aggregate human capital share of approximately $^1/_3$. Consequently, the implicit shares for the aggregate case are 0.17 for primary, 0.11 for secondary and 0.05 for tertiary schooling.

Finally, before taking a look at the results, it is important to emphasize some methodological caveats of growth accounting. TFP reflects a whole range of factors since it captures everything that is not accounted for. It is hard to distinguish the effect of technological change from that of improved resource allocation, or from bias resulting from model deficiencies and poor data quality. Thus, TFP estimates may be affected by scale economies and can be sensitive to data perpetuation.

In addition, findings in the area of growth accounting require careful interpretation because the technique does not provide information about the interdependencies of the variables. For instance, an increase of output growth could be due to a percentage change in educational attainment. This would not imply that, in the absence of educational improvements, the growth rate would have been precisely the same percentage point lower. Quite the contrary, education could impact on output growth due to fertility, attitudes and labor force participation, investment and productivity. Therefore, growth accounting should be treated with caution and only be regarded as a useful technique for examining growth.

7.2 Sources of Growth in Traditional Framework

Table 11 presents a basic decomposition of GDP growth for Guatemala for 1951-2002. TFP is measured as the residual representing the component of growth not explained by labor or capital accumulation. There are no adjustments for the quality of inputs. The results suggest that growth in Guatemala is largely due to the accumulation of inputs. Labor plays the dominant role in explaining about 50 percent of Guatemala's growth rate of GDP, followed by the accumulation of capital with approximately 32 percent. Growth of TFP? unadjusted for the quality of inputs? was about 18 percent.

Introducing quality change in factor inputs brings the relative roles of capital and labor into a sharper focus. Table 12 presents a decomposition of GDP growth for 1971-2002. Average annual growth was about 3.5 percent, while it was 3.9 percent during the whole five decades. Compared to the basic growth accounting framework, the results change dramatically. In particular, quality-adjusted labor now explains about 78 percent of the growth rate of GDP, compared to 50 percent explained by the

Table 11. Guatemala: Decomposition of GDP Growth in Basic Framework, 1951-2002 (in percent) [a/]

Time Period	GDP Growth Rates	Contribution of		
		Capital	Labor	TFP
1951-55	2.3	0.6	-2.3	4.0
1956-60	5.4	1.7	4.0	-0.3
1961-65	5.3	1.1	3.8	0.3
1966-70	5.8	1.7	3.6	0.5
1971-75	5.6	1.6	2.2	1.9
1976-80	5.7	2.3	5.4	-2.0
1981-85	-1.1	0.6	-2.0	0.2
1986-90	2.9	0.4	3.1	-0.5
1991-95	4.3	0.9	1.2	2.2
1996-00	4.0	1.5	0.8	1.6
2001-02	2.3	1.3	1.6	-0.7
Average	3.9	1.2	2.0	0.7
		32%	50%	18%

Source: Author's calculations. a/ Discrepancies are due to rounding.

Table 12. Guatemala: Decomposition of GDP Growth Adjusted for Quality of Inputs, 1971-2002 (in percent) [a/]

Time Period	GDP Growth Rates	Contribution of		
		Capital	Labor	TFP
1971-75	5.6	1.5	3.6	0.5
1976-80	5.7	1.5	6.4	-2.1
1981-85	-1.1	0.2	-0.7	-0.5
1986-90	2.9	-0.1	3.5	-0.4
1991-95	4.3	1.1	0.6	2.6
1996-00	4.0	1.8	2.6	-0.4
2001-02	2.3	1.1	3.4	-2.3
Average	3.5	1.0	2.7	-0.2
		28%	78%	-6%

Source: Author's calculations. a/ Discrepancies are due to rounding.

unadjusted labor variable. This finding unambiguously suggests that the effect of the increase of education, now captured by the labor quality index, was the main driving force behind TFP growth during the past decades.

By contrast, quality-adjusted capital only explains about 28 percent of growth, compared to 32 percent explained by the unadjusted variable. Consistent with earlier findings, the decrease of capital accumulation in explaining GDP growth reflects the deterioration of the quality of the country's physical capital base. This is most likely associated with the disastrous effect of the civil war and a negative investment climate, among other factors. The finding of a negative rate of TFP growth of about 6 percent for the period 1971-2002 is a somewhat odd result. Rather than 'technological regress' it should be interpreted as an indication of the declining efficiency of the economy, due to the conflicting political and social environment of the country. Notice that TFP growth is consistent with the earlier regression results. In most specifications the constant term was found to be significantly negative.

