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An Essay on Economic Growth - Classical Determinants, Convergence and Financial Development
Paulo Jorge Baptista Vieira

UNIVERSIDADE da MADEIRA

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DISSERTAÇÃO DE MESTRADO

Paulo Jorge Baptista Vieira
MESTRADO EM ECONOMIA

UNIVERSIDADE da MADEIRA
A Nossa Universidade
www.uma.pt

Fevereiro | 2011

DIMENSÕES: 45 X 29,7 cm

PAPEL: COUCHÊ MATE 350 GRAMAS

IMPRESSÃO: 4 CORES (CMYK)

ACABAMENTO: LAMINAÇÃO MATE

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Tese de Mestrado em Economia

"An Essay on Economic Growth: Classical Determinants, Convergence and Financial Development"

Aluno
Paulo Jorge Baptista Vieira
Nº 2002008

Orientador
Prof. Doutor Corrado Andini
Universidade da Madeira

February 2011

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ACKNOWLEDGEMENTS

I would like to thank Prof. Dr. Corrado Andini for his guidance and helpful suggestions. I also benefited of the comments from my colleague Renato Marques and the advice of Dionísio Nascimento. A special thanks to Antonio Correia for helping me to access the b-on database.
The usual disclaimer applies.

I dedicate this dissertation work to my family, especially to my wife Rita and my son Eduardo.

CONTENTS

ABSTRACT

This dissertation surveys the literature on economic growth. I review a substantial number of articles published by some of the most renowned researchers engaged in the study of economic growth. The literature is so vast that before undertaking new studies it is very important to know what has been done in the field. The dissertation has six chapters. In Chapter 1, I introduce the reader to the topic of economic growth. In Chapter 2, I present the Solow model and other contributions to the exogenous growth theory proposed in the literature. I also briefly discuss the endogenous approach to growth. In Chapter 3, I summarize the variety of econometric problems that affect the cross-country regressions. The factors that contribute to economic growth are highlighted and the validity of the empirical results is discussed. In Chapter 4, the existence of convergence, whether conditional or not, is analyzed. The literature using both cross-sectional and panel data is reviewed. An analysis on the topic of convergence using a quantile-regression framework is also provided. In Chapter 5, the controversial relationship between financial development and economic growth is analyzed. Particularly, I discuss the arguments in favour and against the Schumpeterian view that considers financial development as an important determinant of innovation and economic growth. Chapter 6 concludes the dissertation. Summing up, the literature appears to be not fully conclusive about the main determinants of economic growth, the existence of convergence and the impact of finance on growth.

Keywords: Economic Growth; Convergence; Financial Development

RESUMO

Esta dissertação versa sobre a literatura relacionada com temas de crescimento económico. É feita a análise de um número significativo de artigos publicados por alguns dos mais reconhecidos investigadores que se dedicam ao estudo do crescimento económico. A literatura é tão vasta que antes de se empreender novo estudo empírico é muito importante saber o que está feito na área. Esta dissertação é composta de seis capítulos. O capítulo 1 é uma introdução ao tema do crescimento económico. No capítulo 2, apresenta-se o modelo de Solow e outras contribuições à teoria de crescimento exógeno propostas na literatura. De forma resumida, é feita também referência às teorias de crescimento endógeno. O capítulo 3 contém uma síntese da variedade de problemas econométricos que afectam principalmente as regressões com dados seccionados por país. De seguida, são expostos os factores que contribuem para o crescimento económico bem como a discussão à volta da validade desses resultados. No capítulo 4, a existência de convergência, seja ela condicional ou não, é também abordada, começando-se por rever a literatura que assenta em regressões com dados seccionados e com dados de painel. É feita ainda uma análise à questão da convergência à luz de métodos assentes em regressões quantílicas. No capítulo 5, a controversa relação entre o desenvolvimento financeiro e crescimento é também abordada. São discutidos os argumentos a favor e contra a visão schumpeteriana, que considera que os instrumentos financeiros são importantes para a inovação e crescimento económico. O capítulo 6 conclui a dissertação, sendo que muitas das questões relacionadas com os determinantes do crescimento económico, a existência da convergência e o impacto do desenvolvimento financeiro no crescimento, não encontram respostas unívocas na literatura.

Palavras-chave: Crescimento Económico; Convergência; Desenvolvimento Financeiro

1. INTRODUCTION

One of the eternal discussions in economic science is about the nature and characteristics of economic growth. This debate started long time ago, with economists trying to decipher the factors that drive or hinder growth, whether there is convergence among countries and if so at what speed.

The model created by Robert Solow, published in 1956, is the starting point of the investigation made in the last 54 years. Many of the most relevant articles that have been published since then, tried to test, criticize or expand it. The development of computers and appropriate software in the 1980's made possible to test empirically the Solow model, with its variants and alternatives.

In this dissertation I chose to focus on three topics: the discussion about the factors that determine growth, the debate about convergence and the relationship between finance (including the stock market) and growth. A selection of the relevant articles on these topics was made, as I try to summarize and interconnect them when possible. The literature on this subject is too vast. Some works are only briefly discussed and others are inevitably left out, which does not mean that they are not relevant.

As usual in the field of scientific investigation, it is difficult to draw absolute truths, so the debate will go on…

Understanding the process of economic growth is an important starting point to build up more effective development strategies. It is fundamental to examine this process in all its complexity, considering the economic, social and political dimensions. In doing so, a lot of questions arise:

- Who are the winners and the losers in the growth process?
- What are the mechanisms that determine income distribution?

- Why does the population of the countries with higher growth rates do not necessarily have a correspondent human development level?
- What form of government and governance is more suited to economic growth and development?
- What is the most efficient combination of economic actors/players?

In fact, without economic growth, the living standard of the residents of a country is seriously compromised, reflecting a lack of productivity gains and therefore no increase in real wages.

2. THE SOLOW MODEL AND ITS PREDECESSORS

Historically, there are four models that form the basis of modern thought on economic growth. The first is the model of Adam Smith (1776). However to consider it a model is somehow far-fetched. Smith established a link between the process of specialization (resulting from international trade or from a market size increase) and the total output of an economy, *i.e.*, more specialization brings an increase in an economy's output.

The model of Malthus (1798, 1803) is the first to relate, in a comprehensive and systematic way, growth with changes in the population. Taking the concept of diminishing returns, Malthus foresaw stagnation in the long run, the result of steady population growth, which annulled the increases in real output *per capita*.

We can attribute the third model to Joseph Schumpeter (1912), who exacerbates the role of innovation and creative destruction, which is nothing more than replacing old processes with new, something that can lead the economy to a higher degree.

The Harrod-Domar model became popular in the years following World War II. It is a simple model in formal terms, but hardly appropriate for the analysis of economic growth in the long run, as one of its creators acknowledged in later works. The model does not put limits on growth, since a continued existence of a certain level of investment, (which was equal to the savings) could sustain growth indefinitely. The model does not include depreciation of capital, being the output proportional to capital stock. Consequently, the rate of output growth was directly proportional to the rate of saving. The weakest point of the model was in the constancy of the capital-output ratio.

Obviously I could mention other models, such as that presented by David Ricardo, who considered international trade and comparative advantages, as ways that allow the economies to overcome stagnation.

Karl Marx had more radical ideas. Cutting with classical thinking, he advocated the weakening of capital and strengthening of labour due to a declining rate of profit that would result from imbalances in the capitalist system. This would generate overproduction on one hand and in the other hand a failure in the ability to redistribute income (damaging the working classes).

Going back to the twentieth century, I will now focus in the Solow model. This model suggests that technology is the cause of long-term economic growth. It does not establish a linear relationship between savings and growth, and considers that the saving rate and investment have not a long-term effect on economic growth. The simplicity of the model, combined with the ability to distinguish the sources of growth in the short, medium and long term contributed to labelling it as a reference model after more than 50 years since its publication.

2.1 THE SOLOW MODEL

Solow (1956) makes an analysis inspired by neoclassical authors of the nineteenth century, and that is why the model is known as the neoclassical growth model.

For Solow, each production input is subject to diminishing returns, which means that it takes increasingly larger increments of the input to increase production (as other factors remain constant).

Let us now look more carefully to the basic structure of Solow's model. We start with the production function given by:

$$y = f(k) \text{, with } k = \frac{K}{L} \tag{1}$$

Therefore economic growth is defined in terms of output *per capita*. Each increase in K relatively to L will cause smaller and smaller increments of *y*.

The Consumption per worker function is defined by:

$$c = y - p = (1 - s) \cdot y \tag{2}$$

where *s* is the rate of saving and *p* stands for savings per employee.

The stock of capital increases with investment (savings), but is affected by the phenomenon of depreciation. In per worker terms we have:

$$\Delta k = i - \delta \cdot k = s \cdot y - \delta \cdot k = s \cdot f(k) - \delta \cdot k \tag{3}$$

where *i* is investment *per capita* and δ the depreciation rate.

Population growth is another of the parameters present in the Solow model. The author considers it a constant, something that could be labelled as unrealistic, because population growth varies from one country to another and from one period of time to another.

In order for K to be constant, the investment, i, must be great enough to cover for the capital that depreciates and the equipment of new workforce units. Adding this feature, we have:

$$\Delta k = i - \delta \cdot k - n \cdot k = \sigma \cdot f(k) - (\delta + n) \cdot k \quad (4)$$

where n is the rate of increase in labour force.

Countries with higher population growth rates have lower levels of output *per capita*. Thus, the obvious candidate to explain growth in the Solow model turns out to be technological progress, which can be described as a better ability of a country in converting resources into welfare by increasing production. Economic and cultural factors can matter too (trade union restrictions, environmental restrictions, etc…).

This part of output growth which cannot be attributed to the accumulation of capital and labour is called the Solow residual. It is related to efficiency in the use of these factors, and the measure of this efficiency is usually referred to as Total Factor Productivity.

Technological progress improves the efficiency of the labour force. So, our production function can be now defined by:

$$Y = F[K(L \cdot E)] \quad (5)$$

E, being the efficiency of each worker.

The variation of the capital stock per efficient unit is:

$$\Delta \hat{k} = i - (n + \delta + g) \cdot \hat{k} = s \cdot f(\hat{k}) - (n + \delta + g) \cdot \hat{k} \quad (6)$$

where g stands for the rate of improvement of the work efficiency through technological progress, and $\hat{k} = \frac{K}{L \cdot E}$.

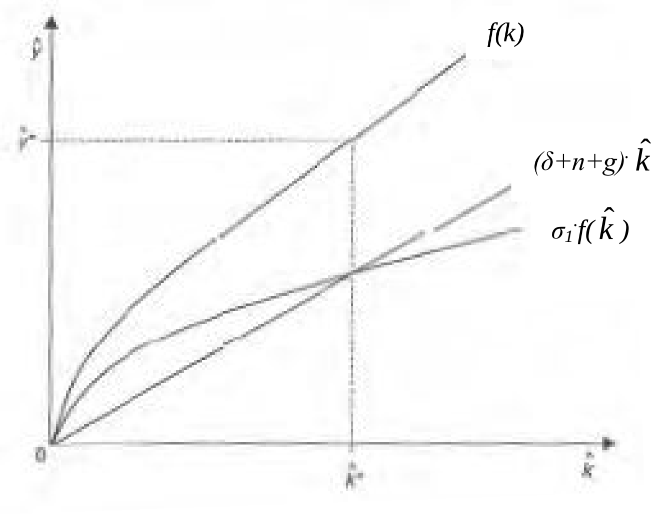
Therefore, the higher the savings rate, the higher the output per worker. The Solow model predicts that the economy will evolve into a steady state, a point where there is no growth in output (or in capital stock). Keep in mind that s, n, g and δ are exogenous.

The economy tends toward a steady state (see figure 1, below) when $\triangle$ k = 0, *i.e.*:

$$s \cdot f(k^*) = (n + \delta + g) \cdot k^* \qquad (7)$$

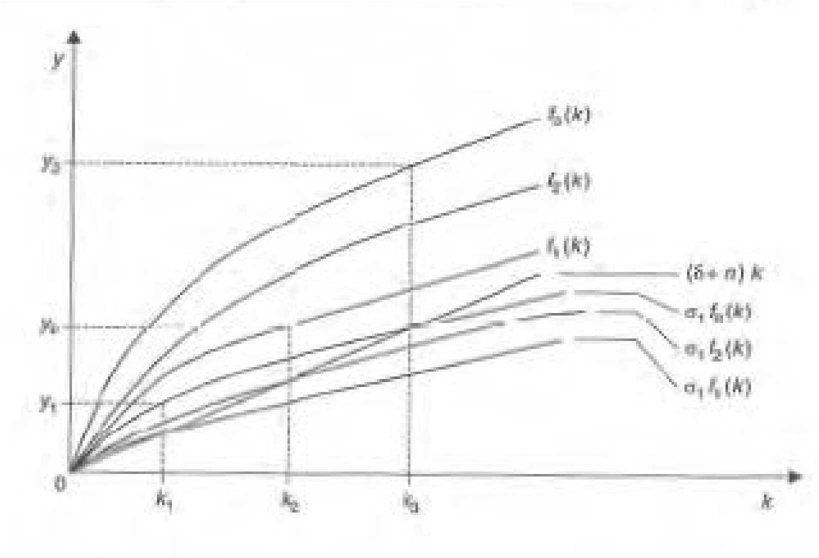
In steady state, income per efficiency unit is constant ($\hat{y}$*=f($\hat{k}$*)), while income per person grows at rate g, and total income grows at rate (n+g).

Figure 1. Steady state with technological progress



In figure 2 below (y and k are in *per capita* terms), we can see the effect of technological progress in the production function. The initial steady state for income per capita is y_1. With technology progress, the production function shifts from $f_1(k)$ to $f_2(k)$. This will have a repercussion in the total savings ($\sigma \cdot f_1(k)$), and so k will also rise, changing income per capita from y_1 to y_2.

Figure 2. Technological progress and economic growth



Mankiw (1995) lists the predictions of the Solow model:

1. In the long run, the economy approaches a steady state which is independent of initial conditions;
2. A higher saving rate leads to a higher steady state level of income per person, while a higher rate of population growth has the opposite effect;
3. It is the technological progress that influences the steady state rate of growth of income per person;
4. In the steady state, the capital-to-income ratio is constant;
5. In the steady state, the marginal product of capital is constant, and the marginal product of labour grows at the rate of technological progress.

These predictions have been evaluated over time, especially 2, 4 and 5.

According to Mankiw, the goal of the Solow model is to explain why some countries grow more than others in a certain period of time, rather than to explain the existence of economic growth. Mankiw also refutes most of the criticisms concerning this neoclassical growth model. Neither the fact that technological progress is exogenous (which motivated the appearance of the theories of endogenous growth), nor the apparent unrealistic option of considering the same production function for all countries are strong enough to discard Solow's model.

Durlauf, Kourtellos and Minkin (2001) do not share the same opinion. They state that there is a substantial country-specific heterogeneity in Solow's model parameters, which is associated with differences in initial income. To prove this, they built a model which incorporates this heterogeneity and the results show that the explanatory value of the Solow model increases strongly when using differentiated production functions. Durlauf *et al.* conclude that empirical exercises that neglect this factor lead to misleading results.

However, Mankiw (1995) points out three main problems about the validity of the Solow model. First, the model does not reflect the disparity in international living standards (the absence of human capital as a variable could explain this). In second place, the rate of convergence that the model predicts is twice the rate that actually occurs, which is about 2 percent per year according to most studies. The third problem is in the fact that the return to capital differentials between countries predicted by the Solow model is much greater than that observed empirically.

2.2 A BRIEF NOTE ON ENDOGENOUS GROWTH THEORIES

To avoid the assumption of exogenous advances in technology, some researchers have developed endogenous growth theories. One of the best known is the AK model, created by Rebelo (1991).

With a production function, Y=AK, the accumulation equation is:

$$\Delta K = s \cdot Y - \delta \cdot k \tag{8}$$

implying that:

$$\frac{\Delta Y}{Y} = \frac{\Delta K}{K} = s \cdot A - \delta \tag{9}$$

As long as s·A is greater than δ, income will grow indefinitely, even without assuming an exogenous technological progress. In this case, saving will lead to permanent growth, in opposition to the neoclassical model. The AK model is the simplest of all endogenous growth models. However the AK is unable to explain growth in the last 200 years, since investment in physical capital cannot, alone by itself, explain the rising of the world GDP *per capita*.

Mankiw (1995) states that other authors have developed more complex approaches creating models with more than one sector of production (one sector produces goods and the other innovations in technologies), and also including microeconomic decisions behind the research process. The advantage they bring is a more detailed view of the process of innovation. However, there are few empirical studies based on endogenous growth theories.

3. EMPIRICAL STUDIES ON ECONOMIC GROWTH

The Solow model dates from the 1950´s, however empirical tests have become common more recently, with the most prominent works being published in the last 25 years. The important work of Summers and Heston (1991) was fundamental to make international data suitable for cross-section analysis for the majority of the world countries.

In the typical empirical papers on economic growth, the authors gather a sample of countries and then run a cross-sectional regression. Usually, on one side we have the countries average growth rate and on the other side a set of variables that may or may not determine that growth rate. Of course the variables change from study to study, and also the interpretation of the results.

Mankiw (1995) points out the most important findings:

- the existence of conditional convergence, *i.e.* a low initial level of income is associated with a high subsequent growth rate when other variables are held constant;
- the share of output allocated to investment is positively related to growth as well as enrolment rates in primary and secondary schools (both measures of human capital);
- population growth is negatively related with growth in income per capita, as well as political instability and market distortions (impediments to trade, black market premium to foreign exchange);
- countries with better developed financial markets, tend to have higher growth rates.

3.1 MAIN PROBLEMS IN GROWTH REGRESSIONS

However there is a lot of discussion about the validity of some results, and most of the time, the root of this discussion is in some problems that affect growth regressions.

According to Mankiw (1995), three different types of problems arise in cross-country growth regressions: simultaneity, multicollinearity and the degrees of freedom problem.

Simultaneity happens when the right-hand-side variables are not in fact, exogenous.

Let us focus on investment and growth. Which causes which? Or is there a third variable that causes both investment and growth? The solution is to find exogenous variables to use as instruments, which is not an easy task. Correlations between endogenous variables can never establish causality with total certainty.

Multicollinearity is another problem that affects the interpretation of cross-country regressions. It happens when a strong correlation exists between the right-hand-side variables. For example high-growth countries have more political stability, more educated individuals and higher rates of investment. So when we look at the results of the regression we get coefficients with less precision. The multicollinearity problem is relevant in multiple regressions for two reasons. The first is because each country is treated as if it were an independent observation. The residuals of different countries have to be uncorrelated, if we want to get correct standard errors (or else we can have overstated statistical significance). The second reason is related to the prevalence of the measurement error in international data sets. Cross-country data is limited and a lot of proxies are used. When growth rates are regressed as a group of crude proxy variables that suffer from multicollinearity, the set of coefficients reflects the differing measurement errors in the right-hand-side variables.

The degrees of freedom problem is related to the number of variables that establish the condition for quick growth. It is impracticable to include 100 variables in a cross-country growth regression, but if we choose to select a subset of variables it is not satisfactory either. For Mankiw, the only solution to this problem is to accept the limitations of cross-country growth regressions.

