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Innovation and institutions: Examining the black box

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INNOVATION AND INSTITUTIONS:

EXAMINING THE BLACK BOX

by

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DEDICATION

This dissertation is dedicated to my wife, Analia Maria, my daughter Heloisa Gabriela, my mother Aparecida Palma, my father Sebastião Leonardo and to my sister Creuza Maria. Creuza was my first grade teacher (in a small rural village in Brazil) and guided me through my first steps in the learning process.

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ABSTRACT

INNOVATION AND INSTITUTIONS:

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This dissertation contributes to the literature by investigating the links between institutions and innovation from both a theoretical and an empirical standpoint. Specifically, this dissertation (i) develops a theoretical growth model that explicitly accounts for the influences of institutions on technical innovation and output production; (ii) specifies an empirical model suitable to examine the affect of institutions on technical innovation based on a theoretical model; and (iii) tests if different measures of institutions (i.e., Control of Corruption, Rule of Law, Regulatory Quality and Expropriation Risk) have differentiated impacts on innovation.

A major prediction of the theoretical model is that better institutional arrangements boost innovation and thus economic growth. The lack of right institutions will retard or prevent the utilization of newly invented inputs in the productive process, leading to relatively lower levels of output. Therefore, controlling for all other determinants of income, countries or regions that experience institutional constraints preventing the adoption of newly invented technologies will be expected to lag behind in terms of growth and levels of output per capita. Additionally, the

theoretical model shows that this gap does not vanish over time. The model also predicts that in the steady state the stock of human capital should not be associated with the growth rate of output, but rather that the growth rate of human capital should be associated with the growth rate of output.

The empirical analysis uses cross-country data and instrumental variables in order to examine the influences of institutions on technical innovation. The results support the argument that institutions explain much of the variation on patent production across countries and this finding is consistent across countries that are both on and off the technological frontier. The empirical results also provide evidence that control of corruption, market-friendly policies, protection of private propriety and a more effective judiciary system have growth effects on income because institutional quality affects an economy's rate of innovation. Ultimately, innovation is the engine of economic growth. This study also finds evidence that geography, *per se,* does not explain innovation across countries. Geography affects innovation, but only through institutions.

INTRODUCTION

A fundamental challenge for the economics profession lies in explaining the mechanisms of economic growth. There is little doubt that significant progress has been made during the last five decades in growth modeling and economists' understanding of the mechanisms of economic growth. It also appears that economists have reached a consensus on the notion that long-run economic growth is primarily a product of technical innovation. However, there is still much to learn about the factors that ultimately determine a country's rate of innovation. This study endeavors to shed light on the determinants of innovation by examining the links between innovation and institutional arrangements from both a theoretical and an empirical standpoint.

Chapter 1 reviews both the theoretical and empirical literature on institutions and economic performance and discusses the challenges of empirical examinations of the institutional influences on economic performance as well as the challenges of modeling institutions in a formal growth framework. A major finding from this review is that it has proven difficult to provide conclusive empirical evidence supporting the idea that institutions matter for economic growth. Although several studies have attempted to demonstrate that institutions affect transitional growth rates of output per capita (e.g. Kormendi and Meguire, 1985; Barro, 1991 and 1996; Mauro, 1995; Dollar and Kraay, 2003), there is still no empirical evidence that supports a finding that institutions determine the steady state growth rate of per capita GDP. The review of the literature also shows that evaluations of the impacts of institutions on technical innovation have generally been disregarded in both empirical investigations of cross-country economic performance and formalized growth models. The survey of the literature also establishes the *ad hoc* nature of the econometric specification found in studies that evaluate the links between institutions and economic performance. More specifically, this review identifies the following important gaps in the institutional growth literature: i) the econometric specification used in institutions-related growth studies is not entirely supported by formal theoretical models; ii) the impact of institutions on technical innovation is overlooked in empirical investigations of cross-country economic performance; iii) there is no empirical evidence supporting the claim that institutions affect an economy's steady state growth rate and iv) economists are still struggling to construct a methodology that incorporates institutions in formal growth models. Thus, an immediate and important task for economists agenda lies in addressing the effects of institutions on technical innovation. One could put these gaps together and argue that the relationship between institutions and economic performance has been treated as a black box. Ultimately, it is what is inside that black box that determines long-run economic performance.

This dissertation endeavors to contribute to the literature by investigating this black box. The study's primary goal is the examination of the links between institutions and innovation from both a theoretical and an empirical standpoint. Specifically, this dissertation (i) develops a theoretical growth model that explicitly accounts for the influences of institutions on technical innovation and output production; (ii) specifies an empirical model suitable to examine the affect of institutions on technical innovation based on a theoretical model; and (iii) tests if different measures of institutions (i.e., Control of Corruption, Rule of Law, Regulatory Quality and Expropriation Risk) have differentiated impacts on innovation.

This study allows us to evaluate the interactions between institutions and innovation by incorporating institutions into a formal growth framework. The model is used to compare growth outcomes under scenarios with institutional constraints with the outcomes of standard growth models. In addition, the model may potentially contribute to the debate on an open question in the growth literature: do institutions have a *growth* or *level* effect on income?

The theoretical model is built upon the endogenous growth literature, which emphasizes that innovation is a key mechanism in the generation of long-run economic growth. The model economy hypothesizes that poor institutions[1] may inhibit the use of new technologies in the productive process as well as slow down the production of new and improved technologies. A major prediction of the theoretical model is that better institutional arrangements will boost innovation and thus steady state economic growth. For instance, the lack of proper institutions will retard or prevent the utilization of newly invented inputs in the productive process, leading to relatively lower levels of output. Therefore, controlling for all other determinants of income, countries or regions that experience institutional constraints preventing the adoption of newly invented technologies will be expected to lag behind in terms of growth and levels of output per capita. The model shows that this gap does not vanish over time. In addition, the model also predicts that in the steady state the stock of human capital should not be considered a determinant of the

[1] In this study, "better institutional arrangement" or "better institutions" means that a country has market-friendly policies (e.g. no price controls and no excessive burden imposed by regulations), controls for corruption, a judiciary system that is effective and predictable and a legal system that enforces contracts and protects property rights.

growth rate of output, rather that the *growth* rate of human capital should be considered a determinant of the *growth* rate of output. This result contrasts with that found in Romer (1990) but conforms to Lucas (1988) and Jones (1995).

The empirical analysis conducted in this inquiry follows a growing branch of growth literature - starting with the influential papers of Kormendi and Meguire (1985) and Barro (1991) - that utilizes subjective measures of institutions, such as enforcement of property rights, corruption, rule of law, regulatory quality and civil liberty, to evaluate the effects of institutional arrangements on economic performance. The approach used here adds to the literature by specifying a non ad hoc empirical model that relates institutions to innovation that is developed from the theoretical model constructed in chapter 2. This study also takes a more focused approach by examining the affects of different kinds of institutions (i.e., control of corruption, regulatory quality, rule of law and risk of expropriation) on patent production (innovation). This approach may shed light on two open questions in the growth literature. First, do institutions have a *growth* effect? Given that innovation is widely accepted as the engine of economic growth, the empirical model developed in this study may help to answer this question by showing that institutional quality does or does not affect an economy's rate of innovation. Second, the empirical analysis has potential to contribute to appraise the following question: what types of institutional arrangements maximize growth and under what conditions? For example, are the institutions that promote growth the same for countries that are on the technological frontier as for those countries that are off the frontier? In other words, are the institutional arrangements that promote technological innovation similar or different from those that promote technological transfer?

Chapter 3 presents the empirical analysis - which uses cross-country data and instrumental variables - of the influences of institutions on technical innovation. The results support the claim that institutions explain much of the variation on patent production across-countries. The positive influence of *good* institutions on innovation is consistent across countries both on and off the technological frontier. In addition, the results provide evidence that control of corruption, market-friendly policies, protection of private propriety and a more effective judiciary system have growth effects on income because institutional quality affects an economy's rate of innovation. Ultimately, innovation is the engine of economic growth. This study also finds evidence that geography, *per se,* does not explain innovation across countries.

The rest of this study is organized as follows: Chapter 1 reviews both the theoretical and empirical literature on the connections between institutions and economic performance. It also discusses the limitations inherent in studies that attempt to examine empirically the association between innovation and institutions as well as the challenges involving modeling institutions within a formal growth framework. Chapter 2 develops a formal model that examines how institutions affect technical innovation and economic growth. Comparative statics are utilized to evaluate the impacts on growth and levels of output from changes in human capital and also from the intensity of the institutional constraints preventing the adoption of new technologies. Chapter 3 presents a workable empirical model for evaluating the impacts of institutions on innovation and also reports the results of the regression analysis. Chapter 4 is a brief summary of this study.

CHAPTER 1

A LITERATURE REVIEW ON INSTITUTIONS AND ECONOMIC GROWTH: RECENT DEVELOPMENT AND PROSPECTS

1.1 Introduction

A major challenge in assessing empirically the relationship between institutions and economic performance lies in the measurement of institutions. Until recently, it was not possible to evaluate the impact of institutions on economic performance due to the lack of a reliable dataset. Cross-country datasets created by Gastil (1979), the International Country Risk Guide (ICRG), Transparency International (TI), Business Environmental Risk Intelligence (BERI) and Kaufmann, Kraay and Mastruzzi (2003) helped to remedy this lack. These datasets provide *subjective* measures of the quality of institutions at the country level. They greatly contributed to the development of a new branch of empirical research into the association between institutions and economic growth.

Empirical research in this subject has been fruitful. It has been shown, for instance, that civil liberties (Kormendi and Meguire, 1985; Knack and Keefer, 1995), property rights (Knack and Keefer, 1995), democracy (Barro, 1991) and corruption (Mauro, 1995) affect the growth rate of per capita income. In addition, Hall and Jones (1999), Acemoglu *et al.* (2001 and 2004) and McArthur and Sachs (2001) show that a risk of expropriation index and a constraint on executive index also affect the level of output per capita. However, robustness investigations have shown that these findings are dependent on the specification of the econometric model, choice of explanatory variables and instruments used as proxies for institutions (see Levine and Renelt, 1992; McArthur and Sachs, 2001; Dollar and Kraay, 2003).

From a theoretical standpoint, only a few studies have incorporated institutions into the formal *mainstream* framework currently used to evaluate economic growth (e.g. Huang and Xu,1999; and Gradstein, 2004). According to Sala-I-Martin (2002), economists are still only scratching the surface of the linkages between institutions and economic factors that power growth.

The main goal of this chapter is to review both the theoretical and empirical literature on institutions and economic performance. This chapter also discusses the limitations inherent in studies that attempt to examine empirically the association between innovation and institutions as well as the challenges involved with modeling institutions in a formal growth framework.

The rest of the chapter is organized as follows. Section 2 highlights the definition of *institutions* and presents the *workable* quantifications of institutions currently available. Section 3 discusses the methodology and key findings from empirical studies that evaluate the links between institutions and growth rates of per capita output. Section 4 focuses on the impact of institutions on levels of output per capita. Section 5 summarizes the key lessons from the empirics of institutions. Section 6 presents a survey of the theoretical models that link institutions and economic growth. Section 7 summarizes the chapter's findings.

1.2 Quantifying Institutions

The Merriam-Webster dictionary defines an institution as a "significant and persistent element (as a practice, a relationship, an organization) in the life of a culture that centers on a fundamental human need, activity, or value, occupies an enduring and cardinal position within a society and is usually maintained and stabilized through social regulatory agencies" (Merrian-Webster, 1993:1171). In line with this definition, Engerman and Sokoloff (1997) argue that the concept of institutions should be "interpreted broadly to encompass not only formal political and legal structures but culture as well" (p. 261). However, these definitions are very general and provide little aid in building a workable framework for the measurement of institutional arrangements. Sala-I-Martin (2002) suggests defining institutions as a set of elements related to the ways that a society and its economy works in modern capitalist countries. This study follows Sala-I-Martin (2002) and the word *institutions* (or institutional arrangements or institutional capital) is utilized to refer to a hypothetical aggregate variable that accounts for the following elements:

i) *Law enforcement*: enforcement of property rights, existence of a working legal system and the independence of the judiciary system;

ii) *Political institutions*: democracy, political stability, public representatives chosen by vote and the existence of class organizations;

iii) *Market structure*: economic freedom, anti-trust regulations, openness to international trade, modern bank system, working credit system and organized stock and bond markets;

iv) *Transparency of the Public Administration*: red tape, corruption and bureaucracy;

v) *Sociocultural context:* religious practices, entrepreneurial spirit and social ties.