How stable are these findings? The TFP estimate was found sufficiently robust. A sensitivity analysis based on alternative assumptions on the factor shares yielded TFP growth estimates ranging from –4 percent (capital share 0.4 and labor share 0.6) to –1 percent (capital share 0.5 and labor share 0.5). The associated changes of the contribution of labor and capital was negligible. Applying alternative data sources to calculate the residual was not found to be helpful. The robustness tests of the regression analyses clearly indicate that both the labor (based on IGSS data) and capital variable (5 percent depreciation) provide a higher explanatory power than other sources.

7.3 Disaggregation by Education Level

Table 13 shows the results of the extended growth accounting exercise for the period 1951-2002. The human capital variables now enter directly into the production function by level of education. They capture improvements in the country's skill base, which were formerly measured by quality-adjusted labor. At first sight, the overall results are somewhat similar to the decomposition of GDP growth in the traditional framework. With about 32 percent explaining growth, the role of physical capital accumulation is moderate.

At second sight, the contrast to the traditional framework is apparent. Table 13 suggests that human resources are the main engine of growth. In fact, the human capital variables alone explain approximately 50 percent of output growth. Of these, the main contribution comes from secondary education with about 21 percent. This is closely followed by primary education, which explains about 19 percent of growth. The contribution of tertiary education was only 10 percent.

Insofar, *both* primary and secondary schooling constitute major determinants of GDP growth. The fact that secondary education constitutes the dominant role reflects its rapid increase in the share of the economically active population. Approximately 20

Table 13. Guatemala: Decomposition of GDP Growth with Education Level Disaggregation, 1951-2002 (in percent) [a/]

Time Period	GDP Growth Rates	Contribution of					
		Capital	Labor	Education			TFP
				Primary	*Secondary*	*Tertiary*	
1951-55	2.3	0.6	-1.1	*0.0*	*0.7*	*-1.1*	3.2
1956-60	5.4	1.7	2.0	*1.3*	*1.1*	*1.1*	-1.7
1961-65	5.3	1.1	1.9	*1.2*	*1.2*	*0.7*	-0.8
1966-70	5.8	1.7	1.8	*1.4*	*0.8*	*0.7*	-0.5
1971-75	5.6	1.6	1.1	*0.9*	*0.9*	*0.7*	0.5
1976-80	5.7	2.3	2.7	*1.5*	*1.7*	*0.8*	-3.4
1981-85	-1.1	0.6	-1.0	*-0.3*	*0.1*	*0.0*	-0.6
1986-90	2.9	0.4	1.5	*0.8*	*0.8*	*0.6*	-1.3
1991-95	4.3	0.9	0.6	*0.1*	*0.2*	*0.5*	2.0
1996-00	4.0	1.5	0.4	*0.7*	*0.5*	*0.2*	0.6
2001-02	2.3	1.3	0.8	*0.6*	*1.3*	*0.3*	-2.1
Average	3.9	1.2	1.0	*0.8*	*0.8*	*0.4*	-0.3
		32%	25%	*19%*	*21%*	*10%*	-7%

Source: Author's calculations. a/ Discrepancies are due to rounding.

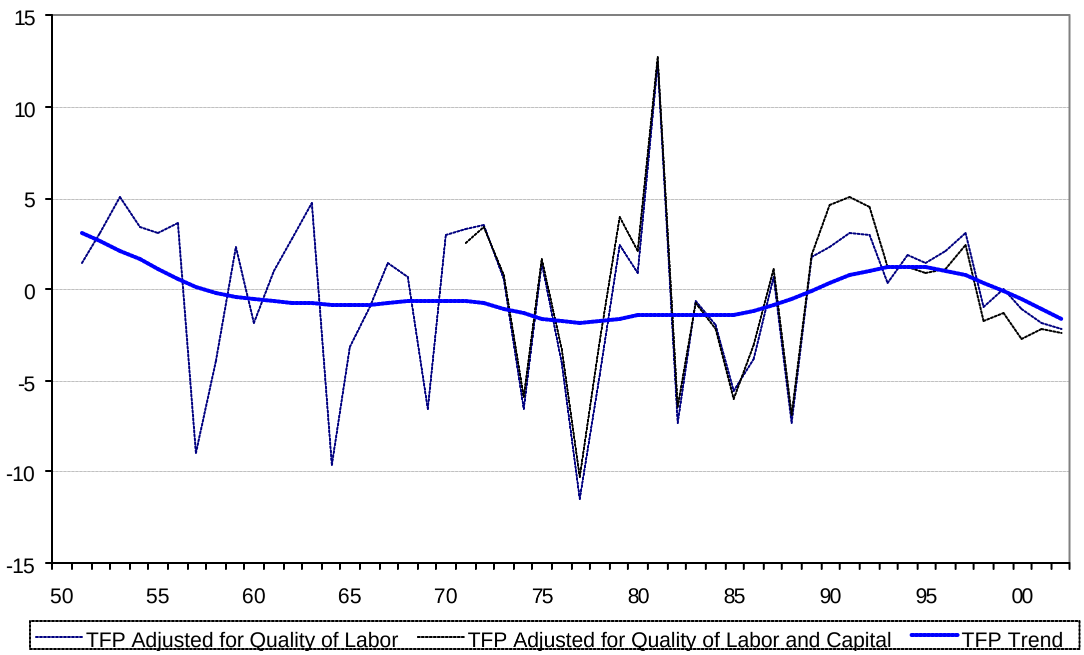
Table 14. Guatemala: Decomposition of GDP Growth with Education Level Disaggregation and Adjusted for Quality of Capital, 1971-2002 (in percent) [a/]