Brock and Durlauf (2001) are more pessimistic about modern empirical growth literature. Besides the problems already listed by Mankiw, they claim that there are a lot of assumptions which are unrealistic in terms of economic theory and incoherent with the historical experiences of the countries under study. In their opinion, the lack of explicit decision-theoretic lines undermines the use of empirical growth work for policy analysis.

These authors refer that there are around 90 variables considered as potential growth determinants and what most researchers do is to test the robustness of these variables.

Leamer's (1978, 1983) extreme bounds procedure and Sala-i-Martin´s (1997a) approach (which will be presented ahead) are for Brock and Durlauf useful but not definitive ways of assuring model robustness. In both approaches, a coefficient is not robust if its associated variable is highly collinear with variables suggested by other candidate growth theories. However, both Leamer and Sala-i-Martin´s procedures will only give sensible answers when lack of collinearity is a "natural" property for a regressor which causally influences growth. In fact, collinearity is expected for important causal determinants of growth. Another criticism is the parameter homogeneity, something already mentioned before, when I analyzed the problem of the identical production functions.

An interesting point is also the causality versus correlation problem. In fact, variables like democracy, trade openness, etc…are used to explain growth; however, they are also a result of growth. When we have an endogeneity problem, instrumental variables are usually the solution to face it. An instrument is a variable that does not itself belong to the explanatory variable set and is correlated with the endogenous explanatory variable, but uncorrelated with the residuals. Brock and Durlauf are critical of the way that these instrumental variables are chosen by most researchers. In a regression of the form:

$$y_i = R_i \cdot \beta + e_i \qquad (10)$$

being I_i the set of instrumental variables (IV) for R_i, each element cannot be correlated with the error term. This should be the criteria to choose the IV.

However, the instruments are chosen on the basis of being exogenous. Therefore they may not be valid, since they are predetermined with respect to the error term.

Also in cross-country regressions it is usually assumed that the errors are jointly uncorrelated and orthogonal to the model's regressors, but omitted factors and parameter heterogeneity can endanger this assumption.

All is not lost however, because for Brock and Durlauf, even if the model does not comply with the statistical "ideal", the researcher must guarantee that those violations do not bring down his empirical claims.

The uncertainty present in cross-country regression (both in theory and in the parameters), is interpreted by these researchers as a violation of the concept of conditional exchangeability, which relates to the properties of random variables, conditional on some informational set. To solve this, they created a complex model that deals with uncertainty.

However, they acknowledge that there are no infallible panaceas for the before-mentioned problems.

3.2 THE IMPORTANCE OF HUMAN CAPITAL

Mankiw, Romer and Weil (1992) applied some statistical tests to the Solow model, estimating the parameters of a multiple regression. They used post World War II data, to check if the Solow model really explains the observed economic growth in a large sample of countries.

The neoclassical Solow model predicts that, *ceteris paribus,* an increase in the saving rate, leads to a higher income per capita and that an increase in the population rate reduces it. To test these hypotheses, Mankiw *et al.* (henceforth MRW) used a Cobb-Douglas production function, where *Y* is output, *K* capital, *L* labour and *E* the level of technology:

$$Y = K^{\alpha} \cdot (E \cdot L)^{1-\alpha} \qquad (11)$$

This equation can be presented in terms of effective worker:

$$\hat{y} = \frac{Y}{E \cdot L} = \left(\frac{K}{E \cdot L} \right)^{\alpha} = \hat{k}^{\alpha} \qquad (12)$$

Assuming that the population grows at the rate *n* and considering a technological progress tax *g*, then:

$$\Delta\hat{k} = s \cdot y - (n + \delta + g) \cdot \hat{k} = s \cdot \hat{k}^{\alpha} - (n + \delta + g) \cdot \hat{k} \qquad (13)$$

in which *s* and δ, stand for the saving rate and the depreciation rate. In steady state $\Delta\hat{k}=0$ and $s \cdot \hat{k}^{\alpha} = (n + \delta + g) \cdot \hat{k}$. It follows that $k^* = \left(\frac{s}{n + \delta + g} \right)^{\frac{1}{1-\alpha}}$, being that the asterisk stands for the steady state. As y=k^{α}, then we can replace *k* for the above expression and apply the logarithm:

$$\ln \hat{y}^* = \left(\frac{\alpha}{1-\alpha}\right)\cdot \ln s - \left(\frac{\alpha}{1-\alpha}\right)\cdot \ln(n+\delta+g) \qquad (14)$$

So we have two independent variables (the dependent is ln $\hat{y}^*$) that share the same coefficient $\alpha/(1-\alpha)$. This coefficient is the elasticity of the dependent variable in regard to the independent variable. In this case, the coefficient of *ln s* defines the proportional variation in the real income per capita, when the saving rate varies.

Using OLS (*n* and *g* are independent of the error term), MRW tested the Solow model for 98 countries that are not oil producers, 75 countries with intermediate economies and 22 countries of the OECD. They excluded extremely small countries and also those with doubtful data. The data comes from the Real National Accounts (World Bank), comprising all economies except centrally planned economies in the period between 1960 and 1985.

As we can see in table 1, significance was found for the first two groups of countries, but the same did not happen for the 22 OECD countries. The values between brackets identify the standard errors (the other numbers are, of course, the estimated coefficients), which are, for the last group of countries, extremely small when compared with the values of the parameters in the first two sets of countries. This makes the coefficients of the OECD sample non-significant.

Table 1. Results of Mankiw *et al.*'s regression

98 countries non-oil producers	ln (y)=	5.48 + 1.42 ln s - 1.97 ln (n+δ+g) (1.59) (0.14) (0.56)	R^2 : 0.59
75 intermediate economies	ln (y)=	5.36 + 1.31 ln s - 2.01 ln (n+δ+g) (1.55) (0.17) (0.53)	R^2 : 0.59
22 OECD countries	ln (y)=	7.97 + 0.50 ln (s) - 0.76 ln (n+δ+g) (2.48) (0.43) (0.84)	R^2 : 0.01

SOURCE: Mankiw, N.G., Romer D., and Weil, D. (1992) A Contribution to the Empirics Growth, Quarterly Journal of Economics, 107, Table I, p.414

The independent variables explain 59% of the growth of the 98 countries that are not oil producers (*i.e.* saving and population growth account for 59% of the variation in income per capita), and the percentage is similar for the 75 intermediate economies. For the third sample (which is the smallest), the coefficients are not significant and the Solow model does not fit. Another relevant result is that in the pure Solow version α is higher (around 0.6) than expected (the share of capital in income is between 0.25 and 0.4).

MRW tried to improve the Solow model adding it human capital. In fact, human capital had already been labelled by some economists as being very important in the process of growth. For example Kendrick (1976) estimated that more than half of the total U.S.A. capital stock in 1960 was human capital.

One of the first to include human capital in a growth model was Lucas (1988).

In the augmented version of the Solow model, MRW included β that stands for the proportion of human capital in the production function, which is:

$$Y = K^{\alpha} \cdot H^{\beta} \cdot L^{1-\alpha-\beta} \tag{15}$$

The coefficients α and β range between 0 and 1, and $\alpha+\beta<1$. Human capital is the knowledge of the workers, which comes from investment in education, training, and self-teaching. As it happens to physical capital, human capital can depreciate as individuals inevitably die (or get severely injured), and we must keep in mind that certain skills can become lost with time due to sloppiness.

The authors assume that both physical and human capital depreciate at the same rate.

Following the same logic as in the pure Solow model and after some algebra we find the expression:

$$\ln \hat{y}^* = \ln A(0) + (\frac{\alpha}{1-\alpha-\beta}).\ln s_k + \left(\frac{\beta}{1-\alpha-\beta}\right).\ln s_h - \left(\frac{\alpha+\beta}{1-\alpha-\beta}\right).\ln(\delta + n + g) \quad (16)$$

s_k and s_h are, the proportions of income invested in physical and human capital.

As a proxy to human capital accumulation (s_h) the authors use data of the population enrolled in secondary school (aged 12 to 17), obtained from UNESCO.

Table 2. Results of Mankiw *et al.*'s regression with human capital

98 countries non-oil producers	ln (y)=	6.89 + 0.69 ln(s_k) + 0.66 ln (s_h) - 1.73 ln (n+ξ⇐g) (1.17) (0.13) (0.07) (0.41)	R^2 : 0.78
75 intermediate economies	ln (y)=	7.81 + 0.70 ln(s_k) + 0.73 ln (s_h) - 1.50 ln (n+ξ⇐g) (1.19) (0.15) (0.10) (0.40)	R^2 : 0.77
22 OECD countries	ln (y)=	8.63 + 0.28 ln(s_k) + 0.76 ln (s_h) - 1.07 ln (n+ξ⇐gξ (2.19) (0.39) (0.29) (0.75)	R^2 : 0.24

SOURCE: Mankiw, N.G., Romer D., and Weil, D. (1992) A Contribution to the Empirics Growth, Quarterly Journal of Economics, 107, Table II, p.420

The inclusion of human capital proves to be an improvement to the model with the investment (saving) rate, the log of (n+δ+g) and the log of the percentage of population in secondary school explaining nearly 80% of the cross-country variation in income per capita in the non-oil and intermediate samples.

α and β are about one third for the first two samples (the estimate for OECD is not different but less precise), which is a much more expected result.

Temple (1998) made some robustness tests to the model developed by MRW. This author divides the tests in two parts, the first one related to parameter heterogeneity and outliers and the second to measurement error. Outliers can influence the conclusion one draws of a certain cross-country regression and the measurement error can also be problematic because if many variables are under this circumstance, coefficient estimates can be biased away from zero.

In the work of MRW, initial efficiency A(0) is unobserved and hence omitted, but if initial efficiency is correlated with the regressors then estimates will be biased. To solve this, Temple uses dummy variables for Sub-Saharan Africa, Latin America and the Caribbean, East Asia, and the set of industrialized countries.

Other problem identified by Temple is the assumption of identical rates of technical progress, which implies that income per capita will grow at the same rate in steady state. Lee, Pesaran and Smith (1997) had already demonstrated that this assumption led to biased estimates of convergence rates. However, this simplification proves to be useful and Temple maintains it.

When outliers are removed, Temple considers that the MRW model has no explanatory power for OECD countries. Measurement errors in initial income and in the conditioning variables cause problems in the estimated convergence rates. We will see this in detail in chapter 4.

Literature is fertile in suggesting methods to treat the problem of outliers, however Temple chose robust statistics. He applies Least Trimmed Squares (LTS) estimator, which works by minimizing the sum of squares over half the observations, picking the half with the smallest residual sum of squares. He also applied a procedure called Reweighted Least Squares (RWLS), which helps in tagging observations with high residuals as unrepresentative, since these are distant from the robustly fitted regression line.

The use of LTS on the OECD sample identifies 3 unrepresentative observations: Greece, Portugal and Turkey. When these last two countries are removed from the sample, the R-squared drops from 0.35 to 0.02 and the explanatory value of the augmented Solow model simply vanishes.

With the RWLS procedure, we can see that without outliers the augmented Solow model holds, with the R-squareds around 0.6, as shows Table 3. There are apparent problems. For example, the relation between per capita income and population growth (the term in $\ln(n+\delta+g)$), has different coefficients depending on the sample, suggesting that the augmented Solow model fails in capturing that relation. However, differences across countries in technical progress (g) and capital depreciation (δ) could account for this.

Table 3. Temple's robust regression estimates, by RWLS, stratified sample

Dependent variable: log GDP per working-age person in 1985

Quartile observations	Poorest 20	Second 20	Third 20	Richest 20
Constant	7.64	11.9	8.20	8.39
	(1.70)	(1.98)	(1.02)	(1.03)
ln (I/GDP)	0.18	0.04	0.44	0.32
	(0.08)	(0.24)	(0.20)	(0.25)
ln (n+g+δ)	-0.15	1.17	-0.53	-0.90
	(0.61)	(0.81)	(0.31)	(0.28)
ln (SCHOOL)	0.20	0.40	0.16	0.38
	(0.06)	(0.12)	(0.16)	(0.17)
R^2	0.58	0.58	0.62	0.67
Restriction p-value	0.62	0.07	0.91	0.68
RESET p-value	0.97	0.82	0.80	0.14
Implied α	0.13	0.03	0.28	0.19
Implied β	0.14	0.28	0.10	0.22

Quartile	Unrepresentative observations dropped in RWLS
Poorest	Botswana, Cameroon, Egypt, Indonesia, Zaire
Second	Brazil, Ghana, Korea, Papua New Guinea, Tunisia
Third	Hong Kong, Jamaica, Japan, Mexico, Singapore, Spain
Richest	Argentina, Chile, Ireland, Uruguay

Notes: MacKinnon-White (1985) HCSEs in parentheses. The technology parameters α and β are calculated using the coefficients on ln (I/GDP) and ln (SCHOOL).

SOURCE: Temple, J. (1998) Robustness tests of the Augmented Solow Model, Journal of Applied Econometrics, 13, Table I, p.367.

The way Temple split the sample was inspired in Durlauf and Johnson's work (1995). They divided the MRW sample using 1960's income and literacy rates and argue that common technology is not a realistic assumption, since technology parameters vary across samples.

These authors reject the linear model, and adopt a multiple regime alternative in which different economies obey different linear model when grouped according to initial conditions. The regression tree analysis allows the identification of subsets of countries which have different production functions.

Table 4. Durlauf and Johnson's Cross-section regressions: regression tree sample breaks

Dependent variable: $\ln(Y/L)_{i,1985} - \ln(Y/L)_{i,1960}$

	Terminal node number			
	1	**2**	**3**	**4**
Observations	14	34	27	21
		Unconstrained regressions		
Constant	3.46	-0.915	0.277	-7.26[a]
	(2.27)	(1.79)	(1.42)	(1.59)
$\ln(Y/L)_{i,1960}$	-0.791[a]	-0.086	-0.316[a]	0.069
	(0.269)	(0.131)	(0.123)	(0.139)
$\ln(I/Y)_i$	0.314[a]	0.129	1.110[a]	0.475[a]
	(0.109)	(0.159)	(0.165)	(0.119)
$\ln(n+g+\delta)_i$	-0.429	-0.390	0.059	-1.75[a]
	(0.678)	(0.489)	(0.451)	(0.270)
$\ln(SCHOOL)_i$	-0.028	0.469[a]	-0.014	0.341[a]
	(0.073)	(0.095)	(0.167)	(0.141)
$\overline{R}^2$	0.57	0.52	0.57	0.82
σ_ε	0.16	0.28	0.28	0.12
		Constrained regressions		
θ	4.107[a]	0.539	-3.95	-11.0
	(0.552)	(1.809)	(2.67)	(7.64)
α	0.306[a]	0.186	0.758[a]	0.333[a]
	(0.083)	(0.123)	(0.095)	(0.100)
γ	-0.034	0.416[a]	-0.073	0.455[a]
	(0.083)	(0.080)	(0.114)	(0.103)
$\overline{R}^2$	0.64	0.40	0.55	0.71
σ_ε	0.19	0.32	0.30	0.18

Note: [a] Significance at asymptotic 5% level.

SOURCE: Durlauf, S. N., and Johnson, P. A. (1995) Multiple Regimes and Cross-Country Growth Behavior, Journal of Applied Econometrics, 10, Table V, p.375.

While MRW's unconstrained model explains 46% of the growth variation[1], we can see in the upper table, that this multiple regime model, for the poorest economies (terminal node 1) explains 57%, for the intermediate-output economies with low literacy rates (terminal node 2) 52%, for the intermediate-output economies with low literacy rates (terminal node 3) 57% and for high-output economies (terminal node 4) 82%, of the total growth variation. The results for the constrained version (it differs from the unconstrained version because of the imposition of cross-coefficients restrictions) are alike.

[1] This value is presented in Table II of Durlauf and Johnson´s article, that reports the original MRW cross-section regression using $\ln(Y/L)_{i,1985}-\ln(Y/L)_{i,1960}$ as a dependent variable.

Different estimates of both physical and human capital shares across subsamples suggest that economies with unequal initial conditions have different aggregate production functions.

3.2.1 LEAMER'S SENSITIVITY ANALYSIS

Levine and Renelt (1992) were not convinced by the existing studies at their time and took specific measures to deal with the lack of adherence of the regression results to reality, which was caused by missing (the majority of investigators uses a small number of explanatory variables) or biased variables. Multicollinearity was also a reason for the aforementioned problem. Another criticism was that those who examine the impact of fiscal policy ignore trade policy and vice-versa.

For them, linkages between growth rate and sets of variables related to political, economic and institutional indicators based on cross-country regressions should be looked upon with caution.

These authors applied the sensitivity analysis suggested by Leamer (1983, 1985), which is the extreme-bound analysis (EBA). It tests the robustness of coefficient estimates to changes in the conditioning set of data.

The procedure consists in estimating the regression with all the independent variables, one at a time or in small groups, together with a focus variable. If we want to estimate the effect of trade in income per capita, then we could use a simple linear regression like:

$$y = d_0 + d_1 \cdot \text{(international trade)} \qquad (17)$$

Let us suppose we could think of more than 50 different variables that influence the level of income per capita, although we have only data for 16 countries. Because of the degrees of freedom, we cannot run the multiple regression with the other 50 variables. Leamer suggests running 50 regressions using the equation:

$$y = d_0 + d_1 \cdot \text{(international trade)} + d_2 \cdot X \tag{18}$$

in which X is a variable or a group of variables. If d_2 remains with significance and does not change sign in every regression, we can say that y is positively related to trade and that the estimated coefficient is not accidentally selected through other variables included in the equation. In this case, international trade is robustly related with income per capita.

Levine and Renelt ran regressions for different focus variables and concluded that there are few variables with this characteristic (robustness). They aimed to prove that many popular cross-country growth findings are sensitive to the conditioning information set. In fact it is hard to isolate a strong empirical relationship between any particular macroeconomic policy indicator and long run growth.

Few of the relationships found in cross-country regressions escape from Levine and Renelt´s scrutiny. A positive and robust correlation between growth and the share of investment in GDP really exists and the ratio of trade to output is also robust and positively correlated with the investment share.

The authors state that only when we identify a significant correlation while controlling for other relevant variables, should we have much confidence in the correlations.

An objection to the EBA is the introduction of multicollinearity, which as we have seen before, changes the standard error of the coefficients. In order to minimize this, the authors apply a series of restrictions. Nevertheless, Leamer (1978) points out that the appearance of multicollinearity derives from a weak-data problem.

They use data from 119 countries, compiled from the World Bank, IMF and also other authors (Barro, Summers and Heston).

Originally, the EBA uses equations of the form:

$$y = \beta_i \cdot I + \beta_m \cdot M + \beta_z \cdot Z + \mu \tag{19}$$

where y is either the GDP per capita growth or the share of investment in GDP, I is a set of variables, M the variable of interest, Z a subset of variables chosen from a group of variables (up to three) identified in past studies as important explanatory variables of growth, and μ the error term.

For each model, one finds an estimate β_m and the standard deviation σ_m. The EBA test for variable M says that if the lower extreme bound is negative and the upper extreme bound is positive, then variable M is not robust.