Empirical analyses on institutions have been conducted using *objective* and *subjective* measures of institutional quality. Objective measures quantify institutional aspects that are observable cross-country, such as the number of political assassinations, number of revolutions and coups and policy volatility. For instance, Barro (1991)'s study of the determinants of economic growth utilizes the number of revolutions between 1960 and 1985 and the number of political assassinations per year as right hand explanatory variables that control for institutional quality. The key argument for including such variables in growth-related regressions is that "property rights will be better guaranteed and transactions cost will be lower ... the more democratic the regime, the higher government stability, the lower political violence and the lower the policy volatility." (Moers, 1999:5). A major drawback in using number of political assassinations, number of revolutions and coups and policy volatility as measures of institutional arrangements is that such variables are measures of the *output* of institutions, rather than direct measures of institutional arrangements.

The subjective measures of institutions are mainly assembled by private companies (e.g. ICRG, BERI and the TI) and based on an assessment of *perception*. These companies conduct perception surveys of "economic agents who make growth-relevant decisions" (Moers, 1999:8) about factors such as corruption, contract enforcement, protection of property rights, political instability, etc. These perception assessments are compiled from surveys that ask both resident business people and non-resident *experts* for their appraisals of a specific institutional aspect. For instance, the Transparency International computes the Corruption Perceptions Index (CPI) using data from three groups of sources. One group of sources assembles data from the perceptions of non-resident experts, who reside in developed countries (Western Europe and North America), with regard to corruption in foreign countries. A second group of sources assembles data from the perceptions of non-residents experts, who reside in less developed countries, with regard to corruption in foreign countries. The perception's assessments from these two groups are supposed to not be vulnerable to a "home-country bias", which could cause cross-country comparison problems (Lambsdorff, 2004). However, they may reflect the *analyst's* perspectives about the factors been analyzed and so they may be biased toward analysts' beliefs (Lambsdorff, 2004; Glaeser *et al.,* 2004).

The third group of sources assembles data from the perception of residents (mostly elite businesspeople and businesspeople) with regard to corruption in their home country. This assessment of corruption may suffer from measurement errors because "local economic agents may not be able to compare institutions across countries" (Moers, 1999:8). In addition, all three groups use different questionnaires to assess the perception of corruption[2]. However, according to Lambsdorff (2004), the assessment of corruption made by these three groups is highly correlated, which "ameliorate fears that any aforementioned biases are important to the results" (Lambsdorff, 2004:6).

The concerns about the assessment of perception discussed above also apply to most of the subjective measures of institutions. In addition, Glaeser *et al.* (2004) criticize the use of subjective institutional measures in growth related empirical analysis, arguing that such variables "measure *outcomes*, not some

[2] For instance, one of the sources of the third group asks the following question: "thinking about officials ... It is common for firms in my line of business to have to pay some irregular "additional payments" to get things done". (Always, Mostly, Frequently, Sometimes, Seldom, Never, Don't know)" and "Using this scale (No Obstacle=1 ; Minor Obstacle= 2 ; Moderate Obstacle=3 ; Major Obstacle=4 ; Don't know/no answer=5)". On the other hand, a source of the first group asks if the "rate the severity of overall corruption within the state on the following scale": Low; Low/Modest; Modest; Modest/Severe; Severe." (Lambsdorff, 2004:4).

permanent characteristics" (p. 8) of a society's institutional arrangements. Conversely, it has been argued that these institutional measures provide relevant information about growth-promoting institutional arrangements and that the mere existence of organizations such as the ICRG and BERI and the considerable price that entrepreneurs are willing to pay for this kind of data provide evidence on the accuracy of such institutional measures (Mauro, 1995; Moers, 1999).

Table A.1 provides a detailed list of workable variables that measure cross-country institutional quality. Notice that specific elements of institutions have been quantified by different organizations. Therefore, one must choose particular indicators from the large set of institutional measures when conducting empirical analysis. Of course, a variable collected from different sources may produce conflicting results, which lessens the appeal for using such measures. To minimize this problem, Kaufmann *et al.* (2003) developed a dataset with six aggregate measures of institutions that combines data from more than a hundred variables and data sources from 18 different organizations.

The next sections discuss the methodology used to conduct empirics on institutions and economic performance and emphasize the key findings from previous literature.

1.3 The Empirics on Institutions and the Growth Rate of Output Per Capita

A vast literature uses cross-country data to evaluate the impact of institutions and other factors suggested by the theory, on growth rates of per capita income. This literature greatly benefited from the workable empirical framework developed by Kormendi and Meguire (1985) and Barro and Sala-I-Martin (1991), which is constructed around a Solovian-type model. Consider the well-know solution of the Ramsey-Cass-Koopmans model[3]:

$$\dot{k} = f(k) - c - (x + n + \delta)k \tag{1.1}$$

$$\frac{\dot{c}}{c} = \frac{1}{\theta}(f'(k) - \delta - \rho - \theta x) \tag{1.2}$$

where K denotes physical capital, C consumption, Y output, x is the growth rate of technology, n is the growth rate of population, δ=depreciation, ρ is the intertemporal elasticity of substitution, f is a production function and f' denotes the marginal product of capital. Lowercase case variables denote 'per effective labor' measures, i.e., k=K/AL, c=C/AL, y=Y/AL. Equation 1.1 shows how capital is accumulated in the economy and equation 1.2 - the famous Euler equation – shows the time path of consumption. Consider that output is produced using a CRS Cobb-Douglas production function given by $Y = K^{\alpha}(AL)^{1-\alpha}$. This equation can be easily rewritten in terms of "effective labor" units as $y = f(k) = k^{\alpha}$.[4] Combining the production function and equations 1.1 and 1.2 and using log-differentiation allows one to write the system of equations as follows:

$$\frac{d[\log k]}{dt} = e^{-(1-\alpha)\log(k)} - e^{-\log(c/k)} - (x + n + \delta) \tag{1.3}$$

$$\frac{d[\log(c)}{dt} = \frac{1}{\theta}\left[\alpha e^{-(1-\alpha)\log(k)} - \delta - \rho - \theta x\right] \tag{1.4}$$

---

[3] This derivation is based on Barro and Sala-I-Martin (1995).

[4] Although labor does not explicitly appear in this equation, from a firm's perspective, labor is still a choice variable. Technology (A) is assumed to be exogenous.

Using the fact that at the steady state c and k are constant, that is, $\frac{d[\log k]}{dt} = \frac{d[\log c]}{dt} = 0$, taking a first-order Taylor expansion around the steady state and writing the system in matrix form gives:

$$\begin{bmatrix} \frac{d(\log(k)}{dt} \\ \frac{d(\log(c)}{dt} \end{bmatrix} = \begin{bmatrix} \rho - n - (1-\theta)x & x + n + \delta - \frac{(\rho + \theta x + \delta)}{\alpha} \\ \frac{-(1-\alpha)((\rho + \theta x + \delta)}{\theta} & 0 \end{bmatrix} \begin{bmatrix} \log(k/k^*) \\ \log(c/c^*) \end{bmatrix} \tag{1.5}$$

It can be shown that the system's two eigenvalues have opposite signs, which implies saddle-path stability. The solution for k takes the form:

$$\log(k) = \log(k^*) + \lambda_1 e^{\varepsilon_1 t} + \lambda_2 e^{\varepsilon_2 t} \tag{1.6}$$

where λ_1 and λ_2 are arbitrary constants, $\varepsilon_1>0$ and $\varepsilon_2<0$ are the roots of the system and "*" denotes steady-state values. The system will converge to the steady state only if $\lambda_1=0$. Therefore, the growth path of the economy is stationary only if we assume $\lambda_1=0$. Imposing this condition and using $k(0)=k_0$ produces:

$$\lambda_2 = \log(k_0) - \log(k^*) \tag{1.7}$$

Substituting (1.7) into (1.6) and using the fact that $\varepsilon_2 = -\beta$ [5] generates

$$\log(k) = (1 - e^{-\beta t})\log(k^*) + e^{-\beta t}\log(k_0)$$

Since $\log(y) = \alpha \log(k)$, the time path for log(y) is given by:

$$\log(y) = (1 - e^{-\beta t})\log(y^*) + e^{-\beta t}\log(y_0) \tag{1.8}$$

---

[5] $\beta = 0.5\left\{\xi^2 + 4\left(\frac{1-\alpha}{\theta}\right)(\rho + \delta + \theta x)\left[\frac{\rho + \delta + \theta x}{\alpha} - (n + x + \delta)\right]\right\}^{1/2} - 0.5\xi$

where $\xi = \rho - n(1-\theta)x > 0$. With a constant savings rate, $\beta = -(1-\alpha)(x+n+\delta)$.

Therefore, log(y) is a weighted average of the initial and steady state values of income. Moreover, the weight on the initial value declines exponentially at the rate β. Equation 1.8 implies that the average growth of per capita output $\hat{y}$, over an interval from an initial time 0 to time T, augmented by an error term is:

$$\frac{\log(\hat{y}(T)/\hat{y}(0))}{T} = x + \frac{(1-e^{-\beta t})}{T}\log[y^*/y(0)] + u_T$$

Most studies on economic growth write this equation in vector form:

$$g = \beta\log(y_0) + X\eta + \varepsilon \qquad (1.9)$$

where g is the growth rate of per capita income, y_0 is initial per capita income, X is a matrix of determinants of steady-state per capita income, β measures the speed of convergence, η is a vector of parameters and ε is a random error term.

Moving from this theoretical equation to a workable empirical model requires strong assumptions. First, the choice of variables that proxy for differences in steady state positions is in general *ad hoc*. Table B.1 shows that initial income, investment and schooling are present in almost all growth regressions in the literature. However, it also shows that the conditioning set of variables change a lot across studies. Levine and Renelt (1992) demonstrate that a regression's results may change significantly due to "small alterations" in the set of explanatory variables. Second, other than for convenience, there is no rationality for using initial values of the explanatory variables (e.g. education and investment) to proxy steady state income; y*. If the contemporaneous performance of the explanatory variables matters for current growth, the use of initial values will bias the coefficient estimates. Third, variables that proxy for differences in steady state may be endogenous or correlated with the error term[6]. Fourth, without proper controls, spatial variation and shocks that benefit/hurt specific countries/regions will bias the parameter estimates (Barro and Sala-I-Martin, 1995). In addition, this concept of convergence has been thought to be basically a "regression toward the mean" and may suffer from Galton's fallacy problem (Barro and Sala-I-Martin, 1995; Bliss, 1999; Cannon and Duck, 2000, Bliss, 2000).[7]

Despite these shortcomings, equation 1.9 motivates most of the empirical analyses that link institutions to growth of GDP per capita. Particularly, institutional measures are added in the regression as part of the set of explanatory variables that proxy for steady state output per capita. Moreover, standard practice suggests using 'averages' of the institutional measures over the sample available. The 'averages' are intended to capture the permanent characteristics of institutions. However, this procedure may hide directional change effects that may take place during the time period under examination. Table B.1 summarizes the most prominent analyses that utilize equation 1.9 to assess empirically the links between institutions and growth of GDP per capita. It shows that several alternative measures of institutions have been used in empirical analysis and the results concerning institutions and economic performance vary significantly across studies.

[6] It is standard in the literature to use lagged values of the explanatory variables to address endogeneity.

[7] Galton evaluated the height of fathers against the height of their sons. The results of his analysis supported that i) sons of tall fathers tended to be tall, but on average not as tall as their fathers; ii) sons of short fathers tended to be short, but on average not as short as their fathers. Based on these findings, he concluded that the population height was regressing toward the mean. "The reason for Galton's observation lines in basic genetics. A tall father may not have married an equally exceptionally tall wife. And even if the father has married a tall wife, not all tallness genes of the parents will express themselves in their offspring because some will be recessive.... Galton's fallacy was to wrongly infer from these valid observations that a general contraction of the spread of heights in the population was taking places; a reduction in the variance of heights." (Bliss, 1999:5).

The influential paper written by Kormendi and Meguire (1985) is the first study that includes the quality of institutions in growth regressions. The authors utilize a dichotomous transformation of the Civil Liberty Index[8], developed by Gastil (1979), as a measure of institutions. This transformation was supposed to purge spurious cardinality and account for measurement errors in the index. The regression analysis uses data from 47 countries and shows that the Civil Liberty Index is not significantly correlated with growth of per capita GDP, but it alone explains about 45% of the variation in investment. In other words, institutions seem to not affect growth rates of per capita output, but do affect investment. Knack and Keefer (1995) argue that these findings may not be robust because institutional quality is likely endogenously determined in the specification.