Time Period	GDP Growth Rates	Contribution of					
		Capital	Labor	Education			TFP
				Primary	*Secondary*	*Tertiary*	
1971-75	5.6	1.5	1.1	*0.9*	*0.9*	*0.7*	0.6
1976-80	5.7	1.5	2.7	*1.5*	*1.7*	*0.8*	-2.5
1981-85	-1.1	0.2	-1.0	*-0.3*	*0.1*	*0.0*	-0.2
1986-90	2.9	-0.1	1.5	*0.8*	*0.8*	*0.6*	-0.7
1991-95	4.3	1.1	0.6	*0.1*	*0.2*	*0.5*	1.8
1996-00	4.0	1.8	0.4	*0.7*	*0.5*	*0.2*	0.4
2001-02	2.3	1.1	0.8	*0.6*	*1.3*	*0.3*	-1.8
Average	3.5	1.0	0.9	*0.6*	*0.7*	*0.5*	-0.2
		28%	25%	*18%*	*21%*	*14%*	-6%

Source: Author's calculations. a/ Discrepancies are due to rounding.

percent of the labor force has had secondary schooling in 2000, compared to only about 2 percent in 1950. The increase of primary schooling in the labor over time was much slower. As evidenced on Table 3, during the past five decades it has essentially doubled. Finally, Table 14 presents a decomposition of GDP growth by level of education. Capital is here adjusted for quality. Notice that the quantitative results for the period 1971-2002 are almost identical to Table 12. Capital explains 28 percent of growth, compared to 78 percent explained by labor and education. Of these, secondary education plays the dominant role, followed by primary and tertiary education. Thus, the results of the different accounting exercise were found consistent over time.

Figure 8. Guatemala: Evolution of Total Factor Productivity, 1951-2002 (annual growth rates, in percent)



Source: Author's calculations.

Figure 8 plots the annual TFP growth rates for the period 1951-2002. It contains two measures of TFP. The dotted line indicates TFP growth adjusted for the quality of labor. The thin solid line presents TFP growth adjusted for the quality of capital and labor. Both lines show similar patterns. Productivity growth is volatile according to Figure 8. Also, it is apparently not free of measurement errors. For instance, the strong increase in 1981 is probably best interpreted by data deficiencies. Therefore, to facilitate the interpretation of the results, the bold trend line was included using the Hodrick-Prescott filter. Productivity growth has been positive, although slightly decreasing until the late 1950s. This was followed by a substantial deterioration from the early 1960 until the end of the 1980s. In the 1990s, TFP growth became positive again, but from 1999 on has eventually decreased.[31] All in all, Figure 8 obviously suggests that TFP growth in Guatemala was closely associated with political events.

7.4 Comparison of Results with International Evidence

How do these estimates compare to other Latin American countries? The Appendix summarizes the results of a study that applies a comparable methodology. Loayza et al. (2002) focus on the growth performance of 20 Latin American and Caribbean countries. Similar to the approach used here, they adjust for changes in the quality of labor associated with increased educational attainment.[32] Consistent with international evidence, Loayza et al. find that during the 1990s the recovery in output growth for the 'best' performers in the Latin American region was driven by increases in their rates of TFP growth, and less so by factor accumulation.