Table 5. Sensitivity analysis for basic variables

Dependent variable: growth rate of real per capita GDP, 1960-1989

M-variable		β	Std. Error	t	Countries	R^2	Other var.	Robust/fragile
INV	high:	19.07	2.87	6.66	98	0.54	STDI, REVC, GOV	robust
	base:	17.49	2.68	6.53	101	0.46		
	low:	15.13	3.21	4.72	100	0.49	X, PI, REVC	
RGDP60	high:	-0.34	0.13	2.53	98	0.54	STDI, PI, GOV	robust
	base:	-0.35	0.14	2.52	101	0.46		
	low:	-0.46	0.13	3.38	85	0.56	GDC, X, REVC	
GPO	high:	-0.34	0.23	1.48	100	0.48	X, STDI, PI	fragile
	base:	-0.39	0.22	1.73	101	0.46		
	low:	-0.49	0.20	2,42	85	0.56	X, GDC, REVC	
SEC	high:	3.71	1.22	3.04	84	0.55	X, GOV, GDC	robust
	base:	3.17	1.29	2.46	101	0.46		
	low:	2.50	1.15	2.17	85	0.62	X, STDD, GDC	

Notes: The base β is the estimated coefficient from the regression with the variable of interest (M-variable) and the always-included variables (I-variables). The I-variables, when the dependent variable is the growth rate of real per capita GDP, are INV (investment share of GDP), RGDP60 (real GDP per capita in 1960), GPO (growth in population), and SEC (secondary-school enrolment rate in 1960). The high β is the estimated coefficient from the regression with the extreme high bound (βm +two standard deviations); the low β is the coefficient from the regression with the extreme lower bound. The "other variables" are the Z-variables included in the base regression that produce the extreme bounds. The robust/fragile designation indicates whether the variable of interest is robust or fragile. STDI – Standard Deviation of inflation; REVC – Number of revolutions and coups; GOV - Government Consumption share of GDP; X – Export share of GDP; PI – Average inflation of GDP deflator; GDC – Growth rate of domestic credit; STDD – Standard deviation of GDC.

SOURCE: Levine, R., and Renelt, D. (1992) A Sensitivity Analysis of Cross-Country Growth Regressions**,** The American Economic Review, 82, Table 1, p.947

The results above show that (in table 5 the dependent variable is the growth rate), the investment (INV) coefficient is positive and robust, thus validating previous studies. With RGDP60, we can see that poor countries tend to grow faster than the rich ones (all other things equal), *i.e.*, there is convergence. Also Barro’s (1991) finding that the initial secondary-school enrolment rate (SEC) has a positive effect in growth is confirmed.

However, other familiar correlations in cross-country regression about growth do not pass Levine and Renelt's tests. For example population growth (GPO) is not clearly associated with the per capita growth.

They did the same considering investment share as the dependent variable, but none of the relationships were robust.

Table 6 below (again with the growth rate of real per capita GDP as the dependent variable) shows that all tested correlations are fragile, *i.e.*, none of the fiscal-policy indicators are robustly correlated with growth rates.

Table 6. Sensitivity results for fiscal variables

Dependent variable: growth rate of real per capita GDP

M-variable (period)		β	Std. Error	t	Countries	R^2	Other var.	Robust/fragile
GOV (1960-1989)	high:	-0.85	3.20	0.27	85	0.61	REVC, STDD, GDC	fragile (0)
	base:	-4.17	2.96	1.41	98	0.52		
	low:	-5.52	3.33	1.66	85	0.57	X, PI, GDC	
TEX (1974-1989)	high:	-1.22	2.22	0.55	75	0.45	X, STDD, GDC	fragile (1)
	base:	-5.03	2.05	2.46	85	0.36		
	low:	-5.51	2.02	2.73	86	0.41	REVC, PI, STDI	
GOVX (1974-1989)	high:	-12.95	7.81	1.66	64	0.48	X, STDD, STDI	fragile (2)
	base:	-21.96	5.64	3.90	74	0.43		
	low:	-23.73	5.64	4.21	75	0.57	REVC, PI, STDI	
DEF (1974-1989)	high:	14.17	5.36	2.64	82	0.41	REVC, PI, STDI	fragile (1)
	base:	15.45	4.90	3.16	82	0.40		
	low:	6.22	5.98	1.04	72	0.47	STDD, REVC, PI	

Notes: The base β is the estimated coefficient from the regression with the variable of interest (M-variable) and the always-included variables (I-variables). The I-variables, when the dependent variable is the growth rate of real per capita GDP, are INV (investment share of GDP), RGDPxx (initial real GDP per capita), GPO (growth in population), and SEC or SED (initial secondary-school enrolment rate). The high β is the estimated coefficient from the regression with the extreme high bound (β_m +two standard deviations); the low β is the coefficient from the regression with the extreme lower bound. M-variable definitions: GOV= government consumption share; TEX = total government expenditure; GOVX =government consumption share minus defense and educational expenditures; DEF = central government surplus/deficit as share.

The "other variables" are the 2-variables included in the base regression that produce the extreme bounds. The underlined variables are the minimum additional variables that make the coefficient of interest insignificant or change sign. The robust/fragile designation indicates whether the variable of interest is robust or fragile. If fragile, the column indicates how many additional variables need to be added before the variable is insignificant or of the wrong sign. A zero indicates that the coefficient is insignificant with only the I-variables included.

Check the notes in table 5 for the definition of the "other variables".

SOURCE: Levine, R., and Renelt, D. (1992) A Sensitivity Analysis of Cross-Country Growth Regressions**,** The American Economic Review, 82, Table 6, p.951

The relationship between growth and trade indicators (as for example imports) is also fragile. The authors say that the linkage between trade and growth is based on enhanced resource accumulation and not in a better allocation of resources. When using the investment share as the dependent variable some of the variables are positively and robustly correlated with it, as we can see in table 7.

Table 7. Sensitivity results for trade variables

Dependent variable: investment share

M-variable (period)		β	Std. Error	t	Countries	R^2	Other var.	Robust/fragile
X (1960-1989)	high:	0.16	0.030	5.31	87	0.26	GDC, STDI	robust
	base:	0.14	0.024	5.90	106	0.25		
	low:	0.09	0.024	3.90	101	0.35	GOV, REVC, STDI	
LEAM1 (1974-1989)	high:	0.15	0.055	2.68	40	0.20	DEF, STDD, GDC	robust
	base:	0.15	0.043	3.40	50	0.19		
	low:	0.10	0.050	2.08	48	0.24	REVC, STDD	
LEAM2 (1974-1989)	high:	0.24	0.044	5.32	48	0.39	GOV, STDD	robust
	base:	0.22	0.039	5.55	50	0.39		
	low:	0.18	0.041	4.30	52	0.46	REVC, PI, GOV	
BMP (1960-1989)	high:	-0.0002	0.0001	1.58	79	0.19	GDC, GOV, REVC	fragile (3)
	base:	-0.0004	0.0001	4.54	95	0.18		
	low:	-0.0004	0.0001	3.78	81	0.18	PI, STDD, GDC	
RERDB (1974-1989)	high:	-0.0002	0.0002	0.96	52	0.07	DEF, REVC	fragile (0)
	base:	-0.0002	0.0002	1.12	63	0.02		
	low:	-0.0003	0.0002	1.46	59	0.15	STDD, GDC	

Notes: The base β is the estimated coefficient from the regression with the variable of interest (M-variable). When the dependent variable is the investment share, no I-variables are included. The high β is the estimated coefficient from the regression with the extreme high bound (β_m + two standard deviations); the low β is the coefficient from the regression with the extreme lower bound. M-variable definitions: X = exports as percentage of GDP; LEAMl = Leamer's (1988) openness measure based on factor-adjusted trade; LEAM2 = Leamer's (1988) trade-distortion measure based on Heckscher-Ohlin deviations; BMP = black-market exchange-rate premium; RERDB = Dollar's (1992) real exchange-rate distortion for SH benchmark countries.
The "other variables" are the Z-variables included in the base regression that produce the extreme bounds. The underlined variables are the minimum additional variables that make the coefficient of interest insignificant or change sign. The robust/fragile designation indicates whether the variable of interest is robust or fragile. If fragile, the column indicates how many additional variables need to be added before the variable is insignificant or of the wrong sign. A zero indicates that the coefficient is insignificant with only the I-variables included.

DEF – Ratio of central-government deficit to GDP. Check the notes in table 5 for the definition of the “other variables”.

SOURCE: Levine, R., and Renelt, D. (1992) A Sensitivity Analysis of Cross-Country Growth Regressions**,** The American Economic Review, 82, Table 9, p.955

When testing monetary and political indicators, all correlations are not robust except for the one between investment share and revolutions and coups. A country with less turmoil benefits from more investment in comparison with a country that has an unstable political environment.

Summing up Levine and Renelt’s conclusions I can point out:

- Positive and robust correlation between average growth rates and the average share of investment in GDP, and between the share of investment in GDP and the average share of trade in GDP.
- A great variety of trade policy measures were not robustly correlated with growth when the equation included the investment share.
- A significant set of fiscal indicators are not correlated with growth or investment share, and the same happens with a broad array of institutional indicators.

3.3 RUNNING MILLIONS OF REGRESSIONS

Sala-i-Martin (1997a) handled the sensitivity analysis in a different way. He stated that the Levine and Renelt's tests are so powerful that no variable would survive to the significance permanence criteria (and in keeping the same sign), through successive regressions.

He analyses the entire distribution and not only the extreme bounds. Denying the pessimistic view of Levine and Renelt, Sala-i-Martin found that a large number of variables can be strongly related to growth.

This author states that one of the problems in economy growth theory is the inexistence of a consensus on what variables cause growth.

Another problem is the empirical estimation of these determinants. Questions like: "How do we measure human capital?" and "How do we compare degrees of corruption in the government?" between the countries, have not an easy answer.

When the economists run the regressions, they combine the various variables but often find that a first variable is significant only when the regression includes second and third variables, becoming non-significant only when a fourth variable is included.

As we have seen, what Levine and Renelt do is to use the EBA approach to identify robust empirical relations in the economic growth literature.

Sala-i-Martin develops a less dogmatic approach. He looks at the whole distribution of $\beta_{m.}$ In order to proceed, Sala-i-Martin had to operate under two different hypotheses about the normality of the distribution (firstly that it is normal, and secondly that it is not).

This leads to different ways of calculating the weighted average of the N estimated variances (there are N possible combinations of Z, and Z belongs to a vector of up to three variables taken from all the available variables).

Sala-i-Martin keeps the Levine and Renelt model specification, following them in the procedure that allows all the models to include 3 fixed variables considered *a priori* to be important determinants of growth. Regressions have always seven explanatory variables (three fixed variables, the tested variable and trios of the remaining 58 variables).

Sala-i-Martin chose 62 variables that supposedly explain growth. The selection was based upon availability for the first years of the sample period, and also by the inexistence of endogeneity problems.

Thereby, he tests the 62 variables found in literature, plus the growth rate of GDP. The only considered dependent variable is the average growth of rate per capita GDP between 1960 and 1992.

To choose the fixed variables, Sala-i-Martin demanded three properties: they had to be very common in the literature, they had to be evaluated in the beginning of the period (1960), and they had to be robust (*i.e.* systematically relevant in the regressions ran in the previous literature). Consequently, he selected the following variables: level of income in 1960, life expectancy in 1960 and the primary school enrolment in 1960.

Therefore, from the 62 variables, Sala-i-Martin, three are fixed and for each variable tested he combines the remaining 58 and hence he estimates 30 856 models (58!/3!*55!).

Sala-i-Martin concluded that from the 62 variables tested in one or more statistical studies in the last years, 22 have positive or negative coefficients, *i.e.*, are related to economic growth. It turns out that many of these variables have an institutional nature.

Table 8. Variables with significance in Sala-i-Martin's two million regressions

Dependent variable: growth

Independent variables	Coefficient (♦)	Standard deviation
Equipment Investment	0.2175	0.0408
Number of Years Open Economy	0.0195	0.0042
Fraction of Confucian	0.0676	0.0149
Rule of law	0.0190	0.0049
Fraction of Muslim	0.0142	0.0035
Political rights	-0.0026	0.0009
Latin American Dummy	-0.0115	0.0029
Sub-Sahara African Dummy	-0.0121	0.0032
Civil Liberties	-0.0029	0.0010
Revolutions and Coups	-0.0118	0.0045
Fraction of GDO in Mining	0.0353	0.0138
S.D. Black Market Premium	-0.0290	0.0118
Primary Exports in 1970	-0.0140	0.0053
Degree of Capitalism	0.0018	0.0008
War Dummy	-0.0056	0.0023
Non-Equipment Investment	0.0562	0.0242
Absolute Latitude	0.0002	0.0001
Exchange Rate Distortions	-0.0590	0.0302
Fraction of Protestant	-0.0129	0.0053
Fraction of Buddhist	0.0148	0.0076
Fraction of Catholic	-0.0089	0.0034
Spanish Colony	-0.0065	0.0032

SOURCE: Sala-i-Martin, X. (1997a), I just run two million regressions, American Economic Review, 87, Table 1, p. 181

Table 8 presents these variables and we can see that the environment in which the economy operates, the incentive structure that affects the individual behaviour, the level of competition and the market regulations by the government are to be taken in account in the process of economic growth.

Five of the variables that stand for religious beliefs (Buddhism, Catholicism, Confucianism, Protestantism and Islamism) are related to economic growth, but not all in the same way. Countries where Buddhism, Confucianism and Islamism are predominant, grow quicker, *ceteris paribus*, than those inhabited by Catholics and Protestants in majority. Variables of political nature as the number of revolutions and *coups d' état*, wars, political and civic freedom and democracy have the expected signs.

Institutions related to international trade and financial system are also important. That can be understood by looking at the coefficient of variables like the number of years as an open economy and the black market premium.

The list of the other 37 variables, that when tested do not have a relationship with growth, can be found in a paper by the same author (1997b).

Sturm and de Haan (2000) suggest a different approach. As we have seen before, Sala-i-Martin analyses the entire distribution, instead of analysing the extreme bounds of the estimates of a particular variable like Levine and Renelt did.

Sturm and de Haan state that in modelling cross-country growth models the first thing to do is to identify the outliers. They use the Least Median of Squares (LMS) estimator of Rousseeuw (1984, 1985) to identify outlying observations. Its basic principle is to fit the majority of the data. After that it is possible to identify the outliers, *i.e.* those cases with big positive or negative residuals. However this estimator is not adequate for inference. Rousseeuw (1984) suggested Reweighted Least Squares (RLS) to surpass this problem. For Sturm and de Haan this is a better procedure than the one Sala-i-Martin followed. So, variables insignificant to the LMS/RLS method are not significantly related to economic growth.

The LMS estimator can be written as

$$\min_{\hat{\beta}} \underset{i=1,..,n}{median}\, e_i^2 \qquad (20)$$

where e_i is the residual of case i with respect to the LMS fit. The use of RLS consists in putting weight zero if the observation is an outlier and one if otherwise. The resulting estimator is more efficient and gives the usual inferential output as t-statistics and R-squared.

In the empirical analysis, Sturm and de Haan follow Sala-i-Martin. They use the same standard variables (level of income in 1960, life expectancy in 1960 and the primary-school enrolment rate in 1960). The sample has 103 countries, however data availability problems reduced it to only 65 in some cases.

In table 9, we can see the 27 variables that are correlated with growth according to Sturm and de Haan’s methodology, plus 3 variables related to growth according to Sala-i-Martin, but not for Sturm and Haan (bottom 3 of the table).

Table 9. Estimation results with OLS and RLS

Dependent variable: growth

Variable	Obs	OLS t-stat	Outl.	RLS t-stat
Fraction Buddhist	103	3.00	8	7.98
Fraction Confucian	103	6.26	5	6.57
Fraction Muslim	103	3.39	11	6.27
Sub-Saharan dummy	103	-2.41	11	-6.15
Number of years open economy	103	6.22	5	6.04
Non-Equipment investment	82	2.15	11	5.94
Terms of trade growth	89	-0.35	16	-5.20
Latin American dummy	103	-4.04	14	-5.16
Revolutions and coups	103	-1.48	12	-4.81
S.D. Of black-market premium	95	-2.94	17	-4.54
Poltical rights	103	-2.28	10	-4.50
Equipment investment	82	6.97	9	4.21
Democratic freedom	93	-1.44	12	-4.06
Rule of law	92	3.64	5	4.06
Absolute latitude	103	2.53	11	3.77
Liquid liabilities	65	3.25	12	3.15
Spanish colony dummy	103	-2.91	6	-3.13
Fraction Catholic	103	-3.66	8	-2.83
Public defence share	96	1.89	7	2.67
Fraction Protestant	103	-2.25	4	-2.39
Primary exports	100	-3.75	8	-2.33
Ratio workers to population	100	-0.47	9	-2.32
Civil liberties	103	-1.86	9	-2.24
Public consumption share	96	-1.35	5	-2.18
Fraction speaking foreign language	103	1.42	7	2.12
Degree of capitalism	103	2.61	10	2.08
Age	103	-2.46	8	-2.04
Exchange rate distortions	102	-2.18	7	-1.74
Fraction GDP in mining	103	1.05	3	1.34
War dummy	102	-1.83	8	-1.30

Note: Bold variables are found to be related to economic growth by Sala-i-Martin (1997a,b)

SOURCE: Sturm, J.E., and de Haan, J. (2000) No need to run millions of regressions, CESinfo Working Paper, No. 288, Table 1

The results obtained by both authors are similar. However, terms of trade growth is not significant according to Sala-i-Martin, while for Sturm and de Haan it is (this is the result of reweighting the outliers). The opposite happens for the war dummy. Removing the outliers turns it insignificant.

So, Sturm and de Haan conclude that the detection of outliers is a short-cut for solving the specification uncertainty.

4. WHAT ABOUT CONVERGENCE?

Another issue that is frequently present in growth studies is convergence. It was Baumol (1986) who started this discussion. The appearance of Maddison (1992) and Summers and Heston's (1993) data sets generated a vast literature on this subject. In simple terms, convergence is defined as the tendency of poor economies to grow more rapidly than rich economies. Mankiw (1995) wrote that finding convergence or not depends on the sample. If we have only homogenous economies then we have convergence, something that does not happen if the sample has diverse economies. According to the same author, the neoclassical model does not necessarily predict convergence. This only happens when countries are in the same steady state and have different initial conditions. If the steady states are different then the rich countries continue to be rich, and the poor countries remain poor.

4.1 CONDITIONAL CONVERGENCE AND σ AND β CONVERGENCE

At this point I have to introduce another concept, which is conditional convergence. As we have seen convergence takes place when we have a negative slope coefficient between the dependent variable (average GDP growth rate) and the explanatory variable (level of income). If we control the differences between the countries steady states and find a negative relation between growth rates and income levels, then we have conditional convergence. It exists in the neoclassical model because there is the prediction that each economy will converge to its own steady state (determined by saving and population growth rates). Still we can divide convergence, in β convergence (when poor economies grow faster than rich ones) and σ convergence (when the dispersion per income or product decreases over time). For example, we have conditional β-convergence when we run a cross-sectional regression on initial income, holding constant a group of variables, and find a negative coefficient in initial income.

Barro and Sala-i-Martin (1991) argue that β convergence matters when we want to know how fast and to what extent the per capita income of an economy will reach the average per capita of a group of economies. If we want to know how was or will be the distribution of income across economies, the σ convergence is the concept that is relevant.