Barro (1991)'s prominent study shows that the frequency of coups and revolutions and number of assassinations per capita are inversely correlated with growth of GDP per capita and investment. This study supports the viewpoint that better institutional arrangements contribute to increased capital accumulation and boost transitional economic growth. However, this study's finding does not support the view that institutions affect the steady-state growth of output per capita.

Levine and Renelt (1992) test if the results generally found in growth regressions, e.g. Kormendi and Meguire (1985) and Barro (1991), are robust to changes in the set of explanatory variables. They conclude that only the investment share of gross product and initial level of output are correlated with growth rates of per capita income. Variables such as the Index of Civil Liberties, frequency of coups and revolutions and regional dummies are not robust, that is, they turn insignificant

[8] This index ranges from 1 (most free) to 7 (least free). It takes into account subjective measures of freedom of expression and conscience, independence of the judiciary, absence of political prisoners and the like.

as other variables are included (excluded) in (from) the regression. This finding suggests that either institutions do not matter for growth or that poor model specification or unreliable measures of institutions have been used in these empirical studies to appraise the effect of institutions on economic growth[9].

Knack and Keefer (1995) introduces two new measures of institutions into their growth regression and show that the ICRG and BERI indexes are positively correlated with both growth of GDP per capita and investment[10]. The authors also find that the frequency of coups and revolutions and assassinations per capita are inversely correlated with growth of GDP per capita and investment. This study contradicts Kormendi and Meguire (1985) and provides evidence that the Index of Civil Liberties is not correlated with investment. They believe that simultaneity between investment and the index of Civil Liberties and small sample size explain the discrepancies in the results. Mauro (1995)'s main contribution is to show that corruption discourages investment and negatively affects the growth of GDP per capita. Controlling for corruption, Mauro (1995) finds that the frequency of coups and revolutions neither affects growth rates of GDP per capita nor investment.

Knack and Keefer (1997) revisit cross-country growth regressions using a different set of institutional variables. They find that the civil liberty index, political freedom index and Putnam's measure of social capital do not explain growth. The

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[9] Sala-I-Martin (1997) argues that the procedure used by Levine and Renelt (1992) to test the significance of the variables "is too strong for any variable to pass it" (Sala-I-Martin, 1997:79). Sala-I-Martin (1997) runs "two million regressions" and concludes that the following proxies for institutions are significant in growth regressions: rule of law, political rights, civil liberties, number of revolutions and military coups and war dummy.

[10] The International Country Risk Guide (ICRG) index is an average of the following indicators: quality of bureaucracy, corruption in government, rule of law, expropriation risk and repudiation of contracts by government. The Business Environment Risk Intelligence (BERI) index is an average of four indicators: bureaucratic delays, nationalization potential, contract enforceability and infrastructure quality.

coefficients on Trust and Civic Cooperation are positive, but only marginally significant, which suggests that they may not be robust. It is worth noticing that Knack and Keefer (1997) and Mauro (1995) use ethnolinguistic fragmentation as an instrument for institutions. However, Easterly and Levine (1997) and Acemoglu *et al.* (2000 and 2004) argue that ethnolinguistic fragmentation is not a good instrument for institutions because it may be endogenous. Ethnolinguistic heterogeneity may create political instability and have a direct effect on economic performance. Therefore, the findings from studies that use ethnolinguistic fragmentation as an identifier for institutions may be plagued by endogeneity problems.

More recent articles provide mixed evidence about the correlation between institutions and growth of per capita GDP. For instance, Esfahani and Ramirez (2003) find that democracy is negatively related with the growth of GDP per capita, while Oliva and Rivera-Batiz (2002) find a positive relationship but Levine and Renelt (1992) find no robust correlation between these variables. Hsiao and Shen (2003) find that corruption does not affect growth of per capita output, which contradicts Mauro (1995).

This brief review of the literature shows that "nearly all empirical studies of growth include the initial levels of income as a conditioning variable" (Bosworth and Collins, 2003:117) and are constructed around a Solovian-type theoretical model. Regardless these similarities, it also shows that differences in sample size, choice of the time period and differences in the set of explanatory variables have generated inconclusive predictions about the effect of institutions on growth of GDP per capita. Specifically, empirical studies on institutions and growth of per capita GDP provide only weak evidence to support the argument that institutions affect the growth rate of GDP per capita. This question remains open for further empirical investigation.

Moreover, there is an additional fundamental problem in the previous studies. Kormendi and Meguire (1985) regression-type (i.e., equation 1.9) does not provide evidence that institutions affect long-run growth rates of the economy. The dependent variable (growth rates of output per capita) only accounts for the transitional dynamics of per capita income over a specific period of time and cannot be interpreted as steady state growth rates of per capita income. Even if the coefficients on institutions were significant in this type of regression, they would only support the claim that institutions have a level effect on steady state per capita income. Nevertheless, this should not be interpreted as saying that institutions are not important. Level effects are welfare increasing.

1.4 The Empirics on Institutions and Levels of Output Per Capita

There is an indivisible link between *growth* and *levels* of GDP per capita, but empirical analyses that focus on *levels* of output differ fundamentally from those studies that evaluate *growth* of output. According to Hall and Jones (1999), empirical evaluations of levels of output per capita provide valuable information about standards of living, which is overlooked in the growth analyses. Moreover, Easterly *et al.* (1993) shows that the correlation between growth rates across decades is relatively low, which suggests, "that differences in growth rates across countries may be mostly transitory" (Hall and Jones, 1999:85). Therefore, studies focusing on different time periods may find different patterns of growth, leading to findings of an unstable relationship between institutions and growth rates of income per capita.

From an econometric standpoint, empirical analysis of levels of output per capita is very demanding in terms of techniques and controls for inherent endogeneity in the set of explanatory variables. Recent contributions to the literature have proposed specifying a model for levels of per capita output in terms of institutions and geography, which are deemed 'deeper' determinants of income. Hall and Jones (1999) hypothesize that *social infrastructure* is the "primary, fundamental determinant of a country's long-run economic performance" (p.95).[11] Acemoglu *et al.* (2000) argue that differences in institutions account for most of the differences in income per capita and that institutional are the basic determinant of income. This branch of the literature proposes to estimate the following *ad hoc* equation:

$$y = \alpha_1 + \alpha_2 T + X\alpha_3 + \varepsilon \tag{1.10}$$

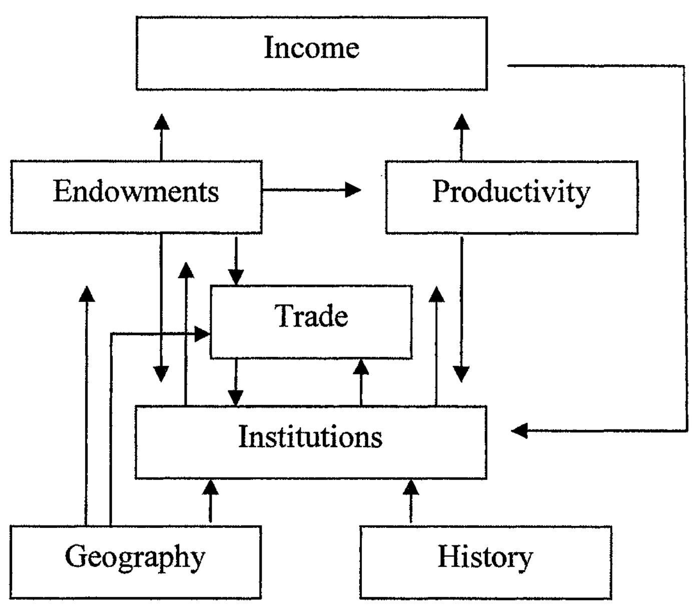
where y is log of income per capita, T measures institutions, X is a matrix of "other" exogenous determinants of income, ε is random error term and α_s are parameters.

Equation 1.10 has several drawbacks. First, it implies a linear relationship between institutions and log of per capita GDP. However, there is no theoretical reason to believe that this relationship is linear. Second, institutions (T) are not directly observable. We only observe a set of variables that are potential proxies for institutions (T). Third, the choice of the set of 'other' exogenous determinants of income, X, is *ad hoc* and, in general, includes geographical variables such as mean temperature (as a proxy for climate), distance from the Equator and coastland. Finally, a key issue in this literature concerns the nature of institutions, that is; institutional arrangements (T) seem to be endogenously determined because institutions affect economic performance, but the economic environment may also affect the institutional arrangements of a society.

[11] "By social infrastructure we mean the institutions and government policies that provide the incentives for individuals and firms in an economy. Those incentives can encourage productive activities such as the accumulation of skills or the development of new goods and production techniques, or those incentives can encourage predatory behavior such as rent-seeking, corruption and theft." (Hall and Jones, 1999:95).

Figure 1.1 provides a schematic model of the interactions between institutions and income suggested by the literature on institutions.[12] This diagram explicitly makes the case that institutions are endogenous. First, human capital (endowment) is expected to be correlated with institutions and the causation goes both ways, that is; better institutions may provide incentives to accumulate more human capital and more human capital may help to create and/or develop better institutions. Social arrangements such as the quality of the judiciary, the strength of property right protection, government stability, and democracy, among other factors, can foster factor productivity. On the other hand, new technologies may affect the role and the need of institutions in a society. Therefore, the causation between factor productivity and institutions may also go in both directions.

Figure 1.1 – Determination of Income



[12] Similar, but not identical versions of this diagram can be found in Rodrik (2003) and McArthur and Sachs (2001).

Figure 1.1 also allows for a feedback effect from income on institutions. One could argue that as income increases, economic agents could change their pattern of consumption, social interaction, social needs, etc., which would then require changes in social arrangements and institutions. Moreover, better institutions may lead to large flows of trade. In addition, more openness to trade requires better institutional arrangements. Geography and historical facts are assumed to be *deep* determinants of both current institutions and income. Undoubtedly, this approach advocates that institutions must be treated as an endogenous variable. This proposition is consistent with Bloom *et al.*, 1998; Gallup *et al.*, 1999; Acemoglu *et al.*, 2000 and 2004; McArthur *et al.*, 2001; and Rodrik, 2000 and 2003.

The diagram above shows the hypothesized links between institutions and income and allows one to specify an empirical model for the determinants of institutions (T). Consider the following equation:

$$T = \beta_1 + X\beta_2 + \beta_3 H + \eta \tag{1.11}$$

where H is an identifying variable(s), X is a matrix of geographically related variables, β_s are parameters and η is a random error term.[13]

Equations 1.10 and 1.11 form a system where income level is a function of the institutional arrangements and geographical characteristics, which are considered to be deep determinants of income. A key issue in estimating this system of equations is the model identification, that is; can one come up with a variable (H) that is correlated with current institutions, but uncorrelated with current income? The empirical literature on institutions has proposed several different instruments to

[13] Hall and Jones (1999) propose the following structural model:

$$y = \alpha_1 + \alpha_2 T + \varepsilon$$
$$T = \beta_1 + \beta_2 y + X\beta_3 + \eta$$

handle this problem and in general; H is associated with the historical determinants of institutions such as ethnolinguistic fragmentation and colonial legacy (e.g. colonization status and origin of the legal system).

Table B.2 reports the most influential studies that have attempted to estimate this model. Hall and Jones (1999) use an index of government antidiversion policies (GADP)[14] and the extent to which a country is open to international trade as proxies for institution quality. In addition, they utilize absolute latitude (as a proxy for climate) and the extent to which the primary languages of Western Europe countries are currently spoken as first languages as instruments for institutions. Using a sample with 127 countries, this study shows that good institutions lead to higher levels of per capita GDP. Specifically, "[d]ifferences in social infrastructure across-countries cause large differences in capital accumulation, educational attainment and productivity and therefore large differences in income across countries" (Hall and Jones, 1999:114).

The use of ethnolinguistic fragmentation as an instrument for institutions however, has been criticized in the literature. It has been argued that ethnolinguistic fragmentation has a direct effect on income, implying that it will not help to properly identify the model (Bloom *et al.*, 1998; Gallup *et at.*, 1999; Acemoglu *et al.* 2000 and 2004; McArthur *et al.*, 2001).

Acemoglu *et al.* (2001, 2002 and 2004) utilize settler mortality rates[15] during the colonial period as an instrument for institutions, which are proxied by a risk of

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[14] The GADP is created using data from the Political Risk Service and is calculated as the average of five measures of perceived institutional quality [i) law and order, ii) bureaucracy quality, iii) corruption, iv) risk of expropriation and v) government repudiation of contracts] for the years 1986 to 1995.

