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The New Growth Theories and Their Empirics after Twenty Years

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Abstract
In this work the author updates the reviews on endogenous growth theories in order to explore whether recent empirical studies have become more supportive of their main predictions. Among the core topics studied in the growth econometric framework, namely convergence, identification of growth determinants and factors responsible for growth differences in the data, the primary focus of this paper is on the last two. The author will review, from macro growth regressions, studies that test primarily the performance of endogenous models in terms of significance and robustness of the coefficients of growth determinants. By highlighting methodological issues and critical discussion, she argues that: (i) causal inference drawn from the empirical growth literature remains highly questionable, (ii) there are estimates for a wide range of potential factors but their magnitude and robustness are still under debate. Her conclusion, however, is that, if properly interpreted, the predictions of endogenous growth models are gathering increasing empirical support.

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1 Introduction

This survey updates the research program on new growth theories (henceforth NGTs) after two decades of significant theoretical and empirical contributions. With the term NGTs, we refer to the class of endogenous growth theories that have been developed in the last two decades, dating back to the contributions of Romer (1986) and Lucas (1988)[1]. In the two decades since the original papers the literature on this topic has grown steadily and thousands of articles have been published in the most important journals, some of which have been created specifically for this scope. One feature of this literature is that empirical studies outperform the theoretical ones. In the last years, in fact, many empirical works have been published in which, contrary to previous studies, evidence seems to be consistent with many predictions of the new theories. We shall update existing reviews since the focus has shifted from convergence issues to an assessment of the economic and statistical significance of the wide array of potential growth determinants.

It may be questioned whether there is a call for a further survey, especially after the publication of the *Handbook of Economic Growth* edited by Aghion and Durlauf (2005), in which many determinants of growth are fully explored by leading economists in the field. This paper cannot be a substitute for that two-volume work. Our motivation is to build a survey that offers in a single article an integrative view of the entire empirical debate and an assessment of where it stands today. The undertaking is not straightforward. The 87 variables, identified as potential growth determinants in the 1999 survey by Durlauf and Quah, have increased to 145 in the more recent 2005 survey by Durlauf, Johnson and Temple. This figure is destined to increase further if interactions between variables are considered. Is this large number of identified growth determinants supported by theoretical and empirical studies?

We will search for “salient” growth determinants, even if not in the detail that would be possible if explorations were limited to one or few of them. In our view a salient growth determinant should be considered one that has been modelled in growth theories and has been found significant in a sufficient number of empirical studies.

The appearance of the NGTs has generated an extensive literature – that continues to flourish – characterised by two phases. The first focused on convergence *versus* divergence of per capita income and growth rates across countries and across time. The issue was considered relevant for an empirical assessment of the validity of the old and the new theories of growth. Whereas a key aspect of exogenous models of growth was the convergence of all countries to a common level of steady state per capita income, the implication of convergence in the NGTs may not occur at all. This seems to be consistent with the casual observation that poor countries are not able to catch up with the leading economies and to converge towards the same steady state as predicted by a simple version of the traditional growth model.

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[1] The NGTs contrast with the neoclassical growth view, which asserts that the steady state growth rate is determined exogenously by technical change. In the NGTs growth is generated from within the system as a direct result of internal processes by means of innovations and both human and physical capital accumulation which do not respond to the law of diminishing returns.

Following the empirical studies by Barro (1991), Barro and Sala-i-Martin (1991) Young (1991, 1995), Mankiw, Romer and Weil (1992), Jones (1995a, b), in which convergence among countries was measured conditional on factors that determine the steady-state, we have observed the weakness of the endogenous growth paradigm and the revival of the canonical Solow (1956) model. Subsequent studies have led to a wide array of empirical outcomes and to the failure of the original intention of using convergence as a test for the validity of the two competing growth theories. Convergence issues, even if they still capture the interest of many scholars, are by no means – as claimed by Durlauf, *et al.* (2005) –"the bulk of empirical growth studies"[2].

In fact, the finding that poor economies converge to *their own steady states* does not provide an explanation for why these steady state levels are so low, and it fails to give devices to policy makers both in developing and developed countries[3]. Although the prediction of convergence still remains as a testable hypothesis, the focus has shifted from convergence to the explanation of the growth mechanisms and the determinants of the steady state levels. From this perspective it might be interesting to investigate, according to cumulate evidence, whether or not the predictions of the NGTs have become more robust and which problems still remain open. Ironically, the growth debate, instead of reaching a consensus, has assumed a new divergent path between those economists (Mankiw, Romer and Weil [1992] from a neo-classical perspective) who believe that international variations in income across countries are accounted for almost exclusively (80%) by differences in factor accumulation and those who attribute all the observed differences (90%) to total factor productivity (TFP).

The diverse emphasis posed on these two factors, ideas gap against factor accumulation (A against K) in the recurring contention is lessened by new researches that carefully distinguish between these *proximate* sources of growth as opposed to *fundamental* sources (Klenow and Rodriguez-Clare 1997, Easterly and Levine 2001, Henderson and Russell 2005, Caselli 2005, and Easterly 2005). In a broader interpretation, fundamental sources include economic institutions (Hall and Jones 1999, Acemoglu *et al.* 2001), legal and political systems (La Porta *et al*. 1998, 1999) as well as culture and social norms (Glaeser *et al*. 2004, Tabellini 2005) and geography (McArthur and Sachs 2001, Sachs 2001, 2003). Before discussing econometric outcomes and special features of the *institutions view*, it is indubitable that the new stylised fact that has emerged in recent years is the focus on factors which go beyond the traditional ones. One of the objectives of the NGTs is to eliminate the dichotomy between growth and development theories. To achieve this aim, it is reasonable to think that deep factors of growth should be included in the endogenous growth paradigm.

For understandable reasons this paper cannot be a comprehensive review of all the approaches to the empirics of growth. Our proposal is to discuss the state of the general debate by reviewing empirical studies, from both journal articles and working papers, devoted to assessing the robustness of the sources of economic growth emanating from

[2] Convergence and identifications of growth determinants are closely related since their treatment requires the specification of a regression model of cross-country growth differences from which the effects of different factors on growth may be identified (see Durlauf *et al* 2005).

[3] See Islam (2004) for an interesting and updated survey on the convergence issue.

the NGTs, in order to ascertain the objectives achieved and the context on which further research can be pursued[4].

The overall picture we expected from *a new theory* is one in which there is not only one factor that trigger growth but a combination of several endogenous factors and their strategic complementarities. Unfortunately, this message does not emerge from a unified theoretical framework (see Galor [2005] who calls for a unified micro-founded model): each model of the NGTs captures only one factor and it alone is capable of generating sustained growth. Investigation of the NGTs from an empirical perspective offers the option to avoid this restriction. Empirical specifications of growth theories allow us to introduce more than one factor at a time and interactions among them. We examine the state of this literature without any pretence that this examination will be exhaustive.

The survey is not organised around the different approaches applied in growth empirics. Our choice is motivated by the fact that such a perspective has already been followed by Temple (1999) and Durlauf *et al.* (2005) in their outstanding reviews; and in any case, our specific interest is to draw inferences from different studies that focus on the identification of leading growth determinants. The major weakness of the bulk of studies aimed at testing the NGTs is the inability of econometric specifications to capture accurately the mechanisms of growth stressed by these theories, and the proxies used for measuring key determinants of growth are often imprecise. Although there is lack of consensus on the methods used for distinguishing the NGTs empirically, we believe that a review structured around empirically useful categories of growth determinants may be a contribution to the current state of the art. These categories include the evidence on factor accumulation *versus* research-based theories of growth as well as institutional factors.

The outline of the paper is as follows. Section 2 discusses the main criticisms to the empirics of growth and the substantial advances in the econometric tools developed over the decade. Section 3 (and subsections) shows from growth regressions the evidence on endogenous sources of growth according to the most influential classes of models. By discussing the robustness of the estimates we will evaluate basic regression findings on: (i) initial conditions, (ii) physical and human capital, (iii) R&D, (iv) openness to trade. Section 4 introduces the evidence on public policy and institutions to gain insights into government activities and organizations and the way in which they affect a country's performance. The last section provides concluding remarks and proposes some possible directions for future research.

2 Methodological Critiques on Growth Empirics

2.1 Technical Issues in Testing the Robustness of the Determinants of Growth

It is common knowledge that (at least in terms of interest by economists and papers written on the subject) a non-marginal contribution to the success of the NGTs has been the increasing use of econometrics to test their predictions.

[4] The number of papers on this topic is enormous. We will select the ones whose publication in leading journals has provoked debates or has favoured further researches.

Typically, the broad quantitative growth approach, to deal with these facts, is based on linear cross-country regressions. The motivation for using this approach has been twofold. Firstly, second generation NGTs, and specifically those based on endogenous technological progress, should not rely on growth accounting since the latter fails to give precise estimates of TFP. Secondly, growth accounting attributes to physical capital and labour a weight that depends on their shares of GDP, while in regression analysis the significance and magnitude of the coefficients of each determinant of growth are left to data. Growth regressions, however, as economists unanimously agree, show how variables are correlated with the growth of nations, but are far from implying the direction of causation.

Although the econometrics of growth based on the basic framework of Barro (1991) and Mankiw-Romer-Weil (1992), has been contested by many authors (i.e. Klenow and Rodriguez-Clare 1997, Dinopoulus & Thomson 2000, Brock and Durlauf 2001), we agree with two opinions expressed by Temple (1999) in his worthy review article: (i) many interesting things have been learnt from these researches but, (ii) it is time to argue for a different, *non-neoclassical*, vision of growth.

It is worth mentioning, however, that the primary purpose of cross-country regressions was and still is the investigation of what determines growth differences in GDP per capita across countries in the long run. Growth empirics should explain if these differences were due to factor accumulation or to TFP, a combined effect of the two, or to other identified factors that can supplement the orthodox explanations. While some mechanisms pertain to the domain of neoclassical and endogenous growth theories, others, developed under the rubric of socio-political institutions, lie, at least partly, outside the field of theoretical models. Simply referring to specific historical circumstances is no longer sufficient to prove the validity of this approach which needs a broader analytical context. Thus, the inclusion of institutional factors in the theoretical framework of the NGTs is highly auspicious. The availability of standardised data sets[5], can serve to test both mechanisms.

The criticisms to the empirics of growth have been very numerous. A prevalent concern is the causality *versus* the correlation issue. This problem remains central and cannot be satisfactorily solved in the empirical framework of both cross-section and panel data growth regressions. Proponents of empirical studies based on this methodology share the belief that regression studies involve an implicit form of causality, otherwise they would not be suitable for growth investigations and for policy assessments. A researcher that wishes to explain economic performance will introduce in the growth equation vectors of independent variables that he believes are the moving force of the former. But is this procedure appropriate? Regression techniques are applicable only if the causal structure of the model is determined a priori. Typically, this

[5] Although the most used sets of data are the Penn World Tables (now updated, [PWT 6.2]) by Heston, Summers, and Aten (2002), data on different variables has been made available by many growth scholars. The sites of the World Bank and NBER as well as those of many other institutions, such as the Centre of International Development (CID), provide various data series. We still lack, however, the detailed data necessary to construct measures of TFP, R&D capital and other variables that are very useful for a direct test of the second generations' growth models. Detailed data for EU countries are provided on-line by the Groningen Centre of Economic Development. Other sets of data for specific growth issues are those by Barro and Lee (1993, 2000), Beck *et al* (2000), Knack and Keefer (1995), Kaufman *et al* (2006), among many others. See, for further information, the growth page cured by C. Jones and other growth economists (http://elsa.berkeley.edu/~chad/growth.html).

does not occur if regressors are introduced arbitrarily into the analysis. Brock and Durlauf (2001) have pointed out that the extended sets of variables used to explain growth patterns in cross-country regressions, such as democracy, rule of law, social capital, are of a socio-cultural nature and cannot be treated as if they were derived from an a priori specified structural model. The lack of agreed theoretical bases to apply in empirical work has motivated the practice of abandoning any a priori model and enables the data to show which variables are correlated with growth. This practice has led to unwieldy sets of explanatory variables (*model uncertainty*).

The concern about model uncertainty is at the centre of the recent empirical debate, but it is still in its infancy given the difficulties of finding accepted methods to deal with this issue. Among the enormous number of regressors that have been included in the empirical analysis, most have been found to be statistically significant according to conventional tests. This means that we have as many growth theories as the number of significant regressors and we cannot distinguish among them (model identification)[6]. To resolve the issue we need theoretical models that provide restrictions to this great number of regressors.

Other frequent motives of concern with regard to conventional techniques are related to issues extensively discussed in the literature such as omitted variables, serial correlation in the disturbance terms, collinearity between the variables and the presence of measurement errors, which may lead to violation of a set of conditions necessary for consistent coefficient estimates.

Recently, the criticisms have intensified by emphasising problems associated with parameter heterogeneity, and non-linearities. The argument raised is that conventional cross-country linear regressions impose strong homogeneity among parameters, which lead to the implausible assumption that a change in a particular variable has the same effects across countries. Several studies (Liu and Stengos 1999, Kalaitzidakis *et al.* 2001) find strong evidence of parameter heteogeneity that may arise from non-linearities in the production function, multiple steady-states and poverty traps. New empirical methods and tests have been employed to account for failures of standard growth regressions (Doppelhofer, Miller and Sala-i-Martin 2004, Easterly and Levine 2001, Lee, Pesaran and Smith 1997, 1998, Hansen 2000, Fernandez, Ley and Steel 2002, Masanjala and Papageorgiou 2004 among others).

Although a widespread discussion of these issues and methods to deal with are contained in Brock and Durlauf (2001) and Durlauf *et al.* (2005), what it is still lacking in the literature is a consensus on accepted methods to test the robustness of parameters and their importance in growth theories.

The most cited paper that has addressed this issue still remains Levine and Renelt's 1992 study (henceforth LR). Their method involves the identification of empirically robust determinants of growth that can explain observed differences in growth when the range of possible factors is large. Robustness consists of identifying a variable the importance of which is confirmed across different specifications. LR carried out the Leamer (1985) extreme bound-analysis (EBA), which involves estimating the upper and the lower extreme bounds of a coefficient of a variable of interest across different model specifications. If the signs of these extreme bounds are significantly different from zero and maintain their signs or their statistical significance when other variables are

[6] These remarks are well illustrated by Durlauf *et al.* (2005).

included, then the variable is considered to be robust. The models are distinguished by alternative combinations of 1 to 3 variables taken from the following set: initial income, the investment share to GDP, secondary enrolment rates, population growth.. According to LR, there is little chance to find significant empirical results for endogenous growth factors. LR report cross sectional studies conducted with over 50 different regressors, and only the share of investment, other than initial income, is found to be strongly correlated with growth.

Extreme bounds have been criticised by various authors (Granger and Uhlig 1990, McAleer 1994). Durlauf *et al.* (2005) consider the EBA methodology as an excessively conservative approach for policy evaluation, because from a “decision theoretic perspective, it corresponds to an extreme risk-averse way of responding to model uncertainty” (p.610). In other terms, the authors argue that the policy makers cannot decide on important political economy concerns on the basis of *t statistics* and other similar mechanical criteria.

The same criticism applies to the alternative approach taken by Sala-i-Martin (1997). The method involves studying the entire distribution of estimators of a variable of interest. The robustness test is based on cumulative density functions to establish a ranking variable performance. A variable is robust, according to Sala-i-Martin's method, if, by averaging the statistical significance levels, it rests significant and with a given sign in 95% of the different regressions estimated. Applying this methodology to 60 variables, Sala–i-Martin found, differently from LR, that 22 variables out of 59 appeared to be significantly linked to growth. This outcome depends on the less restrictive concept of robustness adopted. Nevertheless, also applying this procedure, there are many variables – theoretically expected to be important – that are not correlated significantly with growth. If we look at the list of variables reported by Sala-i Martin (1997), it is remarkable to note that, except for investment in equipment and initial income, the other robust variables include almost exclusively measures of geography, religion, rules of law, political rights and other institutional attributes[7].

According to this evidence, scholars should explain why institutional variables seem so robustly correlated with growth even if they are historically the same and do change very slowly in the growth process of developed countries. We expect to find a strong impact on growth for developing countries, but how can we explain that in any regression more robust estimates are obtained by simply introducing institutional variables as instruments for endogenous proximate factors? The answer may embrace the way these variables are constructed or the fact that researchers include too many of them, by simply arguing that they serve as good instruments, being predetermined with respect to current growth rates in per capita income.

Alternative approaches have been proposed to solve the controversy over the selection of growth-regression models. Model selection methods are classical models used to investigate the importance of a variable. Different statistical criteria can be employed to choose the subset of variables to be included in the best model. One of these methods is the Hendry and Krolzig (2003, 2004) program for selecting econometric models through an automatic procedure, which substitutes the data-based selection. Instead of millions of regressions, the authors just run one regression (choose

[7] See Jensen and Wurtz (2006) for criticisms of this methodology. The authors claim that under a series of statistical assumptions, Sala-i-Martin’s method does not identify the partial effect nor the importance (robustness) of a variable of interest.

one model) to individuate the determinants of growth based on a set of statistical tests. According to the *general-to-specific methodology* the "true" equation should be characterised by a general regression that includes all information about the effective sources of growth but this general unrestricted model should be appropriately reduced to a more congruent representation (specific regression) which encompasses every other restricted regression of the general specification[8]. The endeavour is to select among the different models the one that is consistent with some theoretical views. The authors argue that, in cases in which there are more potential candidate variables (as in growth theories) than available observations, it is still possible to run regressions by repeated applications. The model selected by the authors, out of the space of possible models based on a set of statistical tests, includes the rate of equipment investment, an index of openness and some institutional measures.

Hoover and Perez (2004), using the methodology associated with Hendry and Krolzig (2004), have re-examined LR and Sala-i-Martin's conclusions by using, in a Monte Carlo experiment, a variant of the EBA. By comparing this approach with a version of the general-to specific methodology, the authors conclude that the *modified* extreme-bound procedure used by Sala-i-Martin possesses higher power to detect potential significant regressors than the LR approach. The latter is able to reject important growth determinants as fragile and at the same time to consider spurious relationships with growth as robust.

Another prominent approach advocated by many researchers that can account for model uncertainty is the Bayesian Model Averaging Approach (BMA). This methodology has already been applied in the context of economic growth by Fernandez, Ley and Steel (2001), Brock, Durlauf and West (2003), and Doppelhofer, Miller and Sala-i-Martin (2004)[9], among others. The multiplicity of regressors introduced in growth equations is solved in classical econometrics by leaving it to data to sort out the significant ones. The robustness of a variable is determined by the average of the estimates over different models. But when the number of regressors exceeds the number of observations in the data set the analysis may become flawed. If one does not know which model is the true one, it becomes necessary to attach probabilities to different models and then use the Bayesian approach to average across models using some selection criteria. Model averaging seems to be a powerful tool that can help policy makers to gather more information than simply that offered by parameter estimates and other conventional summary statistics. The strategy of constructing posterior probabilities is considered appropriate to evaluate alternative policies without identifying a priori the best growth model. The application of this approach to sub-Saharan African countries, for example, helps to explain why ethnic heterogeneity affects growth in these countries but not in others (Brock and Durlauf 2001).