4.1.1. EMPIRICAL STUDIES ON THE SUBJECT OF CONVERGENCE

In the following sections I will analyze the topic of convergence according to several empirical studies that are based on different approaches, namely cross-section regressions, panel data and quantile regression.

4.1.1.1 CONVERGENCE AND CROSS-SECTION REGRESSIONS

In the neoclassical model, income converges to its steady state level as follows:

$$\dot{y} = -\lambda \cdot (y - y^{*}) \qquad (21)$$

where $\lambda = (1-\alpha)\cdot(n+g+\delta)$.

λ is the speed at which the gap between the steady state level of capital and its current level is closed and is usually known in the literature as the rate of convergence.

The majority of empirical studies point to a rate of conditional convergence of 2 percent per year, meaning that each country moves 2 percent closer to its own steady state each year.

Mankiw (1995) calibrated the formula above for the U.S.A. and reached a rate of convergence of 4 percent per year, the double of what most empirical studies predict. This means that the initial condition weighs more than the model says.

Barro and Sala-i-Martin (1991) examined the existence of convergence in the U.S. states and also between regions of 7 different European countries. In the first case, they worked with a sample from 1880 to 1988 and found a λ of 0.0175, very close to the aforementioned 2 percent a year. The inclusion of regional dummies or sectoral variables plus regional dummies led to a similar λ, although in the last case λ is stable across periods, something that did not happen in the other specifications. However, the results proved the existence of convergence in the sense that economies grow faster in per capita terms when they are further below the steady state position.

The dispersion of personal income across in the U.S.A. states, measured by σ, also falls from 1880 (0.545) to 1988 (0.194). In this study, Barro and Sala-i-Martin also trace the importance of government transfers payments, which obviously reduce the dispersion.

In the case of the European regions the results are similar.

In a subsequent paper, Barro and Sala-i-Martin (1992) try to evaluate if there is convergence between 98 countries and also between 20 OECD countries. They find that there is convergence only in a conditional sense, *i.e.*, only holding constant variables like initial school enrolment rates and the ratio of government consumption to GDP. Barro and Sala-i-Martin argue that the mobility of labour and technology speed up convergence.

Sala-i-Martin (1996) using a sample of regions of U.S., Japan, U.K., France, Italy, Spain and Canada confirms that the initial income per capita is very important (check R-squared in the table below), and the λ is close to 2 percent a year, whether we look at long periods (US, 1880-1990) or shorter ones (Spain, 1955-87). In this paper, Sala-i-Martin rebuffs possible criticisms to this finding. Based on the previous work done by Barro and Sala-i-Martin (1992), (where they regress the growth rate of income on the lagged level of income and find the same results), he says that measurement error is an unconvincing argument.

Table 10. Sala-i-Martins' regressions results

Countries	Long-run Single regression		Panel Estimates	
	λ (s.e)	R^2 (s.e. Reg.)	λ (s.e)	R^2 (s.e. Reg.)
United States	0.017	0.89	0.022	-
48 States (1880-1990)	(0.002)	[0.0015]	(0.002)	-
Japan	0.019	0.59	0.031	-
47 Prefectures (1955-1990)	(0.004)	[0.0027]	(0.004)	-
Europe Total	0.015	-	0.018	-
90 regions (1950-1990)	(0.002)	-	(0.003)	-
Germany	0.014	0.55	0.016	-
(11 regions)	(0.005)	[0.0027]	(0.006)	-
UK	0.030	0.61	0.029	-
(11 regions)	(0.007)	[0.0021]	(0.009)	-
France	0.016	0.55	0.015	-
(21 regions)	(0.004)	[0.0022]	(0.003)	-
Italy	0.010	0.46	0.016	-
(20 regions)	(0.003)	[0.0031]	(0.003)	-
Spain	0.023	0.63	0.019	-
(17 regions) (1955-87)	(0.007)	[0.004]	(0.005)	-
Canada	0.024	0.29	-	-
10 Provinces (1961-91)	(0.008)	[0.0025]	-	-

Note: The regression use nonlinear squares to estimate equations of the form $(1/T)\ln(y_{it} / y_{i,t-T})=$ $=a-[\ln(y_{i,t-T})](1-e^{-\beta T})(1/T)+$"other variables", where $y_{i,t-T}$ is the per capita income in region I at the beginning of the interval divided by the overall CPI. T is the length of the interval; "other variables" are regional dummies and sectoral variables that hold constant temporary shocks that may affect the performance of a region in a manner that is correlated with the initial level of income (recall that when the error term is correlated with the explanatory variable, then the OLS estimate of λ is biased).
Each column contains four numbers. The first one is the estimate of λ. Underneath it, in parentheses, is standard error. To its right, the adjusted R^2 of the regression and below the R^2, the standard error of the equation. Thus, constant, regional dummies and/or structural variables are not reported in the Table.
The coefficients for Europe Total include one dummy for each of the eight countries.
Column 1 reports the panel estimates when all the subperiods are assumed to have the same coefficient λ. This estimation allows for time effects. For most countries, the restriction of λ being constant over the subperiods cannot be rejected (see Barro and Sala-i-Martin, 1995).
Column 2 reports the value of λ estimated from a single cross section using the longest available data. For example, for the United States, the coefficient λ estimated by regressing the average growth rate between 1880 and 1990 is λ=0.022 (s.e.=0.0002).

SOURCE: Sala-i-Martin, X. (1996) Regional cohesion: Evidence and theories of regional growth and convergence, European Economic Review, 40, Table 1, p.1331

Studies with regional prices that reach the same λ, like the one by Shioji (1992) for Japan, and Coulombe and Lee (1993) for Canada, deny the influence of interregional price dispersion in explaining convergence. Quoting the work of Quah (1996), Sala-i-Martin refutes the criticism that the results are generated because of the sample's small size. Other hypothesis that could explain convergence is the redistribution of income across regions, with the government spending more in the poor states. In his PhD dissertation (1990), Sala-i-Martin had already proved that results do not change despite government redistribution.

Mankiw *et al.* (1992) had found that unconditional convergence exists only for the OECD countries. Temple (1998) confirms it and says that unrepresentative observations are irrelevant in this case.

When it comes down to conditional convergence, Temple argues that his methodology shows that the augmented Solow model explanation power is not as strong as one could think. For example, the population growth and schooling in the non-OECD samples are wrongly signed and are not significant, as we can see in the following table.

Table 11. Temple's tests for conditional convergence: RWLS estimation

Dependent variable: log difference GDP per working-age person in 1960-1985

Sample observations	Non-oil 92	Intermediate 69	OECD 21	Non-oil, non-OECD 71	Intermediate, non-OECD 50
Constant	3.82	3.50	1.34	4.37	4.18
	(0.79)	(0.75)	(1.19)	(1.14)	(1.29)
ln(Y60)	-0.30	-0.30	-0.32	-0.23	-0.24
	(0.06)	(0.07)	(0.07)	(0.08)	(0.10)
ln (I/GDP)	0.59	0.66	0.13	0.56	0.61
	(0.09)	(0.12)	(0.20)	(0.10)	(0.13)
ln (n+g+δ)	-0.04	-0.24	-0.94	0.45	0.29
	(0.24)	(0.24)	(0.29)	(0.35)	(0.43)
ln (SCHOOL)	-0.01	0.00	0.13	-0.07	-0.04
	(0.06)	(0.10)	(0.17)	(0.06)	(0.10)
R^2	0.71	0.75	0.74	0.70	0.72
Restriction p-value	0.05	0.13	0.05	0.01	0.05
Implied λ	0.014	0.014	0.015	0.010	0.011

Sample	Unrepresentative observations dropped in RWLS
Non-oil	Chad, Chile, Hong Kong, Mauritania, Somalia, Zambia
Intermediate	Argentina, Cameroon, Chile, Hong Kong, India, Zambia
OECD	Japan
Non-oil, non-OECD	Cameroon, Chad, Papua New Guinea, Somalia, Zambia
Intermediate, non-OECD	Cameroon, Chile, Zambia

Note: MacKinnon-White (1985) HCSEs in parentheses.

SOURCE: Temple, J. (1998) Robustness tests of the Augmented Solow Model, Journal of Applied Econometrics, 13, Table II, p.368.

Temple also analyses the sensitivity of the MRW data to measurement error. He claims that the data quality is in some cases low, and that there are crude proxies. Temple uses reverse regression and method-of-moments estimators to demonstrate the sensitivity of MRW results to measurement error. When several variables are measured with error, coefficient estimates can be biased away from zero and this can influence the results. Temple finds that the measurement error has great influence in drawing conclusions about convergence from cross-country regressions. For Temple, MRW's claim that countries converge at about 2% per year is not valid.

Durlauf and Johnson (1995), in their multiple regimes approach also studied the issue of convergence. In table 4 (check page 25), we can see that the estimated coefficient for ln $(Y/L)_{i,1960}$ is -0.791 for the first group and 0.069 for the fourth group (although not significant). This means that convergence is rejected among the high-output economies. Intermediate-output economies are a convergent subgroup, as ln (Y/L) is in both cases (low and high literacy rate countries) negative.

4.1.1.2 EVALUATING CONVERGENCE USING PANEL DATA

Some researchers advocate a panel data approach. One reason for this preference is that panel data allows to control for variables that you cannot observe or measure like cultural factors. This is, it accounts for country unobserved time-invariant heterogeneity. It is in this context that Islam (1995) argues that panel data makes possible to correct the bias created by the absence of differentiation of the countries' production functions, a problem that affects cross-country regressions. According to the same author, an example of a panel data formulation is obtained by moving from a single cross-section spanning the entire period (1960-1985) to cross sections for the shorter periods that constitute it. Islam compares the results he obtained using the panel data approach with those in Mankiw *et al.*'s (1992) article. Using the minimum distance estimator (an estimator suited for models where the individual effects are correlated with the included exogenous variables), the implied value of λ is much higher than the corresponding single cross-section values, which means a higher rate of convergence, especially in OECD countries. Of course here, I am speaking of conditional convergence.

Table 12. Islam's Minimum Distance Estimation with correlated effects

Dependent variable: y_{it}

Sample	NONOIL	INTER	OECD
γ	0.8050	0.8117	0.7155
	(0.0306)	(0.0284)	(0.0098)
β	0.1530	0.1389	0.1203
	(0.0274)	(0.0243)	(0.0264)
Implied λ	0.0434	0.0417	0.0670
	(0.0076)	(0.0070)	(0.0026)
Implied α	0.4397	0.4245	0.2972
	(0.0614)	(0.0524)	(0.0433)

Note: Figures in parentheses are asymptotic standard errors.

SOURCE: Islam, N. (1995) Growth Empirics: A Panel Data Approach, Quarterly Journal of Economics, 110, Table III, p. 1145

The elasticity parameter (α) is very different, although close to the estimates MRW presented after including the human capital variable.

Islam also tried the Least Squares with Dummy Variables (LSDV) estimator, which is based on the fixed-effects assumption and the results were close to those obtained with the minimum distance estimator.

The inclusion of human capital did not change the results significantly, which may seem a bit surprising. Islam suggests that the way how it is included in the production function could be incorrect since the channel through which human capital affects growth can be more complicated.

Caselli, Esquivel and Lefort (1996) argue that the rate of convergence of 2% per year is a result of wrong estimation procedures.

Caselli *et al.* list the estimation problems. The first is the treatment of country-specific effect. They state that a country with high income is not necessarily closer to its steady state than a country with a low observed income. We have to control for differences in steady states, or we will end up interpreting the results as the effect of slow convergence. Endogeneity, a concept that I have mentioned before, is another problem. The authors mentioned that, for example, population growth is influenced by economic growth.

Panel data regression using a GMM estimator is the solution applied by Caselli *et al*. They consider that this estimator is immune to inconsistency problems that affect cross-country regressions, and end up finding striking differences with MRW empirical tests, to both the Solow model and the augmented version. MRW had showed that only when the determinants of the steady state are controlled, we find convergence (*i.e.*, conditional convergence)[2]. The table below shows the compared results.

Table 13. Comparative results of different estimations of the textbook Solow model

	MRW	OLS	KLV	CEL
λ unrestricted	0.00606	0.00621	0.0626	0.128
(s.e.)	(0.00182)	(0.00219)	(0.0124)	(0.030)
δ1 + δ2 = 0 test		-0.398	0.798	-2.549
(p- value)		(0.691)	(0.372)	(0.011)
λ restricted		0.00588	0.0652	0.135
(s.e.)		(0.00202)	(0.0121)	(0.055)
implied α		0.757	0.335	0.104
(s.e.)		(0.048)		(0.147)
countries	98	97	98	97
observations	98	479	490	382

Note: Colums labelled MRW and KLV reproduce results reported, respectively, in Mankiw, Romer and Weil (1992, Table IV), Knight, Loayza and Villanueva (1993, Table 1). Column OLS reports results from a pooled, ordinary least squares regression. The last column corresponds to a generalized method of moments estimate, applied by Caselli *et al*.

SOURCE: Caselli, F., Esquivel, G. and Lefort, F. (1996) Reopening the Convergence Debate: A New Look at Cross-Country Growth Empirics, Journal of Economic Growth, 1, Table 1, p.375.

In Knight *et al.* (1993) estimation (henceforth KLV), there is a correct treatment of the correlated individual effect, although endogeneity remains a problem. So looking to convergence coefficient λ, the difference between MRW and KLV estimation show the tremendous influence of the first problem (individual effects), while the impact caused by endogeneity is expressed in the difference between KLV and the last column. As it had happened with MRW,

[2] For MRW, unconditional convergence was found only in the OECD sample.

the capital share calculated by GMM estimation is implausible. In MRW case it was too high, in Caselli *et al.*´s case it is too low.

Caselli *et al.*'s test leads to a rejection of the textbook Solow model because they find a λ of 0.135 (too high). MRW rejected it too, but because their λ was too low.

MRW, as we have already seen, developed the augmented Solow model, inserting human capital as another variable. The use of GMM estimation by Caselli *et al.*´s gives completely different results. For instance, the share of human capital implied by the restricted regression is negative and strongly significant. This means that for Caselli *et al*. both the textbook Solow model and the augmented Solow model are inconsistent.

Then, they present their own specification which is consistent with the neoclassical growth models that accepts as a solution a log-linearization around the steady state of the form:

$$\ln(\hat{Y}_t) - \ln(\hat{Y}_0) = -(1 - e^{-\lambda t}) \cdot \ln(\hat{Y}_0) + (1 - e^{-\lambda t}) \cdot \ln(\hat{Y}^*) \qquad (22)$$

where Y_t is GDP per effective worker at time t, $\hat{Y}_t$ is its steady state value, and λ, as before, is the convergence rate.

Using panel data they reach the value of 0.10 for λ, which is a high value. This means that most economies are normally close to their steady states. So, differences in per-capita levels across countries are due to discrepancies in their steady state values.

Islam (2003) says that the Arellano-Bond GMM estimator used by Caselli *et al.* is not the best to correct the effects of endogeneity. He argues that Monte Carlo studies have generally found this estimator to display large small sample bias. The value of 0.10 for λ implies an α of 0.1258, which is too low for an estimate of capital's share in output.

Paul Evans (1998) also wrote an article making use of the panel data approach to evaluate endogenous and exogenous growth theories. First of all, it is necessary to explain that as we have seen in chapter 2, endogenous growth models have in common the fact of considering the trend growth rate of per-capita output as endogenous because some set of reproducible factors of production can be produced with constant social returns in terms of themselves. This framework allows to explain why countries have different growth rates since they have different preferences, institutions, government policies, etc… His main finding is that technical knowledge may not be accessible to the poorer countries, and so Baumol´s idea (1986) of convergence clubs is plausible.

This means that we can have multiple equilibriums, depending on an economy's initial position or some other attribute. A group of countries may approach a particular equilibrium if they share the initial location or attribute corresponding to that equilibrium (Islam, 2003).

Still in the scope of the data panel approach, Lee *et al.* (1997) developed a stochastic (so, opposite to the deterministic models we have seen until now) Solow model to evaluate convergence. Their finding was similar to Islam's, pointing to a higher speed of β-convergence (to a country-specific steady state), around 30% *per annum*, much more than what MRW predict (2% *per annum*). However Lee et *al.* consider that this coefficient is imprecisely estimated and the interpretation of it as a measure of β-convergence is questionable in the context of a stochastic Solow model. Another important result was the rejection of the hypothesis that considered similar technology growth rates across countries. In fact, growth is greater in OECD countries, suggesting that global dispersion is increasing, and so, rich countries are becoming richer and poor countries poorer.

4.1.1.3 EVALUATING CONVERGENCE USING QUANTILE REGRESSIONS

In a seminal work, Koenker and Bassett (1978), brought to light quantile regression. It is a statistical technique that allows estimating and conducting inferences about conditional quantile functions. The distribution is divided in segments (the quantiles) and differences are examined, allowing to draw conclusions. The presence of heteroskedacity in the data (which can cause the variance of the coefficients to be underestimated) makes quantile regression very useful, since "estimating conditional quartiles at various points of the distribution of the growth rates will allow (…) to trace out different marginal responses of the growth rates to changes in the explanatory variables at these points" (Canarella and Pollard, 2004, p.5).

Ram (2008) uses quantile-regression methodology to analyse the problem of convergence comparing the growth rates of the high-growth (top quartile) and low-growth countries (bottom quartile).

As we can see in the table below, the rate of convergence is around 2% in the top quartile and much smaller in the bottom 25%.

It is another proof of heterogeneity in the rate of convergence.

However quantile regressions also shed a light on the question: can a factor be important in the growth of the rich countries and not relevant for the poor countries?

Table 14. Ram's OLS and Quantile-regression estimates of cross-country growth regressions

	OLS	Top quartile	Bottom quartile
A. Mankiw–Romer–Weil (1992, Table V) model and non-oil sample, 1960–1985, N=98			
Constant	3.021*	4.820*	1.031
	(0.827)	(0.896)	(1.282)
ln (Y60)	−0.288*	−0.416*	−0.216*
	(0.062)	(0.066)	(0.098)
ln (I /GDP)	0.524*	0.573*	0.434*
	(0.087)	(0.129)	(0.176)
ln (n+g+δ)	−0.506+	−0.393	−0.905+
	(0.289)	(0.252)	(0.530)
ln (SCHOOL)	0.231*	0.300*	0.224+
	(0.059)	(0.072)	(0.117)
Adj. R^2	0.46	–	–
Implied rate of convergence	0.0136	0.0215	0.0097
B. Estimates of MRW model from a more recent sample, 1960–2000, N=96			
Constant	0.395	2.433	−0.868
	(1.026)	(2.100)	(1.495)
ln (Y60)	−0.339*	−0.536*	−0.199+
	(0.073)	(0.156)	(0.108)
ln (I /GDP)	0.455*	0.464*	0.461*
	(0.109)	(0.150)	(0.211)
ln (n+g+δ)	−1.395*	−1.349*	−1.396*
	(0.331)	(0.542)	(0.557)
ln (SCHOOL)	0.331*	0.420*	0.173
	(0.109)	(0.193)	(0.188)
Adj. R^2	0.41	–	–
Implied rate of convergence	0.0103	0.0192	0.0056

Notes: Part A corresponds to MRW~(1992, p. 426) Table V, and the data are taken from their Appendix (pp. 434–436). Variables in part B are very similar to theirs, except that the period is 1960–2000 and SCHOOL is the average of mean years of schooling from Barro and Lee (2001). For quantile regressions, Stata has been used, and bootstrapped standard errors (from 1000 replications) are shown. Stata commands used are REGRESS and SQREG for OLS and quantile regression respectively. Adjusted R^2 is not generated by Stata for quantile regressions.
Significance at the 5% and 10% levels is denoted by * and + respectively.