[15] "We use data on the mortality rates of soldiers, bishops and sailors stationed in the colonies between the 17^{th} and the 19^{th} centuries" (Acemoglu *et al.*, 2000:2).

Expropriation Index and a Constraint on Executive index[16]. These authors argue that settler mortality rates explain the process by which early institutions were created because the "colonization strategy was influenced by the feasibility of settlements. In particular, in places where the disease environment was not favorable to European settlement, the cards were stacked against the creation of Neo-Europes, and the formation of the extractive state was more likely. ... The colonial state and institutions persisted even after independence" (Acemoglu *et al.*, 2000:2). This study finds that three-quarters of the cross-country differences in income per capita is explained by differences in institutions. This study has two drawbacks. First, its sample is restricted to ex-colonies, so its results may not be applicable for a large cross-section of countries. Second, McArthur and Sachs (2001) criticize the use of settler mortality rates as an instrument by arguing that the burden of disease should be expected to have a direct effect on income rather than an indirect effect through institutions.

The strongest criticism of both Hall and Jones (1999) and Acemoglu *et al.* (2000) comes from Dollar and Kraay (2003). These authors find that the instruments proposed by Hall and Jones (1999) and Acemoglu *et al.* (2000) are not robust. Specifically, "we find that our specification is *very weakly* identified in the sense that

[16] Constraint on Executive measures operational (de facto) independence of the chief executive. "This variable refers to the extent of institutionalized constraints on the decision-making powers of chief executives. Such constraints may derive from a legislature, a mass party – not all such parties are wholly under control of the national leader – or some other accountability group, including the military." (Gurr *et al.*, 1990). This variable rages from 1 to 7, with a higher score indicating more constraints on the executive. Score of 1 indicates that there are no regular limitations on executive authority (unlimited authority); score of 2 is an intermediate category; score of 3 indicates slight to moderate limitations on executive authority; score of 4 is an intermediate category; score of 5 indicates that the executive has more effective authority than any accountability group but is subject to substantial constraints by them (substantial limitations); score of 6 is an intermediate category; and score of 7 indicates that the accountability groups have effective authority equal to or greater than the chief executive in most areas of activity (executive parity or subordination). (Gurr *et al.*, 1990).

both sets of instruments have very strong explanatory power for both endogenous variables. As a result, we encounter overwhelming problems of multicollinearity in the second-stage regressions, which preclude the estimation of meaningful partial effects of either variable" (Dollar and Kraay, 2003: 135). Moreover, these authors find that the effect of institutions disappears when the United States, Canada, Australia and New Zealand are excluded from the sample. To sum up, Dollar and Kraay (2003) claim that the effect of institutions – measured by six different indicators – on income per capita is not robust because the positive correlation is mainly driven by four outliers. Dollar and Kraay (2003) suggest that one should carefully reinterpret previous results and search for new instruments for institutions.

1.5 Lessons from the Empirics on Institutions

Several important lessons can be drawn from this literature review. First, there are intrinsic difficulties in examining the impact of institutions on economic performance that may be difficult to overcome. It is very hard to find data that totally describes the nature of institutions. Subjective measures of institutions, such as enforcement of property rights, corruption, rule of law, democracy, civil liberty, economic freedom etc., have been used to conduct empirical analysis, but the results are highly dependent on the quality of such statistics and as shown in Tables 1.2 and 1.3, the use of different indicators may produce ambiguous predictions. Second, the literature review also suggests that it is difficult to provide conclusive empirical evidence supporting the idea that institutions matter for economic growth. Although several studies have attempted to demonstrate that institutions affect the transitional growth rate of output per capita, there is still no empirical evidence that supports the claim that institutions determine the steady-state growth of GDP per capita. Third, the survey of the literature also demonstrates the *ad hoc* nature of the econometric specifications found in the studies that evaluate the links between institution and economic performance. Except for making strong and general assumptions about the association between institutions and levels of output, these studies do not provide a formal theoretical rational that links institutions to output per capita and growth of output per capita. Moreover, the impact of institutions on technical innovation is typically ignored. However, as emphasized in the growth literature, innovation is a key mechanism for the generation of long-run economic growth. Hence, if one wants to both diagnostic the problem of growth and also search for ways to stimulate growth, it becomes very important to understand the links between institutions and innovation. The identification of which institutional arrangements are more suitable for innovation and the adoption of new technologies will provide valuable insights on the mechanisms of economic growth.

This study endeavors to evaluate some of the issues discussed above. For instance, the theoretical model developed in chapter 2 provides the foundations for specifying an empirical equation for innovation as well as for income, circumventing the need for *ad hoc* empirical specifications. In addition, the empirical analysis conducted in chapter 3 provides evidence that institutional arrangements affect a country's rate of innovation, implying that institutions determine the steady state growth rate of output per capita. Therefore, this study contributes to the literature by providing empirical evidence that institutions affect the steady state growth rates of output.

1.6 Modeling the Links between Institutions and Economic Growth: A Review

While neoclassical economists acknowledge that institutions are important for growth, they usually take institutions for granted when writing down their macroeconomic theories. As a consequence, the emergence of an empirical literature on institutions was not matched by a similar trend on the theoretical front. Only a few studies have incorporated institutions into the formal mainstream framework currently used to evaluate economic growth (e.g. Huang and Xu ,1999; and Gradstein, 2002 and 2004). This section discusses the challenges of writing down a formal model that explicitly incorporates institutions and reviews a few studies that have previously endeavored in this journey.

1.6.1 Challenges for Modeling the Links between Institutions and Economic Growth

Solovian Models and Endogenous Growth Models are built from the premise that income is determined by resource endowments (capital and human capital) and factor productivity (technology). Growth literature provides a large family of theoretical models that link physical capital, human capital and technical innovation to long-run growth and income levels (e.g., Solow, 1956; Romer, 1986 and 1990; Lucas, 1998; Grossman and Helpman (2001 [1991]), Aghion and Howitt (1992); Jones, 1995; Young 1998; Segerstrom 1998). Models in this tradition do not specify the role of institutions and geographic factors on the determination of income. In contrast, the literature on institutions has developed an analytical framework that argues that institutions are a pillar of economic growth (North and Thomas, 1973; Dawson, 1998; Rodrik, 2000). Therefore, ignoring the role of institutions may oversimplify the analysis and put out of sight important linkages in the dynamics of economic growth. There is still a great deal of work to be done in terms of modeling the association between institutions and economic performance (Sala-I-Martin, 2002:18).

The rational behind the links between institutions and income, shown in Figure 1.1, is not clear and no rigorous theoretical and empirical analyses have been developed supporting such linkages. For instance, it could be argued that without a connection to technological change, institutional improvements will lead to an income level effect, but not to an income growth effect. Hence, a formalized model of the economic system may provide a much deeper understanding of the channels by which institutions and income are connected. However, given the complexity of the interactions between institutions and other components of the economic system, it is very difficulty to write down a mathematical model that would account for all of those interactions and still yield a well-behaved analytical solution. Economists, in general, focus the analysis on a particular set of variables or economic interactions, holding the other variables constant. Attempts to model institutions in a growth framework that follow this approach overlook much of the dynamics between institution and economic performance.

1.6.2 Recent Developments on Modeling Institutions

i) Financial Institutions and Growth

Huang and Xu (1999) develop a theoretical model in which financial institutions affect the economy's rate of innovation. In this model, financial institutions help "to solve informational and incentive problems related to R&D activities" (p.440) and improvements in financial institutions would thus lead to higher rates of technical innovation and economic growth. The model assumes that a representative firm can produce a final good and also generate new R&D projects (innovation). It is assumed that the firm lacks sufficient resources to finance the development of new technologies (innovation), so financial institutions play a key role in financing 'risky' R&D activities. The total production of the firm is carried out with the following technology:

$$y_t = [\overline{A}(1-\alpha_t) + \widetilde{A}\alpha_t]k_t \tag{1.12}$$

where $\overline{A}$ and $\widetilde{A}$ are productivity parameters of the final good and R&D sectors, respectively, α_t is the share of investment in R&D and k is capital. The consumer side is modeled in terms of a representative agent who maximizes $U_t = E_t(\sum_{s=t}^{\infty} \beta^{s-t} \ln(C_s))$ subject to:

$$K_{t+1} = [(1-\alpha_t)(1+r) + \alpha_t(1+\widetilde{r}_t)]K_t - C_t \tag{1.13}$$

where E_t is the expectation operator, K is the total amount of capital accumulated, r is the marginal product of capital, $(1+\widetilde{r})$ is the expected return for each unit of investment in R&D and C is consumption. The solution of the model around the steady state is given by:

$$E_t \frac{C_{t+1}}{C_t} = \frac{E_t(\widetilde{r}_{t+1} - r)^2}{(1+r)\beta\sigma_t^2(\widetilde{r}_{t+1} - r)} + (1+r)\beta \tag{1.14}$$

The key role of financial institutions in this model is financing R&D activities, which are, by nature, risky. It is assumed that financial institutions contribute to the project screening process by financing those projects more likely to be successful – or refusing to finance bad projects. This leads to a better allocation of resources in the R&D sector, stimulating innovation and promoting growth (Huang and Xu, 1999:440).

Huang and Xu (1999) show that bad projects are terminated in their first stages when they are multibank financed. However, bad projects may be continued when they are financed by a single bank. This happens because multibank financed projects are better screened, leads to a selection of superior projects. Therefore, an economy with well-developed financial institutions will tend to allocate resources for R&D more efficiently, leading to higher expected rates of return. Higher expected rates of return to R&D investments will further stimulate innovation and according to equation 1.14, augment economic growth (Huang and Xu, 1999:440).

Huang and Xu (1999)'s model predicts that better financial institutions will boost innovation and have *growth* effects on the economy. The model's main drawback is that it defines better institutions as a function of the number of banks that finance the production of R&D projects. Specifically, economies whose R&D activities are financed by a large number of banks are classified as having better financial institutions than those whose R&D activities are financed by single banks. One could argue that Huang and Xu's model shows that an economy whose financial system is more competitive tends to experience higher rates of innovation and economic growth. In addition, it could be also argued that this model rules out transactions costs and economies of scale.

ii) Institutions in Solovian-based Models

Fedderke (2001) develops a Solovian-type model in which income and institutions are simultaneously determined. In this model, institutions are modeled as a positive function of the capital stock of the economy, implying that economic growth leads to better institutions. The relationship between institutions and output is specified in several different ways. For brevity's sake, only the general case is discussed here.

It is assumed that aggregate output is produced with labor and capital. The production technology is a CRS Cobb-Douglas production function given by:

$$y = Tk^{\alpha} \tag{1.15}$$

where y is per capita income, k is the stock of capital per capita, T denotes institutions and $0 < \alpha < 1$. It is assumed that institutions are "determined by the per capita productive potential of the technology of production" (Fedderke, 2001:653), such that:

$$T = k^{\alpha\gamma} \tag{1.16}$$

where γ is a free parameter. Combing equations 1.15 and 1.16 gives:

$$y = k^{\alpha(1+\gamma)} \tag{1.17}$$

The model is fully specified by assuming that capital is accumulated according to the following rule:

$$\dot{k} = sk^{\alpha(1+\gamma)-1} - g \tag{1.18}$$

where s denotes the savings rate and g is the growth rate of the labor force adjusted for the depreciation of capital.

This specification implies that institutions are generated as a by-product of capital accumulation. Under the assumption that $\gamma > 0$, institutions impact the production function as a positive externality that increases the productivity of capital. This allows for increasing returns and an unbounded growth rate of output. The author restricts the parameters of the model and derives the steady state solution, which behaves much like the traditional Solow model.

The model suggests that institutions and economic performance are interdependent. If $\gamma > 0$ economies with a large stock of capital will have better institutions[17]. In addition, better institutions lead to higher productivity and larger output per capita. However, when the possibility of unbounded growth is excluded, the model generates a steady state solution with a zero growth rate of per capita output and no institutional change. This model attempts to formalize the relationship between output and institutions, but it does not explain long-run growth and adds very little to our understanding of the links between institutions and technical innovation. Because savings is exogenously determined, capital accumulation is not determined inside the model implying that the development of institutions and growth of output are also exogenously determined.