Fernandez *et al.* (2001) show the superiority of BMA over other techniques in selecting regressors to explain cross–country growth. Their findings, by comparing LR

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[8] The basic methodology is to start with a general *unrestricted model*. Then, by eliminating all the variables with low t statistics, the model is re-estimated and the final model is the one in which all the coefficients are relevant.

[9] Doppelhofer *et al*. (2004) label the approach as BACE, which stands for "Bayesian Averaging of Classical Estimates". The authors estimate 89 million randomly chosen regression specifications. From these estimations they compute posterior probabilities measured as the average goodness of fit of models and then compare the results from models that include (and exclude) a particular regressor.

and Sala-i-Martin procedures, appear to favour the latter. The Sala-i-Martin procedure, even if not based on firm theoretical statistical methods, leads to the conclusion that large numbers of variables are important for growth. However, independently of what Fernandez *et al.* claim, if we look at the table of results (Table 1, page 181), many variables considered important by Sala-i-Martin show a lower posterior probability than the weighted average probability estimated with the previous method by Sala-i-Martin. The set of variables with a lower posterior probability are variables regarded as important growth determinants, such as rule of law, numbers of years an economy has been open, degree of capitalism, primary school enrolment in 1960, black market premium etc. The variables (for which there is also a correspondence with the average probability assigned by Sala-i- Martin) identified as strong explanatory variables consist only of the GDP levels in 1960, life expectancy, and equipment investment. Except for life expectancy, the other two variables are those found robust also by LR.

By averaging OLS coefficients of 68 variables across models for 88 countries, over the 1960-1996 period, Doppelhofer *et al.* (2004) find that 18 out of 67 explanatory variables are significantly partially correlated with long-term growth. But just four seem to be robustly associated with growth: the relative price of investment, initial GDP per capita, primary schooling and the number of years a country has been open.

Other non-parametric approaches to test the robustness of LR results have been performed by Kalaitzidakis *et al*. (2000). They propose a method in which auxiliary variables enter non-parametrically in the growth regression to ascertain if variables, considered key determinants of growth, enter linearly and, hence, are valid candidates for a robustness assessment. Extending the sensitivity analysis of LR, they confirm the robustness of previous results concerning variables such as investment and initial GDP (for the period 1960-89). Differently from LR, however, they find government spending to be robust as well as some distortionary variables, like standard deviation of gross domestic credit, inflation and real exchange rate distortion proxies.

The issue of robustness of a variable has been dealt with recently by Aldrich (2006) and Jensen and Wurtz (2006). The former does not address the problems of classical against Bayesian inference but considers the assessment of sturdiness and fragility in empirical econometrics by stressing the role of sensitivity analysis in changing model specifications (assumptions). The critical attitude of econometric theorists towards this common procedure is justified only when data are not informative about the assumptions. But there are other eventualities in which this analysis can be “the only resort” in assessing the validity of an empirical relationship. Sensitivity analysis allows comparable evidence of different specifications, without assessing the credibility of assumptions, by using their posterior probabilities. The author states that if the posterior probabilities are either not available or are such that the stronger forms of inference are not possible then sensitivity analysis should be recommended. If, for example, a parameter implied by a theory is not satisfied in the majority of the regressions two explanations are equally probable. The first explanation is that the theory is incorrect, the second one is that the OLS is not adequate to estimate the theoretical relationship. However, what is important for inference is the truth contained in the assumptions: “the fragility of a variable has no implications for the credibility of the assumptions but it is informative about the world in other respects” (p.170). According to the author if fragility is obtained for all the assumptions then inference may be unsatisfactory but if one of the assumptions predicts fragility this should not be considered as an element of misspecification. With the same reasoning if the assumptions do not cover the truth also sturdiness may signal misspecification.

Jensen and Wurtz (2006) analyse more deeply the classical and Bayesian methods already discussed (Bayesian, Leamer, Sala-i-Martin and Hendry-Krolzig) to face the problem basically encountered in growth empirics when the number of regressors is large in relation to the number of observations in the data set. In general no method is appropriate to identify the importance of a variable in small and *undersized samples*. Some of the methods have a higher probability of accepting a variable as important when it is not. Therefore, according to the two authors neither the Leamer method, nor the Sala-i-Martin and the Doppelhofer *et al.* methods are adequate to assess the robustness of a variable of interest. Monte Carlo simulations confirm this claim. Bayesian averaging and general-to-specific methods give correct inference only when the true model is sufficiently small. The method suggested by Jensen and Wurtz endeavours to identify the partial effect of a variable under the assumption of conditional mean independence (CMI). If this assumption is satisfied the method determines the importance of the regressor and its partial effect. The implementation of the method involves multiple testing. In the first step a general to specific approach is used, then partial regressions of the variable of interest are run and the number of variables found in the first step to be included in the short regression should be conditionally mean independent. When compared with the other methods mentioned, the Jensen and Wurtz method seems to provide an unbiased estimator coefficient of the variable of interest. In particular, when compared with the Sala-i-Martin method, the CMI and the EBA methods have a lower probability of Type I errors in the estimate of the coefficient robustness.

Before concluding this section, it is worthwhile to point out that Bayesian Model Averaging and General-to specific model's selection procedures used to assess the robustness of growth determinants are very sensitive to the international datasets used in the analysis as shown, recently, by Ciccone and Jarocinski (2007). A Monte Carlo study conducted by the two authors confirms that by implementing these approaches across different versions of well known international datasets (World Bank and Penn World Table) many determinants of growth become insignificant. In particular, with the two versions of Penn World Table (6.0 and 6.1) it is possible to show that Bayesian Model Averaging procedure disagrees on 13 of 25 determinants of growth and with the latest version of PWT (6.2) 13 of 23 variables become insignificant.

Aside from more or less complicated methods to assess the robustness of a variable of interest, empirical refinements should be a priority in this field. What we expect from statistical inference is its ability to show if the data is consistent with the hypothesis that one wants to test. It is possible that an empirical relationship exists but does not appear from an inference simply because the information contained in the data is not sufficiently strong.

2.2 Methodological Advancements in Canonical Growth Regressions

Much of the above discussion typically refers to advanced tools in the empirics of long run growth that each researcher would like to possess when he faces model uncertainty. However, applications of some of these tools would require a change in the standard econometric approach. Even if the computational power available to researchers is enormously increased, we are not able to make predictions about widespread acceptance of Bayesian procedures or other econometric tools among the generality of researchers. However, also in performing canonical growth regressions, some progress has been made for parameter estimates to be more precise and consistent.

It is common knowledge that in a cross section framework, in which data are averaged for periods of 40 years or more, the estimated regression of the Barro-type has the following form:

$$g_i = \beta_0 + \beta_1 y_{i0} + \beta_2 X_i + u_i \tag{1}$$

where g_i denotes the growth rate of real GDP per capita (or per-worker) averaged 30-40 year period, y_{i0} is the initial level of real GDP per capita, X_i is a vector of explanatory variables considered proximate determinants of economic growth, u_i indicates the error term (for the country index i = 1,…, N), which contains unobserved country specific effects due to differences in initial conditions. Hence, in a pure cross-sectional regression the unobserved country-specific effect, being part of the error term, results in biased coefficient estimates.

To avoid endogeneity of regressors, simultaneity bias, as well as to control for country-specific effects, recent empirical studies have used dynamic panel data approaches (Islam 1995, Caselli, Esquivel and Lefort 1996, Hoeffler 2000, Bond Hoeffler and Temple 2001). Scholars agree that the dynamic panel data estimator is a more powerful methodology to overcome the rather frequent endogeneity bias in the context of growth analysis. To exploit the time series dimension of data, averages for shorter periods of 5 years are used in the regression. This allows unobserved country specific effects η_i to be taken into account (country varying time invariant):

$$g_{it} = \beta_0 + \beta_1 y_{i,t-1} + \beta_2 X_{it} + \eta_i + v_{i,t} \tag{2}$$

where g_{it} indicates the average growth rate over a series of five year periods, and the error components include η_i, which is the country-specific effect as well as $v_{i,t}$, which reflects serially uncorrelated measurement errors.

Although Equation (2) is able to treat unobserved heterogeneity (omitted variables that are constant do not bias the estimates) it has problem of its own. Firstly, as pointed out by Nickell (1981), panel data with fixed effects has seriously biased coefficients because these estimators are based on a small number of time periods T and a large number of individuals (N). Typically, this is true for micro-panel data but it is equally true for macro-panel data (Judson and Owen 1999). In fact, in the growth context we, generally, work with sizeable cross-section dimensions and a moderate time dimension because the data are averaged over 5 or 10 years. Secondly, the individual effects η_i are likely to be correlated with the observed exogenous variables X_{it} in the model because they are not strictly exogenous[10]. Therefore, if the fixed effect estimator improves over OLS since it captures the omitted variables ignored by single cross-section, the specific effects are likely to be correlated with the regressors.

The problem has been addressed through the generalised method of moments estimator (GMM) of Arellano and Bond (1991). In the empirics of growth this approach was thought to avoid many of the pitfalls of regression analysis. Particularly, this

10 The exogeneity is expressed in terms of correlation with past and current realization of the error.

technique, eliminating the fixed effects, circumvents the problem raised by the omission of the initial level of technology and, in using lagged values of the variables as instruments, also avoids the problem of regressor's endogeneity.

Since g_{it} is the logarithmic difference of GDP per capita, equation (2) can be rewritten as:

$$y_{i,t} - y_{i,t-1} = \beta_0 + \beta_1 y_{i,t-1} + \beta_2 X_{it} + \eta_i + v_{i,t}$$

and taking first differences, yields:

$$y_{i,t} - y_{i,t-1} = \beta_1^* (y_{i,t-1} - y_{i,t-2}) + \beta_2 (X_{it} - X_{i,t-1}) + (v_{i,t} - v_{i,t-1}) \qquad (3)$$

where $\beta^* = (\beta+1)$.

Thus, moving to a panel approach and instrumental variables for all regressors, provides more precise estimates of the growth determinants, if moment conditions are satisfied. On the assumption that the error term is not serially correlated and that the explanatory variables (X) are weakly exogenous (not correlated with future realisation of the error term) the following moment conditions should hold:

$$E[y_{i,t-s}(v_{i,t} - v_{i,t-s})] = 0 \qquad \text{for } s = 2,\ t = 3,\ldots,T$$

$$E[X_{i,t-s}(v_{i,t} - v_{i,t-s})] = 0 \qquad \text{for } s = 2,\ t = 3,\ldots,T$$

This approach raises a conceptual drawback that relates to the long run effect of the variables in the regression. Data averaged over five or ten-year periods is arbitrary and most likely does not adequately proxy for steady-state relationships. In contrast to cross-section estimations, it is highly probable that with panel data estimators the coefficients capture the cyclical variability of the time series.

From a statistical standpoint, there are additional problems with the GMM difference estimator. When the time series of the explanatory variables such as GDP are persistent, and the number of time series is small, this estimator appears to produce unsatisfactory results in a growth context (see Hahn et al. 2002, 2007). The lagged levels of the variables are weak instruments for the variables in differences and this would cause large finite-sample biases in the presence of short panels. To address these problems the alternative GMM system estimator has been employed, which uses jointly lagged values of the explanatory variables (X_{it}) in levels and lagged differences of the variables as instruments [11].

Although dynamic panel methodology applied to growth analysis seems promising, it should be recalled that just in the last years it has been used for testing NGT hypotheses[12].

Some weaknesses emphasised in the literature of panel data must be recalled: (i) taking a full set of instruments as evidenced by Arellano and Bond (1998) may introduce sample over fitting biases, (ii) the use of differenced variables changes the

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11 See Arellano and Bover (1995) and Blundell and Bond (1998) for econometric details, and Durlauf *et al*. (2005) for possible drawbacks and economic interpretations.

12 Typically, it has been used to verify the neo-classical Solow model and the plausibility of the rate of income convergence to their steady state levels (see, for example, the test to convergence by Bond, Hoeffler and Temple [2001]).

interpretation of regression results especially for convergence analysis, (iii) the range over which average of variables are computed (five years or more) is shorter with respect to cross section studies and, hence, not adequate to capture long run effects. Moreover, we rarely find serially uncorrelated disturbances in macroeconomic data and this indicates that the problem of serial correlation in the errors needs to be further explored (see Lee, Pesaran et al. 1997, Phillips and Sul 2003, Baltagi 2008).

In our subsequent discussion we will not address statistical issues that have been extensively reviewed in the literature, even if there remains concern about divergent outcomes from econometric studies. Why do some researchers find weak effects from physical and human capital accumulation in the process of growth, whereas others find a robust correlation? Why is the theoretical substantive role of externalities and the TFP stressed by the NGTs so difficult to isolate in growth regressions? We firmly believe that, in the first case, a consensus would be attained if estimations were performed in strictly comparable conditions with the same period data, the same model-estimation techniques and the same sample of countries. In the second case our belief is that it is not the econometric methodology that is questionable but the difficulty of measuring accurately some key variables such as human capital, TFP and political-institutional variables.

3 Models and Their Empirical Validation

3.1 Evidence on Initial Conditions

We start reviewing the empirical analysis by looking at initial conditions. The empirical evidence is mostly based on *convergence equations* in which estimates of the sign of the coefficient of the initial level of per capita GDP (typically $y_{i,0}$ in 1960) is considered the main test for endogenous versus exogenous models of growth[13]. We argued that the convergence issue no longer matters since it is unresolved from both a conceptual and statistical point of view. Although these remarks are well-illustrated by the recent literature, we cannot discuss initial conditions without linking their impact on convergence of income per capita across countries. Predicted convergence in the traditional model is based on the assumption of a single worldwide production function featuring decreasing marginal returns to capital. In such a framework differences in growth rates may be justified by initial differences in capital intensities. Therefore, the disparities in growth performances that we observe across countries are determined by different levels of capital accumulation as demonstrated by Barro (1991, 1997) and by Mankiw Romer and Weil (1992). According to Klenow and Rodriguez-Clare (1997), these studies represent the "neoclassical revival" in the economics of growth. The augmented Solow model was considered suitable to explain almost 80% of the cross-

[13] A convergence equation is a reduced form of a basic growth model and has been used to find not only evidence of convergence paths (the estimated coefficient of initial income), but also as an indirect test of how different variables are correlated with growth. The inclusion of such variables is appropriate to control for the steady state, since other variables can affect the growth rate of the economies under study, but is not satisfactory to draw inferences about the determinants of growth or to discriminate between alternative models. See the criticism of KRC (1997). Barro (1997) claims instead that the procedure is quite correct.

country variance of output per-capita attributed to differences in steady state levels of physical and human capital. Is a model that stresses convergence and initial conditions the best approximation to the true model?

Even though it is very difficult to conclude in favour of one model or the other, the main results of this literature have been severely criticised. Bernard and Durlauf (1995), Quah (1995), Durlauf and Quah (1999), Phillips and Sul (2003) raised substantial criticisms by claiming that convergence patterns are too complicated to be captured by simple growth regressions.

The first challenge to the old model and its prediction of convergence comes from the application of panel data models. When controlling for differences in steady states by using country-fixed effects in panel regressions, the speed of convergence is much higher than the one implied by the classical studies, which is in the neighbourhood of two percent per year. The range of estimates found in studies using dynamic panel models (GMM approach) goes from zero to 30% a year (Canova and Marcet 1995, Caselli, Esquivel and Lefort 1996, Lee, Pesaran and Smith 1997, Islam 1995)[14]. These results are difficult to reconcile with the prevailing theoretical framework and with the earlier consensus on the convergence hypothesis. These estimates of the rate of convergence imply that the steady state is already here and the transitional dynamic is too short as an explanation of cross country productivity differences.

This high rate of convergence is also supported in the study by Cook (2002), although the author criticises the use of panel techniques in estimating the rate of convergence. His main argument is based on the fact that measurement error is higher in cross-country data set at high frequency and the determinants of persistent differences in income levels “will be corrupted by higher frequency phenomena such as business cycles” (p.132). The natural experiment performed by Cook, by using standard cross-section, is to estimate through instrumental variables (IV) the rate of convergence for 42 countries for the period 1950-1990. The statistical model is based on the neo-classical growth model and the natural experiment performed by Cook consists of measuring the speed at which European countries and Japan recovered from the destruction of capital after-WWII using as instruments the number of civic casualties as a share of population. The estimated rate of convergence to the long run growth path is between 4 and 6%, significantly higher than the 2% observed using standard regressions. Importantly, this work does not support the Mankiw *et al* (1992) finding that, by introducing human capital, the Solow model fits well the facts of growth. Intuitively speaking, an implied convergence rate of 4.7% is consistent with just the observed physical capital share of income.

Recently, the effort to apply the GMM system to an estimation of the Solow model has moved the rate of convergence across countries towards a more reliable value, which stays in the range of 1%-4% (see Bond, Hoeffler and Temple 2001, Doppelhofer *et al.* 2004).

The analysis has so far dealt with convergence, but there are other challenges against the prediction of the neoclassical convergence hypothesis and its theoretical implications.

One more challenge is the technology gap view, which moves a substantial and direct attack to the Mankiw-Romer and Weil (MRW) results, in which a consistent rate

[14] See Temple (1999) for a wide and critical discussion on the early literature on convergence.

of convergence is obtained by adding human capital to the convergence regression. In fact, a by-product of the panel approach to convergence study is the estimated values of technology levels across countries. These levels according to Islam (1995, 2003) differ enormously across countries and the highest value is about forty times larger than the lowest.

The claim that technological progress matters more than factor accumulation in the explanation of cross-country growth differences appeared firstly in a provocative way in the already cited Klenow and Rodriguez-Claire study (KRC, 1997) followed very rapidly by similar claims by Prescott (1998), and Hall and Jones (1999). KRC argue that the "ideas gap" is more important in explaining differences in output levels and growth rates than physical and human capital. Updating the data and adding primary and tertiary schooling, which were absent in the MRW study, they offer new evidence that technology-based models are more reliable in explaining income divergence across countries than differences in human capital. Since primary school attainments vary much less across countries than those of secondary school, the findings of MRW overestimate the effect of variation in human capital across countries. After the correction in the data, the earlier well-established outcome is reversed. Roughly, 90% of differences in per capita income growth between countries are attributable to technology differences. If, for comparison with MRW, we express the differences across countries in terms of per capita income *levels* then, human and physical capital are responsible for roughly 50% of cross country variations and the other 50% is attributable to changes in technology.

These new empirical studies on convergence were sufficient to shift the interest of researchers from the Solow model to the NGTs. A further strong support to the NGTs has appeared in a provocative paper by Easterly and Levine (2001), which complements the main conclusion of KRC and offers new elements to the debate. The KRC and Easterly and Levine’s findings are confirmed by Caselli (2005). Updating the sample and the period of analysis the author tries to assess the performance of the *factors-only model*, and finds that this model explains from 0.35 to 0.40 of the variance of income across countries. This value is less than the value found by KRC. However, his basic message is that the differences in TFP, responsible for the majority of income differentials, may be the result of the different composition of GDP across countries and across sectors.