SOURCE: Ram, R. (2008) Parametric Variability in Cross-Country Growth Regressions: An Application of Quantile-Regression Methodology, Economics Letters, 99, Table 1, p.388.

In table 14 we can see that investment and education are not as important in the low-growth countries as in high-growth countries (in part A), while in part B this is only true for education.

In a broader study, Mello and Perrelli (2003) adopted a similar methodology and argue that in the high-growth countries, unconditional convergence can be found, and so they are in disagreement with authors like Baumol (1986) and Barro (1991), that using OLS regression stated that there was no evidence of unconditional convergence.

For Mello and Perrelli, quantile regression has two advantages. On one side, the estimator is robust to outliers of the dependent variable. On the other side, the estimator gives only one solution to each quantile, which helps a lot in analysing the countries' heterogeneity. They argue that policy variables cannot be measured only looking at the conditional mean (estimated by the common cross-country regressions), so quantile regression is a good technique to suppress this problem, allowing for a better characterization of the conditional distribution. Applying the quantile regression to equations of different growth studies (e.g. Barro, MRW) they conclude that there is unconditional convergence for countries that are in upper quantiles but not for countries in the lower quantiles.

In table 15, we have in the first two columns the MRW original data set and in the last two an update of MRW's data set (1960-1985) presented by Bernanke-Gurkaynak (2001) for the years 1960-1995. In the upper row of each quantile we have the results for speed of convergence and half-life (the number of years that the economy takes to transit half way to its steady state level of income per capita) for the unconditional growth equation and in the bottom the same for the conditional growth equation. The first and third column relate to the OECD sample (24 countries) and the second and fourth to the large sample (104 countries).

The results suggest an increase (in the OLS and in quantile process spanning the interval [0.20;0.80]) in the speed of convergence from the 1960-1985 period to 1960-1995, in both samples.

There is also a large difference in the speed of convergence and the half-life observed across the quantiles. Looking at the last column, we can see that in the bottom 20% of the conditional growth distribution, the half-life for a country is 63.44 years, while in the top 20% this value drops to half. The same happens in the OECD sample.

This finding reinforces the concept of convergence clubs already mentioned.

Table 15. Comparison between the MRW and BG: speed of convergence and half-lives – OECD and large sample

Quantile	MRW		BG	
	Speed of Convergence	Half-life (in years)	Speed of Convergence	Half-life (in years)
q10	0.69%	100.84	0.43%	161.94
	0.69%	99.75	0.79%	87.68
q20	1.36%	51.09	1.98%	35.07
	1.09%	63.73	1.09%	63.44
q30	1.53%	45.43	2.41%	28.81
	1.19%	58.48	1.63%	42.50
q40	2.06%	33.70	2.31%	30.00
	1.25%	55.36	1.44%	48.02
q50	1.83%	37.88	2.34%	29.62
	1.46%	47.58	1.62%	42.75
q60	1.71%	40.64	2.28%	30.46
	1.56%	44.35	2.25%	30.79
q70	1.90%	36.48	2.30%	30.10
	2.03%	34.15	1.91%	36.30
q80	1.91%	36.35	2.34%	29.67
	2.11%	32.89	2.24%	30.89
q90	5.59%	12.40	3.78%	18.31
	2.22%	31.26	2.95%	23.49
OLS	1.67%	41.54	1.81%	38.26
estimate	1.41%	49.11	1.60%	43.43

Notes: On the first and third columns the observation on the top is the speed of convergence for the unconditional growth equation for the OECD sample, and the observation on the bottom is the speed of convergence for the conditional growth equation for the large sample. On the second and fourth columns the observation on the top is the half-life for the unconditional growth equation for the OECD sample, and the observation on the bottom is the half-life for the conditional growth equation for the large sample. The speed of convergence is calculated according to $-(1- e^{-bT}) / T = b$, where b is the estimated coefficient, T is the sample period, and b is the speed of convergence. The half-life is calculated according to the formula - ln(0.5)/b .

SOURCE: Mello, M., and Perrelli, R. (2003) Growth Equations: A Quantile Regression Exploration, Quarterly Review of Economics and Finance, 43, Table 6, p.664

Canarella and Pollard (2004) also studied the parameter heterogeneity problem, making use of the quantile regression and resorting to cross-sectional data of 86 countries covering the period from 1960 to 2000. They analyzed the validity of the neoclassical growth model and some of the results are in the table below. We have to keep in mind that while in OLS growth regressions the coefficient of $\ln(s_k)$, e.g., represents, *ceteris paribus*, the impact of a change in

$\ln(s_k)$ on average growth. In the quantile model, instead, the quantile coefficient of $\ln(s_k)$ represents the change, other things equal, in the θth conditional quantile of the growth distribution due to a change in $\ln(s_k)$.

Table 16. Canarella and Pollard's unrestricted quantile regression estimates

Dependent variable: log difference GDP per working-age person, 1960-2000

	θ= 0.10	θ= 0.25	θ= 0.50	θ= 0.75	θ= 0.90
Constant	1.7431	2.1621	2.8479	4.3364	5.0740
	(2.3741)	(1.7013)	(1.3871)	(1.8369)	(2.2808)
$\ln(y_0)$	-0.3563	-0.3091	-0.4100	-0.4803	-0.5213
	(0.1893)	(0.1414)	(0.1117)	(0.1105)	(0.1186)
$\ln(s_k)$	0.1862	0.2990	0.3049	0.3627	0.2154
	(0.1951)	(0.1542)	(0.1642)	(0.1801)	(0.1524)
$\ln(n+g+\delta)$	-0.8978	-0.8118	-0.9972	-0.8350	-1.0082
	(0.8716)	(0.5982)	(0.4158)	(0.5913)	(0.7459)
$\ln(s_h)$	0.1426	0.1456	0.2552	0.3455	0.6796
	(0.1621)	(0.1339)	(0.1509)	(0.1540)	(0.1535)
East Asia	0.0776	0.3792	0.3821	1.0215	0.9317
	(0.3901)	(0.3491)	(0.3055)	(0.3715)	(0.3129)
Latin America and	-0.1243	-0.4523	-0.0858	0.0347	-0.0122
Caribbean	(0.3263)	(0.2292)	(0.1855)	(0.1611)	(0.1551)
Sub-Saharan Africa	-0.6439	-0.7757	-0.4003	-0.2221	0.2575
	(0.2957)	(0.2593)	(0.2369)	(0.2315)	(0.2844)
Industrialized Countries	0.5071	0.1325	0.2073	0.2522	0.0631
	(0.5067)	(0.3538)	(0.2644)	(0.2781)	(0.2872)
Pseudo R^2	0.496	0.4993	0.5131	0.5034	0.5755
Interquantile Tests					
θ= 0.10		0.7300	0.8400	1.8800	2.5200
p-value		0.6669	0.5689	0.0755	0.0172
θ= 0.25			1.1200	1.7100	2.4200
p-value			0.3580	0.1091	0.0218
θ= 0.50				0.8300	1.4200
p-value				0.5830	0.2002
θ= 0.75					0.9400
p-value					0.4899

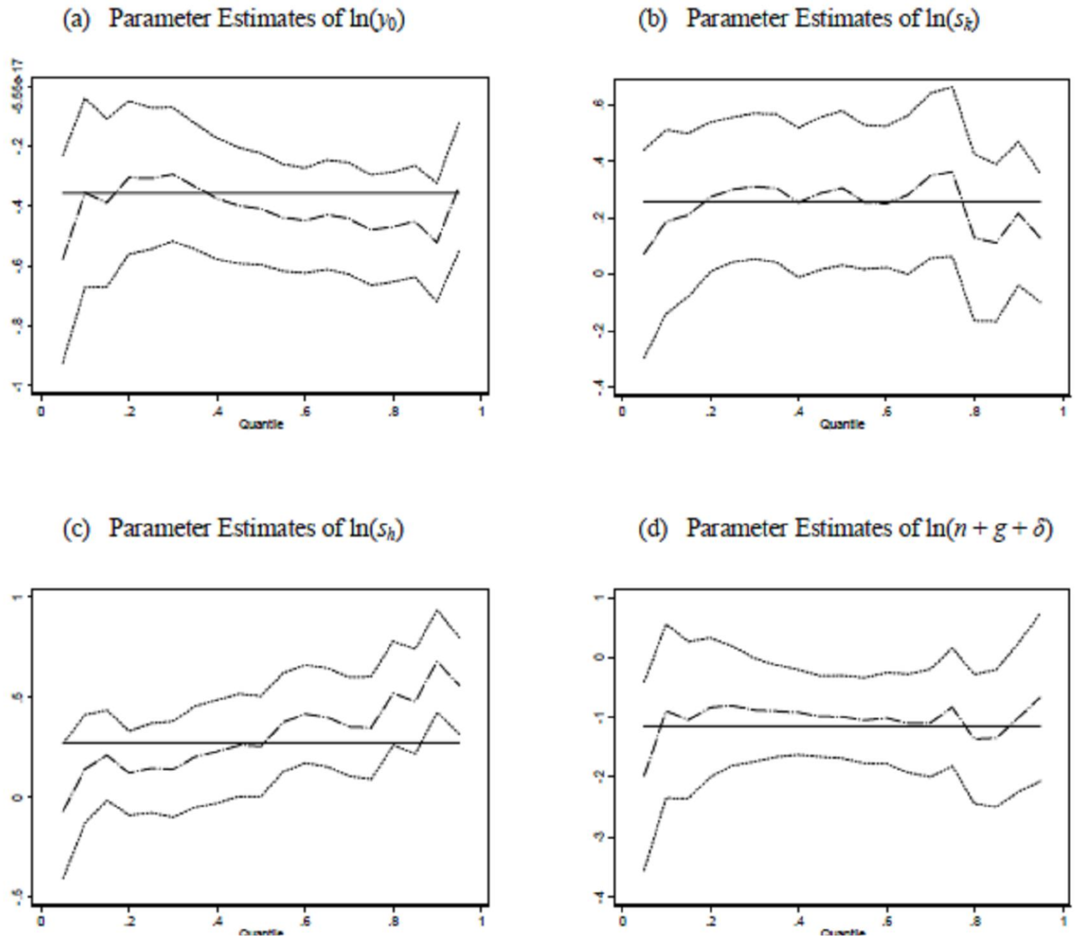
Note:Bootstrapped standard errors in parentheses.

SOURCE: Canarella, G., and Pollard, S. (2004) Parameter Heterogeneity in the Neoclassic Growth Model: A Quantile Regression Approach, Journal of Economic Development, 29, Table 3, p.17.

The pseudo R-squared is a quantile measure of goodness of fit, and it is higher in the upper quantiles, which means that the model explains better the growth phenomenon in countries with higher growth rates.

The answer about parameter heterogeneity comes from the graphs below that show that slope coefficients are not flat at all.

Figure 3. Parameter estimates of the unrestricted model



Notes: The graphs plot the unrestricted parameter estimates associated with each variable, together with a 90% confidence band, against the quantile at which the model is estimated. The superimposed horizontal solid line refers to the corresponding OLS (invariant) parameter estimate.

SOURCE: Canarella, G., and Pollard, S. (2004) Parameter Heterogeneity in the Neoclassic Growth Model: A Quantile Regression Approach, Journal of Economic Development, 29, Fig. 1, p.18.

An important result is the fact that quantile estimates for investment in human capital are lower in the bottom quantiles and higher in the upper quantiles, which suggests that after controlling for technology and institutions, only the countries with higher growth rates can benefit from human capital. Population growth affects mainly the countries that are close to the median, being insignificant in the upper and lower quantiles, while physical investment is significant only in the interquantile range. It seems that after controlling for differences in technology and institutions, the countries in the upper and bottom quantiles have difficulty in benefiting from physical capital.

Once again, the speed of convergence is found to be higher in the upper quantiles.

Canarella and Pollard analyzed parameter heterogeneity through interquantile tests. These tests examine if the position in growth distribution differentially affects how capital (both physical and human), initial level of income per capita, population growth and regional location are related to growth.

They found that the countries in the upper and bottom quantiles show parameter homogeneity within the respective quantile. There are however, significant differences from one quantile to another. This means that the growth dynamics is very different from one group to another.

The results that we have seen until now are all from the unrestricted model. In the restricted model the estimate for the rate of convergence is lower than the famous 2% value, except for the 90^{th} quantile. They found evidence that there is conditional convergence only in the top 75% of the countries (and conditional divergence for the rest). Hence, conditional convergence gains another dimension; a country converges as long as that country is not on the bottom quantiles of the growth distribution. Convergence is local rather than global.

5. FINANCE AND GROWTH

Another topic of great debate among economic researchers is the relation between financial development and growth. Some deny it, others say that finance is important for growth, while another group suggests that it happens the other way around, *i.e.*, that it is economic growth that stimulates the development of more efficient financial instruments. Greenwood and Jovanovic (1990) point out that it is a two-way causal relationship.

The first to argue that the services provided by financial intermediaries are important for innovation and therefore growth was Schumpeter (1912). Empirical works by Goldsmith (1969) and McKinnon (1973) underpinned this idea. Robinson (1952) thought differently and pointed out that financial development followed growth and not the other way around. For Lucas (1988), the link that some researchers establish between finance and growth is “over-stressed”. In the Schumpeterian view, finance affects the allocation of savings, but does not alter its rate. On the contrary, a large group of economists say that growth depends largely on capital accumulation, so, better financial intermediation will lead to an increase in the domestic savings and attract foreign capital. According to Levine, Loayza and Beck (2000) the main advantages of the financial intermediation instruments are the reduction of costs for R&D, the minimization of managing risks and the mobilization of savings.

Those who argue that financial development can hurt growth, say that, by enhancing resource allocation and hence the returns to saving, financial development can contribute to lower saving rates. If there are large externalities associated with saving and investment, then financial development can slow long-run growth.

For Pagano (1998) financial development has a positive effect on growth, causing an impact on the saving rate, on the fraction of saving allocated to investment, or on the social marginal productivity of investment. There are only two exceptions: improvements in risk-sharing and in the household credit market. Both can cause a decrease in the saving rate, which will reflect in the growth rate.

So, financial intermediaries can influence savings and the allocation decisions, something that can reflect in the long term growth rates.

5.1 IS SCHUMPETER RIGHT?

For a deeper analysis on this subject, I will start with the work of King and Levine (1993a). They used cross-sectional procedure, with data from 80 countries for the period 1960-1989. To define financial development they constructed four indicators: ratio of liquid liabilities to GDP; deposit banks relative to the central bank in allocating domestic credit; credit issued to nonfinancial private firms divided by total credit and credit issued to nonfinancial private firms divided by GDP. To try to understand in what form financial development accelerates growth, they studied the rate of physical capital accumulation (per capita growth rate of physical capital and the ratio of investment to GDP) and the efficiency with which a society allocates capital (measuring the growth residual after controlling for physical capital accumulation).

It is important to mention that one of the shortcomings of the debate about the impact of financial development on growth is the construction of accurate and consistent indicators, as points out Levine (2003).

For King and Levine the results are clear, there is a "positive, significant and robust partial correlation between the average annual rate of real per capita GDP growth and the average level of financial sector development" in the abovementioned period (after controlling for initial conditions and other economic indicators).

In the tables published in King and Levine's article it is clear that in the high-growth countries there is an increased importance of financial development (represented by the four indicators mentioned above) in comparison to the low-growth countries.

Still, the authors assure that they conducted a series of sensitivity checks – changing the conditioning set of information, using subsamples of countries and time periods and looking at the error term. They even used Levine and Renelt's extreme-bound analysis (EBA), a method that has been presented before in this dissertation. None of this changed the results.

King and Levine went further ahead and stated that "finance does not only follow growth; finance seems importantly to lead economic growth". They reached this conclusion by looking at the relationship between the initial values of the financial development indicators and the subsequent economic growth (using OLS). As we can see in the table below LLY in 1960 (liquid liabilities in 1960) is highly correlated with economic growth (GYP) in the following 30 years. The pooled decade data did not change this outcome, nor did the sensitivity analyses.

Table 17. King and Levine's regression results

Growth and initial financial depth: 1960-1989

Independent variable	(1)	(2)	(3)	(4)
constant	0.042***	0.035***	0.033***	0.035***
	(0.005)	(0.007)	(0.009)	(0.010)
LYO	-0.014***	-0.016***	-0.016***	-0.014***
	(0.003)	(0.003)	(0.003)	(0.003)
LSEC	0.013***	0.013***	0.013***	0.010***
	(0.002)	(0.002)	(0.002)	(0.003)
GOV in 1960		0.070*	0.072*	0.044
		(0.035)	(0.036)	(0.040)
PI in 1960		0.037	0.032	0.040
		(0.031)	(0.033)	(0.033)
TRD in 1960		-0.003	-0.004	0.001
		(0.006)	(0.006)	(0.001)
Index of civil liberties			0.001	0.001
			(0.002)	(0.002)
Number of revolutions			-0.010	-0.010
			(0.009)	(0.009)
Number of assassinations			-0.001	-0.002
			(0.004)	(0.003)
Sub-Saharan Africa dummy				-0.011
				(0.007)
Latin American dummy				-0.010*
				(0.005)
LLY in 1960	0.030***	0.028***	0.028***	0.020***
	(0.007)	(0.007)	(0.008)	(0.009)
R^2	0.57	0.61	0.63	0.66

Notes: Dependent variable: GYP – Real per capita GDP growth, 1960-1989
Observations: 57
* significant at 0.10 level, ** significant at 0.05 level, *** significant at 0.01 level.
LYO = log of initial real per capita GDP in 1960, LSEC = log of secondary school enrolment rate in 1960,
GOV = government consumption/GDP, PI = inflation rate, TRD = (imports & exports)/GDP.
Standard errors in parentheses

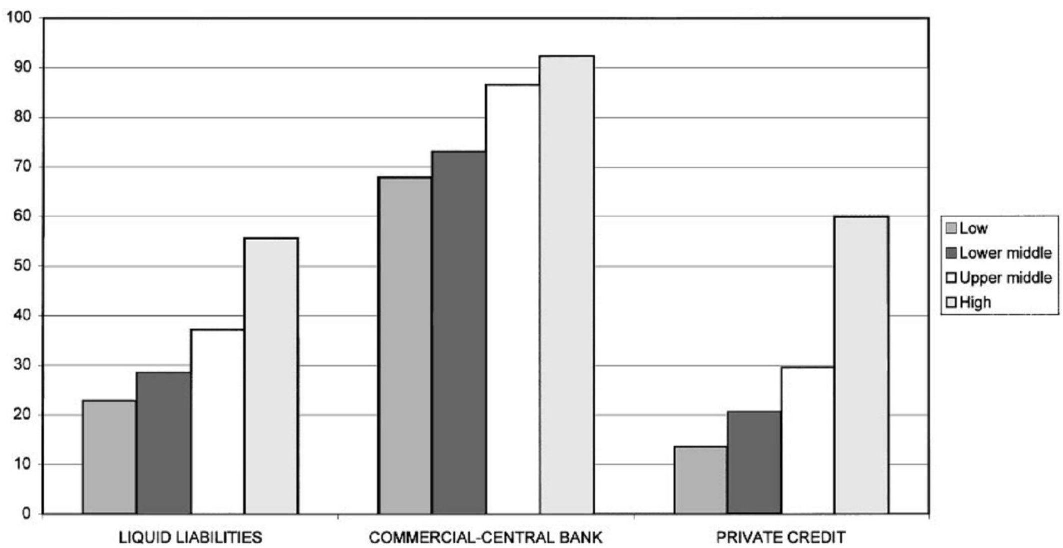
SOURCE: King, R.G., and Levine, R. (1993a), Finance and Growth: Schumpeter Might Be Right, Quarterly Journal of Economics, 108, Table VIII, p. 731

Aware that the conclusion drawn by King and Levine may have been influenced by the problem of simultaneity, and that the initial level of financial development may be a leading indicator rather than a causal factor, Levine *et al.* (2000) - henceforth LLB - decided to try to resolve this issue, using new data and different econometric procedures that, besides the problem of simultaneity, could also confront other difficulties as the omitted variables and the unobserved country-specific effects. The techniques used were: generalized method-of-moments (GMM) dynamic panel estimators and a cross-sectional instrumental-variable estimator. For the first method the assembled data belongs to 74 countries and to the period between 1960 and 1995. The dependent variable is the growth rate of the real per capita GDP, while the regressors include the level of financial intermediary development, and a set of variables that function as conditioning information. For the cross-sectional instrumental-variable estimator the period is the same, but only for 71 countries. The cross-sectional estimator serves as a consistency check on the panel findings.