Esfahani and Ramirez (2003) develop a Solovian-type model that takes into account the effect of institutional factors on the provision of infrastructure. This model is not markedly different from the standard Solow specification, but adds, *ad hoc*, the idea that institutional factors affect negatively the return to savings, implying that households do not receive the full marginal benefits from their savings. Therefore, poor institutions reduce both the savings rate and capital accumulation, which ultimately, affects the provision of infrastructure and economic growth. This model is also not able to explain the sources that generate growth of output and provides no formal explanation for the links between institutions and economic growth.

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[17] Other than for modeling's sake, the author provides no explanation supporting the statement that a large stock of capital causes an improvement in institutions.

iii) Institutions in an Overlapping Generation Framework

Gradstein (2004) models institutions in an OLG (Overlapping Generation) framework. This model assumes that individuals must pay the costs of financing a system that enforces property rights and that "property rights can be fully secured by incurring a cost" (Gradstein, 2004: 506). In addition, the production of property rights enforcement is characterized by indivisibility. The model economy takes for granted that income can be divided between consumption, savings and the costs of enforcing property rights (law and order), that is:

$$y_{it} = c_{it} + k_{it} + T\delta_t \tag{1.19}$$

where y denotes income, c consumption, k capital, T is the costs of securing full protection of property rights and δ is a indicator function, which assumes the value of 1 if property rights are fully protected and 0 if no investment is made to guarantee property rights. Gradstein (2004) also assumes that technology is exogenously determined and the production function is characterized by diminishing returns to scale.

$$z_{it+1} = Ak_{it}^{\alpha}w_{it} \tag{1.20}$$

where A measures technology, w denotes labor and $0 < \alpha < 1$.

The next period income is defined as the sum of current income plus the income from rent seeking:

$$y_{it+1} = L_t z_{it} + (1 - L_t)Z_{t+1}r(u_{it}) / \int r(u_{it})di \tag{1.21}$$

where $0 < L < 1$ denotes the level of protection of property rights, $Z_{t+1} = \int z_{it+1}di$ is aggregate income, u denotes time allocated for unproductive activity and $r(u_{it}) / \int r(u_{it})di$ denotes rent seeking income. Despite the dynamic setting shown in the form of these equations, the model is "essentially a static one" (Gradstein, 2004:508) because the equilibrium condition is solely determined by the one-shot decision of the parents, who chose consumption and determine, collectively, the level of protection of property rights, by maximizing the following utility function:

$$V(c_{it}, y_{it+1}) = (1-\beta)\log(c_{it}) + \beta\log(y_{it+1}) \quad (1.22)$$

Were c is per capita consumption and y is aggregate per capita income.

The equilibrium conditions support the claim that an increase in the protection of property rights leads to lower current consumption and higher investment, but generates higher steady state levels of consumption. Moreover, the model predicts that optimizing agents may choose a regime of minimal protection of property rights in poor countries because it leads to a higher welfare level, but a regime of full protection will be preferable in rich countries. The model also suggests that initial conditions play a key role in determining steady state equilibrium, i. e., countries with low income and low initial level of property rights will converge to a low steady-state income level and low protection of property rights. However, countries with low-income levels, but moderate level of protection of property rights may converge to a high steady-state income level (Gradstein, 2004:512).

The main message of Gradstein (2004) is that the level of enforcement of property rights will determine the steady state level of income. However, because property rights levels is an endogenous variable and its enforcement requires a substantial amount of resources, optimizing agents who live in poor countries may choose to not invest the required resources in the development of a system that secures property rights. Moreover, full protection of property rights may only be feasible in rich countries because full protection is "costly and requires resources which only exist in sufficiently affluent economies" (Gradstein, 2004:517).

The main drawbacks of Gradstein's model are that innovation is assumed to be exogenous and the links between innovation and enforcement of property rights are ignored. This undermines much of the model's appeal since innovation is a key channel through which property rights will affect economic performance. In addition, the model is static and explains levels of income, but cannot explain long-run growth of income. Gradstein (2002) writes down an OGL model that evaluates how political stability affects agents' decisions. This earlier model shows that countries that experience political stability will tend to have policies governed by *rules,* which favor a more equal distribution of income. This, in turn, is expected to stimulate investment and boost economic growth. The caveat found in Gradstein (2004) also applies to the Gradstein (2002) model.[18]

1.6.3 Lessons from Modeling Institutions

The models of growth and institutions discussed above focus the analysis on particular kinds of institutions and examine very specific issues. However, the dynamic linkages among institutions, innovation and income are not evaluated. For instance, unfavorable institutions (e.g. poor protection of property rights) may affect the returns to investment in R&D, which may discourage R&D activity and affect the rate of technical innovation. On the other hand, *good* institutions may enhance the diffusion of knowledge among researchers, leading to higher R&D productivity. In addition, the techniques of production used to produce final and intermediate goods

[18] Despite the fact that Gradstein (2002) has a different focus, the model's formal specification is in line with Gradstein (2004).

may be a function of institutional arrangements. For instance, government regulations may require that the technology of production follow certain environmental 'standards', which may prevent a firm from using a newly invented non-compliant technology. This important issue is discussed in detail in chapter 2.

1.7 Conclusion

This literature review provides important insights into the empirics of institutions and shows that the econometric specifications used in institutions-related growth literature is not grounded on formal theoretical models. In addition, it also demonstrates that the impact of institutions on technical innovation is disregarded in both empirical investigations of cross-country economic performance and formal growth models. The review also shows that economists are still struggling with the problems of to incorporating institutions in formal growth models. A current important task for economists lies in addressing the effects of institutions on innovation. A major goal of this study is contributing to this research program; thus, the next chapter develops a growth model that examines how institutions affect technical innovation and economic growth. The model is built upon the premise that institutions influence an economy's rate of innovation as well as the adoption of existing technologies. The model contributes to the literature by allowing one to evaluate the affects of institutions on innovation and on the *transitional* and *steady state* growth rates of output. In addition, the model provides the basis for specifying an empirical model for studying innovation, circumventing the need to rely on *ad hoc* empirical specification. Specifically, the theoretical framework developed in chapter 2 motivates the empirical analysis of the determinants of innovation that is conducted in chapter 3.

CHAPTER 2

MODELING INSTITUTIONS IN A GROWTH FRAMEWORK: A CONTRIBUTION

2.1 Introduction

Economists have become increasingly aware that institutional arrangements play a key role in explaining long-run economic performance (e.g. Rodrik, 2000; Sala-I-Martin, 2002; Gradstein, 2004). The so-called New Institutional Economics (NIE) literature is an attempt to provide a theoretical framework capable of explaining the channels by which institutional arrangements affect a country's economic performance. Despite the fact that the NIE underlines the importance of institutional arrangements for economic performance, it has been criticized because it does not provide a formal framework of analysis and fails to explain how institutions are built.[19] In addition, difficulties in introducing institutions into standard growth models have inhibited the development of a growth framework that explains the dynamic linkages between institutions and economic performance. According to Sala-I-Martin, "we are still in the early stages when it comes to incorporating institutions to our growth theories" (Sala-I-Martin, 2002:18).

A contribution of this study consists of filling this gap in the growth literature by constructing a formal model that examines how institutions affect technical

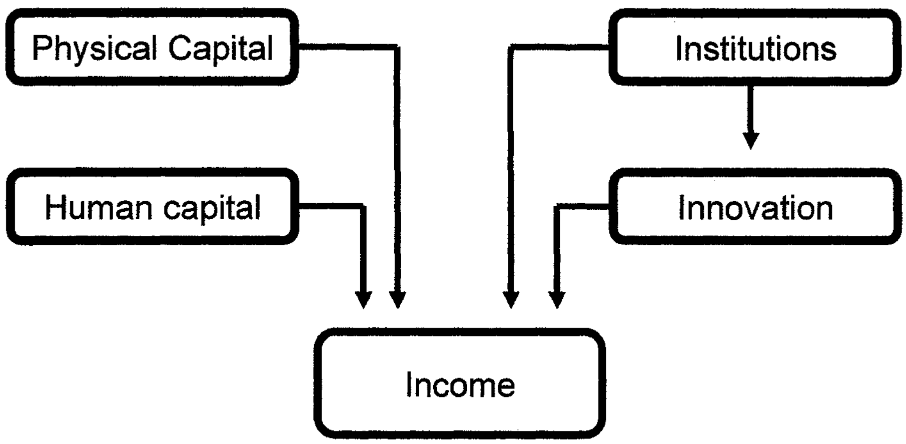
[19] The "main weakness of the NIE as a grand theory of socio-economic development is that it is empty. As a critique of other theories which altogether ignore the role of institutions... it is welcome. But when it comes to new general insights about how determination works, the theory *adds nothing to what we already have*" (Toye, 1993, emphasis added).

innovation and economic growth. It extends the Romer (1990) model by explicitly incorporating institutions in the productive process. This improvement allows us to evaluate the channels through which institutions affect technical innovation, income levels and income growth.

Given the complexity of the interactions between institutions and other components of the economic system, it is very hard to write down a mathematical model that accounts for all of those interactions and yet obtain a well-behaved analytical solution. Economists, in general, have focused their analysis on a particular set of variables or economic interactions, holding other variables constant. This study follows this methodological approach. Specifically, the links between institutions and technical innovation are examined assuming that population and human capital are exogenously determined. Moreover, the basic model overlooks the effects from technical innovation and human capital accumulation on the formation of new institutions (Figure 2.1 shows a schematic model economy). This assumption is relaxed afterwards and its implications evaluated. While this approach simplifies the problem at hand, it may shed light on the channels by which institutions affect technical innovation and consequently, economic growth.

The rest of this chapter is organized as follows. Section 2 develops the theoretical model. The model is built upon a set of assumptions that shape the links between institutions, innovation and the adoption of new technologies in the productive process. Section 3 uses comparative statics to evaluate the impact of human capital accumulation on economic performance. Section 4 models the links between institutions and human capital. Section 5 discusses the implications of the model. Section 6 presents the chapter's conclusions.

Figure 2.1 – A Schematic Model Economy



2.2 Theoretical Framework

The model economy has the structure used by Romer (1990). The economy has three sectors. One sector produces a final good using human capital, physical capital and a weighted aggregate measure of intermediate inputs. A second sector produces intermediate inputs using forgone consumption and the projects (knowledge) developed in the third sector, which conducts R&D. The complete specification of each of these sectors is fully discussed below. For simplicity's sake, it is assumed that population and human capital are constant[20].

i) Final Good Sector

The firm that produces the final good utilizes a constant-returns-to-scale (CRS) technology and operates in a market characterized by perfect competition. Output is produced using the following production function:

[20] Marinho, Ataliba and Tebaldi (2003) extend the Romer model by allowing, among other changes, that population and human capital are not constant. This greatly complicates the analysis of the model's dynamics.

$$Y = K^{1-\alpha-\beta} H_Y^{\beta} \int_0^{f(A,T)} x(i)^{\alpha} di \qquad (2.1)$$

where K is the stock of physical capital, H_Y is human capital employed in the manufacturing sector, x(i) denotes intermediate inputs, A denotes knowledge, T denotes institutions, i indexes the variety of intermediate inputs, $0 < \alpha < 1$, $0 < \beta < 1$, $\beta + \alpha < 1$ and *f* is a function whose functional form is discussed below[21].