However, in most Central American countries TFP growth was only moderate. In some cases it was even negative. While TFP growth in Guatemala appears to be on the high side compared to its Central American neighbors, it is worth recalling that the estimate presented in the Appendix does not take into account quality changes of the physical capital stock. Given the decay of Guatemala's quality-adjusted capital stock, TFP growth is likely to be overstated. In addition, a one-to-one comparison is hampered by the nature of the different data sources.[33] Overall, Guatemala's growth experience shows some similarities with its neighbors, in particular with Costa Rica and El Salvador. During the 1990s these countries have experienced much faster growth than during the 1980s. In particular, quality-adjusted labor — associated with increased educational attainment — was the main source of growth.

8. Conclusion

Human capital has a highly significant and positive impact on long-run growth in Guatemala. The importance of human capital is substantial. An increase by 1 percentage point of average years of schooling would raise output by about 0.33 percent. The effect is of similar magnitude to that in micro studies. A disaggregated analysis by level of education reveals that primary schooling is most important for productivity growth, followed by secondary schooling. Over the past decades, it appears that general education and basic technical skills have been the main

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31 This finding is in agreement with other recent growth accounting studies for Guatemala, which are presented in Box 3.

32 Roldós (1997) examines the growth experience for Chile, and adjusts for changes in the quality of labor *and* capital. These results are in the Appendix.

33 For example, Loayza et al. (2002) rely on the Barro and Lee (2001) data set on educational attainment.

determinants for the diffusion of technological innovations, and people with primary education have particularly benefited from policies that promote competitiveness, such as trade openness. The stability of the error-correction model with respect to data issues and endogeneity concerns are the main reasons for confidence in the overall results. The robustness is even more remarkable in the context of heavy distortions within the Guatemalan economy.

Accounting for the sources of growth supports the importance of human capital in Guatemala. Such an exercise reveals that the increased skill level has been the main driving force behind productivity growth, and that education explains more than 50 percent of output growth during the past five decades. A differentiation by level of education suggests that the growth of secondary schooling was the predominant factor, closely followed by primary education. Tertiary education ranks last. Due to an environment of social and political conflict, however, total factor productivity has been slightly negative over the past decades. The evolution of productivity growth is linked to political events — such as the civil strife and military rule — and suggests a declining efficiency of the economy over time.

The study contains additional findings of interest, which ultimately point towards the importance of an institutional and political environment conducive to growth. They can be summarized as follows:

First, Guatemala's growth process was accompanied by the exclusion of large parts of society from wealth and by underlying social conflict. The growth rates of the sectors that employ the poor and rural people lagged behind other sectors of the economy. Extreme social imbalances and weak institutions for conflict management gave rise to an internal military conflict that imposed high costs for long-run growth. Regarding Guatemala's future growth prospects, a key factor for reducing the vulnerability of the economy to external shocks is to reduce inequality and to strengthen democratic institutions.

Second, mean education of the labor force has increased over time, although it suffered from the civil strife. The attention to education since the Peace Accords has only compensated the loss of human capital caused by the civil war, but does not represent a major improvement regarding the long-run growth of human capital. This means that considerably more effort is needed to strengthen the country's human capital base. The strong impact of life expectancy on growth suggests that human capital policies should not only focus on the expansion of the quantity as well as the quality of primary and secondary education, but in particular also place a great deal of emphasis on the health status of the population.

Finally, there is evidence of a missing complementarity between Guatemala's skills and its technology base. That is, for the period 1970-2002 the quality of Guatemala's physical capital stock decreased by about 20 percent. Prominent explanations for this decline are the destructive impact of the civil war, and a negative investment climate due to an unstable policy environment and a lack of good governance. The apparent gap between the evolution of quality of labor and physical capital could be a key factor for decreased output growth during the past decades. Decreased efficiency in capital accumulation also tends to reduce the returns to education, in particular for primary schooling. Hence, measures to stimulate investment and imports of foreign capital goods — for example by reducing trade distortions and improving the investment climate — are important complementary factors to human capital policies.