LLB use three indicators of financial development: credit by deposit money banks (and other financial institutions) to private sector, divided by the GDP; the ratio of assets of deposit money banks by assets of deposit money bank plus central bank assets; and finally liquid liabilities of the financial system divided by the GDP.

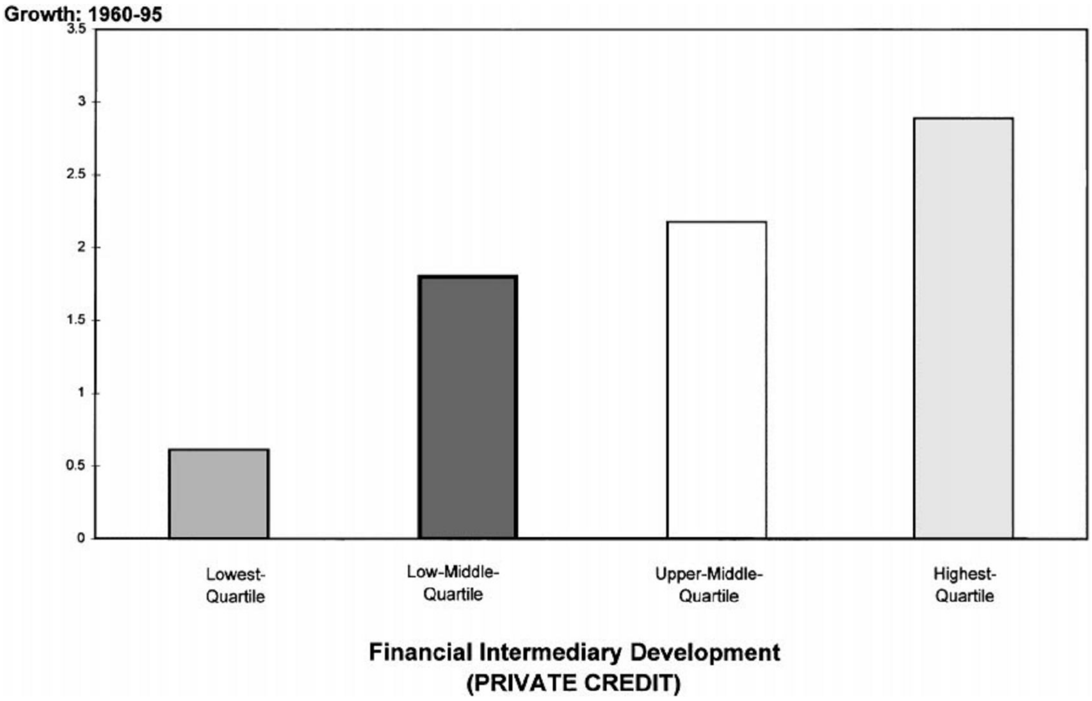
Graphically (figure 4), it is clear that the financial intermediary development indicators are higher in the high-income countries. Figure 5 shows that countries with higher levels of liquid liabilities of the financial system divided by the GDP (Private Credit) have higher growth rates in the period between 1960 and 1995.

Figure 4. Financial development across income groups, 1960-1995



SOURCE: Levine, R., Loayza, N., and Beck, T. (2000) Financial Intermediation and Growth: Causality and Causes, Journal of Monetary Economics, 46, Fig. 1, p.40

Figure 5. Economic growth and financial intermediary development, 1960-1995



SOURCE: Levine, R., Loayza, N., and Beck, T. (2000) Financial Intermediation and Growth: Causality and Causes, Journal of Monetary Economics, 46, Fig. 2, p.41

To solve the problem of simultaneity, LLB made use of the work by La Porta, Lopez-de-Silanes, Shleifer and Vishny (1998). These authors argue that the protection of investors is greater in the anglo-saxon countries, smaller in the countries that have French civil law tradition, while in between are the countries that implemented the German or Scandinavian civil law. Their findings suggest that "countries with legal and regulatory systems that give a high priority to creditors receiving the full present value of their claims on corporations have better functioning financial intermediaries than countries where the legal system providers weaker support to creditors". So, countries that assure compliance with the established laws have better financial intermediation.

As we can see in the table below, the countries linked to a German legal tradition have better developed financial intermediaries. This information was useful to create dummy variables, to be included in the model.

Table 18. Legal origin and financial intermediary development, 1960-1995

	Financial intermediary development					
	Liquid liabilities		Commercial-central bank		Private credit	
Constant	3.829	0.958	4.506	3.063	4.027	-0.674
	(0.000)	(0.081)	(0.000)	(0.000)	(0.000)	(0.386)
ENGLISH	-0.134	0.249	-0.170	0.022	-0.717	-0.090
	(0.325)	(0.038)	(0.002)	(0.716)	(0.002)	(0.646)
FRENCH	-0.434	-0.052	-0.270	-0.078	-0.894	-0.268
	(0.001)	(0.703)	(0.000)	(0.152)	(0.000)	(0.190)
GERMAN	0.477	0.683	0.048	0.152	0.401	0.738
	(0.016)	(0.000)	(0.100)	(0.010)	(0.076)	(0.002)
INCOME		0.330		0.166		0.541
		(0.000)		(0.000)		(0.000)
Obs.	71	71	71	71	71	71
Prob(F-test)	0.001	0.000	0.040	0.000	0.000	0.000
R^2	0.23	0.44	0.12	0.30	0.26	0.55

Notes: LIQUID LIABILITIES = liquid liabilities of the financial system (currency plus demand and interest-bearing liabilities of banks and non-bank financial intermediaries) divided by GDP, times 100. COMMERCIAL-CENTRAL BANK = assets of deposit money banks divided by assets of deposit money banks plus central bank assets, times 100. PRIVATE CREDIT = credit by deposit money banks and other financial institutions to the private sector divided by GDP, times 100. Values for the financial intermediary development indicators are averages over the 1960-1995 period. ENGLISH = English legal origin. FRENCH = Napoleonic legal origin. GERMAN = German legal origin. Scandinavian legal origin is the omitted category. INCOME = Logarithm of real per capita GDP in 1960.

SOURCE: Levine, R., Loayza, N., and Beck, T. (2000) Financial Intermediation and Growth: Causality and Causes, Journal of Monetary Economics, 46, Table 2, p.43

If we want to estimate the causal effect of financial development on economic growth, then an IV is needed. Correlation between those two variables does not imply that finance causes growth because other variables may affect them both. If legal origins only affects growth because it affects finance, correlations between legal origins and growth are evidence that finance causes growth.

LLB use three types of conditioning sets: the simple conditioning set (that includes the average number of schooling years and the GDP in 1960); the policy conditioning set (that extends the former set by adding variables like inflation, openness of trade, black market premium and government size); and the full conditioning set in which the policy conditioning set is extended by considering indicators like revolution and coups, political assassinations and ethnic diversity.

The regression form of the cross-sectional estimator is:

$$G_i = \beta_0 + \beta_1 \cdot F_{ji} + \beta_2 \cdot X_{hi} + e_{i,}, \tag{23}$$

where G stands for the average growth of real GDP per capita in countries 1 to 71 from 1960 to 1995, F represents the financial development of type j (one of the three previously described indicators), X is a conditioning set of type h (also described before), and β_1 is the main parameter of interest.

In the first-stage regression, results are based on the following regression model:

$$F_{ji} = \alpha_0 + \alpha_1 \cdot Z_i + \alpha_2 \cdot X_{hi} + u_i \tag{24}$$

where Z is a set of legal-origin dummies playing the role of instrumental variables for financial development.

In the cross-section analysis, where the estimated coefficient is the effect of the exogenous component of financial intermediary development on growth, and after different considerations in sensitivity analyses (estimation for the period 1980-1995, including instrumental variables for religion, and distance to the equator, etc…), the results do not change. Financial development is positively, significantly and robustly linked with economic growth as we can see in table 21 (check page 64, column named GMM LLB).

For LLB there are three advantages of GMM estimation using panel data. The first is that this enables to account for the influence of financial development over time in a country's growth. The second is that GMM can eliminate the problem that often affects cross-sectional regression which is the fact that an unobserved effect can become part of the error term, leading to biased coefficients. Last but not the least, GMM allows to control for the endogeneity of all explanatory variables. Two GMM estimators are normally used; the difference estimator - which often suffers of weak instrumentation - and the system estimator, that works under special circumstances.

The panel approach gives identical results to the cross-section, *i.e.*, the exogenous component of financial intermediary development is positively related to economic growth.

LLB tried to go further and figure out if cross-country differences were due to the legal rights of creditors, the efficiency of contract enforcement, and the accounting system standards.

As it is clear from the table below the protection of creditors, the legal systems that enforce contracts and high accounting standards all lead to better financial intermediaries.

Table 19. Legal environment and financial intermediary development (1980-1995)

	Liquid liabilities				Commercial-central bank			
	OLS	OLS	OLS	IV	OLS	OLS	OLS	IV
Constant	2.830	3.880	4.830	4.402	3.950	3.640	4.200	4.403
	(0.000)	(0.002)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)
CREDITOR	0.216	0.179			0.009	0.020		
	(0.001)	(0.027)			(0.641)	(0.504)		
ENFORCE	0.178	0.229			0.008	0.014		
	(0.000)	(0.003)			(0.022)	(0.454)		
ACCOUNT	-0.002	-0.001			0.005	0.004		
	(0.745)	(0.866)			(0.024)	(0.042)		
INCOME		-0.174	-0.099	-0.05		0.052	0.031	0.007
		(0.395)	(0.387)	(0.672)		(0.236)	(0.325)	(0.844)
LEGAL			0.412	0.361			0.091	0.115
			(0.003)	(0.009)			(0.014)	(0.002)
Obs.	36	36	36	36	36	36	36	36
Prob(F-test)	(0.000)	(0.000)	(0.000)	(0.003)	(0.000)	(0.001)	(0.000)	(0.000)
R^2	0.57	0.59	0.39	0.39	0.51	0.52	0.51	0.50

	Private credit			
	OLS	OLS	OLS	IV
Constant	1.480	2.557	4.368	4.322
	(0.000)	(0.020)	(0.001)	(0.003)
CREDITOR	0.125	0.088		
	(0.033)	(0.173)		
ENFORCE	0.200	0.253		
	(0.000)	(0.000)		
ACCOUNT	0.017	0.018		
	(0.005)	(0.002)		
INCOME		-0.179	-0.044	-0.039
		(0.262)	(0.711)	(0.804)
LEGAL			0.606	0.600
			(0.001)	(0.001)
Obs.	36	36	36	36
Prob(F-test)	(0.000)	(0.000)	(0.000)	(0.000)
R^2	0.68	0.69	0.66	0.66

Notes: LIQUID LIABILITIES = liquid liabilities of the financial system (currency plus demand and interest-bearing liabilities of banks and nonbank financial intermediaries) divided by GDP, times 100. COMMERCIAL-CENTRAL BANK = assets of deposit money banks divided by assets of deposit money banks plus central bank assets, times 100. PRIVATE CREDIT = credit by deposit money banks and other financial institutions to the private sector divided by GDP, times 100. CREDITOR = index of secured creditor rights. ENFORCE = index of law and contract enforcement. ACCOUNT = index of the comprehensiveness and quality of company reports. LEGAL= index of legal environment. Specifically, LEGAL is the first standardized principal component of CREDITOR, ENFORCE, and ACCOUNT.

SOURCE: Levine, R., Loayza, N., and Beck, T. (2000) Financial Intermediation and Growth: Causality and Causes, Journal of Monetary Economics, 46, Table 7, p.61

Roodman (2007) calls for caution in the use of instrumental variables, present in the GMM estimators that we have seen in the studies that try to find an answer on the subject of finance and growth. This author analyses LLB procedures and concludes that they used too many instruments, and so there is a problems of overidentification. When collapsing the instrumental variables he finds out that for example, the relation between private credit and GDP growth has no significance. To reduce the danger of presenting invalid results, Roodman, among other suggestions, considers that researchers should report the number of instruments present in the regressions and also run sensitivity tests in order to look out for changes in the results when the number of instrumental variables is reduced.

In the table below we can see how results change when Roodman collapses instruments, while testing for all the LLB System GMM regressions.

Table 20. Roodman's tests of Levine *et al*. (2000) System GMM regressions, all variants

Financial development proxy	Simple controls	Simple controls, collapsed instruments	Policy controls	Policy controls, collapsed instruments
Log private credit/GDP	1.82	1.49	1.41	2.34
	(2.42)**	(1.50)	(2.04)**	(2.21)**
Instruments	35	11	75	19
Difference-Hansen tests (p values)				
All system GMM instruments	0.41		0.75	
Those based on lagged growth only	0.13	0.65	0.97	0.001
Log liquid liabilities/GDP	1.75	1.97	3.03	4.19
	(1.86)*	(1.41)	(3.14)***	(3.48)***
Instruments	35	11	75	19
Difference-Hansen tests (p values)				
All system GMM instruments	0.46		0.33	
Those based on lagged growth only	0.24	0.90	0.20	0.03
Log bank credit/total credit	2.29	–0.09	1.34	2.73
	(0.82)	(0.02)	(1.34)	(1.10)
Instruments	35	11	75	19
Difference-Hansen tests (p values)				
All system GMM instruments	0.26		0.27	
Those based on lagged growth only	0.19	0.17	0.47	0.002

Notes: All regressions are two-step System GMM. *t* statistics clustered by country, incorporating the Windmeijer (2005) correction, in parenthesis. Simple controls are initial GDP/capita and average years of secondary schooling. Policy controls are those and government consumption/GDP, inflation, black market premium, and trade/GDP.
*significant at 10%. **significant at 5%. ***significant at 1%.

SOURCE: Roodman, D. (2007), A Short Note on the Theme of Too Many Instruments, Center for Global Development, Working Paper, No. 125, Table 4, p.27

With controls for policy, p-values on the Difference-in-Hansen tests of the System GMM instruments are below 0.03 suggesting trouble in the instruments.

The simple-control set shows a different behavior, with the p-values for the Difference-in-Hansen tests for instruments based on lagged growth rising when instruments are collapsed. Roodman suggests that, in this case, the Hansen test is weakened by the low degree of overidentification in the collapsed regression with simple controls (11 instruments and 9 regressors including period dummies).

Andini (2009) is another critic of LLB's article. He replicates the results of LLB's empirical findings using a two-step efficient GMM estimator. To avoid problems of the endogeneity of *F* (check equation 24), a two-stage process is used. In phase one Andini ran an OLS for the second model and replaced the *F* results in equation (23). In the second stage, Andini ran a quantile-regression estimation of the first model, using an estimator of Koenker and Bassett (1978). This estimator is highly robust to the presence of outliers, and this is very helpful in the identification of the presence of extreme values.

Table 21. The impact of financial development on growth

	GMM LLB	GMM Replication	IVQR5	GMM without Korea, Malta and Taiwan	GMM without Korea	GMM without Korea and Malta
Simple conditioning set						
Private credit	2.515 (0.003)	2.515 (0.004)	2.576 (0.001)	1.023 (0.118)	2.088 (0.027)	2.070 (0.034)
Commercial-central bank	10.861 (0.001)	9.954 (0.003)	7.986 (0.021)	4.785 (0.097)	7.552 (0.014)	7.436 (0.020)
Liquid liabilities	1.723 (0.045)	1.844 (0.041)	1.973 (0.101)	1.046 (0.127)	1.633 (0.046)	1.608 (0.067)
Policy conditioning set						
Private credit	3.222 (0.012)	3.364 (0.037)	2.871 (0.074)	1.168 (0.439)	3.011 (0.139)	2.943 (0.164)
Commercial-central bank	9.641 (0.021)	10.627 (0.160)	11.180 (0.401)	3.542 (0.483)	5.135 (0.382)	4.397 (0.461)
Liquid liabilities	2.173 (0.020)	1.934(0.063)	2.290 (0.369)	1.120 (0.251)	1.817 (0.070)	1.820 (0.088)
Full conditioning set						
Private credit	3.356 (0.005)	3.462 (0.020)	1.934 (0.139)	1.492 (0.265)	3.390 (0.076)	3.329 (0.094)
Commercial-central bank	11.289 (0.001)	12.971 (0.057)	8.673 (0.320)	8.581 (0.363)	12.964 (0.168)	12.427 (0.192)
Liquid liabilities	2.788 (0.003)	2.648 (0.010)	2.812 (0.024)	1.404 (0.124)	2.319 (0.016)	2.337 (0.027)

Note: P-values of t-statistics in parentheses.

SOURCE: Andini, C. (2009) Financial Intermediation and Growth: Causality and Causes without Outliers, Portuguese Economic Journal, 8, Table 1, p.19

Now, I am going to focus on some of the results of Andini´s tests. The GMM replication confirms the results obtained by LLB with the exception of the coefficient commercial-central bank that in the replication is not statistically significant at 5% level.

IVQR5 estimation brings doubts to the causality between financial development and growth, because 6 of the 9 coefficients have p-values higher than 0.05. These results are in contrast with those obtained by LLB. IVQR5 is a median-based estimator, so these results suggest that financial development does not affect the median of the conditional long-run growth distribution. Outliers can be the explanation for the results obtained by LLB, and this hypothesis is proved correct when the GMM is ran without 3 countries (Korea, Malta and Taiwan), with none of the coefficients being significant at 5%, and only one at 10%. Removing Korea, the results become mixed (part of the results are similar to LLB's). The exclusion of both Korea and Malta provokes a strong contrast when comparing to LLB's findings.