A is measured by the number of intermediate inputs already invented and available for use at any time with x(i)=0 for all i > A. Moreover, A only increases if a newly invented intermediate input is superior in productivity compared to the existing intermediate inputs. T is a measure of institutional arrangements and refers to a set of elements related to the way that a society and its economy operates in modern capitalist countries. More precisely, T is a hypothetical variable that accounts for the enforcement of contracts and property rights, perceptions that the judiciary system is predictable and effective, transparency of the public administration, control of corruption and pro-market regulations (e.g., no price controls). In other words, this model treats institutions, T, as a set of growth-promoting attributes. In addition, T is assumed to be increasing with the quality of institutions, i.e., the better the institutions, the bigger T. This may seem to be a too narrow characterization of institutions. However, this formulation is only for conceptual purposes and serves the positive purpose of describing the evolution of a complex variable. More specifically, an increase in T does not imply that a society is changing all of its institutions (or fundamental institutional principles). This only indicates that a society has a certain

[21] See Table C.1 in Appendix C for a list of variable's definitions used in this chapter. Also, notice that the argument time (t) is suppressed in all equations.

degree of freedom to make institutional changes compatible to growth-promoting objectives.[22]

Equation 2.1 has several features not found in Romer (1990). First, Romer's model hypothesizes that all newly invented technologies can be instantaneously used in the productive process. Instead, the specification here expands on Romer's analysis by modeling potential institutional barriers to the adoption of new technologies into the productive process. This improvement allows one to evaluate the influences of barriers to the adoption of new technologies on both levels and growth rates of output. Second, Romer (1990) assumes that the parameters of physical capital and of the variety of intermediate inputs are equal. This study relaxes this assumption by allowing different productivity parameters for physical capital and the for variety of intermediate inputs, x. The logic behind this formulation is that the degree of substitutability and complementarity between the stock of physical capital and the variety of intermediate inputs are differentiated. The impact on output from an increase of one unit of a specific intermediate input may be different from the impact on output due to an increase of one unit in the aggregate stock of capital. This approach is consistent with Grossman and Helpman (2001). Third, Romer (1990) specifies the production function in terms of the variety of intermediate inputs, but overlooks the overall affect of the stock of physical capital on production. This study specifies the production function as a function of both the stock of physical capital and the various types of capital goods that are produced by

[22] Issues related to moral, values and ethics are beyond the scope of this study. For instance, a society may choose to have growth hindering institutions because of its moral values. This model does not discuss whether this is wrong or right. It only says what the opportunity costs of making such decision are. For instance, a society may choose to not engage in any rent-seeking transactions because of beliefs that this is not morally right. Suppose that as a result this society experiences slower output growth rates. In this case, lower output growth rates are the opportunity cost of choosing to not engage in rent-seeking operations.

an economy. Therefore, equation 2.1 incorporates features that allow for a richer analysis of an economy.

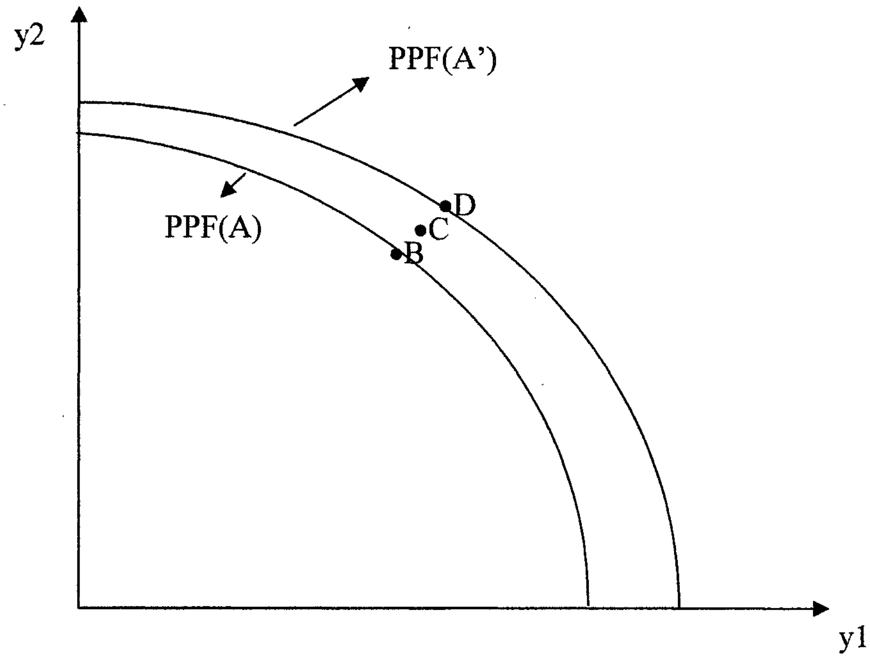
ii) Modeling the Institutional Barriers for Adopting New Technologies

In a competitive market, firms are willing to use all intermediate inputs already invented and available if the cost of buying that input is equal to its marginal product. However, firms may face various problems in their decision to adopt productivity-increasing technology. Specifically, organizational problems and institutional-related constraints, such as labor market imperfections (e.g. restrictive labor contracts or a union's bargaining power) and government regulations may hold back the introduction of newly invented technologies in the production process (Baldwin and Lin, 2002, Haucap and Wey, 2004). In other words, institutional constraints may prevent firms from operating on the production possibility frontier –PPF.[23]

Figure 2.2 illustrates the case where an economy - that produces two goods – originally was operating at point B. Technology improves from A to A', which shifts the PPF rightwards. Without constraints, the economy would operate at point D, but it may end up operating at point C due to institutional arrangements constraining the adoption of the new technology. In this case, poor institutions affect adversely the marginal product of the input newly invented. In specific situations, a new technology may be available, but firms would not be able to use it in the productive process because of a restrictive regulation, which leads the marginal product of that intermediate input to become zero. In such a case, the demand for such an intermediate input would be zero for any price greater than zero.

[23] More details and examples on this point are presented in Box 1.

Figure 2.2: Technical Change and Institutions



A suitably chosen *f* function may communicate these ideas mathematically. A particular functional form is considered in here:

$$Y = \begin{cases} K^{1-\alpha-\beta} H_Y^{\beta} \int_0^{A} x(i)^{\alpha} di & \text{if } A < \psi T \\ K^{1-\alpha-\beta} H_Y^{\beta} \int_0^{\psi T} x(i)^{\alpha} di & \text{if } A \geq \psi T \end{cases} \tag{2.2}$$

where $\psi \geq 0$ is a scale adjusting parameter that accounts for the influence of institutions on the adoption of new technologies and ψ can be interpreted as a measure of the importance of institutional arrangements for the adoption of new technologies.

Equation 2.2, therefore, assumes that either technological improvements (A) or Institutions (T), but not both, have marginal effects on output. The logic behind this formulation is that an economy may face institutional constraints to the adoption of new technologies in the productive process. In this case, only improvements in institutions (T) will allow the economy to incorporate newly invented inputs in the production process. The assumptions below shape the final specification of the production function.

Assumption a: New technologies change the production modes and ultimately, require new institutional arrangements to allow the economy to operate at the production possibility frontier.

Assumption b: In the long run, the rate of innovation (production of new intermediate inputs) is at most equal to the rate in which institutions change.

Assumption *a* recognizes that "institutions need continual adaptation in face of a changing environment of technology" (Matthews, 1986:908). Without changes in current institutions, the economy cannot fully exploit the efficiency gains from current innovation and so "institutional change is a necessary part of economic growth" (Matthews, 1986:908). Assumption *b* implies that an economy cannot innovate indefinitely without adapting its institutions to the new technologies.

Under these assumptions, an economy may not be able to utilize available new technologies due to institutional barriers. Mathematically, we represent this case by setting $A \geq \psi T$, so the production function becomes

$$Y = K^{1-\alpha-\beta} H_Y^{\beta} \int_0^{\psi T} x(i)^{\alpha} di \ . \tag{2.3}$$

This specification seems reasonable and may be corroborated by real world events. Specifically, one could utilize case studies associated with institutional-related constraints on the adoption of new technologies to support this specification. While this study does not intend to pursue a detailed discussion of this issue, a couple of examples are briefly discussed in boxes 1 and 2 and a more detailed discussion is presented in this chapter's appendix .

Box 1: Institutional Constraints for the Adoption of New Technologies: The Case of Labor Market Imperfection

Labor market imperfection is an example of institutional arrangements that constrain the adoption of new technologies. For instance, it has been argued that unionization structure can influence firms' decisions concerning the adoption of labor-saving technologies. Specifically, firms operating under strong union bargaining power may be prevented from adopting technologies that reduce the demand for unskilled labor, but increase overall productivity (Baldwin and Lin, 2002; Haucap and Wey, 2004). A case study of the Canadian manufacturing industry, by Baldwin and Lin (2002), finds a significant association between unionization and impediments for the adoption of new technologies*. Specifically, a "plant that reports its employees are covered by a collective agreement [unionized] increases its probability of reporting impediments [to adopt new technologies] in each of these areas [labor and organizational impediments] by about 3 to 5 percentage points" (Baldwin and Lin, 2002:15). Therefore, labor market imperfections may hamper the adoption of new technologies in countries with restrictive regulations in their labor markets.

Despite the fact that these examples do not prove the hypothesis that institutional arrangements hinder the adoption of new technologies, they do suggest that this assumption is reasonable and should be considered as part of the modeling of technical innovation in an economic growth model.

* The studies cited above do not consider the role of unions as an agent that battles for equity and workers' rights. While important, these issues are not the focus of this study.

Box 2: Institutional Constraints for the Adoption of New Technologies: The Case of Genetically Modified Crops

One can easily make the case that government regulations prevent the use, production and commercialization of genetically modified crops; a productivity-increasing technology*. Consider the following facts: i) there is a noticeable concentration of the production of transgenic crops in a few countries (James, 2004)** and ii) transgenic seeds have been widely available for commercialization since 1996 (James and Krattigger, 1996).

It appears that institutional arrangements can explain much of this observable fact. First, innovating countries may be afraid of delivering new technologies to countries with a poor system of property rights protection (Krattiger, 1997). In this case, institutionally backward countries are not able to learn and adapt the new technologies because they have no access to the technology needed to manipulate the genetically altered seeds. This may lessen the benefits of using transgenic seeds in institutionally backward countries. However, these countries would still be able to buy transgenic seeds from the leading innovating countries. Second, biosafety regulatory laws impose strong constraints on the implementation of the production and commercialization of genetically altered seeds in many countries around the world (Krattiger, 1997, James, 2004). Appendix B discusses this issue in detail and provides a brief study of the Brazilian regulatory constraints on the adoption of genetically modified crops.

* As discussed before, this study is focused on growth-promoting mechanisms. Issues related to morals, values and ethics are beyond the scope of this study.

iii) Intermediate sector

A key feature of endogenous growth models is that they allow for imperfect competition in the intermediate sector, which makes the market structure relatively complex and constrains the researcher to model this sector in terms of a representative firm. In this study, it is assumed that there is a distinct producer for each input i, who must buy the patent of that input from a R&D producer. Models in the Romer (1990) tradition assume that the intermediate inputs can be produced using the same technology utilized to produce the final good, where consumption is forgone (in the form of capital) in order to produce the intermediate inputs. For simplicity, it is assumed here that each unit of consumption forgone can generate one unit of capital that can be used in the production of intermediate inputs[24]. The fact that there is only one producer of input i implies that there is only one seller of input i, who will face a downward sloping demand curve. One can derive the inverse demand function for a specific input from the profit optimality conditions of the producer of final good. The inverse demand function for input is given by:

$$p_i = \alpha K^{1-\alpha-\beta} H_Y^{\beta} x_i^{\alpha-1} \quad (2.4)$$

The producer of intermediate inputs faces an opportunity cost of capital equal to the interest rate (r). In addition, the cost of buying a patent is fixed and so it can be omitted from the profit function of the producer of input i, so that:

$$\pi(i) = p(i)x(i) - rx(i) \quad (2.5)$$

Substituting equation 2.4 into equation 2.5 gives:

$$\pi(i) = \alpha K^{1-\alpha-\beta} H_Y^{\beta} x(i)^{\alpha} - rx(i)$$

The first order condition generates:

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[24] Romer (1990:S81) provides a detailed discussion about this specification.

$$x(i) = \left(\frac{\alpha^2 K^{1-\alpha-\beta} H_Y^{\beta}}{r} \right)^{\frac{1}{1-\alpha}} \tag{2.6}$$

We can use the first order conditions to manipulate equation 2.5 and obtain:

$$\pi = \pi(i) = \left(\frac{1-\alpha}{\alpha} \right) r x(i) \tag{2.7}$$

Substituting equation 2.6 into equation 2.4 generates $p(i) = p = \frac{r}{\alpha}$, that is; the price of the intermediate inputs are identical for all *i*. This result implies that the producer of the final good will demand an identical amount of each intermediate input *i*, that is, x(i)=x.

A potential new producer of an intermediate input decides to enter in the market by comparing the discounted stream of profit generated by producing that input and the price that must be paid for the patent. If the price of a patent (new design) is determined in a perfectly competitive market then its price (P_A) will be equal to the present discounted stream of profit that the producer of intermediate inputs could make producing the intermediate input i. Formally,

$$P_A = \int_0^{\infty} \pi e^{rt} dt = \pi / r \tag{2.8}$$

This equation can be written as $\pi = rP_A$. This shows that the profit rate of the producer of intermediate goods is equal to the discounted price of innovation, which is equivalent to the present value of the innovation costs.

iv) The R&D Sector

The new growth theory a-la-Romer assumes that innovation results from ordinary economic activities, where firms demand inputs and decide production in such a way that profit is maximized. Moreover, new growth theory suggests that innovation depends primarily on personnel engaged in R&D and the existing knowledge (Romer, 1990; Aghion and Howitt, 1992; Grossman and Helpman, 2001 [1991]; and Jones (1995)). Models developed in this tradition completely ignore the role of institutions in the innovation process. Despite the fact that institutions are not explicitly present in growth models, economists in this field readily accept the idea that institutions are an important input for innovation. For instance, Sala-I-Martin (2002) argues that "it is hard to come up with new and better technologies if an economy does not have the right institutions" (p.18).