The consensus on the role of technology as a source of growth differentials is weakened by the work of Henderson and Russell (2005). Using a non-parametric production function approach, the two authors reverse the KRC outcome. Through the decomposition of productivity growth in shifts in the production frontier (technological progress), movements towards the frontier (technological catch-up) and movement along the frontier (capital accumulation), the authors find that on average shifts of the frontier account for only 8% while movement along the frontier accounts for 57%. This indicates that the majority of growth productivity in 52 countries in their sample is attributable to broad capital accumulation and only a small fraction of it to an increase in TFP.

A distinguished explanation of these conflicting findings is covered in the papers by Acemoglu and Zilibotti (2001), Aiyar and Feyrer (2002), Banerjee and Duflo (2005). According to the first set of authors technology-skill mismatch could account for a large fraction of the observed output per worker differences across countries. They argue that many technologies used in LDCs, but discovered and implemented in OECD countries, are designed for the workforce skills of industrialised countries. Therefore, even if we assume that all countries have access to the same technology, the low skill supply of workers in poor countries can lead to sizeable differences in TFP.

Aiyar and Feyrer, in an attempt to reconcile different points of view, present evidence that shows how TFP differences are important in accounting for the cross sectoral (static) variation in GDP but that other factors (human capital in their work) are crucial in determining the dynamic path of TFP. Besides human capital, other factors may include all kinds of spillovers from countries at the frontier towards developing countries, such as the degree of openness, the composition of a country's trade, FDI etc. This means that studies should consider the possibility of interactions and spillovers between physical capital, human capital and TFP.

More articulated and plenty of extensive evidence, especially from the LDC, is the paper by Banerjee and Duflo. In order to solve the puzzle of non-convergence they re-propose an old criticism based on the use of an aggregate production function and its underlying assumptions of optimal resources allocation within each economy. In contrast to what the aggregate production function approach implies, they show evidence from micro-development literature of the wide range of rate of returns to a single factor in each economy and of how such heterogeneity parallels the one existing across countries. The authors argue that this striking evidence is a clear indication of factor misallocation, which can have different causes, and to a lesser extent that of overall technological backwardness. Various possible sources of inefficiencies, such as government failures, credit constraints, insurance failures, externalities, and the existence of large fixed costs in production, are all considered as potential explanations of cross-country growth differences and are discussed in depth.

On the same line of reasoning is the technical paper by Phillips and Sul (2003), which adds further arguments to the discussion. By allowing for parameter heterogeneity, not only across-countries but also over-time, and using filtered techniques to extract estimates of a transition parameter, they examine the evidence for growth convergence by testing whether the transition parameter converges. By eliminating the restriction that the growth rate of technical progress is the same across units and over time, they argue that a poor country may grow faster because its speed of technical learning or technological transfer is faster than the speed of technological creation in a rich country. When the rate of technological creation is higher than the rate of technological transfer, divergence in growth paths is likely to occur. Applying their technique to the Penn World table (PWT) data set from 1960 to 1989 for 120 countries, they find that transitional dynamics "reveal an elusive shadow" of conditional convergence in both the US regional and the OECD growth rates.

In what follows we discuss more extensively empirical studies for each variable considered as a determinant of growth to investigate whether the empirical literature is supportive of competing NGTs. As stated at the outset, we believe that the interplay between factor accumulation, technological progress, and national policies and institutions are the driving force for long run growth. The bulk of the succeeding subsections consists of investigating the potential for improvements in the measurement of inputs such as physical and human capital as well as technology in order to better understand their specific role on cross-country income differences.

3.2 Evidence on Broad Capital

Although the empirical evidence on the AK model would include in K either physical or human capital, we follow the empirical literature and in this section we look at the impact of physical capital. There exists a substantial body of historical evidence on economic growth and investment. Although the traditional model does not recognise any long-run correlation between investment and growth rate because of diminishing returns, historical data in almost all countries show a tight relationship between the two[15].

Cross-section regression analyses have evidenced a significant coefficient for the investment variable included in the regressions. DeLong and Summers (1991), who found physical investment in equipment and machinery to be significantly correlated with growth, have opened the debate on the role of investment as engine of growth. They examined investment across a sample that includes OECD and developing economies over the period 1960-1985. We recalled in the previous section the study by LR (1992) in which the authors found that the most reliable result in much econometric work is the stable and robust link between investment and growth. For a broad cross sectional sample based on Summers & Heston‘s (1991) data, the regression estimated by LR was the following:

$$GYP = -0.83 - 0.35RGDP60 - 0.38GPO + 3.17SEC + 17.5INV$$

where GYP is the growth rate of GDP per capita, RGDP 60 is real income per capita in 1960, GPO is the population growth rate, SEC is the secondary school enrolment rate, INV is the share of investment in GDP. The scope of many econometric studies was to test directly the predictions of NGTs of the AK type. Oulton and Young (1996) considered evidence from a wide range of countries from investment data in the Penn World Tables and data on the share of capital taken by OECD Economic Outlook. They found very different results for each country. The mean of a broad capital share, for the period 1979-1990, of 23 OECD countries, was 47%, but it ranges from a minimum of 38% for Switzerland to a maximum of 77% for Turkey. According to the two authors, who use different approaches for their investigation (cross section, panel data and time series) of the role of physical capital on growth and of how it is associated with externalities, no strong case has emerged that social return to physical capital exceeds the private return. In the absence of externalities, they conclude that the impact of capital on growth seems to be very modest.

A closer examination of regressions shows that, even if the coefficient for investment is the highest with respect to other variables, the most common value is only 17.5. This means that an increase in the rate of investment of 1% would raise the growth rate only by 0.17 percentage points. It also means that the gross rate of return to investment is just 17%, or less if instrumental variables are used. If we add the coefficient of human capital (0.3%) the growth rate will increase to 0.20%[16]. This

[15] Historical evidence shows that among the factors that have contributed to the economic success of East Asian economies, there has been the ability to keep the price of capital goods low relative to general price level. It is commonly held that this has favoured equipment investment. By contrast, it is similarly agreed that Latin American and African economies have displayed very low rates of investment per capita.

[16] This commonly used interpretation of regression results is much contested. See, for example, KRC (1997).

finding is far from supporting the AK model, in terms of both the unitary elasticity of capital with respect to output and in terms of lack of convergence (the coefficient of the initial capital is not non-negative or equal to zero). The empirical result seems in line with the neo-classical model validating the presence of diminishing returns.

The AK model has been highly criticised also by Jones (1995a). He tested the prediction of the model by comparing investment as a share of GDP and the growth rate for 15 OECD countries. By using time series methods in which growth is regressed on lagged investment rates, the estimated equation is:

$$g_{i,t} = A(L)g_{i,t-1} + B(L)x_{i,t-1} + \varepsilon_{i,t}$$

where x is the growth determinant (investment or other policy variables) and A(L) and B(L) are lag polynomials. Endogenous growth models predict that the sum of the coefficients on the lagged variables should be greater than zero, whereas in exogenous growth models it should be exactly equal to zero. Therefore, if the sum of coefficients in the lag polynomial B(L)=0, then the variable has no long run effects on the growth rate[17]. Using data for the period 1950-1989, Jones argues that the AK model is inconsistent with the time series evidence. He notes that after the World War II there was a large increase in the investment-output ratio in all the countries included in the sample but growth rates in these countries was almost constant or fell. Jones focuses on investment on durables. Over the 40 year period the investment /output ratio nearly doubled in countries like the US and nearly tripled in Japan. In some countries an increase in investment coincided with decreasing growth rates.

Related studies such as Bloomstrom, Lipsey and Zejan (1996) tried to detect the direction of causation between investment and growth. The result of this causality test rejects the hypothesis that investment (and also equipment investment) is the anticipating factor of economic growth. What they found is that past growth has a significant effect on current capital formation, but capital formation does not induce subsequent growth.

Against the rejection of the AK model is the work by McGrattan (1998). Her benchmark model is a two-sector AK with human capital and with endogenous labour supply. The author revaluates the AK theory from a different empirical standpoint by considering evidence over a longer time-period and greater numbers of countries than Jones does. Extending Jones' sample to include the data for an entire century (using Maddison's data for 1870-1989) she found that periods of high investment rates coincide with periods of high growth. For investment-output ratios, data are constructed using fixed domestic investment as a percentage of GDP valued in current prices. Regarding the growth rates, nine-year moving averages of per capita GDP growth were used in order to smooth out some of the large cycles that occurred during wars. Extending the analysis to many more countries than the Jones sample, and including some less developed countries, she is able to confirm a positive and robust association between investment and output growth. The slowest growing countries exhibit an average investment rate of around 7%, whereas the fastest growing countries have an average rate of around 25%.

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[17] The same method is used by Kocherlakota and Yi (1997) to estimate the effects of policy variables in the U.S and the UK by using time series data.

Cooley and Ohanian (1997) performed further estimates. Like McGrattan, they show that data for investment and growth in the UK are consistent with an extended version of the AK–type endogenous growth model. These new studies on long run data seem to support the main predictions of the AK model.

However, even if it is certain that investment has a positive effect on growth, this does not mean that capital is the only source of growth, as the model would imply. What these studies show is that the theory is consistent with available data and that the theory's quantitative implications are in line with the empirical observations. The main prediction of the model is to see if changes in investment rate would lead to permanent changes in the growth rate. The empirical estimates of the AK model concentrate quite exclusively on investment in physical capital but other influences, in particular human capital, are important in this model.

The debate on investment and growth remains open. Some arguments from prior studies refer to the endogeneity of the variable. Since investment is clearly endogenous it is necessary to use instrumental variables in a cross-country regression. It has been argued that if the endogeneity of investment could be correctly treated then the coefficient of investment would be very small.

This conclusion is not supported by recent empirical works, which control for the endogeneity of the variable. Dinopoulos and Thomson (2000), Xu (2000), Bond, Leblebicioglu and Schiantarelli (2004) contradict Jones' influential 1995 paper showing evidence of a positive and long lasting investment-growth relationship. These different results may depend on the definition of investment adopted, on the data sources (updated or not updated Penn-World Tables) and sample periods. Similarly, Xu (2000) finds that the rate of investment exerts a long run impact on growth for four of the five industrialised countries investigated in his study for the period 1870-1987 and in fourteen of the twenty-four OECD countries for the period 1950-1992. Bond *et al*. (2004) present evidence, using annual time series data for 98 countries for the period 1960-1998, that an increase in the share of investment predicts a higher growth rate of output per worker in the steady state. The long run effect is quantitatively substantial and statistically significant. They conclude by arguing that the suggestion that capital accumulation plays a minor role in economic growth is "premature". In their study the authors allow for heterogeneity across countries in all regression coefficients, following the approach of Lee, Pesaran and Smith (1997), but the finding is strongly confirmed with pooling cross section regressions as well as five-year average panel estimations.

How can these divergent findings be reconciled? Many of the marked differences outlined above are due to distinct investment measures. Which measure is more appropriate to test NGTs? Some argue that total investment is a good proxy to test the AK model. Others, such as Bosworth and Collins (2003), assert that the change in the capital stock, not the investment rate, should be used to estimate the contribution of capital to output growth. By reviewing familiar results from regression analysis, they show that R^2 is higher when the capital stock is used, while a very small correlation is obtained in their sample between the change in the capital stock and the mean investment rate. The argument of Bosworth and Collins is worth noting: it would be a good practice to use the correct measure, which reflects the specification of the true variable, to test theoretical models. If the capital stock is used, a benchmark value of its share in GDP around 1/3 would imply that most of the variation in income per-capita is explained by TFP. But, as its share increases to 60%, almost all of the cross-country income dispersion is explained by capital stock (see Caselli 2005). Additionally, Eaton and Kortum (2001), well aware of the difficulties in taking account of the great heterogeneity of capital stock, emphasises that once capital is correctly measured, augmenting for its quality across country, it reveals a strong impact on growth.

3.3 Estimated Contributions from Education

The role of human capital has drawn considerable attention in the NGTs. It may be disappointing to realize that the original idea that capital stock should include human capital, as to justify high values of its share in national accounts, leads to the rejection of the AK model. Is the theoretical model wrong or is the decomposition of capital into its constituent elements very difficult to estimate? Unluckily, even if carefully studied from a theoretical viewpoint, this variable presents many problems of measurement. Wolff (2000) summarises the three paradigms that have dominated the current debate on the role of education on growth. Interpreting his arguments, we claim that these paradigms are linked with different human capital theories: (i) the general framework of Lucas (1988), (ii) the interaction hypothesis with technological change of Romer (1990), and the catch up process of Grossman and Helpman (1991). In Lucas (1988) human capital is the only engine of persistent growth, but also in the research-based models the growth rate is predicted to monotonically increase with human capital levels. Despite the theoretical role assigned to human capital, the empirical results are highly unsatisfactory. With only a few exceptions, both educational levels and growth in educational attainment are not statistically significant and often their impact is wrongly signed.

What is the reason for this disappointing result, which continues to hold, despite the progress in the econometric tools and the different measures of schooling used in cross-country analysis? Even when a variable is found not significant, as stressed by Durlauf *et al* (2005) it does not necessarily mean that the variable is not important for growth: “a more accurate interpretation is that its effect cannot be identified using the data at hand” (p. 631). In particular, human capital shows little variation over time and is measured with errors.

In prior studies (Barro 1991, MRW 1992, LR 1992) the proxy used as a measure of human capital was the schooling enrolment ratios of the labour force. This measure is defined as the number of people (regardless of age) enrolled at different schooling levels over the population of the age group that officially corresponds to that level of education. Schooling enrolment rates, steadily increasing for all countries across time, were found positively correlated with growth. These data, although widely available, are flow variables that do not measure properly the stock of human capital effectively available for current production.

These earlier measures have been rapidly substituted with levels of educational attainment and average years of schooling. The data set constructed by Barro & Lee (BL 1993, 2000) refers to adult population and the attainment levels of education are calculated as the proportion of the population aged 25 and over (or 15 and over, which roughly corresponds to the labour force in developing countries) who have attained the indicated level of schooling. The figures were constructed at five year intervals by using benchmark data on attainment levels from UNESCO census-surveys and then updated on the basis of school enrolment flows in succeeding years for each country at all levels of education. Although these estimates provide a reasonable proxy for the stock of human capital, they perform poorly in the empirical analysis. One reason can be attributed to the complex characteristics that embrace the concept of human capital, which are difficult to quantify with precision. Another reason is the relatively small number of observations on which these measures are calculated which do not provide a sensible basis for panel estimations.

Further reasons have to do with comparison of educational measures across countries especially when one wishes to correct for schooling quality. Using average years of schooling - the most adopted measure - for the stock of human capital means to assume perfect substitutability of workers across different attainment levels and across countries by giving the same weight to any year of schooling independently of the level and the quality already accumulated (Mulligan and Sala-i-Martin 2000, Wößmann 2004).

Additionally, by looking at BL data set, it is easy to find anomalies (such as the decrease of attainment levels also for some OECD countries) which are hard to justify, given worldwide increases in the enrolment rates and in the average years of schooling. In OECD countries the average years of schooling per person aged 25 have increased from 9.3 in 1990 to about 9.8 years in 2000, for middle income countries the increase is much higher from 4.0 to 4.9 years in 2000. The same is true for poorer countries (see the discussion by Barro and Lee 2000, Wolff 2000). Therefore, incongruity in the estimates of human capital figures reflects in the unstable value of the coefficient of education in regression analysis.

When attainment levels are used the coefficient for secondary and higher education, which was expected to be positive according to the predictions of the NGTs, has been found insignificant and often negative. Only primary education has exhibited a positive correlation with growth in both developed and developing countries. A one percentage point increase in primary school is estimated to lead to a 2% point increase in per-capita GDP growth rate. As expected, the impact has been found to be larger for LDCs[18].

A related issue is whether other approaches to estimating human capital are more appropriate to capture its role in output growth. Many attempts have been made to improve international measurements of human capital, such as weighted estimations by rate of return (rather than years of schooling), the use of student international test-scores to correct for quality of education. The International Adult Literacy Survey is an attempt at measuring directly the skills of the work force for international comparison, but data availability is limited to OECD countries.

To date the most widely adopted measurement still remains the data set of BL and it is on their human capital measures that the ensuing discussion is based[19].

Overall, for samples of non-OECD countries, the impact of education on growth seems to be negative (Nerhu *et al.* 1995). In other studies the correlation is positive but not very significant (Barro 1997, Islam 1995, Benhabib and Spiegel 1994). The Behabib & Spiegel analysis is important for two reasons. Firstly, they find a positive coefficient in their regression when level specifications of education are introduced but a small negative coefficient when education growth is considered. Secondly, they suggest that

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[18] See the reviews of Sianesi and van Reenen (2003) and that of Wößmann (2004).

[19] New data sets are de La Fuente and Domenech (2006) for OECD countries and Cohen and Soto (2007) for a broad sample of countries. We will refer to them later in the paper.

the divergence in growth rates across countries may not be due to differences in the rate of accumulation of human capital, as the Lucas (1988) model predicts, but to differences in the *stocks* of human capital in each country. It is this latter measure that would affect the ability to innovate or catch up with the technologies of more advanced countries. The *level effect* of human capital has been criticised on a number of grounds by some authors (see Pritchett 2001).

A broader measure of human capital that includes also non-educated workers has been used by Bils and Klenow (2000), Kueger and Lindhal (2001). This measure is based on the wage regression estimated through a Mincerian equation but with little success. The schooling variable is not significantly associated with economic growth. In particular the study by Bils and Klenow make a strong attack on Barro's initial estimates (1991) and on the issue of causality[20]. On the first issue they show that each additional year of 1960 enrolment rate is not associated with 0.6% increase in the growth rate from 1960 to 1990 as Barro stated. By considering cross-country regression with IV as well as a variety of empirical tests based on model calibration and historical data from UNESCO, they find that the channel from schooling to growth is "too weak to generate even half of Barro's coefficient" (it accounts only for 10%). As regarding the second issue, they find evidence of causality running from expected growth to schooling. This channel is capable of generating a coefficient quantitatively similar to Barro's coefficient.

Empirical studies have produced no strong support for increasing returns to levels of education. Spillovers from human capital have been investigated recently by Acemoglu and Angrist (2000). They use instrumental variable techniques to determine if the high correlation in the USA between average schooling and wage levels is driven by social returns from education. The authors found that the precise private return to education is about 7%, while social returns (around 1%) are not significantly different from zero. However, the finding of lack of spillovers at macro-level is inconsistent with micro data in which a wage premium at the individual level for human capital investment is observed.

In trying to explain the micro-macro paradox of empirical evidence, Pritchett (2001) has argued that the impact of human capital on growth "has fallen short of expectations" for at least three reasons:

- (i) a perverse institutional environment that lowered growth by using educated labour for socially counterproductive activities;
- (ii) a mismatch between an increasing supply of educated labour and a stagnant demand;
- (iii) a poor quality of education that is not capable of creating human capital at all.