Beck, Levine and Loayza (2000) evaluated the empirical relation between the financial intermediary development and economic growth, total factor productivity growth (a residual, the difference between real per capita GDP growth and real per capita capital growth times capital's share), physical capital accumulation and private saving rates, with the goal of figuring out in what way does financial intermediation stimulate growth. In a first stage, they used a pure cross-sectional instrumental variable estimator and data for 63 countries in the period 1960-1995. In a second stage, they applied a GMM estimator since the cross-country regression estimates did not exploit the time-series dimension of the data, nor controlled for the endogeneity of the regressors. Also, the omission of country-specific effects could lead to biased estimates.

This study also makes use of a group of indicators to stand for financial intermediation that has slight differences with previous works. For example, private credit, excludes credits issued by the central bank and development banks, as well as credit to the public sector. The financial intermediary statistics were also deflated.

The instrumental variables developed by La Porta *et al.* (1998) are once again present in the cross-country regression, to control for potential simultaneity bias.

The cross-country regression allows knowing if the variance in economic growth and in the sources of growth can be explained by variance in the exogenous component of financial intermediary development.

To assess the strength of an independent link between financial development and growth variables, they used two of the above-mentioned conditioning sets (simple and policy conditioning information set).

In the table below we can see the results of the regression between growth and financial intermediation.

Table 22. Beck *et al.*'s regression results

	Cross-country data		Panel data	
	(1)	(2)	(3)	(4)
Constant	6.571	2.643	1.272	0.082
	0.006	0.527	0.250	0.875
Initial income per capita	-1.971	-1.967	-1.299	-0.496
	0.001	0.001	0.001	0.001
Average years of schooling	1.936	1.548	2.671	0.950
	0.008	0.078	0.001	0.001
Openness to trade		0.931		1.311
		0.042		0.001
Inflation		4.270		0.181
		0.096		0.475
Government size		-1.207		-1.445
		0.132		0.001
Black market premium		-0.139		-1.192
		0.914		0.001
Private Credit	2.215	3.215	2.397	1.443
	0.003	0.012	0.001	0.001
Hansen test	0.577	0.571		
Sargan test (p-value)			0.183	0.506
Serial correlation test (p-value)			0.516	0.803
Countries	63	63	77	77
Observations			365	365

Notes:The regression equation estimated in columns 1 and 3 is Growth = $\beta 0+\beta 1$ Initial income per capita $+\beta 2$ Average years of schooling + $\beta 3$ Private Credit. The dependent variable is the growth rate of real per capita GDP. Initial income per capita is the log of real per capita GDP in the first year of the respective time period. Average years of schooling is log of one plus the average years of schooling in the total population over 25. Private Credit is the log of credit by deposit money banks and other financial institutions to the private sector divided by GDP. The regression equation estimated in columns 2 and 4 is Growth = $\beta 0$ + $\beta 1$ Initial income per capita + $\beta 2$ Average years of schooling + $\beta 3$ Openness to trade + $\beta 4$ Inflation + $\beta 5$ Government size + $\beta 6$ Black market premium + $\beta 7$ Private Credit. Openness to trade is the log of the sum of real exports and imports of goods and non financial services as share of real GDP. Inflation is the log of one plus the inflation rate, calculated using the average annual CPI data from the International Financial Statistics. Government size is the log of real general government consumption as share of real GDP. Black market premium is the log of one plus the black market premium. The regressions in columns 1 and 2 are cross-country regressions, with data averaged over 1960-1995, and using the legal origin of countries as instruments for Private Credit. The regressions in columns 3 and 4 are panel regressions, with data averaged over seven 5-year periods from 1960-1995, and using lagged values as instruments, as described in the text. The regressions in columns 3 and 4 also contain time dummies that are not reported. *P*-values calculated from White's heteroskedasticity-consistent standard errors are reported under the respective coefficient. The null hypothesis of the Hansen test is that the instruments used are not correlated with the residuals. The critical values of the Hansen test (2 d.f.) are: 10% = 4.61; 5% = 5.99. The null hypothesis of the Sargan test is that the instruments used are not correlated with the residuals. The null hypothesis of the serial correlation test is that the errors in the first-difference regression exhibit no second-order serial correlation.

SOURCE: Beck, T., Levine, R., and Loayza, N. (2000), Finance and the Sources of Growth: Panel Evidence, Journal of Financial Economics, 58, Table 2, p.281

Looking at the cross-country regressions we can see that the Private Credit is significantly correlated with the long-run growth at the 5% significance level and the same happens in the dynamic panel procedures. These procedures were used in order to control for the endogeneity of the regressors and for the country-specific effects in dynamic, lagged-dependent variable models, such as growth regressions.

From the results above I conclude that a robust and positive link exists between financial intermediary development and real GDP growth. The same happens between financial development and total factor productivity growth (a variable which accounts for effects in total output not caused by inputs).

In general, the results confirm what Schumpeter had suggested 90 years before, that more sophisticated financial instruments could affect the speed of productivity growth and stimulate innovation, *i.e.* technological change.

On the contrary, the relation between financial intermediary development and both savings rate and physical capital growth is not clear, and results are classified by the authors as "ambiguous".

Favara (2003) denies the causal relationship between financial development and economic growth and hence contradicts LLB's findings. For this author, there is only correlation between the two, a conclusion already presented by King and Levine (1993a).

When Favara uses instrumental variables in order to solve the endogeneity problem, the results are different from those presented by LLB. Furthermore, he is unable to replicate them.

Regarding the GMM, Favara considers a mistake to apply a two-step estimator like LLB did, because the estimator is "highly inaccurate for inference purposes", a problem that had been already identified by Arellano and Bond (1991) and Blundell and Bond (1998).

The data set used by Favara is similar to LLB, although it has more countries and an extended time period. Only the two first indicators of financial development are present (liquid liabilities of the financial system and loans made by deposit money banks and other financial institutions to the private sector), deflated and expressed in percentage of real GDP.

The author created a series of controls with proxies for initial conditions, measures of macroeconomic stability and indicators of trade openness. Although some of these variables are common to LLB, the source of the data is different.

As mentioned before, the cross-sectional evidence shows that there is a correlation between financial development and growth and it is positive, significant and robust. When addressing the problem of reverse causality (using instrumental variables), the findings show that the contribution of financial development to economic growth is weak.

Table 23. Favara's OLS estimates – Cross Section Data

Dependent variable: log difference GDP per capita, 1960-1998

	(1)		(2)		(3)		(4)	
log(YO)	-0.404	-0.394	-0.367	-0.364	-0.484	-0.476	-0.475	-0.467
	4.14	3.27	3.66	2.96	6.54	5.58	6.10	5.51
log(INV)			0.379	0.329			0.067	0.070
			2.08	1.98			0.41	0.41
log(1+SEC)	0.490	0.516	0.347	0.385	0.423	0.453	0.401	0.427
	3.27	3.18	2.08	2.37	3.63	3.62	2.99	3.17
log(GOV)	-0.277	-0.332	-0.203	-0.249	0.305	-0.336	-0.290	-0.318
	2.26	2.75	1.78	2.27	3.40	3.53	3.13	3.29
log(OPEN)	0.02	-0.021	-0.042	-0.061	0.137	0.105	0.121	0.091
	0.20	0.22	0.40	0.60	1.51	1.18	1.27	0.95
log(1+INF)	0.055	0.437	-0.281	0.010	0.567	0.618	0.470	0.510
	0.11	0.79	0.53	0.02	1.49	1.39	1.03	0.99
log(1+BMP)	-0.021	-0.096	0.001	-0.050	-0.208	-0.228	-0.194	-0.212
	0.11	0.49	0.01	0.29	1.40	1.46	1.32	1.34
AFRICA					-0.837	-0.798	-0.801	-0.764
					5.62	4.79	4.59	3.98
LAC					-0,364	-0,28	-0,339	-0,261
					3,46	2,23	2,77	1,87
log(PCY)	0.389		0.244		0.215		0.198	
	3.88		1.82		2.54		2.09	
log(LLY)		0.612		0.407		0.331		0.301
		4.74		2.71		2.27		1.95
N.obs	83	83	83	83	83	83	83	83
R^2	0.47	0.49	0.52	0.53	0.66	0.65	0.66	0.65

Notes: Estimation by OLS. Robust t-statistics below the corresponding coefficients.

(1) LLB specification
(2) Inclusion of investment ratio as an additional regressor.
(3) and (4) Replication of (1) and (2) including two continent dummies, AFRICA for sub-Saharan countries and LAC for Latin America and Caribbean countries.

SOURCE: Favara, G. (2003) An Empirical Reassessment of the Relationship Between Finance and Growth, International Monetary Fund, Working Paper, No. 03-123, Table 3

In table 23, we can see that investment plays a major effect in growth since that, when investment ratio is included as an additional regressor (column 2) the point estimates for PCY and LLY are reduced. The control for unobserved regional effects (two continent dummies, columns 3 and 4) has the same effect although less pronounced. Both these modifications do not change the positive and significant correlation between PCY and LLY with GDP growth.

Table 24. Favara's IV estimates – Cross Section Data

Dependent variable: log difference GDP per capita, 1960-1998

	(1)		(2)		(3)		(4)	
log(YO)	-0.329	-0.320	-0.303	-0.299	-0.486	-0.472	-0.479	-0.462
	1.81	1.91	1.77	2.05	4.68	4.76	3.80	4.55
log(INV)			0.515	0.516			0.061	0.083
			1.67	1.68			0.23	0.38
log(1+SEC)	0.479	0.621	0.375	0.381	0.422	0.459	0.400	0.428
	2.28	2.67	1.95	2.18	2.64	3.40	2.84	3.16
log(GOV)	0.023	0.006	-0.063	-0.067	0.137	0.111	0.122	0.093
	0.21	0.06	0.54	0.59	1.48	1.13	1.22	0.99
log(OPEN)	-0.305	-0.329	-0.196	-0.201	-0.304	-0.336	-0.291	-0.315
	2.14	2.43	1.70	1.40	3.18	3.50	3.11	2.76
log(1+INF)	-0.306	-0.181	-0.651	-0.635	0.573	0.594	0.489	0.471
	0.35	0.15	0.72	0.55	1.20	1.09	0.66	0.66
log(1+BMP)	-0.008	-0.036	0.020	0.015	-0.208	-0.228	-0.209	-0.885
	0.04	0.16	0.13	0.07	1.39	1.48	1.29	1.28
AFRICA					-0.834	-0.814	-0.800	-0.773
					3.85	3.74	4.40	3.92
LAC					-0.362	-0.296	-0.338	-0.272
					2.66	1.59	2.78	1.76
log(PCY)	0.171		0.041		0.222		0.210	
	0.41		0.10		0.74		0.59	
log(LLY)		0.243		0.050		0.300		0.269
		0.42		0.10		0.81		0.71
F-test (p-value)	0.11	0.00	0.10	0.00	0.07	0.00	0.10	0.00
HS test (p-value)	0.93	0.92	0.93	0.95	0.91	0.91	0.90	0.92
N.obs	83	83	83	83	83	83	83	83
R^2	0.43	0.44	0.50	0.50	0.66	0.66	0.66	0.66

Notes: Estimation by IV. Robust t-statistic below the corresponding coefficients F Test is a test for the hypothesis that the instruments do not belong to the first stage regression. HS test refers to the Hansen-Sargan test for the null that instruments are not correlated with the residuals. A rejection casts doubt on the validity of the instruments. Instruments are: French, German and British legal origins.

SOURCE: Favara, G. (2003) An Empirical Reassessment of the Relationship Between Finance and Growth, International Monetary Fund, Working Paper, No. 03-123, Table 5b

In table 24, we have the IV estimates and the p-values for the F-test of excluded instruments and the Hansen-Sargan (HS) test of overidentifying restrictions. The first helps to detect the presence of weak instruments, while the latter is a test of the validity of the instruments. Comparing the results with the OLS estimates in table 23, we can see that in column 1 the PCY and LLY estimates are less than one half, and the t-statistics show that these variables are not significantly related to GDP growth. In column 2 this drop is even more pronounced. Favara suggests that the OLS estimates may be biased, not only because of reverse causality but also due to the omitted variables. However the results of the HS test confirm the validity of the instruments. He concludes that the contribution of financial development to growth is weak and that "there is no indication that the exogenous component of financial development encourages economic growth".

The GMM results in table 25 show that the more reliable one-step estimator used by Favara proves that the statistical significance of some of the regressors is weak. PCY is not related to economic growth and neither is LLY.

Table 25. Favara's SYS-GMM estimates – Panel Data

Dependent variable: log difference GDP per capita

	Two-Step SYS GMM		One-Step SYS GMM		Two-Step SYS GMM		One-Step SYS GMM	
	(1)		(2)		(3)		(4)	
log(YO)	-0.037	-0.025	-0.030	-0.027	-0.053	-0.051	-0.053	-0.054
	6.23	7.91	1.21	1.06	8.68	13.60	2.10	2.09
log(INV)					0.078	0.033	0.088	0.094
					8.03	3.12	2.57	2.77
log(1+SEC)	0.128	0.056	0.119	0.054	0.101	0.033	0.087	0.048
	11.78	9.20	2.14	1.00	7.88	3.12	1.68	0.91
log(GOV)	-0.075	-0.078	-0.069	-0.078	-0.076	-0.073	-0.080	-0.079
	13.28	14.47	1.77	2.01	7.96	13.75	2.52	2.41
log(OPEN)	0.042	0.028	0.038	0.022	0.040	0.023	0.035	0.021
	11.79	6.22	1.06	0.72	7.57	5.26	1.06	0.75
log(1+INF)	-0.168	-0.104	-0.173	-0.107	-0.170	-0.091	-0.163	-0.121
	19.63	9.41	2.65	1.44	14.70	5.49	2.68	1.67
log(1+BMP)	-0.012	-0.040	-0.015	-0.038	-0.012	-0.031	-0.014	-0.025
	4.04	11.20	0.72	1.75	5.03	7.70	0.73	1.33
log(PCY)	0.024		0.021		0.009		0.006	
	7.32		0.83		4.18		0.29	
log(LLY)		0.072		0.074		0.060		0.048
		10.94		1.4		7.25		0.91
Sargan test	0.81	0.79	0.81	0.79	0.88	0.92	0.88	0.92
m2 test	0.90	0.81	0.90	0.81	0.90	0.75	0.90	0.75
N.countries	87	87	87	87	87	87	87	87
N.obs	529	529	529	529	529	529	529	529

Note: SYS-GMM Estimates. Robust t-statistics are below the corresponding coefficients. Sargan test and m2 test are p-values for the null of instruments validity. Instruments: Y0 and SEC are considered predetermined. The remaining variables endogenous. Data is in deviation from cross-section mean.

SOURCE: Favara, G. (2003) An Empirical Reassessment of the Relationship Between Finance and Growth, International Monetary Fund, Working Paper, No. 03-123, Table 7

Favara also analyzed the parameter heterogeneity and found out that in a group of countries there is a positive relation between PCY and LLY and growth, in another group the opposite happens, while other countries have PCY positive and LLY negative or vice-versa. No pattern can be established. The effect of finance on growth announced by the majority of the studies is based on average effects, which could be a risky conclusion, taking in account such a high degree of heterogeneity. Favara announces his results as being a "cautionary tale" for empirical growth literature.

As we have seen, most of these studies use legal origins to explain differences in financial development. Coviello (2005) looks at the first stage F-statistics, and considers that instrumental variables based on legal origins are weak. If there is a weak correlation between the instruments and the endogenous explanatory variable, then the two stage least squares estimator (which is the estimator normally used when instrumental variables are applied in order to solve endogeneity and reverse causality problems) becomes inconsistent.

Legal origins can have impact in property rights, safe creditors, efficiency of contract enforcement and the quality of accounting standards. To be good instrumental variables, in first place they must not be affected by GDP, (which they are not in this case) and in second place it must exist a correlation between the set of instruments and the endogenous regressor. Checking LLB's work (2000), Coviello finds out that none of the indicators of financial development "is instrumented with strongly correlated variables" and hence "none of the results of table 3 of Levine *et al.* (2000) [column 1 of table 21 in this dissertation] is robust to weak instruments".

He then applies a second stage inference procedure and confirms LLB (2000) claims, except for the Commercial-Central Bank proxy.

Zang and Kim (2007) are not also advocates of the Schumpeterian view about the relation between finance and growth. They observed that some countries in Asia like Japan, South Korea and China had high growth rates and their financial services were not better than other countries with lower growth rates. For them, Robinson (1952), who denied the causal relationship of finance on growth, is right. It is economic growth which comes first, while financial development is just the result of an increase in demand for financial services. The indicators and the data set that Zang and Kim use, are similar to LLB's (2000). The difference arises from the Sims-Geweke causality framework, which tests the direction of causality between the two variables.

As we can see in table 26, the null hypothesis that states that growth does not precede financial development is rejected. However, the null hypothesis stating that financial development does not precede growth is not rejected. Sensitivity checks did not alter Zang and Kim's conclusions. Still, they do not deny in absolute terms the importance of financial development in growth. Claiming that perhaps better indicators must be found, so that future studies may be more conclusive, they encourage a more balanced view in the relationship between finance and growth.

Table 26. Sim's-Geweke test results (one-way fixed effects panel estimation)

Controlling set/financial indicator	BTOT	PRIVO	LLY
Null hypothesis: growth does not precede financial development (c_1=0)			
Simple conditioning information set	0.040***	0.062***	0.074***
	(2.766)	(5.064)	(4.286)
Policy conditioning information set	0.031**	0.049***	0.047***
	(2.278)	(4.175)	(2.865)
Null hypothesis: financial development does not precede growth (f_1=0)			
Simple conditioning information set	-0.160	0.343	0.102
	(-0.766)	(1.380)	(0.554)
Policy conditioning information set	-0.195	0.311	0.070
	(-0.943)	(1.258)	(0.387)

Notes: Numbers in parentheses are t-statistics of the coefficient under the null hypothesis.
*** and ** represent statistical significance at the 1% and 5% levels, respectively.

SOURCE: Zang, H., and Kim, Y.C. (2007) Does Financial Development Precede Growth? Robinson and Lucas Might be Right, Applied Economics Letters, 14, Table 1, p.17

5.2. STOCK MARKET AND GROWTH

Another interesting question is: does greater stock market liquidity stimulate a shift to higher-return projects that could increase productivity growth?

Levine and Zervos (1998) investigate if measures of stock market (liquidity, size, volatility and integration with world capital markets) are robustly correlated with current and future rates of growth.

For this they had to found indicators for size (capitalization measures the size of the stock market and equals the value of listed domestic shares on domestic exchanges divided by GDP), liquidity (turnover, which measures the volume of domestic equities traded on domestic exchanges relative to the size of the market; and value traded, which equals the value of trades of domestic shares on domestic exchanges, divided by GDP), volatility (12-month rolling standard deviation estimate based on market returns) and international integration (international capital asset pricing model - CAPM - and international arbitrage pricing theory - APT - are used to compute measures of integration and figure out if the markets are integrated or not).

For growth, four variables were held in account – real per capita output growth, physical capital stock growth, productivity growth and the ratio of private savings to GDP.