Freeman (1987) argues that institutions are a key component in the process of creating and diffusing new technologies. According to him, when firms are left on their own, they engage in *myopic* innovative processes that will lead to profit maximization in the short-run, but would not maximize long-run profits. In other words, one could argue that some institutions create incentives for firms to focus only on the short-run. Therefore, suitable macro-institutions may provide proper incentives for innovation by changing firms' myopic behavior in the short-run, leading firms to engage in innovative processes that would ensure long-term profitability[25].

Lundvall (1992) states that innovation is not a deterministic process and "together the economic structure and the institutional set-up form the framework for and strongly affect, processes of interactive learning, sometimes resulting in innovations" (Lundvall, 1992:12). In agreement with this argument, Matthews (1986) points out that better institutional arrangements enable economic agents "to co-operate with one another more efficiently" (p.908) thus stimulating innovation. These

[25] Freeman applies these ideas to analyze Japan's innovation system.

ideas are incorporated into a standard growth framework of innovation by explicitly modeling institutions as part of the innovation process. This study assumes that:

Assumption c: Institutional capital directly affects the innovation process;

Assumption d: Improvement in technology changes production modes and increases the complexity of social relationships. On average, this causes existing institutions to become relatively obsolete and changes the institutional structure needed to produce new technologies[26].

These assumptions are included in the model in the following way; a variable that accounts for institutional capital enters directly into the production function of new ideas, but not as a choice variable. Therefore, R&D firms make decisions on the demand for human capital taking institutions for granted. Consider the equation[27]:

$$\dot{A} = \delta A H_A Z(A,T) \tag{2.9}$$

where A measures technical knowledge , H_A is human capital engaged in R&D (it is the only choice variable in the R&D sector), Z denotes the institutional structure controlling for the level of technology and 0 < a < 1. It is assumed that Z increases as the institutional arrangements (T) improve ($\frac{\partial Z}{\partial T} = Z_T' > 0$). Furthermore, the assumption that improvements in technology make existing institutions relatively

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[26] "As circumstances change due to improvements in technology ..., social beliefs [consumers, firms and government] will be altered which require modifications of the institutional structure" (Atkinson, 1998:35-36).

".... [I]nstitutions need continual adaptation in face of a changing environment of technology and tastes" (Matthews, 1986:908).

[27] This specification overlooks the influences of physical capital on knowledge production. The rationality supporting this formulation is the idea that knowledge production is more human capital intensive.

obsolete implies that $\frac{\partial Z}{\partial A} = Z'_A < 0$. To make this specification workable, Z is defined as $Z = T/A$.[28] Accordingly, the production function of new technologies is given by:

$$\dot{A} = \delta A^{1-a} H_A T^a \qquad (2.10)$$

The logic behind this formulation is that institutions are a necessary input for the production of new R&D projects. Good institutions help in the process of registering new patents, diffusion of ideas across researchers, diffusion of current knowledge, enforcement of property rights and reduce the uncertainty of new projects; all factors that stimulate R&D activities.

It is worth noticing that this model of innovation departs greatly from Romer (1990). More precisely, Romer's model represents a special case where a=0. In this case, the model implies that doubling the number of workers devoted to R&D will double the growth rate of knowledge. In the steady state, the growth rate of output per capita is equal to the growth rate of knowledge and the scale effect from the R&D sector extends to output per capita, i.e., doubling the number of workers devoted to R&D doubles the growth rate of per capita output. Jones (1995) shows that such an implication is not consistent with the empirical record and can be easily falsified. Jones (1995) suggests an alternative specification in which the discovery of new ideas becomes more difficult as the stock of knowledge increases, i.e., "the probability that a person engaged in R&D discovers a new idea is decreasing in the level of knowledge" (Jones, 1995:765).

[28] This functional form is very strict. Future research might improve upon this by allowing a more flexible specification.

Because this model does not predict scale effects[29], Jones' critique does not apply to the model developed here. Moreover, the model developed here improves Jones's specification because it provides a rationality for how the discovery of new ideas becomes more difficult as the stock of knowledge increases. Additionally, it accounts for the direct effect of institutions on the innovation process, a dynamic ignored by Jones. This development allows one to evaluate the channels through which institutions affect technical innovation. Moreover, building a formal framework of analysis upon the existing literature may stimulate insightful and inspiring debates and lead to testable implications on the role of institutions in the productive process.

v) Equilibrium in the Labor Market

The model assumes a competitive labor market with human capital perfectly mobile across the final good sector and the R&D sector. In equilibrium wages are equalized across sectors, so $W_Y = W_A$, where W_Y and W_A are the wages in the final good sector and R&D sector, respectively. Using the results from the previous section and calculating the marginal product of human capital from equation 2.3 gives:

$$W_Y = \beta K^{1-\alpha-\beta} H_Y^{\beta-1} \psi T x^{\alpha} \quad . \tag{2.11}$$

The R&D producer is willing to hire more workers as long as the wage is less than or equal to its marginal product. Consider the profit function:

$$\max_{H_A} \pi_A = P_A \dot{A} - W_A H_A = P_A \delta A^{1-a} H_A T^a - W_A H_A$$

[29] Specifically, in this model an increase in the human capital allocated in the R&D sector (H_A) has no impact on the steady state growth rate of technical progress.

The first order condition generates $W_A = P_A \delta A^{1-a} T^a$. Substituting equation 2.8 into this equation gives:

$$W_A = \frac{\pi}{r} \delta A^{1-a} T^a \tag{2.12}$$

The equilibrium condition, $W_A = W_Y$, generates:

$$\frac{\pi}{r} \delta A^{1-a} T^a = \beta K^{1-\alpha-\beta} H_Y^{\beta-1} \psi T x^{\alpha}$$

Substituting equation 2.7 into this equation gives:

$$\frac{1-\alpha}{\alpha} x \delta A^{1-a} T^a = \beta K^{1-\alpha-\beta} H_Y^{\beta-1} \psi T x^{\alpha}$$

Substituting equation 2.6 into this equation and solving it for H_Y produces:

$$H_Y = \frac{\Psi}{\Lambda \delta} Z^{1-a} r \tag{2.13}$$

where $\Lambda = \dfrac{\alpha(1-\alpha)}{\beta} > 0$. Define:

$$g_A = \frac{\dot{A}}{A} = \delta H_A Z^a \tag{2.14}$$

Using $H_A = H - H_Y$, equation 2.13 can be rewritten as follows:

$$H_A = H - \frac{\Psi}{\Lambda \delta} Z^{1-a} r$$

Substituting equation 2.14 into this equation gives:

$$g_A = \delta H Z^a - \frac{\Psi}{\Lambda} Z r \tag{2.15}$$

The behavior of wages in the labor market determines the equilibrium conditions from the supply side of the economy. Therefore, equation 2.15 denotes a supply side equilibrium growth rate of technology. However, it is not a *general* *equilibrium* condition because it does not take into account the effects of the demand side of the economy.

vi) The Consumers

The demand side is modeled in terms of a representative agent. For simplicity's sake, the population is normalized to 1 and the utility function is assumed to have a logarithmic form[30]. The representative agent maximizes an infinite stream of consumption subject to the following constraints:

a) $\dot{K} = Y - C$

b) $\dot{A} = \delta A^{1-a} H_A T^a$

c) $H_A + H_Y \leq H$

The easiest way to solve this optimization problem is to construct a current-value Hamiltonian:

$$H_C = \ln(C)) + \lambda_1 (Y - C) + \lambda_2 \delta A^{1-a} H_A T^a \tag{2.16}$$

The solution to this Hamiltonian is well-know and produces the famous Euler Equation:

$$\frac{\dot{C}}{C} = r - \rho$$

where ρ is the intertemporal discount rate. This model generates a well-behaved steady state solution where output, consumption and capital grow at the same rate $\frac{\dot{Y}}{Y} = \frac{\dot{C}}{C} = \frac{\dot{K}}{K}$. Log-differentiating equation 2.3 and using $\frac{\dot{Y}}{Y} = \frac{\dot{K}}{K}$ and the Euler equation give:

[30] $U(C) = \ln(C)$.

$$\frac{\dot{Y}}{Y}=\frac{\dot{C}}{C}=r-\rho=\frac{1}{\alpha+\beta}g_T \tag{2.17}$$

where $g_T=\frac{\dot{T}}{T}$.

vii) General Equilibrium

By definition, the growth rate of innovation must be constant in the steady state. Using this fact and log-differentiating equation 2.10 produces:

$g_T=g_A=g$

Solving equation 2.15 for r and substituting the solution into equation 2.17 gives:

$$g=\frac{\delta HZ^a-\frac{\psi\rho}{\Lambda}Z}{1+\frac{\psi}{(\alpha+\beta)\Lambda}Z}=\frac{\delta HZ^{a-1}-\frac{\psi\rho}{\Lambda}}{Z^{-1}+\frac{\psi}{(\alpha+\beta)\Lambda}} \tag{2.18}$$

Equation 2.18 takes into account both supply and demand forces and denotes the general equilibrium growth rate of the economy. Because it makes no sense to have an equilibrium growth rate of output negative, it is assumed that g is nonnegative, i.e. $H\geq\frac{\psi\rho}{\Lambda\delta}Z^{1-a}$. It is worth noticing that the model is derived assuming that institutional arrangements bind the adoption of new technologies ($A\geq\psi T$). Given that A and T are nonnegative, Z must also be nonnegative ($Z=(T/A)\geq 0$). These conditions imply that $0\leq\psi Z\leq 1$. This inequality is useful for evaluating the steady-state growth rate of output of two limiting cases:

i) $\Psi Z \to 0$: Institutions bind the adoption of *any* technology. Under this assumption, the steady-state growth rate of output is given by:

$$\lim_{\psi Z \to 0} g \Big| = \lim_{\psi Z \to 0} \left[\frac{\delta H Z^{a} - \frac{\rho}{\Lambda}\psi Z}{1 + \frac{1}{(\alpha+\beta)\Lambda}\psi Z} \right] = 0$$

ii) $\psi Z \to 1$: institutions do not bind the adoption of technology and all old and newly invented intermediate inputs may be utilized in the productive process. In this case,

$$\lim_{\psi Z \to 1} g \Big| = \lim_{\psi Z \to 1} \left[\frac{\delta H Z^{a} - \frac{\rho}{\Lambda}\psi Z}{1 + \frac{1}{(\alpha+\beta)\Lambda}\psi Z} \right] = \left[\frac{\delta H Z^{a} - \frac{\rho}{\Lambda}}{1 + \frac{1}{(\alpha+\beta)\Lambda}} \right] > 0$$

The model suggests that institutional impediments to the adoption of new technologies decrease the steady state growth rate of output. On the other hand, better institutions increase the steady growth rate of output. The impact of the improvement of institutions on the steady state of growth rate of output is augmented when an economy has a relatively large stock of human capital. The results above, therefore, allow one to state the following result:

Proposition 1: At the steady state, the growth rate of output increases as the institutional quality improves $\left(\frac{\partial g}{\partial T}\Big|_{1 \geq \psi Z} > 0 \right)$.

An interesting result can be obtained by evaluating the following situation: Consider a small country[31] that faces a world with perfect and instantaneous diffusion of knowledge, such that A is identical for all countries. In other words, this

[31] A country is small in the sense that its knowledge production does not affect the world knowledge frontier.

country may potentially utilize all of the available technology in the world. Under these conditions and controlling for other determinants of income, a country with poor institutions will lag behind countries with good institutions in terms of growth of output and this gap will grow over time, implying that income convergence is ruled out. Therefore, convergence in terms of income is precluded if institutional convergence does not occur first.

Proposition 2: Controlling for diffusion of technology and other determinants of income, a country with a lower level of income and poor institutional arrangements will not converge to the levels of income extant in countries with better institutions.

The next sections further discuss the implications of the model.