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[20] Bils and Klenow suggest that the Mincerian specification of human capital is the appropriate way to incorporate years of schooling to the aggregate function of human capital. They estimate the following:

$$\varpi_i = \beta_0 + \beta_1 (SCH)_i + \beta_2 (EXP)_i + \beta_3 (EXP)_i^{2_i} + \varepsilon_i$$

It represents a Mincerian wage equation where not only school (SCH) but also the number of years of work-experience is included. Based on this equation the aggregate human capital is $H_{j,t} = L_{jt} e^{f(S_t)}$, where L is the total amount of labour allocated to sector j and S is the average educational attainment in period t. The derivative f'(S) represents the return to schooling and measures the efficiency of an additional year of schooling.

Although the Pritchett analysis is very stimulating and indicates routes for future investigation, we believe that the concern with this large and disappointing piece of empirical evidence has much to do with the ability to construct an accurate measure of human capital. As stressed by Dinopoulos and Thompson (2000) this fact, together with the impossibility of properly treating non-linearity in econometric modelling, may lead to empirical rejection of important factors of growth even when the model is adequate.

An enhancement in measuring human capital goes in the direction of the work by Hanushek and Kimko (2000) who have constructed indexes of educational quality. The adjustments of years of schooling for variation in quality is obtained by the two authors for 38 countries and are based on international tests of students' performances in mathematics and science. In the estimation of the nexus between schooling quality and growth rates the authors found a positive and significant correlation.

While Barro (2001) reconfirms his previous finding of a positive impact of measures of quantity of education on growth in his regressions, such as male attainment (and not female) at secondary and higher levels, he finds much greater positive effects by using qualitative measures similar to those used by Hanushek and Kimko. He found that science scores have a statistically significant positive effect on growth. The coefficient of the science scores of 0.13 (SE= 0.02) implies that a one-standard deviation increase in scores by 0.08 would raise the growth rate on impact by 1.0 percent per year, while the quantitative measure of attainment would increase the growth rate by only 0.2% per year. This result suggests that quality of education is much more important than quantity of schooling. Mathematics scores are positively related with growth but at a lesser extent that science score. Reading scores, instead, are puzzling negatively correlated with growth.

Hanushek and Woessmann (2007) confirm these findings in a more recent work. By applying quality-adjusted measures of human capital, international comparison reveals much larger skill deficits in developing countries than just school enrolment and attainment.

Other studies augment years of schooling by a proxy of the health status of the labour force (Weil 2007). It seems that there are large cross-country variations in nutrition and health status and accounts of these differences improve the explanatory power of human capital on growth.

Attempts at measuring human capital externalities at the aggregate and local levels have not led to appreciable results. Findings about their existence may explain the puzzle between the high correlation of human capital and income observed in the data and the micro evidence, which suggests diminishing (or low) returns to education. The estimated Mincerian returns to schooling of about 10% most likely understates the true value of these returns because it fails to take into account positive externalities generated by more skilled workers. Specifically, as claimed by Banerjee and Duflo (2005), the human capital externalities should be in the order of 20-25% to explain the cross-country relationship between education and income. Unfortunately, this value is too high if we compare it with the true value estimated in some studies (in the order of 3 to 5%). A way to reconcile these conflicting results is the existence of negative externalities. The argument is that workers that increase their investment in education are able to "inflict" losses on the less educated workers. Duflo (2004) estimates that an increase of 10% in the fraction of educated workers resulted in a decrease from 4 to 10% in the wages of the older workers. This would suggest that any positive externality may be compensated by the declining returns that affect all the workers in the labour market[21].

To reassess the robustness of human capital in empirical analysis, Papageorgiou and Chmelarova (2005) have followed a distinguishing line of research. Using a cross section of 46 OECD and non-OECD countries, the authors test the hypothesis of non-linearity in capital-skill complementarity and find that the hypothesis is strongly verified for non-OECD economies. Conversely, in OECDs skills are complementary with technological progress. Additional testing of the hypothesis would also shed light on the dispute about the two competing determinants of economic growth: input accumulation and technological progress. Evidence in favor of complementarity between embodied–technical–progress physical capital and human capital would increase the relative importance of input accumulation. This implication emerges from works by Galor and Moav (2000) and Kalaitzidakis et al. (2001). The former develops a model characterised by ability-biased technological transition in which an increase in the rate of technological change raises the returns to ability but generates a series of collateral effects that can lead to a productivity transitory slowdown. The latter study uses semi-parametric estimation techniques to uncover non-linearities between human capital and growth and provides evidence of their existence.

These recent studies are consistent with the view of many endogenous growth models. The correct estimation of human capital, at aggregate level, is a serious question, which has not yet found a satisfactory solution. If human capital is measured with errors, the coefficient estimates will be biased downward, yielding inconsistent predictions of the NGTs. The attempt to construct new series that take into account the age structure of population and mortality heterogeneity among age groups together with better data on quality of education should produce better estimation of this important growth determinant. Measurement errors are the basis of the criticisms by Krueger and Lindhal (2001), de La Fuente and Domenech (2006), Cohen and Soto (2007). While Kueger and Lindhal's work, correcting for measurement errors, does not reverse the value of the coefficient and the impact of schooling on growth remains very modest, in the other two works, which use new datasets, constructed by the same authors, it seems that the human capital variable performs much better in the regression analysis. Cohen and Soto run simple OLS and panel data regressions on their own series on human capital obtaining a positive and significant coefficient. Further studies using these new series will tell us whether schooling will become more supportive of the NGTs.

Before concluding, it is significant to mention an especially interesting finding on the positive role of human capital for growth that emerges from the work of Glaeser *et al.* (2004). Since the more appropriate context of this paper is institutions *versus* traditional sources of growth, we shall discuss their finding in the section dedicated to the *institutions view*.

3.4 Evidence on Research-Based Models

In this section we will report empirical evidence on the first generation of R&D-based theories, while the empirical evidence on second-generation R&D growth models either

[21] For a discussion and methodological issues on human capital measurement at macro level see Sianesi and Van Reenen (2003).

in the semi-endogenous or full endogenous versions will be discussed in the next section.

The critical variable in these models is R&D and spillovers that derive from this activity. The first wave of empirical evidence focuses attention on the second model of Romer (1990), Aghion and Howitt (1992), Grossman and Helpman (1991), Parente and Prescott (1994) in which innovations and research spillovers generate sustained endogenous growth. Even if old models assign to autonomous and disembodied technical change a prominent role as a source of productivity growth, they have never considered spillover effects of R&D as a systematic force for narrowing the productivity gap across countries. In this class of models long run growth is generated by knowledge spillovers of degree one and may represent the underlying force behind convergence. From the empirical validation of this group of models we can infer whether the "ideas gap" may generate differences in per capita income more than the accumulation of traditional factors. It would be highly reductive, however, to mark this body of literature as a description of a theory that stresses innovations over factor accumulation. This is because in each of the models mentioned there are deep interactions between human capital and embodied technological content in capital equipments.

The empirical analysis very often oversimplifies theoretical modelling and uses proxies, available in the data that give a rough picture of the complexities of growth processes. As Jaffe (1996) claims "A possible excuse for the delay between the time Alfred Marshall talked about spillovers and the time economists made serious efforts to measure them is that they are inherently difficult to observe" (p.13).

To make the empirics of these models tractable it is necessary to overcome a number of issues involving the development of a metrics for measuring technological similarities and geographic proximities among firms, as well as economic relationships among firms and between firms and consumers. As we shall see, the literature aimed at measuring R&D and related spillovers is exposed to complexities which overwhelm those aimed at measuring human capital. This means that the assessment of the effects of R&D productivity and spillovers through empirical analysis remains a controversial subject.

The most interesting piece of evidence on the issue comes mainly from studies that estimate the productivity of research efforts at industry or firm-level data. What is controversial in these studies is not the relationship between R&D and productivity, since microeconomic evidence has always confirmed a positive and strong relationship between the two (Lichtenberg and Siegel 1991, Mairesse and Sassenou 1991, Griliches and Mairesse 1991), but whether econometric studies can characterise such a relationship in a satisfactory way. Regression-based studies to measure productivity growth at firm and industry levels are usually not comparable for practical measurement problems in estimating social and private returns from R&D. What is typically estimated is a gross rate of return from R&D in different industries. To make them comparable a net rate of return must be computed. The problem that emerges is that the rate of obsolescence is not a constant but may vary among firms and sectors depending on the type of investment undertaken. Thus, the contribution to productivity growth can be greatly affected when R&D intensities are not corrected for depreciation.

It is known, however, that the central tenet of the NGTs is that R&D investment not only affects the economic performance of the firms that carry out these activities but has also an impact on the performance of other firms. The various attempts at identifying different type of spillovers related to R&D have led to a wide range of estimates by different researchers for different industries and countries. The effect of spillovers is to create a gap between the private rate of return to R&D (the return earned by the firm undertaking the research) and the social rate of return, which includes all the benefits that accrue to the other firms and to the consumers. There is a plausible basis for the belief that the magnitude of social returns to R&D is very high. In fact the importance and the speed of these spillovers will vary depending on the nature of the research and in particular the products or processes embodying the research results. The estimates depend also on the ability of price agency to capture gains from innovations that derive from quality changes. This last category of gains, even if lower than those obtained directly from R&D processes, is generally not recorded (Griliches 1994). Also the learning processes involved in the implementation of innovations are not captured by conventional measures.

Among the studies developed in the spillover literature it is possible to distinguish:

(i) Contributions aimed at measuring spillovers within a specific economy at various degrees of aggregation (firm, industry or country levels).

(ii) Contributions that provide estimates of spillovers across countries. An assessment of this second category of spillovers is reviewed in the next section.

Current studies have attempted to measure elasticity and rate of returns to R&D. R&D elasticity ranges from 5% to 25% and the rates of returns from 10 to about 80% depending on the econometric methodology: cross-section or time series estimations (Hall and Mairesse 1995, Mairesse and Mohnen 2002, 2003). Cross sectional estimations yield higher and more significant values than time series estimations.

However, the evidence on the magnitude of R&D spillovers presents some ambiguities. Indirect measurements show estimates that vary from positive and very high returns to negative ones[22]. Some studies document that the private rates of returns to R&D are between 20 and 30% whereas the social rate of return seems to be in the order of 50% (see Nadiri 1993). Despite the econometric boundaries of this type of analysis, this finding suggests that there is a large gap between private and social rates of return (see Wieser 2005 for a survey). It is worth noting that the majority of these studies tend to measure in the data not only knowledge (technology) spillovers but also market spillovers (rivalry effects of R&D), which are conceptually different. Whereas technology spillovers are beneficial to firms, market spillovers may have a negative impact. The main criticisms raised in this literature are that econometric estimates do not distinguish adequately among different varieties of spillovers.

Bloom *et al.* (2005) develop a methodology to separate market and technological spillovers and implement it on a large panel of US firms for the period 1981-2001. They find that both types of externalities are present and quantitatively important and that social returns to R&D are positive and about 3.5 times the private returns.

The improvements in the econometric methodology and available data have been substantial in the last few years. It is worth mentioning a recent work by Cincera (2005) in which the author improves the Jaffe (1986) methodology in the construction of R&D spillovers among 625 intensive R&D firms over the period 1987-1994. Technological

[22] The possibility of different spillovers (in the NGTs) is well known. Besides the positive spillovers there are also negative ones (see Jones and Williams 1998).

spillovers are modelled by weighting the firms R&D stock according to their technology space measured by patent distribution. The total spillover pool is split into local and external components and both show a positive impact on productivity growth. The study also confirms that social returns are higher than private ones.

Significant and robust estimates are obtained also by Griffith *et al.* (2004) using a panel of industries across twelve OECD countries. Their opinion is that the low value of spillovers found in previous studies – based mainly on US firms – is that they failed to take account of the R&D based absorptive capacity of a country.

On macroeconomic ground, the first finding of output elasticity of internal R&D stock and the rate of return to R&D investment was found in the same range of microeconomic evidence (respectively 0.3 and between 20 to 40%) even if a higher value was expected (Lichtenberg 1992). In the study by Verspagen (1996) the role of R&D is investigated for Germany, France and UK since 1960. The author shows that R&D accounts for about 25% points of productivity growth in the first two countries whereas for the UK the author is not able to reject the null hypothesis of no impact on the growth rate.

More recent econometric studies have provided support to R&D models. Most of the estimates are statistically significant at the standard 5% confidence level. Eaton and Kortum (1997) document that in some OECD countries (Germany, Japan, the U.S. and France) more than 50 percent of the growth in productivity is due to R&D innovations.

We believe that the evidence on R&D and spillovers at firm and country levels makes less imperative the criticisms of R&D-driven growth models by Jones (1995a). What Jones criticises is that the model implies that a doubling of the number of scientists engaged in R&D means a doubling of the growth rate and this prediction is not found in the data. We will review the problem of scale effects and related empirical studies in the next section. Many scholars argue that the debate on scale effects may be overcome if the focus shifts to the modelling of R&D performing firms and on more solid micro-foundations of firms decisions.

The challenge for future research is to implement models and methodologies suitable for measurement of technological progress and spillovers with increasing precision. On this perspective runs the recent work by Klenow and Rodriguez-Clare (2005). Whereas cross-country growth regressions based over the last fifty years do not show significant effects of R&D spending on income growth rates, the effects seem to be robust when the dependent variable is TFP. However, according to KRC, regression analysis is inappropriate to capture accurately the magnitude and the significance of R&D spillovers. By using quantitative analysis the authors demonstrate that the GDP of the world would be only 6% of its current level or, as they explicitly claim, "on the order of $3 trillion rather than $50 trillion if countries do not share ideas".

In the next section we explore firstly the problem of scale effect and the way it has been solved in econometric analysis and in the following section the possibility that R&D spillovers are channelled by international trade. A country can raise its productivity by investing directly in R&D and also indirectly by trading with research-intensive countries.

3.4.1 Second Generation Research-Based Models

The second generation NGTs divide themselves into two approaches which offer different solutions to the problem of scale effects implied by first generation endogenous growth models.

The approach by Young (1998), Howitt (1999) Dinopoulos and Thompson (2000) Peretto (1998), Peretto and Smulders (2002) – labelled full endogenous growth models (henceforth FEGMs) – preserves the endogenous nature of growth while eliminating scale effects. Before discussing the empirical evidence of FEGMs against semi-endogenous growth of Jones (1995a, b) Kortum (1997) Segerstrom (1998) and Li (2000), (henceforth SEGMs), it is worthwhile to recall briefly the main issues that have been raised in the theoretical debate.

The first generation-research-based models make the strong assumption that the growth rate is an increasing function of scale, typically proxied by the population of educated workers in the research sector where innovation has unit elasticity with respect to human capital. This leads to the scale effect prediction that as the population increases so does the rate of technological progress and the growth rate of output per person. When it is examined closely, as it was by Jones (1995a), this assumption proves to be falsified by empirical studies since the increase in people engaged in research activities in the last decades has grown more than five-fold but without leading to productivity growth. The coexistence of an upward trend in R&D workers and no trend in TFP growth has refuted the first generation growth models[23].

Along the lines of Laincz and Peretto (2006) we plot with data from Heston *et al*. (2006) in Figure 1 the natural log of 1950 population levels against average real per capita growth rates for 137 countries.

There is a negative but not significant relationship between the log of population and the average growth rate [24]. Obviously, it is not by plotting the data that we can deny scale effects in the world economy. As argued by Aghion and Howitt (2005) there is no evidence pointing to the absence of a scale effect at the world level. Also, Dinopoulos and Thompson (1998) admit that the existence of scale effects in the transitional path may serve as an explanation for the dichotomous existence of historical scale effects and their disappearance in modern times. Kremer (1993) has shown persuasively that over the very long run larger population has led to faster technological growth, which in turn allowed population growth to accelerate. Perhaps, if growth rates of countries such as China and India, which have been considered in the past as examples for the non-existence of scale effects on growth, will be included in future research, the evidence on scale effect should be again reconsidered.

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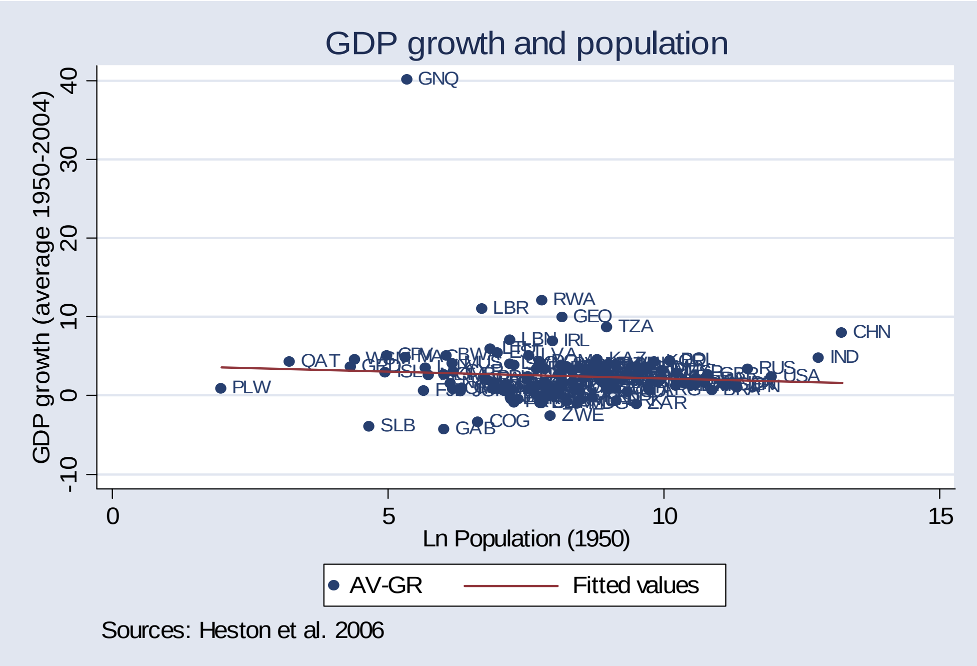
[23] We agree with the argument of Aghion and Howitt (1998) that it is not simply counting the number of scientists and engineers that we can assess the implications of R&D-based models. It is sufficient for the two authors to control for the size of country using R&D intensity (R&D expenditure/GDP) to show that for the USA there is no tendency for this ratio to increase. However, it is not only the empirical evidence offered by Jones that has triggered the research programme of endogenous growth without scale effect. Backus *et al* (1992) found that GDP growth is not related to the scale of the economy. They found instead a scale effect of the growth of TFP in the manufacturing sector. This work will be discussed in an apposite section (3.5).

[24] The regression is :AVERGR= 2.39 –0.1759 Ln (POP); *t statistics*= – 0.90, and $R^2 = 0.06$

Figure 1



A natural but insufficient answer aimed at eliminating this misguided prediction of scale effects for industrialised countries has been the SEGMs built on the idea of diminishing returns to the stock of R&D knowledge. Proponents of this view argue that sustained *growth* in R&D input is necessary just to maintain a given rate of *TFP growth*. This approach motivates decreasing returns to R&D by introducing a *difficulty index*, according to which there is a less than proportional relationship between the number of scientists and the growth rate of the economy (Segerstrom 1998). Therefore, when technologies become more complex sustained growth in R&D workers is necessary just to maintain a given rate of TFP growth. In SEGMs technological change is endogenous but long run growth is determined by exogenous population growth. The main implication of this class of models is that the scale effects are eliminated but so is the potential of policy to affect the long run growth rate of per capita income. The long run rate of TFP and income per capita depends on the (exogenous) rate of population growth, which ultimately limits the growth rate of R&D input (labour in R&D sector). Public policy may affect the level of income and growth rate along a transition path but the long run growth rate is invariant to policy changes[25].