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Appendices

1. Guatemala: Augmented Dickey-Fuller Test for Unit Roots

	ADF test statistic	
Variables	Levels	First differences
log *y*	-2.24	-4.87**
log *k*	-1.85	-4.36**
log *k* (4 percent depreciation)	-1.76	-4.38**
log *k* (disaggregated estimate)	-1.33	-2.99*
log *k* (quality adjusted)	-2.04	-2.97*
log *h*	-0.23	-2.97*
log *h* (Barro and Lee)	-0.72	-4.76**
log *h* (Cohen and Soto)	-1.49	-4.54**
log primary schooling	-1.18	-3.37**
log secondary schooling	-0.07	-3.23**
log tertiary schooling	-1.35	-4.33**
log life expectancy	-2.41	-4.25**
log trade volume/GDP	-1.91	-4.21**
log terms of trade	-2.03	-5.20**
log capital imports/investment	-2.05	-4.74**
log military expenditure/GDP	-1.45	-5.17**

** (*) Rejects the hypothesis of a unit root at the 1 (5) percent significance level assuming 1 lag in the test equation, constant included. The MacKinnon critical values are –3.59 (-2.93) at the 1 (5) percent level.

2. Guatemala: Data Sources of Time Series

Variables	Abbreviation	Source
Gross domestic product (GDP) (in 1958 Quetzals)	Y	Banco de Guatemala.
Capital stock (in 1958 Quetzals)	K	Perpetual inventory estimates, see text.
Gross fixed capital formation (in 1958 Quetzals)	I	Banco de Guatemala. Aggregated data is for 1950-2002, disaggregated information applies for 1970-2002.
Annual rental rates	$v_{i,t}$	Calculations are based on Morán and Valle (2002) data set for implicit price estimates, and Banco de Guatemala for disaggregated gross fixed capital formation and real interest rates.
Physical capital quality index	zq	Estimated, see text.
Imports (in 1958 Quetzals)	IM	Banco de Guatemala.
Imported capital goods (in 1958 Quetzals)	IM_{cap}	Banco de Guatemala.
Exports (in 1958 Quetzals)	EX	Banco de Guatemala.
Commodity terms of trade (1970=100)	ToT	CEPAL and CIEN (Centro de Investigaciones Económicas Nacionales).
Military expenditure (in 1958 Quetzals)	MIL_{exp}	Ministry of Defense expenditures are calculated from Banco de Guatemala, as reported in *Memorias de Labores del Banco Central*. The data compares favorably with information from the Stockholm International Peace Research Institute (SIPRI).
Life expectancy at birth (years)		World Bank (2002).
Average schooling (years)	h	Perpetual inventory estimates, see text.
Participation of primary, secondary and tertiary education in labor force	hr_{pri} hr_{sec} hr_{ter}	Perpetual inventory estimates, see text.
Population statistics (15 and 20 year old, 15-64 year old)	$L15$ $L20$ $L15\text{-}64$	CEPAL and CELADE (2000).

Continued on following page.

Variables	Abbreviation	Source
Labor force, total	*L*	Derived from the number of private contributors to the IGSS, see text. Data for 1960-2002 is taken from Banco de Guatemala (2003). Data for 1955-1959 is obtained directly from IGSS. Missing values for 1950-1954 were derived from SEGEPLAN (1978).
Labor quality index	*hq*	Author's calculations, see text. The weights are taken from Table 6, columns 2, 4 and 6.
Primary and secondary gross enrollment ratios	*PRI* *SEC*	For 1960-1990 UNESCO estimates as reported in World Bank (2002). For 1991-2002 Ministerio de Educación (various years) and UNDP (2002). Primary gross enrollment ratios are that of *nivel primaria*. Secondary gross enrollment ratios are that of *nivel básico*. Missing values were completed with information provided in UNESCO (various), Mitchell (1998) and Ministerio de Educación and SEGEPLAN (1980).
Tertiary gross enrollment ratio	*TER*	For 1960-1987 UNESCO estimates as reported in World Bank (2002). Missing values were either interpolated or completed with information provided in Mitchell (1998), UNESCO (1966) and UNESCO (various). For 1988-2002 ratio of students at San Carlos University (USAC) to the number of persons aged 20-24, as reported in Global Info Group (1999) and UNDP (2003a).