The data belongs to 1976-1993 and to 47 countries. In this study, there are not a lot of differences with those mentioned before in chapter 5. It is a group cross-country OLS regression with the usual cautions (in handling the simultaneity bias and endogeneity problems), and use of control variables and macroeconomic indicators in the conditioning information set. Table 27 has no surprises. The initial level of banking development and the initial level of stock market liquidity have significant relationships with the future values of output growth, capital stock growth and productivity growth, meaning that stock market liquidity and banks are beneficial to long-run growth. On the other side, savings have no statistical significant link with the stock market liquidity or bank development.

Levine and Zervos also assert that initial stock market size and stock return volatility are not robust predictors of the growth indicators, while greater risk sharing through internationally integrated markets do not affect growth nor capital accumulation, productivity growth or saving rates.

Table 27. Initial turnover, banks and growth, 1976-1993

	Dependent variables			
Independent variables	Output Growth	Capital Stock Growth	Productivity Growth	Savings
Bank credit	0.0131	0.0148	0.0111	3.8376
	(0.0055)	(0.0063)	(0.0046)	(2.3069)
Turnover	0.0269	0.0222	0.0201	7.7643
	(0.0090)	(0.0094)	(0.0088)	(5.6864)
R^2	0.5038	0.5075	0.4027	0.4429
Observations	42	41	41	29

Notes: Heteroskedasticity-consistent standard errors in parentheses. Output growth = real per capita GDP growth; Capital Stock Growth = real per capita capital stock growth; Productivity Growth = Output Growth-(0.3) (Capital Stock Growth); Savings = private savings divided by GDP; Bank Credit = initial bank credit to the private sector as a share of GDP; Turnover = initial value of the trades of domestic shares as a share of market capitalization. Other explanatory variables included in each of the regressions: Initial Output, Enrolment, Revolution and Coups, Government, Inflation and Black Market Premium.

SOURCE: Levine, R., and Zervos, S. (1998) Stock Markets, Banks, and Economic Growth, American Economic Review, 88, Table 3, p.546

Basically, this study points in the direction that financial development has a strong and positive link with the growth process and that the banks provide different financial services from those provided by stock markets. For example, the estimated coefficient on turnover implies that a one-standard-deviation[3] increase in initial stock market liquidity (0.30) would increase per capita GDP growth by 0.8 percentage points per year (0.0269*0.3). A one-standard-deviation increase in bank credit (0.5) would increase growth by 0.7 percentage points per year (0.0131*0.5). In the end of the 18-year sample period, GDP would have been much higher.

Levine and Zervos fit the results in a view that considers that a "greater ability to trade ownership of an economy's productive technologies facilitates efficient resource allocation, physical capital formation and faster economic growth".

Zhu, Ash and Pollin (2004) made a critical appraisal of the Levine and Zervos' modelling. They argue that the relationship between stock market

[3] The value of the standard-deviations can be found in Table 1 of the Levine and Zervos article (p.544).

liquidity and GDP growth is not robust due to a failure in the way Levine and Zervos dealt with the outliers present in the data. These outliers are the Asian Tigers (Taiwan, South Korea, Honk Kong, Singapore and Tailand). Zhu *et al.* created a dummy for this group of countries and when this dummy is used to control for the effect of the Asian Tigers, the relevance of the stock market liquidity is no longer significant. To treat outliers, Levine and Zervos used the studentized residuals (Belsley, Kuh, & Welsch, 1980), as a first method. These authors had identified 3 outliers, namely Korea, Jamaica and the Philippines. Zhu *et al.* point out that Cote d'Ivoire should be on this list too. Looking at the scatterplot was the second method, but also in this case, Zhu *et al.* criticize Levine and Zervos' ad-hoc choices.

Besides the methods use by Levine and Zervos, Zhu *et al.* propose additional ways to control for outliers, like a multivariate method (identification of observations far from the "core" of the data, not distinguishing the dependent from the independent variables) due to Hadi (StataCorp 2002), the method of the median regressor, the inclusion of a dummy variable for the Asian Tigers as well as three additional methods proposed by Belsley *et al.* (1980) with the goal of identifying single-row leverage points (fitted-value analysis, covariance matrix analysis and hat-matrix diagonal analysis).

Looking at the table below we can see how Zhu *et al.* methods affected Levine and Zervos' conclusion.

Table 28. Stock market turnover and GDP growth

Dependent variable: annual growth of GDP per capita, 1976-1993

Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
N. obs	42	39	39	38	36	31	37	28	42	40	42
Constant	0.046	0.038 ~	0.065 *	0.062 ~	0.077 *	0.051	0.053	0.103 *	0.058	0.043	0.016
	(0.025)	(0.022)	(0.019)	(0.029)	(0.025)	(0.030)	(0.029)	(0.023)	(0.041)	(0.027)	(0.020)
Initial	-0.014 *	-0.016 *	-0.012 *	-0.015 *	-0.011 *	-0.019 *	-0.016 *	-0.019	-0.011 ~	-0.012*	-0.011 *
Output	(0.005)	(0.004)	(0.003)	(0.005)	(0.003)	(0.007)	(0.004)	(0.010)	(0.007)	(0.005)	(0.004)
Enrolment	0.023	0.028 *	0.012 ~	0.020 ~	0.007	0.032	0.027 ~	0.019	0.013	0.018	0.022 ~
	(0.012)	(0.010)	(0.006)	(0.013)	(0.010)	(0.018)	(0.012)	(0.019)	(0.018)	(0.012)	(0.010)
Revolutions	-0.035 *	-0.012 *	-0.033 *	-0.043 *	-0.021	-0.018	0.003	-0.019	-0.035	-0.029*	-0.022 *
and Coups	(0.011)	(0.018)	(0.006)	(0.013)	(0.018)	(0.030)	(0.027)	(0.022)	(0.027)	(0.011)	(0.007)
Government	-0.062	-0.046	-0.021	-0.064	0.000	-0.053	-0.095	-0.022	-0.013	-0.042	-0.002
	(0.038)	(0.033)	(0.023)	(0.035)	(0.031)	(0.084)	(0.058)	(0.092)	(0.068)	(0.033)	(0.022)
Inflation	-0.007	-0.014	-0.006	-0.008	-0.005	0.007	0.002	-0.047	-0.005	-0.006	0.000
	(0.006)	(0.010)	(0.006)	(0.007)	(0.009)	(0.020)	(0.016)	(0.073)	(0.033)	(0.007)	(0.006)
Black Mkt	0.000	0.000	0.000	0.000	-0.001	-0.001	'-0.001 *	-0.003 ~	0.000	0.000	0.000
Premium	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Banking	0.013 ~	0.014 ~	0.016 *	0.016 *	0.016 *	0.013	0.011	0.016 ~	0.01	0.014*	0.007
Sector	(0.005)	(0.006)	(0.005)	(0.006)	(0.005)	(0.008)	(0.006)	(0.007)	(0.009)	(0.005)	(0.004)
Stock Mkt	**0.027 ***	**0.018 ***	**0.02 ***	**0.049 ~**	**0.022**	**0.013**	**0.031**	**0.018**	**0.023**	**0.018**	**0.002**
Turnover	**(0.009)**	**(0.005)**	**(0.004)**	**(0.022)**	**(0.017)**	**(0.020)**	**(0.033)**	**(0.017)**	**(0.025)**	**(0.018)**	**(0.006)**
Asian Tiger											0.045 *
											(0.007)
R^2	0.504	0.578	0.586	0.46	0.485	0.498	0.542	0.636	0.345	0.407	0.767

Notes: Heteroskedasticity-consistent standard errors in parentheses with p<0.05=~, p<0.01=*

Models:
1. The basic Levine/Zervos equation. Full sample.
2. Levine/Zervos application of Belsley, *et al.* studentized residual method. Excludes Korea, Jamaica, and the Philippines
3. Alternative application of Belsley *et al.* studentized residual method. Excludes Korea and Jamaica as in specfication 2, as well as Cote d'Ivoire substituting for the Phillipines.
4. Levine/Zervos visual inspection method. Excludes Taiwan, Korea, Japan, and India.
5. Belsley *et al.* Fitted-Value analysis. Excludes Zimbabwe, the Philippines, Cote d'Ivoire, Taiwan, Korea, and Jamaica.
6. Belsley, *et al.* Covarance ratio method. Excludes Zimbabwe, Argentina, Taiwan, the Philippines, Israel, Luxembourg, Korea, Nigeria, Jordan, Egypt, and Jamaica.
7. Belsley *et al.* Hat Matrix method. Excludes Zimbabwe, the Philippines, Argentina, Taiwan, and Israel.
8. Hadi method. Excludes Zimbabwe, Argentina, Jamaica, Nigeria, Israel, Chile, Brazil, the Philippines, Taiwan, India, Egypt, Jordan, Korea, and Cote d'Ivoire.
9. Median regression. Full Sample.
10. Alternative Visual inspection. Excludes Taiwan and Korea.
11. Full sample—With dummy variable for the 5 Tigers: Hong Kong, Korea, Singapore, Taiwan, and Thailand.

SOURCE: Zhu, A., Ash, M., and Pollin, R. (2004) Stock Market Liquidity and Economic Growth: a Critical Appraisal of the Levine/Zervos Model, International Review of Applied Economics, 18, Table 1

With the Belsley *et al.* procedures (columns 5 to 7), one of the coefficients drops to 0.013 (Stock Market Turnover in column 6) and the t-statistics are never higher than 1.30.

Hadi's method (column 8) led to the exclusion of 14 observations from the regression, because they were in the 5 percent critical range.

With the median regression method (column 9), the turnover coefficient falls to 0.023 with the t-statistic of 0.92.

The analysis of the scatter plot (column 10) suggested the exclusion of Taiwan and Korea, and without these two countries, the coefficient on turnover falls to 0.018. The adjusted R-squared drops to 0.41.

The creation of a dummy for the Tigers (column 11) increases the R-squared from 0.50 to 0.77, while the coefficient on turnover decreases to 0.002.

So, there seems to be clear evidence that the impact of the stock market on growth as announced by Levine and Zervos was somehow far-fetched.

Beck and Levine (2004) made an effort to improve Levine and Zervos' model. They agree that this model had problems like simultaneity bias. The use of the initial values of stock market and bank development led also to a "potential consistency loss". Beck and Levine try once more to measure the impact of stock market and bank development in economic growth controlling for simultaneity bias, omitted variable bias and unobserved country-specific effects, while using a system panel estimator developed by Arellano and Bover (1995). Introducing variants in the system estimator, they evaluate the robustness of the results. The data is averaged over five-years intervals from 1976 to 1998 to abstract from business cycle relationships.

Using the system estimator (one-step and two-step), they reached the results summarized in table 29, showing that turnover ratio and bank credit have a positive relationship with growth regardless of the control variables.

Table 29. Beck and Levine's GMM estimation – Stock markets, banks and growth

Regressors	(1)	(2)	(3)	(4)	(5)
Constant	-0.774	-1.757	-4.095	-1.062	-0.156
	(0.570)	(0.090)	(0.048)	(0.265)	(0.855)
Logarithm of initial income per capita	-0.717	-0.350	-0.242	-0.189	-0.384
	(0.008)	(0.099)	(0.291)	(0.356)	(0.010)
Average years of schooling[a]	-0.388	-1.156	-1.492	-1.297	-1.629
	(0.646)	(0.111)	(0.076)	(0.040)	(0.013)
Government consumption[b]		-0.073			
		(0.868)			
Trade openness[b]			0.679		
			(0.045)		
Inflation rate[a]				-0.35	
				(0.257)	
Black market premium[a]					0.549
					(0.444)
Bank credit[b]	1.756***	1.539**	0.977	0.538	1.045*
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Turnover ratio[b]	0.958**	1.078***	1.522***	1.667***	1.501***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Sargan test[c] (p-value)	0.488	0.602	0.452	0.558	0.656
Serial correlation testd (p-value)	0.595	0.456	0.275	0.272	0.335
Wald test for joint significance (p-value)	0.001***	0.001***	0.001***	0.001***	0.001***

Notes: p-Values in parentheses.
Countries=40; Observations=146
The regressions also includes dummy variables for the different time periods that are not reported.
*,** ,*** indicate significance at the 10%, 5% and 1% level in the first-stage regression respectively.
a In the regression, this variable is included as log (1 + variable).
b In the regression, this variable is included as log (variable).
c The null hypothesis is that the instruments used are not correlated with the residuals.
d The null hypothesis is that the errors in the first-difference regression exhibit no second-order serial correlation.

SOURCE: Beck, T., Levine, R. (2004) Stock Markets, Banks, and Growth: Panel Evidence, Journal of Banking and Finance, 28, Table 4, p.435.

Their preference on the system estimator over the difference estimator is due to the fact that this estimator eliminates the cross-country relationship and focuses only on time-differences. Moreover, the difference estimator is imprecise and can give biased estimates in small samples.

Beck and Levine also use an alternative system estimator developed by Calderon, Chong and Loayza (2000) that reduces the over-fitting problem of the two-step estimator while obtaining heteroskedasticity-consistent standard errors. The results suggest "an independent link between growth and both stock market liquidity and bank development", which means that stock markets provide different services from banks.

In general, whatever the panel specification, both stock markets and banks contribute to growth (independently).

6. CONCLUSIONS

This dissertation has reviewed selectively a group of papers about some fundamental topics on economic growth: determinants of growth, convergence and the relationship between finance and growth.

In the end of this long voyage through growth economics research, what can I draw from it? With so much argumentation and counter-argumentation, the elaboration of a summary is not an easy task.

The Solow model is undoubtedly an interesting and simple way of describing the process of economic growth. In the table below, there is a summary of the determinants of the level of output per capita according to this model. In the Solow model, only technological progress can sustain indefinite growth in the long term.

Table 30. Determinants of the output per capita level in the pure Solow model

DETERMINANT	INFLUENCE (+/-)
Saving rate	+
Population growth	-
Physical capital depreciation	-
Technological progress	+
Capital share in output	+

However the problems that affect cross-country regressions – namely multicollinearity, simultaneity, the degrees of freedom problem and a deficient analysis of the outliers - have contaminated some of the results and hence in the later years, cross-country regressions have been put aside in favour of panel data procedures. Panel data methods allow to correct some of the biases of cross-country regressions, making possible to control for variables that cannot be observed or measured.

The influence that these limitations seem to have on the conclusions one draws, for example, from the MRW model, is quite impressive. However, in a long run perspective, cross-country regressions are undoubtedly useful. It is from this perspective that I can highlight Sala-i-Martin’s (1997a, 1997b) articles about the determinants of growth. The environment in which the economy operates, the incentive structure that affects the individual behaviour, the level of competition and the market regulations by the government surely are the most important features in the process of economic growth. However, there is not an absolute consensus among researchers about the influence of these determinants.

In table 31 we can see the main determinants of growth for a significant number of empirical studies and the criticisms to those findings.

Table 31. Most common determinants of growth in empirical studies

DETERMINANT	INFLUENCE (+/-)	LITERATURE	CRITICISM
Investment	+	Canarella and Pollard (2004), Caselli et al. (1996), Durlauf and Johnson (1995), Favara (2006), Islam (1995), Levine and Renelt (1992), Mankiw (1995), Mankiw et al. (1992), Mello and Perrelli (2003), Ram (2008), Sala-i-Martin (1997a, 1997b), Sturm and de Haan (2000), Temple (1998)	
Population growth	-	Barro (1991), Canarella and Pollard (2004), Caselli et al. (1996), Islam (1995), Mankiw (1995), Mankiw et al. (1992), Mello and Perrelli (2003), Ram (2008)	Levine and Renelt (1992)
Human capital	+	Barro (1991), Canarella and Pollard (2004), Caselli et al. (1996), Durlauf and Johnson (1995), Evans (1998), Islam (1995), King and Levine (1993), Levine et al. (2000), Mankiw et al. (1992), Mello and Perrelli (2003), Ram (2008), Sala-i-Martin (1997a, 1997b), Sturm and de Haan (200)	
Political instability	-	Barro (1991), Mankiw (1995), Mello e Perrelli (2003), Sala-i-Martin (1997a, 1997b), Sturm and de Haan (2000)	Levine and Renelt (1992)
Civil liberties	+	Sala-i-Martin (1997a, 1997b), Sturm and de Haan (2000)	Levine and Renelt (1992)
Market distortions	-	Barro (1991), Levine et al. (2000), Mankiw (1995), Mello e Perrelli (2003), Sala-i-Martin (1997a, 1997b), Sturm and de Haan (2000),	
Buddhism, Confucianism, Islamism	+	Sala-i-Martin (1997a, 1997b), Sturm and de Haan (2000)	
Catholicism, Protestantism	-	Sala-i-Martin (1997a, 1997b), Sturm and de Haan (2000)	
Government consumption expenditure	-	Barro (1991), Favara (1996), Levine et al. (2000), Mello and Perrelli (2003)	Levine and Renelt (1992), Sala-i-Martin (1997b)
Financial intermediation	+	Beck and Levine (2004), Beck et al. (2000), King and Levine (1993a), Levine (2003), Levine and Zervos (1998), Levine et al. (2000), Mankiw(1995), Pagano (1998)	Andini (2009), Favara (2006), Zang and Kim (2007)
Stock Market Liquidity	+	Beck and Levine (2004), Levine and Zervos (1998)	Zhu et al. (2004)
Initial output level	-	Barro (1991), Beck et al. (2000), Canarella and Pollard (2004), Caselli et al. (1996), Durlauf and Johnson (1995), Islam (1995), King and Levine (1993), Levine and Renelt (1992), Levine et al. (2000), Mankiw (1995), Mankiw et al. (1992), Mello and Perrelli (2003), Ram (2008), Sala-i-Martin (1997a, 1997b), Sturm and de Haan (2000) , Zhu et al. (2004)	
Openness to trade	+	Beck et al. (2000), Sala-i-Martin (1997a, 1997b), Sturm and de Haan (2000), Levine et al. (2000)	Levine and Renelt (1992)

On the topic of convergence, I can conclude that conditional β-convergence exists. In the developed economies, there is some evidence of unconditional β-convergence and σ-convergence. There is also no consensus about the rate of convergence and the elasticity of output with the respect to capital, something that in part can derive from the fact that there are a lot of differences in the studies, *i.e.*, different samples, data, models, etc… However, we should keep in mind that a greater control for the differences in steady state leads to higher convergence rates, particularly when technological differences across countries are taken in account.

A special remark to quantile regressions that prove to be a very useful and reliable statistical technique, enabling to divide the distributions in segments and to see in detail what happens in the different quantiles. Quantile regressions also provide an easy way to detect the outliers that can bias the conclusions.

As table 31 shows, the relationship between finance and growth is one of the hardest things to figure out in economic growth. In fact, countries with better-developed financial systems tend to grow faster. The degree of sophistication of the banking system and the liquidity of stock markets, have both positive relationships with growth, although banks and stock markets provide different services. Nonetheless, there is also evidence against, and the results presented by Andini (2009) and Favara (2006), posing doubts about the relationship between finance and growth are more than a cautionary tale. Another problem that should be held in account is the use of the proxies that stand for banking system and liquidity of stock markets, since corporate governance, risk management and financial exchanges are financial functions though to measure.

Further research must be done in order to clarify some of the abovementioned doubts.

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