On the same theoretical foundations are constructed the second generation FEGMs. The scale effects in innovation are removed by allowing horizontal innovation as well as vertical innovation R&D. While the first generation R&D growth models and SEGMs examine variety or quality innovations, by contrast the FEGMs consider the two types of innovations simultaneously. They build on Young's (1998) idea that as an economy grows proliferation of products varieties (sector expansion) reduces the effectiveness of R&D aimed at quality improvement. Thus, the growth enhancing effect

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[25] It remains to ascertain if population growth is really exogenous or is an endogenous variable determined by fertility choices of individuals. Policy change can affect these choices and hence the long run growth rate, even in models with week scale effects (see Jones, 2003, 2005).

of rising R&D input is offset by the detrimental effect of product proliferation. As a consequence, the reward to innovation resulting from a larger population will be dissipated in the long run by the associated increase in demand and product varieties, which is proportional to population[26]. This causes additional R&D investment to be absorbed by new products and sectors causing the *R&D share* of each sector to remain constant. The FEGMs are able to remove the scale effects and to restore full endogenous growth predictions since a permanent increase in the fraction of R&D workers, rather than the R&D stock or the number of scientists and engineers, will permanently raise the growth rate. As stated by Ha and Howitt (2007):

> “Without denying the deleterious effect of increasing complexity on the productivity of R&D, Schumpeterian theory retains the original assumption of constant returns to the stock of knowledge in R&D and therefore implies that the long run rate of TFP growth will be governed by the same economic factors as in the first generation R&D based theories with the sole exception that the size of a country’s labour force no longer has a positive scale effect on long run growth “ (p. 734).

In the current debate both variants of SEGMs and FEGMs suffer from some theoretical inconveniencies.

In contrast to the knife-edge conditions that characterise the FEGMs, the main criticism to SEGMs is that they are limited to one R&D sector model which proves to be of little interest in a real world in which there are diverse research activities (Li, 2000).

Which predictions are accepted (rejected) by empirical work? Empirical evidence on these classes of models is steadily growing. By reviewing papers favourable to FEGMs we, indirectly, test also the competing SEGMs.

For the FEGMs to be consistent with empirical evidence they require the following conditions to be present in the data:

- stationary TFP growth;
- increasing R&D input (employment);
- TFP growth varies proportionally with research intensity (R&D/GDP or R&D workers/population) which should be roughly constant (SEGMs require that R&D expenditure and TFP grow proportionally);
- Patent statistics and economic growth rates are roughly constant[27].

As Aghion and Howitt (2005) argue the first test of compelling approaches is using observed trends in productivity growth. FEGMs are validated if technological progress and productivity growth depends on R&D intensity. They show that the growth rate of productivity for the USA in the period 1950-2000 does not reveal any trend and the augmented Dickey-Fuller test rejects a unit root at 1% significance level. The same happens to R&D/GDP ratio. The SEGMs, which predict that the growth rate of R&D

[26] Slightly different is the mechanism in Peretto and Smulders (2002). In their model, accumulation of knowledge along the intensive margin expands public knowledge stock and give rise to spillovers as in first generation growth models, while accumulation of knowledge along the extensive margin (new line of research) leads to higher specialization and to dilution of spillovers and therefore of the scale effects.

[27] Substantially we find support for FEGMs if innovation is driven by knowledge stock and R&D intensity and the long run growth rate is determined by the rate of innovation.

and workers in the research sector should be trendless and stationary, show instead a substantial negative trend in the G5 in the period 1950-2000.

This is only a straightforward way to show causal empiricism on the behaviour of some variables. The empirical analysis in favour of FEGM is numerous and we will review some of these recent studies.

Zachariadis (2003, 2004) shows that the FEGMs pass a series of tests using data from USA and from OECD countries. In the first paper he uses US manufacturing industry data for the period 1963-1988 to estimate the overall systems of equations implied by these models. In particular three equations relating R&D intensity to the rate of patenting, patenting to technological progress and finally technological progress to economic per capita growth, are estimated. All these equations show the existence of a positive relationship. If USA is a benchmark for studying the link between innovation and growth, since this country is at the frontier of world technology, then the analysis confirms all the empirical core propositions stated above[28]. The second paper is a direct extension of the first study to OECD countries so as to assess the importance of this class of models for countries behind the world technology frontiers. By using data for the period 1971-1995 for a group of OECD countries which accounts for 90% of R&D expenditure in the world, the author results show that aggregate returns to R&D are much higher than those found in the manufacturing sector or its two digit industries and conclude that while at the micro level R&D intensity often does not affect growth at the aggregate level it does.

In spite of this macro level result we continue to present other evidence also at firm and industry levels that adds to that already reviewed examining the effect of R&D effort on productivity growth in manufacturing firms. Ulku (2007a, 2007b) investigates the relationship using international panel data on R&D expenditure and patent applications from 41 OECD and non-OECD countries to examine the predictions of FEGMs. By employing both aggregate patent data and R&D data, the author finds that an increase in the share of researchers in the labour force leads to an increase in innovation which in turn raises per capita output giving support to FEGMs but only for the OECD countries that include the G7. In the other cited paper, the author performs a sectoral analysis for four manufacturing sectors in 17 OECD countries for the period 1981-1997. The empirical analysis is based on the FEGMs and the relative findings give support to the theory since technological innovation is driven by knowledge stock in three sectors (except drug and medical sector) and this in turn affect the growth rate of output of the same sectors.

A further support to FEGMs which accounts for long run co-movements in R&D and TFP within OECD countries is provided by the study of Ha and Howitt (2007). The aim of the paper is to compare these two varieties of endogenous growth models by focusing on US experience where long series on R&D are available. The authors point out that the lack of cointegration between growth of R&D input and TFP growth does provide strong support to FEGMs. Specifically, since 1953 the growth rate of R&D labour (measured as in Jones by the number of scientists and engineers) has fallen more than three-fold without provoking any reduction in the growth rate of TFP in the USA.

[28] Using the estimates from all the equations the overall impact of R&D intensity on growth rate and technological progress is calculated. In particular an increase in industry R&D intensity by 1% increases the growth rate of output per worker in that industry by 0.08 to 0.16%. Increasing aggregate R&D is much higher and an increase of R&D intensity by 1% increases the growth rate by 0.66 percentage points.

Therefore, if sustained growth in TFP does not require sustained growth in R&D labour " then there is no reason to believe that long-run TFP growth is governed exclusively by population growth" (p. 735). Vice versa, to validate FEGMs it is sufficient to find that a trendless TFP growth is associated with the absence of a trend in R&D intensity. The R&D/GDP ratio in the USA has remained between 0.021 and 0.029 from 1957 to 2000. The authors conducted other specific co-integration tests of the two competing theories and found that FEGMs forecasts the time series of productivity better than SEGMs.

Other studies show similar results. The mechanisms that underlie the paper by Laincz and Peretto (2006) are based on Peretto's (1998) theoretical model. Along the transition to the steady state new firms enter and expand the variety of goods. The scale effect disappears because of the crowding in effect due to entry which generates dispersion of R&D across firms and offsets the positive scale effect. In the empirical paper they look at product line as the main locus of innovation. Among the empirical core of the theory there are two predictions to be tested: (i) the number of establishments, employment and population exhibit a positive trend and (ii) the ratio of employment/establishment is scale invariant. Development of new product lines fragments the economy into submarkets whose size does not increase with population. They present evidence that support these predictions using R&D personnel per establishment as a proxy for R&D per product line over the period 1964-2001. Moreover, Laincz and Peretto suggest that the focus of the debate must be directed not towards the linearity of the knowledge production function but the acknowledgement that the innovation process is local in nature. The main restriction that can come from this kind of evidence is that data on firms' R&D is very limited.

Finally, in some recent papers Madsen (2008a, b) provides further evidence in favour of FEGMs by showing that SEGMs are not consistent with the data. Importantly, the author examines whether FEGMs predictions are confirmed, by using long historical data and various indicators of innovative activity and product variety for the OECD countries. While time series data is consistent with Schumpeterian theory, cross-sectional evidence shows that there is no clear relationship between TFP growth and R&D intensity. Considering the long run relationship, there is a slight positive link between TFP growth and R&D growth that corroborates SEGMs. When the author passes to estimate cointegration models for the G21, in the more recent period (1966-2003) the result for the SEGMs is not confirmed and TFP and R&D (measured by innovations) are not cointegrated. No better results are obtained when research activity is proxied by patents by residents. With panel estimates both theories are validated for some relationships but not for others. Substantially, the results are very mixed, even if they seem more favourable to FEGMs. With very long run data the test of the Shumpeterian theory shows that the variables of interest are cointegrated in 7 of 12 cases at the 10% level, while for SEGMs the variables are not cointegrated for half of the countries. Madsen's conclusion is that evidence is against SEGMs. Finally the paper finds that TFP growth is enhanced by international technology spillover effects through different channels. This is object of discussion in the next section (Madsen 2008 b).

3.4.2 Evidence on International Spillovers

The question of interest to economists is not only the relationship between R&D investment at firm, industry or country levels but how R&D spillovers explain cross country differences in growth rates. It is reasonable to believe that a country productivity growth depends not only on the accumulation of its R&D but also on the R&D performed by other countries. The literature on *international knowledge spillovers* has not a long tradition and has concentrated mainly on international spillovers driven by trade (Coe and Helpman 1995), distance (Eaton and Kortum 1997), as well as trade and foreign direct investment flows (Lichtenberg and van Pottelsberghe de la Potterie 1998), foreign patenting (Nadiri 1993, Mohnen 1996). But obviously the list should continue since there are other potential transmission mechanisms, such as licensing agreements, joint ventures, and the international migration of scientists and engineers, which have been less investigated in the current literature (see Bernstein and Mohnen 1998, Görg and Strobl 2005).

Here, the emphasis is on spillovers driven by international trade, which are an important ingredient of the NGTs. Even if scholars generally agree that international trade may have positive effects on per capita income and on the level of productivity of an economy, they also claim that the reverse may be plausible. In the NGTs there is an array of models which imply that great openness has growth effects, although the impact on growth rate remains ambiguous (Grossman and Helpman 1991, Matsuyama 1992). In the Lucas model (1988), for instance, the economy can grow more rapidly, providing that its comparative advantage at the time of opening is in an industry with faster learning by doing. Along the same lines, however, there are models (Young 1991), in which free trade could lead to a decline in growth rates of countries with no comparative advantages such as often occur for LDCs.

In this section and in the next, we review the most noticeable empirical studies based on the link between the degree of openness and the growth rate as well as the estimated magnitude of international spillovers from R&D, which can be transmitted through international trade. The widespread belief is that both domestic and foreign R&D act as engines of economic growth. Eaton and Kortum (1997) show that even a technological leader such as the US would have grown less than half if it had been isolated.

The majority of existing studies of international R&D spillovers estimate simple Cobb Douglas production functions where for each country both domestic and foreign R&D enter as inputs. Much of the empirical work has been spurred by Coe and Helpman's paper (1995). They show that TFP growth during the period 1971-1990 in some OECD countries was affected by the increase in domestic R&D but also by foreign R&D and this impact is higher the more open is the economy. They construct for every country of their sample (21 OECD plus Israel) a stock of domestic knowledge based on R&D expenditure and a foreign R&D capital stock. The equation estimated relating TFP to R&D is:

$$\log F_i = \alpha_i^{\,0} + \alpha_i^{\,d} \log S_i^{\,d} + \alpha_i^{\,f} m_i \log S_i^{\,f}$$

where i is a country index, log F is TFP, S with superscript d and f represent respectively domestic and foreign R&D capital stocks, the latter being defined as the import share weighted average of R&D capital stock of trade partners. m_i stands for the fraction of imports in GDP, α, is the elasticity of TFP with respect to domestic and foreign R&D capital stocks. The main results are that smaller countries benefit from foreign R&D more than large countries, with the greatest impact on Belgium, followed by Ireland, the Netherlands and Israel. Estimates suggest also that international spillovers are very high and that R&D expenditure raises productivity in foreign countries as well as in the domestic economy.

International R&D spillovers are the focus of another paper by the same authors (Coe *et al*. 1997). They provide quantitative estimates of international spillovers for a group of 77 countries over the period 1971-90 by examining the extent to which less developed countries, with low R&D of their own, benefit from R&D performed in industrial countries. The estimated equation differs from CH (1995) in three main respects: (i) the specification of the regression equation includes a proxy for human capital; (ii) only foreign R&D is included; (iii) the measure of openness to trade is defined as the ratio of imports of machinery and equipment imported from industrial countries to GDP. The results imply that TFP of developing countries depends positively and significantly on all the factors mentioned.

Their model highlights the importance of trade as vehicle for technological spillovers and their estimates suggest that spillovers from industrial countries (the North) to developing countries (the South) are substantial. More precisely, on average an increase of 1% in the R&D capital stock in the US raises output in the developing countries by 0.06%, while a similar increase in R&D in other countries, namely Japan, France, Germany and the UK, increases TFP in the developing countries only in the range 0.004-0.008%.

Keller (1998) questions the results of CH that R&D spillovers are trade related. He runs the same regressions with the only difference that foreign knowledge stock is replaced by a random variable, which is computed on simulated import patterns. The estimated R&D international spillovers, based on simulated foreign knowledge stock, are larger than the coefficients based on the “true” foreign knowledge stock. This casts doubt on the reliability of the results of CH since counterfactual trade patterns generate a better empirical fit. The use of trade-weighted R&D capital stock implies that all international knowledge flows through imported goods. The criticism is that the import composition of a country does not necessarily matter for growth in the way predicted by recent growth theory of openness and growth.

The works by Coe *et al*. have inspired a large number of empirical studies some of which propose alternative econometric techniques, and others question the definition of foreign R&D capital stock used. Criticisms of the first type come from Luintel and Khan (2004) and Funk (2001), while criticisms of the second type come, among others, from Lichtenbergh and van Pottelsberghe de la Potterie (1998, 2001). Even if these authors question the econometrics in the paper of CH, such as the indexation scheme that biases the measurement of foreign spillovers (the first paper) or the modelling of dynamic heterogeneity of knowledge diffusion across countries, which depends on the countries’ organisational structure and social capability for absorbing international technology (the second paper), their studies still confirm significant spillovers, although of reduced magnitude.

Funk (2001) presents results using panel estimation techniques and demonstrates that using weights based on bilateral export shares in defining foreign R&D capital stock, it is possible to capture R&D spillovers from exporters’ customers. The distinctiveness of Luintel and Kahn’s study, instead, is that they find a long run relationship between TFP and domestic and foreign R&D capital stock but the US international R&D spillovers are significantly negative for total R&D data.

By using modern panel cointegration techniques, Lee (2006) questions the measure of foreign R&D capital as a simple average of trading partners' domestic R&D capital stock and shows that a different definition based on inward FDI perform better in detecting R&D spillovers.

There is, however, a piece of literature that using dynamic panel techniques has not confirmed previous results. Kao *et al.* (1999), for example, find that the estimated coefficient of foreign R&D capital stock, by applying dynamic panel techniques, is insignificant. The many criticisms of this literature have motivated a recent paper by Coe, Helpman and Hoffmaister (2008). They use cointegration techniques, that seem to be consistent with issues raised by the econometric literature (omitted variables, simultaneity and endogeneity), and by updating and extending their data set at 2004 with a time series dimension that increases from 20 to 34 annual observations, confirm the key empirical results of CH (1995). They find robust evidence of cointegration between TFP, domestic R&D capital, foreign R&D capital and a measure of human capital[29]. Obviously, the impact on growth is not uniform since the increase in domestic R&D varies enormously across countries, whereas the increase in foreign R&D capital stock shows a more uniform pattern. In particular using the definition of foreign R&D capital stock based on either bilateral import shares, as in CH (1995) or the definition proposed by Lichtenberg *et al.* (1998), both perform equally well. The paper seeks to contribute also to the debate on the predominant role of institutions over international spillovers, by evidencing that countries with better economic institutions (the ease of doing business, the quality of tertiary education) tend to benefit more from their R&D efforts and from international R&D spillovers.

However, in all the previous literature the time lag structure of R&D spillovers has not been considered adequately. In CE, for example, diffusion of technology is instantaneous whereas some recent studies show that an estimated period of about four or five years is necessary for investment in R&D to impact on productivity and in specific cases for incorporating new technologies in both final goods and intermediates. More long run analyses and cointegration techniques, such as those applied by Kao *et al*. (1999) and Coe *et al*. (2008) should improve on previous econometric methodologies.

A distinctive further criticism in measuring the impact of externalities across borders is addressed in the paper by Meister and Verspagen (2005). The authors point to the important distinction between knowledge and rent spillovers. The former are externalities arising from the public good character of knowledge and do not require engagement in economic transactions. Rent spillovers are strictly associated with the exchange of goods[30]. To separate both types of spillovers, in order to avoid measurement errors in attributing "productivity increase to wrong entities", the authors suggest the use of technology flow matrices that use patent data. Patents are classified in terms of their technology class and a matrix represents the share of all patents generated in a sector that spills-over to all other sectors. If a patent is classified in more than a single class which belongs to different industries, then this is taken as a spillover

29 Panel cointegration techniques have been applied recently to growth empirics and are becoming very popular since estimates are robust to a variety of problems that generally plague standard econometric analysis and can be implemented with shorter data spans (see Baltagi and Kao 2000).

30 As stressed by Maurseth and Verspagen this distinction between the two forms of spillovers pertains to Griliches (1979).

between sectors. Their exercise shows that European TFP gaps relative to the USA would not be narrowed very much by an increase in R&D intensity according to the Barcelona target of a share of R&D of 3% for European countries.

Against the widespread character of knowledge flows is the paper by Maurseth and Verspagen (2002). They study the patterns of spillovers between European regions by using patent citations[31] and their findings support the hypothesis that there are relevant barriers to technology transfers. Spillovers occur between geographically close regions that belong to the same industry or the same country and are limited by language differences and country borders.

Comparable conclusions were achieved in the paper by Nadiri and Kim (1996) in a different theoretical framework. They use a translog-cost function to capture spillovers for the highly industrialised G-7 economies. The rate of return to domestic R&D ranges between about 14 and 16% and the total return to R&D (private plus spillovers) is about 23 to 26%. The measurement of bilateral spillovers varies consistently among countries. While the R&D spillovers from the US to other countries are sizable, in Europe only Germany acts as a source of spillovers while the other European countries were just receivers of spillover benefits. Even if international R&D spillovers have contributed to narrowing the productivity gap between the US and the other G-7 economies, the evidence indicates that their magnitude is rather modest.

The works reviewed at micro and macro levels on research-based models indicate that, even if our knowledge and measurement of domestic and international spillovers is still rudimentary, there is no doubt that the phenomenon exists. Spillovers are important in all the three class of the NGTs. They can be derived from learning by doing, from investment in human capital and R&D as well as from development of specialized inputs to production. Regrettably, no firm conclusion has been achieved on their size and relevance. Further researches are desirable for a clear understanding of modes of diffusion and appropriation of R&D spillovers across industries and across countries.