3. Guatemala: Time Series, 1950-2003

	Y	I	$K_{d=0.05}$	IM	EX	IM_{cap}	Mil_{exp}	ToT	zq	hq	IGSS	L	$hr_{no\ school}$	hr_{pri}	hr_{sec}	hr_{ter}	h	h_{pri}	h_{sec}	h_{ter}
Years	thousand of 1958 Quetzals							Indices (1970=100)			workers		percent				years			
1950	722344	81670	1086913	104911	91487	18124	5822	166.0	NA	NA	NA	947442	72.3	24.9	2.3	0.5	1.249	0.951	0.226	0.073
1951	732525	79933	1112501	94472	82006	16018	5725	164.3	NA	NA	NA	917001	70.8	26.1	2.7	0.4	1.315	0.999	0.262	0.054
1952	747724	68940	1125815	84967	91236	12812	6751	165.0	NA	NA	NA	886560	69.5	27.2	3.0	0.3	1.374	1.040	0.293	0.041
1953	775292	67590	1137115	95080	93898	15428	6543	169.1	NA	NA	NA	856118	68.3	28.2	3.3	0.2	1.430	1.077	0.320	0.033
1954	789610	67039	1147298	105768	87010	16300	6760	183.8	NA	NA	NA	825677	67.2	29.1	3.5	0.2	1.483	1.112	0.343	0.027
1955	809107	90420	1180353	121559	97153	23842	8196	181.3	NA	NA	198809	795236	66.1	30.0	3.7	0.2	1.534	1.144	0.364	0.026
1956	882711	142481	1263816	153196	105121	41275	8592	190.2	NA	NA	203572	814288	65.2	30.7	3.9	0.2	1.583	1.174	0.381	0.028
1957	932494	154221	1354847	167210	111078	39731	9310	182.1	NA	NA	236038	944152	64.6	31.2	4.0	0.2	1.618	1.191	0.395	0.032
1958	976055	136315	1423419	164338	121675	36581	9308	153.1	NA	NA	255548	1022192	64.1	31.5	4.1	0.3	1.647	1.203	0.407	0.037
1959	1024223	125518	1477766	163049	145950	35063	9950	142.7	NA	NA	255022	1020088	63.7	31.8	4.3	0.3	1.677	1.213	0.419	0.045
1960	1049199	107812	1511690	165231	152978	33094	9358	124.7	NA	NA	264100	1056400	63.3	32.0	4.4	0.3	1.704	1.221	0.433	0.050
1961	1094267	113473	1549578	152933	156614	31847	9413	113.2	NA	NA	269065	1076260	62.8	32.2	4.6	0.4	1.736	1.229	0.452	0.055
1962	1132984	108678	1580778	164752	162587	35528	9128	114.0	NA	NA	264884	1059536	62.2	32.5	4.8	0.4	1.778	1.242	0.476	0.061
1963	1241064	128805	1630544	213401	223030	46771	11196	117.1	NA	NA	274838	1099352	61.5	32.9	5.1	0.5	1.823	1.257	0.501	0.065
1964	1298557	157790	1706807	234186	214386	57591	9995	123.8	NA	NA	322289	1289156	60.9	33.3	5.3	0.5	1.866	1.272	0.524	0.069
1965	1355156	166770	1788236	246955	242406	54065	14526	111.2	NA	NA	345519	1382076	60.2	33.7	5.6	0.5	1.910	1.288	0.548	0.073
1966	1429923	165886	1864710	251070	297952	52302	15204	103.4	NA	NA	366946	1467784	59.5	34.2	5.8	0.5	1.948	1.306	0.565	0.078
1967	1488609	184262	1955737	267088	278854	53353	16653	99.5	NA	NA	367401	1469604	58.6	35.0	5.9	0.6	1.996	1.335	0.577	0.084
1968	1619203	209430	2067380	277748	313712	62055	15778	97.2	NA	NA	395808	1583232	57.5	35.9	6.0	0.6	2.046	1.370	0.585	0.090
1969	1695892	212709	2176720	271794	353881	59445	15462	100.4	NA	NA	446540	1786160	56.5	36.9	6.0	0.7	2.095	1.408	0.591	0.096
1970	1792754	209627	2277511	293287	346035	61002	27023	100.0	100.0	100.0	448276	1793104	55.3	38.0	6.1	0.7	2.148	1.450	0.595	0.103
1971	1892832	227404	2391040	312071	360376	73122	17643	97.0	99.9	103.3	442842	1771368	53.8	39.2	6.3	0.8	2.225	1.497	0.615	0.113
1972	2031552	226112	2497600	294733	412085	63183	18850	122.6	99.6	106.0	448378	1793512	52.5	40.1	6.6	0.9	2.302	1.532	0.645	0.125
1973	2169378	251898	2624618	324212	451602	69372	17478	109.3	99.1	108.2	468863	1875452	51.3	40.8	6.9	0.9	2.376	1.558	0.681	0.138
1974	2307675	247192	2740579	370700	481581	69703	19051	94.0	98.2	109.9	539792	2159168	50.4	41.2	7.3	1.0	2.442	1.575	0.716	0.150
1975	2352750	270567	2874117	352057	497495	82220	25618	93.3	98.1	111.6	520696	2082784	49.5	41.7	7.7	1.1	2.514	1.591	0.759	0.164
1976	2526537	371393	3101804	457126	530257	123898	27376	105.6	97.3	113.3	577920	2311680	48.5	42.0	8.3	1.2	2.595	1.604	0.812	0.179