3.5 Trade-Openness and Growth

It is remarkable in this sizeable strand of empirical literature to distinguish two types of investigations. The first type tests the relationship between some measures of trade openness and their impact on growth rates. Significant growth rates are often associates with increasing openness since the exchange of goods and services may be the channel for exchange of ideas and technologies, as seen in the previous section. Openness may be considered in the general meaning of imports and exports on GDP or other more general indices constructed on trade variables (Dollar 1992, Ben David 1993, Harrison 1996, Edwards 1998).

The second type of investigation, which is becoming not only large but also very attractive for its policy implications, includes works in which openness is considered in

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[31] There is a body of empirical literature that uses patent citations as an indicator of knowledge spillovers. The rationale of patent citations is based on the argument that knowledge contained in the cited document has been useful for the development of the patent. Thus citations are an indicator of transmission of knowledge between inventors. We do not review this literature since the drawbacks of using patent data are considerable (see Griliches 1991). The main concern is that the quality of patents varies widely and their effects are not comparable across countries. We believe, however, that patent citations may be quite useful in studying spillovers from specific technologies.

terms of trade policy liberalisation by governments. If we consider old evidence on this issue it seems that results in different period and across countries are ambiguous. But almost all the recent studies show a positive and significant correlation between a variety of trade policy indicators and growth. The question of how strong is the relationship between openness and growth and whether open oriented policies are sufficient to ensure sustained growth in developing countries remains an open one.

In fact the finding of a positive association of trade liberalization and growth has been challenged by a paper of Rodriguez and Rodrick (R&R 2001) which shows that the evidence on the impact of policies affecting the openness of countries does not lead to faster growth. The authors carried out a systematic critique of the main existing evidence by arguing that the results are conditioned on an inappropriate indicator of openness used and on severe methodological shortcomings.

The regressions in the works of Dollar (1992), Ben David (1993), Sachs and Warner (1995) and Edwards (1998) are all re-estimated by R&R and the findings now are quite different from the original ones. The Sachs and Warner study is very attractive because it seeks to build a reliable openness measure that combines different indicators. When the regressions are re-estimated, the zero-one dummy variable of openness for 79 countries in the period 1970-89 is shown to be not robust. Three out of the five indicators[32] lose their significance and the other two are not dependent merely on trade policy of a country. In particular, it is shown that if the measure of openness used is trade barriers there is little evidence that lower barriers, in the sense of lower tariffs to trade, are significantly associated with positive growth. Also the paper by Edwards (1998) and his openness index of nine variables is re-examined by R&R and the robustness of Edward's finding vanishes when the authors apply White's method to correct for heteroskedasticity and when data are updated.

Also, Wacziarg and Welch (2003, 2008) have revisited the evidence on the cross-country effects of Sachs and Warner's dichotomous indicator of outward orientation. By correcting some of the problems associated with its construction, they are able to confirm original findings. The authors show that countries that have liberalised their trading regimes (lower average tariff rates) experienced higher average growth rates[33]. However, in the new version of their work (2008) the authors state that these average effects mask large differences across countries. By examining 13 country-cases of trade liberalization, the evidence shows country-specific complexities and great heterogeneity. Typically, trade reforms are associated with other kinds of external reforms and it is difficult to disentangle among them. What the authors find is a considerable heterogeneity in country experience after the trade reforms: at least half of the 13 countries experimented negative or zero differences in their growth rates.

There are papers, such as that by Frankel and Romer (1999), which address the question of causality. The element of novelty in this paper is the attempt to deal with

[32] The openness indicator of Sachs and Warner (1995) includes:.(i) average tariff rates over 40% on capital goods and intermediates, (ii) non tariff barriers that cover 40% of imports in capital goods or intermediates (iii) a socialist system, iv) a state monopoly for major exports of the country, (v) a black market premium on exchange rate over 20% in the period.

[33] However, this result is also questioned by Rodriguez (2006). The index of liberalization constructed by Wacziarg and Welch is subjected to the same criticism of Sachs and Warner since it relies heavily on the black market premium in classifying a country as open or closed. Out of 31 economies in their data set 27 are considered closed exclusively on the basis of their black market premium or state monopoly of exports. The strong reliance on this characteristic may lead to country misclassification.

the endogeneity of trade share by using geographic variables as instruments of the relationship bearing out the positive effect of trade. This paper is also criticised by Rodriguez and Rodrick on the basis that geographic variables are not valid instruments. Geography may affect income and productivity along many channels and not only trade. More recently, however, Noguer and Siscart (2005) confirmed Frankel and Romer's findings even taking into account the geographical control suggested by Rodriguez and Rodrick.

Another study that controls for geographic factors and institutional quality and finds significant and robust correlation between openness and growth is the paper by Alcalà and Ciccone (2004). The two authors use a measure of real openness and a proxy for tradable GDP openness. They find that the effects of international trade on labour productivity and income per capita at country level are highly significant and robust (a 1 percent increase in real openness raises average labour productivity by 1.45 percent). The same robust effect is found when tradable GDP openness is used.

The regression analysis in the paper of Dollar and Kraay (DK, 2002a) focuses on changes in growth rates and changes in the volume of trade among globalizer and not globalizer countries. Their findings show that countries that have increased their exposure to international trade, (i.e. those which had the largest increase in trade volumes or those which had the largest reductions in average tariffs), have increased their growth rates significantly, while non globalizers have exhibited a declining growth rate. Also this paper has been severely criticised by Rodrick (2000) and Nye *et al.* (2002). Rodrick criticised the arbitrary criteria chosen to classify countries. If countries are classified according to their tariff rates, as Rodrick did, it is possible to show that the selection of globalizers on the basis of tariff data leads to results contrary to those reported by DK.

Nye et al. (2002) point to further shortcomings of the DK approach. More precisely, the set of globalizers in the DK taxonomy are economies chosen according to an unconvinced criterion. By considering the two measures of openness adopted (trade/GDP and tariff criterion), these economies may be classified as closed. Therefore, it is only by selecting globalizers "on the basis of change in trade volume or by undertaking an inappropriate comparison over mismatched time periods, that DK come to their conclusion" (p.16). The countries that have increased their openness started from a position of relatively closed economies and this is the main reason of the greater acceleration in their growth rates.

However, as argued by Rodriguez (2006), whether or not the relationship between trade and growth is spurious remains an open question. The positive link, as in the Grossman and Helpman theoretical model, depends not just on trade in goods but on whether or not the forces of comparative advantage push the economy resources in the direction of activities that generate long run growth (externalities, quality upgrading, expanding variety of products). Although the majority of the empirical studies have documented positive R&D spillovers from trade, the econometric critiques both to the measures of openness and the instruments introduced in the regressions remain very pertinent. The impression in fact is that the questions of endogeneity and causality of openness would require more efforts to make empirical results more convincing.

3.6 Scale Effects, Openness and Growth

We have reviewed works on the link between openness and growth by distinguishing two types of studies: those based on trade volume and those based on trade policy. But there is a third strand of literature that focuses on the importance of market size for growth. Even if it is difficult to find empirical evidence of scale effects on growth, as shown in the previous section, there is an evident link between country size and trade openness.

Whereas the macroeconomic literature does not corroborate the scale effect either in a time series or in a cross-country context there is a vast microeconometric literature in which the scale effects are present. The most cited paper in a cross-country context is Backus, Kehoe and Kehoe (1992). They estimate the scale effects by theories of trade and growth and find little empirical evidence between the growth rate of GDP and measures of scale stemming from the theory. The authors concentrate on trade because it is an excellent example to test the theory. Trade influences the pattern of production including both the scale of production and the pattern of specialization and therefore the growth rate. They expected to find both scale and trade positively related to growth. However, at the aggregate level they do not find sizeable scale effects. The coefficient is positive but not large: a hundredfold increase in GDP (measure of scale) is associated with an increase in percapita growth of 0.85 (t statistic = 1.64). Also spillovers from human capital do not help predict aggregate growth. However, when they investigate the measures of scale by looking at the manufacturing sector only, they find a robust relationship between output per worker (log of manufacturing/worker) and measures of scale. They also find a relationship between growth rate and intra-industry trade (Gruber–Lloyd index). The work just cited is often considered as evidence that there are no effects of scale on growth at the country level.

Fortunately, the question of growth effects of international trade due to the extension of the market has been thoroughly investigated and the results are slightly different from those of Backus *et al*. The size of the countries does not matter for economic growth if one does not control for international trade. Market size depends on country size and trade openness and since small countries possess a higher degree of openness, a regression of growth on country size without controlling for international trade is biased towards zero (Alesina et al. 2005).

We have already discussed the works by Frankel and Romer (1999) and Alcalà and Ciccone (2004). By controlling for international trade, both papers found a positive link between country size and growth. Another group of studies found that – as expected – the coefficient of an interaction term between openness and country size is significantly negative (Ades and Glaeser1999, Alesina, Spalaore and Wacziarg 2000, 2005, Spolaore and Wacziarg 2005).

Alesina et al. (2005) estimated a regression of the type:

$$g_y = \beta_0 + \beta_1 \log y_{t-\tau} + \beta_2 \log S_{it} + \beta_3 O_{it} + \beta_4 O_{it} * \log S_{it} + \beta'_5 Z_{it} + \varepsilon_{it}$$

where S is a measure of country size and O is a measure of openness, Z is a vector of control variables. Country size is measured by the log of total GDP or by the log of population in order to capture both economic and demographic sizes. Estimated coefficients with Seemingly Unrelated Regression (SUR) of growth on openness, country size and the interaction term are of the expected sign and all significant at conventional level. The main message of Alesina *et al.* is that when evaluating the scale effects on growth it is of paramount importance to consider scale as attainable either through a large domestic market or through trade openness.

3.7 Some Remarks on New Directions of the NGTs

Our discussion so far has been based on the two major theories of endogenous growth accumulation versus R&D based models. We have dedicated a long discussion to studies on R&D because the theoretical and the empirical debate on this issue is capturing the efforts of many scholars. To put things in perspective, we wish to highlight some new directions of research in the NGTs that have not been treated in this survey but that are worthy of some discussion. We refer, particularly, to the results that come from thinking about the direction of technological change and its impact on factor shares and the degree of substitutability between capital and skilled (or unskilled) labour. This line of research goes back to old growth theories and Kaldorian stylised facts but it departs from the traditional approach by making income shares and non-neutral technological change endogenous. We expect to get new explanations of stylised facts of growth that seem to follow different patterns with respect to the past.

As is well known, labour and capital markets have been severely impacted by changes in technological progress and this poses important puzzles. Widening wage differentials between skilled and unskilled workers have been attributed to technological progress, since a possible explanation is that high-skilled workers are complementary to the new technologies. An alternative explanation is that the new technologies are skill-biased and increase the wages of highly skilled workers relative to low skilled ones. Also, the existence of scale effects may depend on the elasticity of substitution between reproducible and not-reproducible factors. Since we believe that empirical advancements in this field should become a priority in the coming years for the implications that it may have on the direction of technical progress and income distribution, we briefly review the main issues discussed in the literature.

Durlauf and Johnson (1995) found from the side of growth empirics that technologies become more intensive in reproducible factors as economies grow and this implies that the elasticity of output with respect to these factors is higher in rich economies. But how to conciliate this finding with accepted stylised facts of constant income shares over the last century?

Gollin (2002) has reconsidered the problem of income shares, i.e., the fraction of national income that accrues to production factors. Have these shares been unchanged over the last years? He shows that after correction of the income of entrepreneurs and earnings of self employed the factor shares give estimates that are constant across time and across space. However, in order to explain growth in less developed countries, the calculation of factor shares may require distinguishing among the shares of reproducible and non-reproducible factors and different trends according to biased or unbiased technological change. What we observe, in fact, is that the income share that accrues to non-reproducible factors (land and raw-labour) has decreased, while the income share of reproducible factors (physical and human capital) has increased during the last century.

To explain these trends, Acemoglu (2002a) has developed the idea that the direction of innovations is endogenous. If R&D can be directed toward productivity improvements of different inputs, then a direction of technological progress will presumably be chosen which embodies the factor that ensures the largest return. Naturally, this may determine important degrees of inequality among workers in labour markets[34].

In a note, Zuleta (2004) shows that by modifying the production function in the seminal work of Romer (1990) and using a CES function it is possible to show that the elasticity of substitution between reproducible and non- reproducible factors governs the production of goods When this elasticity is higher than one there is a scale effect in the long run and there is a negative scale effect for poor economies. But there are other negative impacts for poor countries. According to Zuleta the incentive to produce new goods is determined by factor abundance. As economies grow, the share of reproducible factors in GDP increases while the share of workers employed in the production of final output decreases.

Interesting theoretical papers on the same issue are: Zeira (1998, 2007), Zuleta and Young (2007), Zuleta (2008), Peretto and Seater (2008).

In the 1998's paper Zeira analyses a model of endogenous growth with technological innovations that reduces labour requirements but raises capital requirements. The implications are that only rich countries can adopt these technologies and therefore technology adoption may be responsible for large and persistent international differences in productivity across countries. In the subsequent paper (Zeira 2007) a model with endogenous biased technical progress is presented in which growth is explained by factor saving innovations. Substantially, higher wages induce more capital-intensive technological progress to replace costly labour. These innovations complement labour by increasing its productivity and its income share (wages) in the future. The model shows that long run growth is feasible only if the cost of machinery is sufficiently low.

This is in line with the empirical finding by Caselli and Feyrer (2007) who present estimates of the aggregate marginal productivity of capital (MPK) from a large cross-section of countries. By separating reproducible from natural physical capital, they report that the returns to capital in poor countries are lower because of the relatively high cost of investment goods, whereas MPK are essentially equalised in their broad sample of developing and developed economies.

Zuleta (2008) presents a growth model that can account for these facts, in which factor income shares are endogenous. Assuming that changing technology is costly, the capital abundant countries are more likely to increase capital intensity than poor economies. Next, capital abundance triggers labour-saving innovations driving the economy to long run growth, whereas poor economies may converge to a steady state without reproducible factors. The stylised fact of constant factor shares is preserved through compensation of the increasing human capital income shares to the decreasing raw-labour income shares. The same logic applies to other factors. In general, the model predicts that the income share of non-reproducible factors decreases with the stage of development and vice versa.

Another interesting paper on the same line of research is that of Peretto and Seater (2008). In introducing reproducible and non-reproducible factors in a standard Cobb-

[34] This literature of non-neutral technological change is strictly linked to the literature on inequality in the labour markets driven by change in technological progress. There is ample evidence indicating skill-biased technological change that would lead to profound transformations in the labour market. For a review of these issues see the interesting works of Acemoglu (2002 b), Hornstein and Krussel (2005).

Douglas production function, the two authors show that endogenous growth might be non-sustainable. However, their model provides an endogenous mechanism, which alters factor intensities, capable of supporting perpetual growth even if an economy starts without any sort of factor augmenting technological progress. The perpetual growth path is feasible because the economy with its own effort will choose a saving rate that conducts the economy on that path. The endogenous growth mechanism will depend on some parameters of the Cobb- Douglas function which are not constant but linked to the kind of technological progress. The model, thus, avoids the restrictions on the production function necessary for perpetual growth and overcomes the incorrect hypothesis that some parameters are constants rather than endogenous. Moreover, it is consistent with data on factor shares that change over time: the shares of reproducible factors will increase and those of non-reproducible factors will fall. If their predictions are consistent with time series and cross section evidence, then differences across countries in growth per-capita income should be re-calculated, allowing for cross-country variation in factor shares to offer an explanation of how much of the variation in cross country performance depends on TFP and how much on factor intensities.

We expect to see more empirical evidence to validate the predictions emanating from these models.

4 Evidence on Public Policy and Institutions

The evidence on public policy, with some exceptions (Fisher 1993, Easterly and Levine 2001, and Easterly 2005) should be extracted from general regressions. There is a large literature on regressions of this sort. The impact on growth is obtained by looking at the sign of the coefficients of policy variables typically included among a broad number of other preference and technology parameters. The issue is now becoming an expanding area of research and public policy and institutions seem to dominate other more traditional growth factors in accounting for differences in per capita income and growth rates. Growth is not a *natural* phenomenon but is influenced by market forces, incentives and consequently by good policy choices.

Before discussing empirical issues on public policy, it may be worth briefly summarising the major theoretical issues that have been raised by the NGTs with respect to the preceding literature. The main distinction between new and old theories of growth is not simply the modelling of non-convexity. This would be of limited importance if the predictions drawn from these new models were roughly the same as the basic neo-classical one. Their peculiarity is the modelling of these non-convexities in such a way that the determinants of the growth rate are variables, which could be affected by government policy. That government policy influences the performance of an economy was well known by many economists but little progress in economic modelling took place in this direction. In the orthodox theory growth is an exogenous process and government policies have only level effects. The growth effects were limited to transitional phases. In the NGTs, on the contrary, government policies can affect the growth rate permanently.

In the NGTs the policies favouring R&D, education, and saving rates, are all conducive to enduring productivity growth (Barro 1990, King & Rebelo 1990, Rebelo 1991, Jones & Manuelli 1990, Jones, Manuelli & Rossi 1993, DeLong and Summers

1991, Turnovsky 1996). Policies capable of affecting growth also include, in a significant way, improvements in financial institutions, industrial relations, as well as law, order and justice. Some economists have stressed different degrees of democracy in developing countries to explain the differentials in growth rates that we observe. Further insights can be gained by focusing on some socio-cultural factors that have been revealed as historically important in case-study-growth processes.

Obviously, government policy is central to the NGTs, not only because of its focus on the determinants of growth which respond to incentives but also because the externalities involved in the growth process create a general role for the government to correct the sub-optimal result generated by the market. The competitive result determines a level of saving that is too low relative to the social optimum because private agents do not take into account the effect of the externalities. Most of the models present non-optimal equilibria creating places for policies of different species. Furthermore, with increasing returns the theory is consistent with permanent maintenance of unequal growth. Increasing growth rates, as in the models of Romer (1990), and Grossman and Helpman (1991), imply that there is a tendency to divergence across countries with different levels of income. Therefore, these models exhibit a multiplicity of steady state growth paths. Again, with multiple equilibria, economic policy really matters in choosing the more appropriate equilibrium path.

Regrettably, the wide variety of models, the multivarious sources of growth and the highly aggregated content of the NGTs, can lead to policy ambiguities and imprecisions (see Fine 2000).

We will discuss dysfunctional tax policies in the next section but there is a piece of evidence that pertains to general discussion on public policy and growth as a whole, which deserves some reflections. Low persistence of growth rates observed empirically should imply that if public policies are central determinants of growth they themselves should not be persistent. Evidence by Easterly *et al*. (1993) shows, instead, that country characteristics and national policies are much more stable over time than growth rates and this finding suggests that policies account for income level effects more than growth effects. Stability of policies and instability of growth rates is inconsistent with the AK model. The provocative title of the paper, "Good policy or good luck?" makes clear that some growth events may be driven by random shocks more than public policy.