1977	2723844	405798	3352512	499819	563254	122124	33697	135.3	95.6	114.8	708815	2835260	47.6	42.3	8.8	1.3	2.673	1.614	0.866	0.192
1978	2859913	435653	3620539	521600	562563	136120	35004	124.4	91.5	116.3	769045	3076180	46.6	42.5	9.4	1.4	2.756	1.623	0.927	0.206
1979	2994650	413362	3852874	482783	619160	109077	39651	112.2	88.0	118.1	756171	3024684	45.6	42.8	10.2	1.5	2.851	1.633	0.997	0.222
1980	3106877	372592	4032822	441194	651135	77301	42822	98.3	85.7	120.0	755542	3022168	44.4	43.0	11.0	1.6	2.956	1.643	1.075	0.238
1981	3127560	401472	4232654	423061	557408	72579	47199	89.0	84.5	122.3	591019	2364076	43.0	43.4	11.9	1.8	3.078	1.656	1.168	0.255
1982	3016573	357665	4378686	334288	510171	58520	56717	82.8	82.8	123.1	609144	2436576	42.5	43.4	12.3	1.8	3.131	1.658	1.207	0.266
1983	2939604	258193	4417945	267857	454593	27213	59962	84.5	82.8	124.3	583548	2334192	41.7	43.7	12.7	1.9	3.190	1.668	1.247	0.275
1984	2953546	234936	4431984	287295	440184	32933	63903	89.0	80.9	128.2	594936	2379744	40.0	45.0	13.1	1.9	3.284	1.720	1.285	0.280
1985	2936062	220153	4430537	250278	454017	32763	58511	80.7	75.8	131.6	631654	2526616	38.4	46.2	13.4	2.0	3.370	1.765	1.317	0.287
1986	2940175	228558	4437568	219598	390455	38735	48044	96.9	76.7	134.4	660444	2641776	37.0	47.1	14.0	2.0	3.460	1.798	1.369	0.293
1987	3044395	266133	4481822	315784	415999	74773	49471	86.4	75.7	135.6	678995	2715980	36.2	47.2	14.6	2.1	3.530	1.802	1.430	0.298
1988	3162873	299826	4557557	327741	437307	72615	49156	65.5	74.3	137.5	779560	3118240	35.1	47.5	15.3	2.1	3.617	1.813	1.503	0.301
1989	3287594	316903	4648582	349883	495427	74471	47291	64.3	73.8	139.3	788367	3153468	34.0	47.7	16.2	2.1	3.714	1.821	1.393	0.300
1990	3389552	286160	4702313	344322	527782	66664	40645	66.8	73.5	135.9	785753	3143012	35.4	46.8	15.0	2.6	3.665	1.788	1.472	0.405
1991	3513627	296816	4764013	369249	502024	70072	41812	94.7	73.1	132.3	786903	3147612	36.7	45.5	14.4	3.3	3.633	1.739	1.417	0.477
1992	3683616	385212	4911025	505961	548886	124052	45730	96.6	72.4	130.0	795708	3182832	37.5	44.5	14.3	3.6	3.585	1.699	1.408	0.528
1993	3828260	411831	5077304	527335	596287	136596	41296	90.8	72.5	128.4	823239	3292956	38.0	43.5	14.6	3.9	3.654	1.666	1.428	0.559
1994	3982682	401036	5224477	553498	615330	124076	43001	103.4	73.7	129.8	830324	3321296	37.1	44.0	14.8	4.1	3.727	1.680	1.457	0.590
1995	4179767	435901	5389134	595513	693745	135417	41367	116.4	75.5	129.9	855596	3422384	36.9	43.3	15.1	4.2	3.771	1.672	1.487	0.612
1996	4303395	427259	5555456	554652	754005	121748	35309	106.8	77.8	130.1	852243	3408972	36.7	43.3	15.2	4.3	3.792	1.674	1.490	0.629
1997	4491199	523411	5802044	662824	815100	160200	33365	115.5	78.9	131.3	844407	3377628	36.0	44.1	15.5	4.4	3.842	1.695	1.518	0.639
1998	4715468	614623	6125565	825223	894516	216659	34002	114.9	79.2	133.9	887228	3548912	34.8	45.1	15.6	4.5	3.912	1.722	1.532	0.658
1999	4896875	650313	6470550	831098	873042	239777	33065	106.2	78.5	140.3	893126	3572504	31.7	47.3	16.2	4.7	4.085	1.807	1.593	0.685
2000	5073597	593028	6740050	881261	906865	217171	41519	103.2	78.4	148.4	908122	3632488	27.6	49.5	17.8	5.0	4.363	1.896	1.749	0.718
2001	5191941	603899	7006946	942247	870201	201074	48695	101.0	77.7	152.9	927768	3711072	25.0	50.5	19.4	5.1	4.576	1.929	1.907	0.740
2002p/	5308677	634792	7291391	1004538	811532	230673	36132	99.6	77.5	156.5	953052	3812208	22.7	50.3	21.3	5.2	4.784	1.940	2.099	0.755
2003e/	5434976	631332	7558153	1028370	622463	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