In a more recent paper Easterly (2005), using variables that capture distinct dimensions of national policies, finds important growth effects. In particular, by including in growth regressions bad policies (inflation, black market premium, real overvaluation index, budget balance) and good policies (financial depth and trade openness), the author provides evidence that all the coefficients of the six policy variables are stable and statistically significant. However, when extreme observations of policies (defined by the author) are excluded from the analysis all the six variables become insignificant. The result suggests that the effect of policy is significant only if countries undergo extreme national policies but there is no reason to expect significant growth effects from moderate changes. The lesson that can be drawn from these asymmetries of results is that bad policies may have a great potential for growth destruction whereas the potential of good policies in fostering log run development is rather modest.

Despite the interesting analysis in the paper just mentioned, we believe that models in which policies are important determinants of growth are worthy of the greatest attention. The argument is explored by looking at the evidence on fiscal policy in the next subsections[35].

4.1 Fiscal Policy and Growth

The ambiguities delineated above can be found in the literature that has explored the effects of fiscal policy on growth. Models of the NGTs have stressed the role of government policy as a key determinant of long run growth. Using an extended AK model, Barro (1990) found that there is a fraction of government expenditure and a tax rate on output that maximises growth and welfare. The main hypothesis in Barro's model is that government expenditure is of the kind that increases productivity in the private sector of the economy (government consumption expenditure or more exactly unproductive government spending is missing from the analysis). However, since government expenditure must be financed, it requires distortionary taxation. If the size of government is small the positive effect of expenditure on private productivity dominates the negative effect of taxation.

Subsequently, many models have explored the link between taxation and growth. Rebelo (1991), Milesi-Ferretti and Roubini (1998a, b), Devereux and Love (1994), Pecorino (1994), Turnovsky (2000), Devarajan *et al*. (1996), Kocherlakota and Yi (1997), Bleaney *et al.* (2001), Peretto (2003) are only some examples of an expanding literature. In an endogenous growth framework these studies show that the equilibrium growth rate depends on the structure of taxes, which generally are growth-reducing. All models imply that taxation has distortionary effects on growth and as is familiar from intertemporal Ramsey-type models (Chamley 1981, 1986), these distortions are higher if it is physical capital income that is to be taxed. This is because a tax on capital income, in a growth setting, induces distorsions by reducing the incentives to save and invest with direct effects on the long run growth rate.

However, the standard outcome in public finance that taxation should be levied less on physical capital and to a greater extent on labour is no longer valid. In some classes of models in which both factors – physical and human capital – can be accumulated taxes levied on both factors can have a negative impact on growth (Milesi-Ferretti and Roubini 1998a). So the only taxes that are not growth-reducing are lump sums as well as taxes on consumption (when in the model labour supply is exogenous).

A limit of the majority of these models is that they investigate the effects of taxes without taking into account its counterpart that is government expenditures. If expenditure is productive, such as expenditure on education, R&D, defence, and infrastructures, taxes are not necessarily growth reducing (Jones, Manuelli and Rossi 1993, Turnovsky 1996, Capolupo 1996, 2000, Denaux 2007).

With endogenous labour supply, Turnovsky (2000, p.199), has shown that, since an increase in the tax-financed fraction of government consumption induces workers to devote a large fraction of their time to work, it can increase the long run growth rate. In a recent paper Peretto (2003) shows that taxation on labour income and on consumption

[35] We do not discuss in this review the role of monetary policy and finance, given the immense literature on this topic that would require a review by itself. Interested readers can consult Levine (2005).

has no impact on the steady state. Both kinds of taxes have only a *level effect* and the impact on growth rates comes mainly through taxes on assets and corporate income.

This brief summary of the literature makes it clear that a firm conclusion on the impact of policy is not yet well settled. Changing some assumptions of the model as well as modes of government financing can lead to different effects on the performance of the economy. Most of the empirical evidence on public policy is based on the use of Real Business Cycle techniques. The approach involves specifying explicit theoretical models which are then calibrated and parameterised so as to derive quantitative implications (see McGrattan and Schmitz [1999] for a review of evidence based on this approach). In general, however, what emerges from these studies is that the adverse effects of different taxes on the equilibrium growth rates rank in terms of distortionary impact according to the following sequence: tax on physical capital > tax on wages > tax on consumption > lump sum taxes (Turnovsky 2000).

On the econometric side the findings are not more reliable than quantitative analyses with results that are extremely mutable. The econometric finding of Barro's seminal work, is in contrast with his theoretical result: government expenditure is negatively correlated with growth. While some studies show negative effects of government expenditure and taxation (Fölster and Henrekson 1999), others open the possibility that the effects may be positive (Easterly and Rebelo 1993, Fisher 1993). Yet, while some works reach agnostic conclusions (Agell *et al*. 1997), others confirm *exactly* the prediction of Barro's (1990) model with public policy. We refer to the paper by Kneller *et al.* (1999). The authors show that if the budget constraint is specified correctly, which means that both expenditure and taxation must be considered properly, then Barro's predictions are accurate. Specifically, they find for a panel of 22 OECD countries (1970-1995) that: (i) distortionary taxation reduces growth while non-distortionary taxation does not; (ii) productive government spending enhances growth, whilst non-productive expenditure does not. Quite apart from robustness and significance of the results of this specific study, one point must be emphasised. When we want to evaluate the impact of taxation on growth, the regression must include expenditure variables otherwise the estimates will be biased by the omission of the variables, which might have positive effects on growth.

Bleaney, Gemmel and Kneller (2001) have replicated the results of the Barro model in a subsequent paper. They illustrate, without ambiguity, the positive long run effects of government policy on growth. However, more than other econometric tests, the estimate of the impact of government spending on growth is very problematic. First, different data quality may induce measurement errors in the estimating equation. Second, there are problems of endogeneity bias and omitted variables that can be correlated with the public sector. Some researchers have shown that when initial income is included in the regression the coefficient of government expenditure on GDP becomes positive. Third, there is a substantial identification problem, which derives from a two-way causation link between the size of the public sector and growth depending on supply and demand side relations. The first is crucial to identify the impact of public spending on growth but finding a set of instrumental variables that isolate the demand side effect seems quite impossible (Slemrod 1995, Agell *et al*. 1997). This lack of robustness in the empirical findings adds to the negligible effects of taxation found in the quantitative method with calibration of theoretical models (Stokey and Rebelo 1995).

Some robustness characteristics have emerged from time series studies. Kocherlakota and Yi (1996, 1997) provide evidence that tax measures significantly affect growth only if public capital expenditure is included in the regression. Their studies are worthy of further comments. The aim of the authors is at testing exogenous versus endogenous growth models using time series data. In the first study (1996), they regress GNP growth rates in the US, for the period 1917-1988, against lags of GNP growth rates, and seven policy variables, and test the hypothesis that the coefficients of the lags of these variables are zero. This may occur in the case of an exogenous growth model. The policy variables used are some measures of taxes, public physical investment and one measure of monetary policy (growth rate of M_2). The sum of the slope coefficients for each policy variable was found to be non-zero, which implies that permanent changes in government policy have a permanent effect on growth rates. In the subsequent paper (1997) the two authors extended the analysis also to the UK using time series data up to 160 years and concluded that the results support endogenous growth models that emphasise constant return to reproducible factors at the aggregate level. The results therefore indicate, as theoretically expected, that policy variables exert a long and persistent effect on growth.

A final observation on cross-country regressions is that the majority of earlier studies reported non-robust correlation, either positive or negative, between tax – spending variables and growth and this does not allow any persuasive conclusion about the effects of government on growth.

However, successive empirical works have addressed the question of the impact of productive government spending (i.e., infrastructure, health, etc.) on growth. Whatever the endogeneity problems are, the findings seem to be robust and crucial especially for developing countries (Batina 1999, Canning 1999), Esfahani and Ramirez 2003).

The observation that historically many development miracles have been spurred by good government policy suggests that the methodology of growth empirics should be improved so as to settle satisfactorily this controversial subject.

4.2 Institutions and Growth

A general implication that arises from the studies reviewed is that institutions may have strong effects on the growth rate and on the level of per capita income. Their impact is not direct but can be substantial. As said at the outset, for some authors institutions are *deep* determinants of growth and contend the *proximate* growth factors that have been discussed at length in the previous sections. According to the *institutions view,* pioneered by Acemoglu *et al*. (2005), neither the neoclassical framework nor that of the NGTs informs us much about the ultimate sources of differences in economic performance. The observation that one country is poorer than another, because of worse technology or capital accumulation, does not explain why this is so. It is very likely that these differences are caused by other, more fundamental, factors.

The argument recently debated in the empirics of growth is whether institutions dominate other traditional factors (Dollar and Kraay 2002b, 2003, Rodrick, Subramanian and Trebbi 2004). Not all researchers agree on the use of proxies for institutions in the empirical growth framework by arguing that their qualitative characteristics cannot be transferred to a quantitative index. Indeed, econometrically the quality of institutions is measured by different indices of accountability, property rights, rules of law, religion, degree of contract enforcement, government effectiveness, social capital etc. Commonly, these indices are built at a point of time through surveys or are collected at five-year periods. The series are very short and typically start from the 1980s. This means that their contribution to the cross sectional variation of income levels or growth rates can only be vaguely tested. Moreover, like other factors, institutions are endogenous and it is necessary to find appropriate instruments to test their impact on growth rates.

There is already considerable empirical work that suggests that a crucial aspect for countries to grow at different rates is the extreme diversity in institutions and public policies that establish the socio-economic environment in which people produce and exchange goods and services. Economic institutions determine the incentives as well as the constraints on individuals and groups in the society by affecting the distribution of resources. As pointed out by Easterly and Levine (2001), divergence is inconsistent with growth that is driven by factor accumulation. If returns are diminishing then factor returns should converge across countries. Differences in institutions and other country-specificities may prevent factor convergence by reducing physical and human capital accumulation. Countries with secure property rights, rules of law and a good quality of political institutions should exhibit high growth, whilst countries whose environment is characterised by corruption, expropriation, limited democracy, and insecure physical and intellectual property rights discourage growth of output generating diversion of resources.

Institutions that may affect the efficiency of an economy refer to aspects of government and political reforms that are related to the possibility to carry out profitable economic transactions. To a larger extent, it is possible to include in the institutional variables also those that have been treated separately in the previous part of this section. Country policy variables may include schooling, openness to trade, the size of government, credit and financial variables, tax policy etc. All of these are in many instances institutional variables. If so, then, institutions and policy variables have a potent role in the growth process. If a distinction is to be made between the *institutions view* and the *policy view*, the former with respect to the latter, holds that geographic and historical conditions produce lasting effects " by shaping economic development today" (Easterly 2005, p. 1054). A further problem arises on testing the institutions view. As claimed by Durlauf *et al*. (2005) empirical evidence on the consequences of democracy may not permit any progress simply because the past century does not provide examples of stable democracies among poorer countries.

Here, however, we examine institutions as a set of social arrangements including indices of democracy, rules of law, and degree of trust among individuals, which a vast number of empirical studies have shown to affect growth. The policy variables just cited should be considered as channels through which institutions affect economic outcomes.

By considering different institutional variables, simple indexes of democratic rights do not seem to be significant in the regressions performed. Once the other explanatory variables are held constant, variations in democracy are not systematically linked to the rate of economic growth (see Barro 1997, Acemoglu *et al*. 2001). It must, however, be pointed out that this variable may operate indirectly from democracy to other independent variables, which have proven to affect growth.

More recently, Kapstein and Converse (2008) in a provocative book challenge the common wisdom that democracy is good for growth. For developing countries democracy is not the only perspective for prosperity, even if it remains the best choice in the long run. The authors document their work with data on democratic transition and reversals since 1960.

Like democracy, also the political instability variable, defined as an average of revolutions and political assassinations (civil disturbance), affects growth, but not significantly. Not surprisingly, the estimated coefficient is negative (an increase in political instability by 0.12 in the period 1965-1975 lowers the growth rate by 0.4 percentage points per year) but, because of difficulties in collecting data for many countries, the proxy used for the variable is open to criticism. Data for political rights are those collected by Gastil (1987). This data set does not refer specifically to aspects of government accountability that affect economic transactions and property rights. In the growth regressions, data from Knack and Keefer (1995) have, in fact, been widely used. Other criticisms relate to potential identification problems: if omitted variables determine institutions and income we would spuriously infer the existence of a causal relationship from biased regression coefficients.

Even though evidence should be regarded with caution, a growing literature has documented the importance of institutions for growth. If one asks whether institutions have been inserted in the theoretical framework of the NGTs, the answer is no. Acemoglu *et al.* (2005) claim that it is necessary in the future agenda of the research program of the NGTs to go beyond models that focus exclusively on proximate determinants of prosperity. As already stated we need a theory that explains why different countries have different economic and political institutions and a theoretical framework that includes them (p.463). Scholars such as Hall and Jones (1999) and Acemoglu *et al.* (2000, 2001, 2005) seem to believe firmly that the explanation of comparative growth is due to differences in institutions. It is reasonable to infer that weak institutions may have a negative impact on economic performance. As claimed by Solow (2005) the emphasis on the role of institutions opens up the possibility of connecting growth theory with the problem of economic development in which issues of institutional change are central (p.6). But the same author expresses scepticism about firm conclusions on this issue.

Other proponents of this view include La Porta *et al.* (1998), Shleifer and Vishny (1993), Sachs and Warner (1995, 1997), Knack and Keefer (1995, 1997), Perotti (1996), Acemoglu *et al.* (2000, 2001) Dollar and Kraay (2003), Rodrick, Subramanian and Trebbi (2004), Tabellini (2005).

The studies just cited take a broad view of institutional variables. Institutions are considered as a collection of laws, government policy, regulations and so on. Hall and Jones (1999), for instance, include in their econometric framework the language spoken in a country as a measure of good institutions, so that countries that inherited the English language are assumed also to inherit English institutions. Moreover, they included in their study different indexes of government, (such as laws and regulations favouring production, private ownership). The finding is that differences in these institutional variables are fundamental to capital accumulation. In particular:

- differences in institutions are associated with a large fraction of the variation of GDP per capita across countries;
- institutions strongly affect GDP per worker. A low institutional index reduces capital stock, the accumulation of skills, and TFP.

Sachs and Warner (1995) use an index of institutional quality taken as an average of sub-indexes for rule of law, bureaucratic quality, and corruption available in data in the *International Country Risk Guide*[36]. The estimated cross-country regression coefficient of the institutional quality index found (for the period 1965-1990) is about 0.32 (*t statistics*: 3.8) which is the highest value among the coefficients of all other independent variables included in the regression. The estimate is robust to the inclusion of several other variables suggested in the literature.

There are many other studies that measure through growth regressions the impact of various institutional indexes on growth rates. The work of Barro (1997) suggests higher priority in exploring the impact of these factors on growth performances.

But the main novelty in this approach comes from the seminal paper by Acemoglu, Johnson and Robinson (AJR, 2001). AJR propose a careful econometric treatment of instruments to solve the endogeneity problem of institution quality in cross-country regressions, by using "exogenous" mortality rates amongst early European settlers in the New World, as instruments. The original idea starts from the observation that the colonization by Europeans is a natural experiment to find a source of exogenous variation in institutions. European colonizers erected solid institutions and rule of law in places in which they encountered relatively few health hazards and where they settled in large numbers (the US, Canada, Australia and New Zealand), whereas in less healthy areas their interest was limited to exploiting resources. Therefore, the crucial determinant of whether Europeans chose the colonization strategy of building solid institutions or that of extractive institutions was based on their settlement, which in turn was dependent on the widely different mortality rates they encountered in these colonies. This argument has motivated the use of potential settler mortality rates as the exogenous sources of variation of institutions and as an instrument (IV) for expropriation risk in an equation determining GDP per capita across colonised countries. AJR show that colonial origin is strongly correlated with current economic performance. In places where the environment was favourable, Europeans settled in large numbers and developed laws and institutions conducive to investment and growth. The authors focus on another important aspect, besides mortality rates, to explain differences in institutions and their effect on per capita income. AJR document that in more densely settled areas, Europeans were more likely to introduce extractive institutions because of the large benefits for them of exploiting both the work force of the indigenous population and the existent system of collecting taxes and tributes.

Replication of the AJR work and reconstruction of the mortality rates as instruments for institutions has led Albouy (2008) to review the historical sources of this data and found that the mortality series used by AJR suffer from severe measurement issues. The author questions the accuracy of the sources used to construct settler mortality rates. In particular, he shows that data are too limited to be assigned to a large number of 64 countries and that the assignments themselves are not only arbitrary but artificially

[36] This Guide is a publication that provides data on the quality of political institutions with respect to the riskness of investment. The data are available for 111 countries. Knack and Keefer have constructed five measures of institutional quality: rule of law, corruption in government, quality of the bureaucracy, expropriation risk, repudiation of contract by government. These indexes can take values from 0 to 6 with the maximum value indicating the most favourable environment. Other institutional indices are: Jaggers and Marshall (2000) known as Polity IV Project and Kaufman et al (2003). Another recent set of data is from Gwartney *et al* (2002).

favour the ARJ hypothesis. By eliminating conjectured mortality rates and by applying clustering corrections, the relationship between expropriation risk and mortality rates virtually disappears. The point estimates are unstable and confidence intervals very large. Data revisions using AJR (2006) do not re-establish the empirical validity of their original hypothesis. Therefore, cross country regressions, according to the author, cannot disentangle the effects of settler mortality from that of other variables which may explain institutions and growth, such as geography, climate, culture and pre-existing development.

Also Dollar and Kraay (2003) have examined the effects of a composite indicator of institutional quality (as well as trade) on per-capita income and found that property rights and rule of law cannot be measured properly because of endogeneity problems and collinearity with other growth variables. Generally, countries are perceived to have good institutions because they are rich (Dollar and Kraay, p. 138). Results are non-robust and the positive correlation between institution quality and growth vanishes when a few countries are dropped from the sample (the US, Canada, Australia and New Zealand). In short, it is not possible to disentangle the partial effect of institutions by other variables. A comment by Pritchett (2003) on this paper argues that the weak significance of the institutional coefficient may be due to the method of IV used and to the choice of an instrument that is not appropriate to produce good information about the coefficient of interest.

Particularly attractive is the paper by Rodrick *et al.* (2004). Using a new data set collected by Kaufman *et al.* (2003), their institutional variable is a composite index of government effectiveness. Their results show the supremacy of institutions over other growth determinants, such as geography and trade openness. However, the authors point out that, although property rights are extremely important, nothing can be said about the proper form that they should take to boost growth. The recent experiences of China, which still retains a socialist legal system, and the private property rights system in Russia, offer examples that what matters for institutions is the possibility to spur incentives which are conducive to desirable economic behaviour.

Despite the fact that most works are close to the consensus that institutions cause growth, particularly acute are the criticisms that stem from a paper by Glaeser *et al.* (2004) and those attributed to proponents of the competing *geography hypothesis*. A historical example – the different patterns of growth of North and South Korea as well as the experience of Taiwan and China– has motivated Glaeser *et al.*. The authors re-examine the debate (institutional view against development view) on whether political institutions cause growth and conclude that there is no evidence on the causality link. It is education (human capital-promoting institutions) and wealth that lead to institutional evolution. They argue that: (i) the majority of institutional quality indexes are "conceptually unsuitable" to test the institution-growth nexus, (ii) the instrumental variable techniques used to control for endogeneity are conducive to flawed regressions.