p/ preliminary.
e/ estimated.

4. Central America and Mexico: Sources of Growth, 1961-2000 (in percent)

Data Adjusted for Quality of Labor [a/]

Country and time period	GDP growth	Contribution of			Country and time period	GDP growth	Contribution of		
		Capital	Labor	TFP			Capital	Labor	TFP
Guatemala		(0.33)	(0.67)		*El Salvador*		(0.42)	(0.58)	
1961-70	5.5	1.4	5.0	-0.9	1961-70	5.6	2.8	2.9	0.0
1971-80	5.7	2.0	5.0	-1.3	1971-80	2.3	3.0	1.8	-2.6
1981-90	0.9	0.5	1.4	-1.0	1981-90	-0.4	0.7	1.9	-3.0
1991-00	4.1	1.2	1.6	1.3	1991-00	4.6	2.0	2.3	0.3
Nicaragua		(N.A.)	(N.A.)		*Honduras*		(N.A.)	(N.A.)	
1961-70	6.8	2.9	3.0	0.9	1961-70	4.8	2.0	2.3	0.5
1971-80	0.4	1.8	2.5	-3.9	1971-80	5.4	2.2	2.9	0.3
1981-90	-1.4	0.8	2.4	-4.7	1981-90	2.4	1.1	3.9	-2.6
1991-00	3.3	0.7	3.2	-0.6	1991-00	3.2	1.8	2.9	-1.5
Costa Rica		(0.26)	(0.74)		*Mexico*		(0.41)	(0.59)	
1961-70	6.1	1.9	3.3	0.9	1961-70	6.7	3.3	2.7	0.7
1971-80	5.6	2.4	4.5	-1.3	1971-80	6.7	3.5	3.1	0.2
1981-90	2.4	1.0	2.9	-1.5	1981-90	1.8	1.7	3.5	-3.4
1991-00	5.3	1.5	2.4	1.4	1991-00	3.5	1.6	1.9	0.1

Source: Author's calculations for Guatemala. Loayza et al. (2002) for Central America and Mexico — data here refers to the growth accounting exercise 2 (adjustments for changes in the quality of labor associated with increases in educational attainment). a/ Factor shares are in brackets. Discrepancies are due to rounding.

5. Guatemala and Chile: Sources of Growth, 1971-2000 (in percent)

Data Adjusted for Quality of Capital and Labor [a/]

Country and time period	GDP growth	Contribution of			Country and time period	GDP growth	Contribution of		
		Capital	Labor	TFP			Capital	Labor	TFP
Guatemala		(0.33)	(0.67)		*Chile*		(0.44)	(0.56)	
1971-75	5.6	1.5	3.6	0.5	1971-75	-2.0	1.1	0.3	-3.5
1976-80	5.7	1.5	6.4	-2.1	1976-80	6.8	0.7	3.4	2.7
1981-85	-1.1	0.2	-0.7	-0.5	1981-85	-0.1	1.5	2.2	-3.8
1986-90	2.9	-0.1	3.5	-0.4	1986-90	6.5	1.9	3.7	0.9
1991-95	4.3	1.1	0.6	2.6	1991-95	7.5	4.1	1.9	1.4
1996-00	4.0	1.8	2.6	-0.4	1996-00	...	...	...	...

Source: Author's calculations for Guatemala. Roldós (1997) for Chile. a/ Factor shares are in brackets. Discrepancies are due to rounding.