Specifically, the authors criticise the AJR (2001, 2002) mortality of European settlers in the countries colonized as instruments for modern day political institutions. They argue that it is more plausible that what Europeans brought with them was their know-how and human capital rather than institutions. The suggestive conclusion of their paper is that poor countries can get out of poverty traps even if are dictators to pursue good policies (i.e. the case of South Korea which started with dictatorship) mostly those which promote human capital accumulation and consolidate pro-market mechanisms devoted to assure property rights and rule of law. Although it is equally likely that it is human capital that causes institutional improvements, their result is at odds with other papers which are unable to find such a basic role for human capital. Indeed, given measurement problems for this variable, what is unconvincing is that the importance of human capital over institutions can be simply proxied by years of schooling in the period 1960-2000. It seems to us a too short horizon to verify the relative role of institution on growth.

An analogous view on the importance of human and social capital in determining the evolution of institutions, is expressed in the paper by Djankov *et al*. (2003).

Since the term institutions means different things to different people, the specific institutions and channels through which these institutions positively influence market growth are still unsettled but the topic is gaining growing interest.

It has been argued that the emphasis should be on the role of the state and its quality. What is important is not the size of the government but its effectiveness in encouraging good habits and behaviour of its citizens, build new capacity in the public administration and create regulatory regimes that positively influence investments, innovations and competition. We plot some of the worldwide governance indicators recently updated by Kaufman *et al* (2006) (now measured yearly) against economic performance measured by the average growth rate of the countries in the international data set of Heston *et al.* (2006). The correlation is positive but simple visual correlation is not sufficient to show any causal link between the two. In Figure 2 the indicator used is Voice and Accountability that measures to what extent a country's citizens are able to participate in selecting their government, while in Figure 3 government effectiveness indicates the quality of public services and the degree of credibility of government's commitment to quality policies. It is worth noting in the inspection of the graphs that global averages of governance display no marked trends during 1996-2005. The impact is more evident if average GDP levels are considered (Figures 4 and 5).

Whatever the empirical evidence, it should be recognised that the predictions that appropriate outward looking government policy and institutional reforms may help in strengthening long run growth performances, is not only appealing to the profession and to policy-makers, but is also historically founded. However, also the view of Djankov *et al.* that institutions have only a second order effect on economic performance and that human and social capital predominate over institutions, needs further investigations.

It is worth noting the rise of some controversies in this field of research between economists that join the *institutions view* against those that join the *culture view*. Quoting Acemoglu (2006), there are two major differences which establish different roles in economic performances:

"First in the institutions view, it is the social organization of the society, which at least in theory is changeable, that is responsible for prosperity. Instead in the culture view, culture or social capital, to a first approximation, cannot be changed. Second, the institutions view emphasizes much more the importance of conflict between different groups or individuals as a determinant of social outcomes, whereas there is a more cooperative undertone to the culture view (especially in the social capital version of this view). Finally, many versions of the culture view, such as those of Max Weber or Landes, emphasize religion or other predetermined factors as crucial determinants of individual's approach to life and economic success" (p.88).

Figure 2

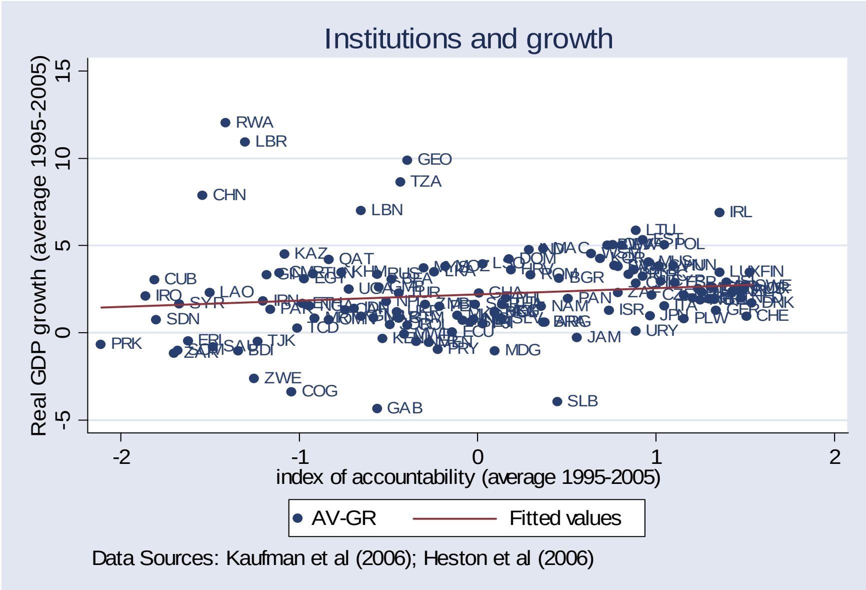


Figure 3

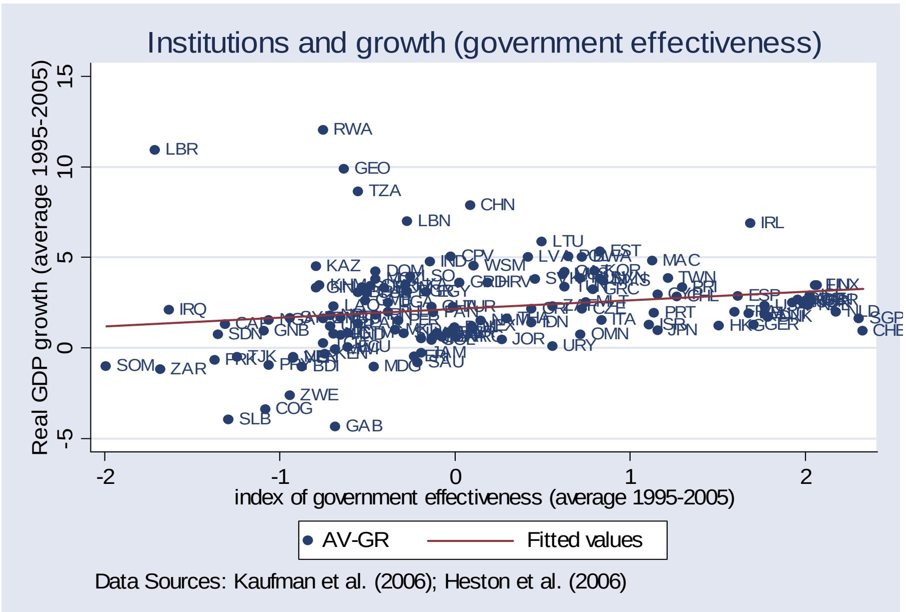


Figure. 4

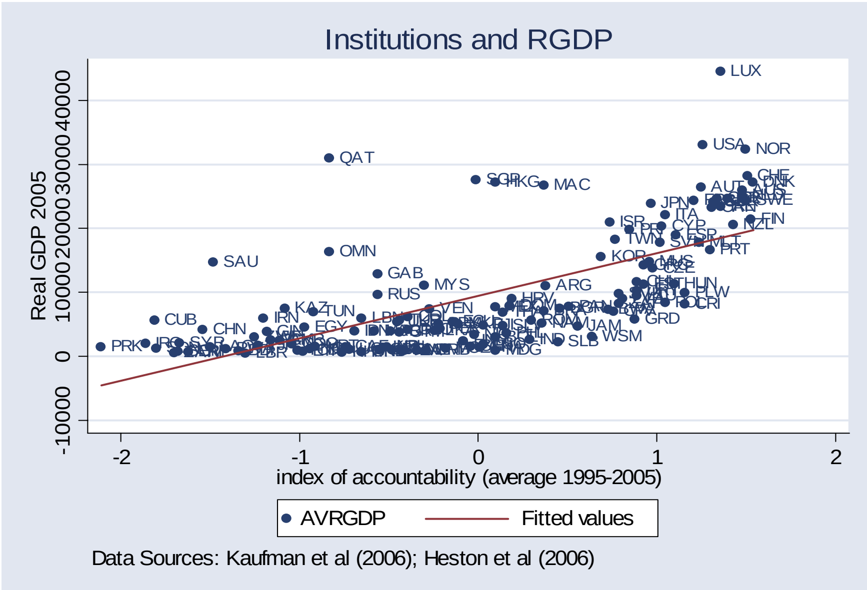
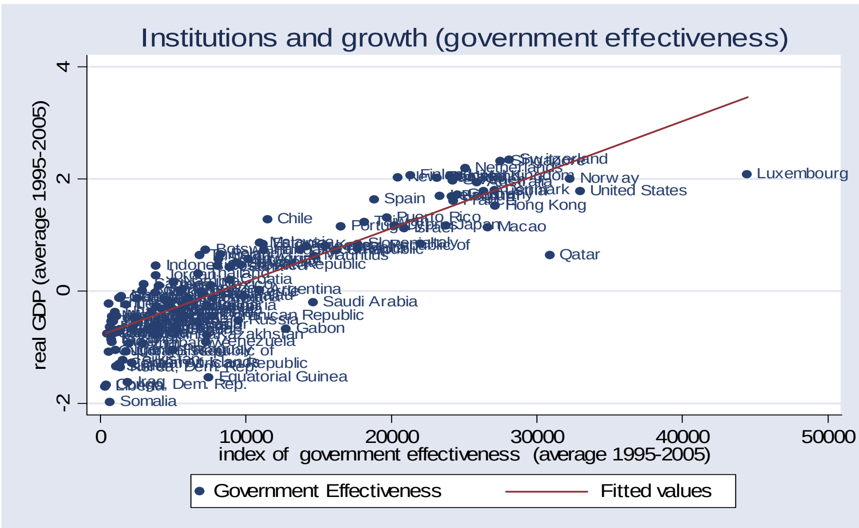


Figure 5



The role of social capital on the growth rate, therefore, pertains to the culture view and is treated briefly in the next section.

Before concluding, however, it is important to underline the criticisms from scholars that, on the contrary, emphasize the pre-eminent role of physical and geographical environment over institutions in explaining cross-country differences in the level of development. Although Acemoglu does not stress the geography view in the reported statement, it is discussed widely in Acemoglu *et al.* (2002, 2005), where the authors emphasise the primacy of institutions over geography. The empirical growth literature on the geography view is, instead, offered in a series of papers by Sachs (2001, 2003), McArthur and Sachs (2001), Gundlach (2004), Batten and Martina (2006) among others. These authors are increasingly aware of the deep link between physical geography and economic development. But, while scholars from the institutions view posit that geography affects income per-capita mainly through the channel of institutions, proponents of the geography view claim that it is climate or disease ecology that affects technology and this through institutions ultimately determine income growth. There may be also direct channels that operate through the impact on productivity, population growth, health (such as infectious disease). If geographical factors lower income, and if lower income in turn reduces technological innovation, then the effects will be amplified over time through the dynamic of endogenous growth. McArthur and Sachs (2001) show that the AJR argument that geography plays a limited role on development is due to the small sample of ex- colonies used and to the limited geographic dispersion of those countries. When they test the specification in a sample of more than 100 countries both institutional and geographical variables are found to be significantly linked to economic development.

4.3 The Role of Social Capital

An additional important piece of evidence on institutions and growth is represented by the role of social capital on country-performance. In an influential paper, Knack and Keefer (1997) present evidence that the main determinant of social capital, proxied by indicators such as TRUST and CIVIC NORMS, characterises the institutional structure of a country. These two indicators are stronger in countries with higher and more equal incomes, with institutions that restrain predatory actions and prevent government from acting arbitrarily. Based on survey data for a sample of 29 countries the finding is that a 1 standard deviation change in Trust is associated with a change in growth of more than 1 half (0.56) of a standard deviation, almost as large as the coefficient of primary education. Since countries in Western Europe form half of the sample, the two authors infer that these variables may have a larger impact in poorer economies, if backwardness is explained by lack of mutual confidence. More surprisingly, it seems that social capital measured by horizontal networks (membership in groups) is unrelated to growth. These results are in contrast with the findings in Putnam (1993), Helliwell and Putnam (1995) and Narayan and Pritchett (1997).

An interesting line of inquiry to test the importance of social capital in growth performance is pursued by Guiso *et al.* (2004) in their paper investigating the effects of social capital on financial development. By measuring social capital differences (through blood donation and electoral participation in referenda) in Northern and Southern Italy, they find that social capital is more important in areas where there is a weakness of both legal enforcement and educated people. In developed areas, households make more use of formal credit rather than take advantage of membership in a certain community. According to their measures, social capital is very low in the South and this could partly explain also a weak impact of their unusual[37] measure of financial development on economic performance.

We cannot conclude on the role of social capital without mentioning the works by Durlauf (2002), Durlauf and Fafchamps (2005). The latter is a survey of the majority of researches on the issue in which the authors highlight a number of conceptual and

[37] The access by households to formal and informal credit is based on data drawn from the Survey of Household Income and Wealth of the Bank of Italy.

statistical problems that flaws the empirical results of this literature. They argue that norms, trust and expectations, usually obtained from survey data, are not suitable for a rigorous empirical analysis. Moreover, especially at aggregate level, this literature suffers to a larger extent from endogeneity and identification problems. In the first case social capital is a choice variable and in the second case it is hard to distinguish social capital from the presence of other group effects such as information spillovers or other common factors such as legal or political institutions. The authors believe that further exploration of this issue should come from micro-level studies, provided that typical econometric problems (identification and endogeneity) can be addressed adequately. We think that the recent work by Tabellini (2005) goes in this direction and also in the direction of integrating culture and institutions as joint determinants of regional economic growth. The author, by collecting historical data on variables such as trust, respect, and confidence in individuals of European regions, identifies some mechanisms of development and their dependence on historical institutions as well as their propagation over time. An implication of this study is that there is no primacy of formal institutions over culture even if this last determinant is still a “black box” and more work is necessary to understand how individual beliefs and social norms are formed and transmitted and how they interact with the economic and institutional environment. In fact, as pointed out by the author, the same formal institutions can operate differently in various cultural environments. In terms of the length of investigations the judicial system works differently in the South and the North of Italy even though the two parts of the country have shared the same legal system since the unification of the country over 150 years ago.

As discussed at length in this section, even if institutional measures do not fit well with the empirical framework of growth, certainly most of them matter for growth and a research effort in this direction should produce major benefits in our understanding of the growth mechanisms.

5 Conclusions

In this paper we have discussed the NGTs and their empirical evidence based on the role of dynamic internal forces as sources of sustained economic growth. Theoretically, there exist two broad classes of models with different predictions in which diverse variables may contribute to long run growth. One group continues to consider capital accumulation as the driving force behind economic growth. The alternative group assigns a prominent role to technological change, which is made endogenous through substantial investment in R&D or is driven by international trade. Finally, even if not yet inserted in a strictly theoretical framework, there is the group of works that assign to economic institutions a fundamental role for achieving economic prosperity.

The theoretical structures of these models are known and have gained much ground in the last two decades in becoming part of mainstream growth economics. However, they differ widely both in their positive and normative implications and it is significant to distinguish among them empirically.

Through their empirical studies, scholars have evaluated the NGTs both directly and indirectly, but there is still a gap between the complexity of mechanisms stressed by formal theoretical models and the indiscriminate use of explanatory variables included in growth regressions. This has produced a number of empirical models that greatly exceed the theoretical ones. We have discussed at length this important issue and reviewed the evidence on the sources of economic growth, the ones considered theoretically founded as well as those for which model's guidance is less obvious.

The *first* piece of evidence was obtained by looking at the convergence issue that has been the main empirical topic in the first wave of the growth debate. Even if subsequent analyses on cross sectional growth have adjusted for the predicted pattern of the conventional model (*conditional convergence*), it must be recognised that convergence is not the central issue for assessing the validity of the NGTs. However, if we interpret convergence as a way of asking whether initial conditions are robustly correlated with growth, we should admit that initial GDP is one of the few growth candidates that pass different tests of robustness. But the convergence issue with its implications is crucial also to shed light on the controversy of ideas gap *versus* factor accumulation.

In fact, the *second* piece of evidence is the possible explanation of cross–country differences in output levels and growth. Many scholars using a variety of techniques have reached the consensus that human and physical capital cannot explain all the divergence we observe. Even if there is compelling evidence that factors-only models increase productivity, the majority of the observed cross-country differences in output levels and growth rates are most likely due to differences in TFP as well as the quality of economic and political institutions. In this work we have re-examined critically the tests of robustness on growth variables drawing mainly, but not exclusively, on the latest researches. Although these studies are much less contested than the previous ones, the econometric results are still the object of many criticisms. The existence of an impressive number of empirical studies has not been sufficient to settle all the debates on the determinants of growth. However new problems are emerging in–growth empirics, such as how to cope with model uncertainty, the adequacy and availability of data to test competing endogenous growth theories, and how to face the problem of non-linearity in growth econometrics.

Apart from these issues, if we ask what emerges from the empirical evidence concerning the relative role of growth factors, three facts stand out that require a major research effort.

First, the weakest results are related to models based on human capital. The empirical analysis on the role of this factor has not produced a strong and robust correlation with output growth, as expected. Part of this result, undoubtedly, comes from measurement issues. It is known that official country statistical agencies do not include the value of human capital in their national statistic accounts, and measures of this factor are available only for a small number of advanced countries. Moreover, by focusing just on education, as a measure of human capital, recent studies fail to capture other levels of knowledge embodied in individuals, which can contribute to an extended and more robust estimate of the human capital stock. All the discussion on this issue in our review shows that the impact of human capital has been understated by previous work but gradual advancements in the specification of human capital and in the quality of data seem to be very promising.

Second, more interesting results concern the role of spillovers, which have been shown to be prevalent at firm and industry levels, but much rests to be done to measure the consistency of the phenomenon at the international level. Also the mechanisms by which R&D generates spillovers may be much larger than those already captured by existing empirical studies. However, the majority of prevailing studies lead to the conclusion that both domestic and foreign spillovers have significant positive effects in promoting productivity growth. Even if strong empirical evidence from human capital and R&D is problematic to obtain, this does not mean that the models that highlight spillover benefits from R&D and human capital do not matter for growth. There are promising signs that their influence on growth is substantial as predicted by the NGTs but measurement problems and the availability of quality data still prevent a correct analysis of these crucial factors.

Third, more robust results are obtained for traditional factors like investment, degree of openness as well as other factors never considered in the old theories, namely various aspects of law enforcement and property rights. The approach is basically descriptive and narrative and also the empirical evidence has been questioned in the last years. The problem with most of these variables is that they are not strictly model-determined and a theoretical effort is necessary along this path. What we expect is that NGTs incorporate institutions, geography and socio-cultural variables together with economic variables in their theoretical framework.

We reported empirical studies that confronted with data the main theoretical predictions of the NGTs and documented that while some results are well established, other important implications need further tests. However, since the statistical tools and methods of analysis of the empirics of growth are continuously improving, we feel confident that further advancements on all the fronts highlighted in this review may be substantial and may help the NGTs to collect stronger support in the near future.

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