2.3 Influences of Changes in Human Capital on Growth of Output

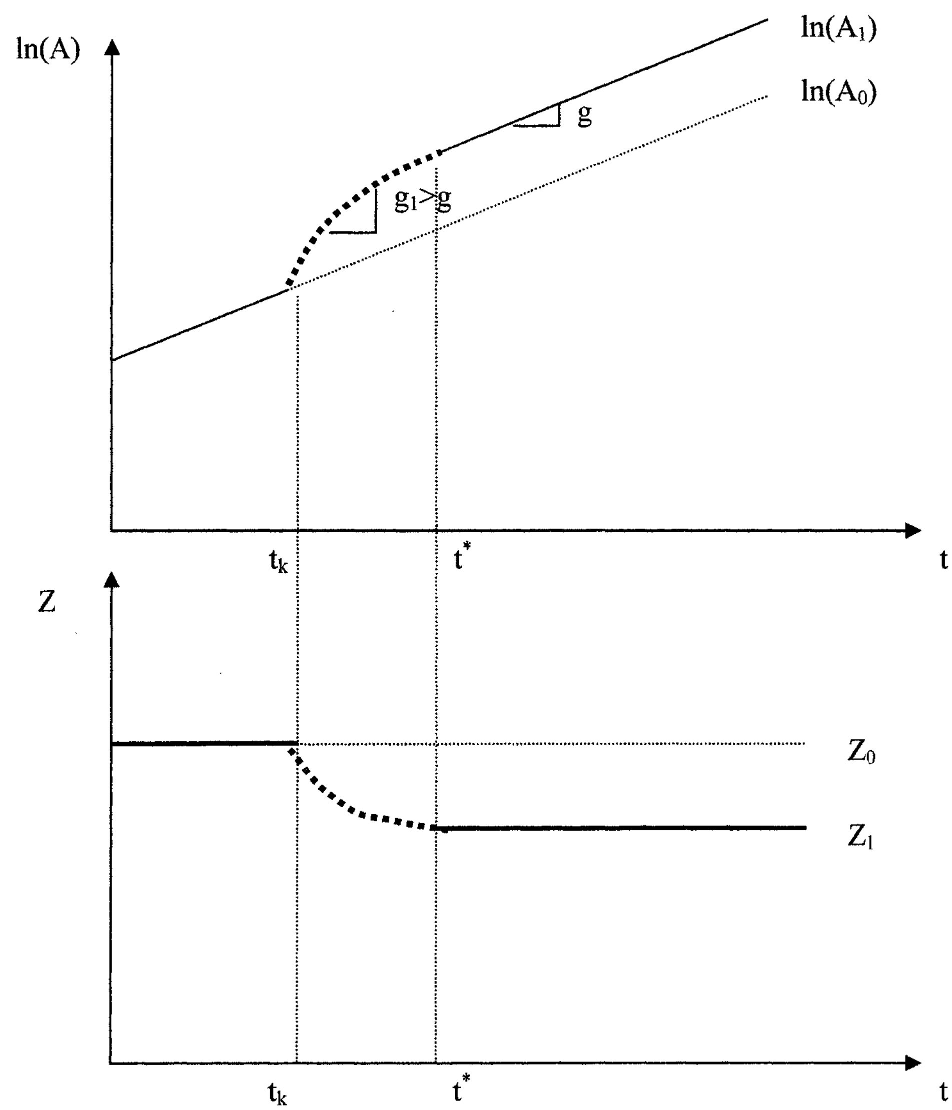
i) Institutions Bind the Adoption of New Technologies ($A \geq \psi T$)

Suppose that an economy is operating at its steady state and at time t_k, the stock of human capital increases from H_0 to H_1 once-for-all. Because equation 2.18 holds at the impact change and Z is allowed to change over time but is constant at a point in time, the growth rate of the economy must shift up to g_1 from g_0. Consequently, an increase in H will boost the short-run growth rate of output. However, the steady state growth rate of output also depends on the dynamics of Z. Because equilibrium in the labor market requires that new human capital will not be allocated in just one sector, both H_Y and H_A will increase. According to equation 2.14, at the impact change, an increase in H will cause A to grow faster than T[32].

[32] Before the change in H, T and A were growing at the same rate (see the model's solution for details).

This implies that Z will decrease over time (Figure 2.3 shows the dynamics of both A and Z). Equation 2.14 shows that a decreasing Z slows down the growth of new technologies. Z only stops shrinking when the economy returns to its long-run path of growth, where A and T grow at the same rate (g).

Figure 2.3: Impact of an Increase in H on the Time Paths of A and Z



The rationality behind these results is as follows: an increase in human capital enhances innovation in the short-run, increasing the production of new technologies. However, new technologies change the production modes and increase the complexity of the social relationships, making the existing institutional structure to become relatively obsolete. In turn, this slows down the innovation rate (g_A) and consequently slows down the growth rate of output. The economy will reach its steady state as soon as the growth rate of A equals the growth rate of T, when Z stops shrinking. Because the growth of output is driven by the growth rate of technology and institutions, this result implies that an increase in H will not affect the long-run growth rate of output. Therefore, a one-time increase in the stock of human capital positively affects the short-run growth of output, but has no effect on the steady state growth rate of the economy. Human capital will affect the long-run growth rate of the economy only if it continually increases over time.

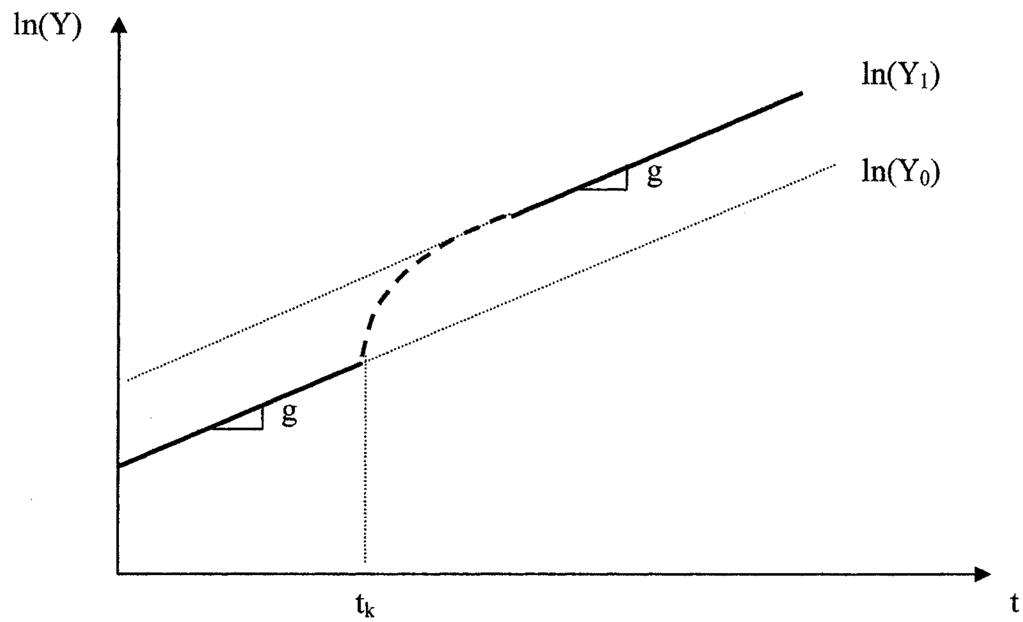
Proposition 3: An increase in the stock of human capital will increase the growth rate of output in the short-run, but this effect disappears in the long-run as the growth rate of output returns to its steady-state growth path, which is equal to the growth rate of innovation (or the growth rate of institutions).

Changes in H will affect the steady state levels of output. Solving equation 2.15 for g and substituting the solution into equation 2.17 gives:

$$r = \frac{\delta Z^{a} H + \rho(\beta + \alpha)}{(\beta + \alpha) + \frac{\psi}{\Lambda} Z} \qquad (2.19)$$

Since Z is constant at any point in time, an increase in H will lead to an increase in r in the short-run. An increase in r, according to equation 2.13, will cause the final goods sector to increase the demand for H_Y. Consequently, the level of output increases above its original long-run trend, as shown in figure 2.4. However, the results also imply that output will return to its long-run trajectory, growing at a rate of g. Therefore, a change in H has a permanent effect on levels of output.

Figure 2.4: Impact on Levels of Output



To sum up, the model predicts that a rise in the stock of human capital increases the level of output, but has no steady state output growth effects. Only sustainable growth in human capital will generate steady state growth effects.

Proposition 4: the stock of human capital should not be associated with the growth rate of output; instead, the growth rate of human capital should be associated with the growth rate of output.

ii) Institutions do not Bind the Adoption of New Technologies ($A < \psi T$)

The model developed in previous sections is suitable for evaluating the case when $A \geq \psi T$. The model needs to be solved again to analyze a situation where $A < \psi T$. To save space, only the key equilibrium conditions are reported below for the case when $A < \psi T$. Specifically, equations 2.13, 2.18 and the equilibrium interest rate are now given by:

$$H_Y = \frac{\psi}{\Lambda\delta}\frac{r}{Z^a} \qquad (2.13A)$$

$$g = \frac{\delta Z^a H - (\psi\rho/\Lambda)}{1 + \frac{\psi}{\Lambda(\alpha+\beta)}} \qquad (2.18A)$$

$$r = \frac{\delta Z^a H + \rho(\beta+\alpha)}{(\beta+\alpha) + \frac{\psi}{\Lambda}} \qquad (2.19A)$$

This case is not markedly different from the one discussed above. First, an increase in H will cause a discontinuous jump in the growth rate of the economy, g. However, the productivity gains in terms of innovation and the consequent expansion of the innovation rate is offset by the inability of the society to adapt its institutions quickly enough to the satisfy the requirements of the new technologies. This decelerates the growth rate of innovation as well as the growth rate of output, bringing the economy back toward its original steady state path. However, an increase in H leads to an increase in r, which causes an increase in the demand for H_Y, permanently augmenting the level of output. While these results are identical to the ones found under the assumption that $A \geq \psi T$, it is worth noticing that the *impact* effect on g is greater when institutions are not binding on the utilization of new technologies, that is:[33]

[33] The assumption that in the long-run the rate of innovation is at most equal to the rate of change in institutions implies that $Z \geq 1$. Therefore, under this assumption the impact effect from a change in H on equations 2.18A and 2.18 implies: $\left.\frac{\partial g}{\partial H}\right|_{A<\psi T} \geq \left.\frac{\partial g}{\partial H}\right|_{A\geq\psi T}$.

$$\left.\frac{\partial g}{\partial H}\right|_{A<\psi T} = \frac{\delta Z^{\alpha}}{1+\frac{\psi}{(\alpha+\beta)\Lambda}} \geq \left.\frac{\partial g}{\partial H}\right|_{A\geq\psi T} = \frac{\delta Z^{\alpha}}{1+\frac{\psi Z}{(\alpha+\beta)\Lambda}}$$

Therefore, the model predicts that a country with no institutional restrictions for the adoption of new technologies will grow faster than a country with such impediments. Moreover, the better the institutional arrangements, controlling for technology (i.e., larger Z), the greater the impact on growth and levels of output from a change in human capital.

This finding suggests that the return to policies aimed at improving the skills of the labor force is lowered when a country's institutional arrangements constrain the utilization of new technologies. In addition, under an endogenous process of human capital accumulation, individuals may choose to accumulate less human capital due to the differential in returns to investment in such skills.

2.4 Modeling the Links between Institutions and Human Capital

The model economy discussed above assumes that institutional changes are exogenously determined. While this assumption simplifies the model and allows one to obtain a well-behaved analytical solution, relaxing this assumption may provide valuable information on the mechanisms of economic growth. Given the fact that the growth literature emphasizes the importance of human capital accumulation for economic growth (e.g. Lucas, 1988; Romer, 1990), we relax the assumption of exogenous generated institutional changes by allowing human capital and institutional changes to interact. Specifically, we incorporate the idea that current institutions depend on human capital accumulation. Consider the following equation:

$$T(t) = \chi \int_{-\infty}^{t} H(s) e^{\eta s} ds \qquad (2.20)$$

where $\chi > 0$ accounts for all exogenous determinants of institutions other than human capital(H) and η weights the impact of human capital and other 'exogenous determinants of institutions' (χ) on current institutions[34].

The form of this equation has a long history in economic thought. Rosenberg (1963) explains Bernard Mandeville (early 1700)'s ideas on the development of good institutions as an evolutionary process dependent on generations of accumulated knowledge. "Human institutions are not to be regarded as the product of human ingenuity, much less the result of a single mind. They are, rather, the fruits of a long gradual growth process. The results of this evolution are not only contrivances beyond the ingenuity of individuals; once they have evolved, they multiple manifold the otherwise crude and limited abilities of the individual human agent... [Institutions] are the product, not of inspiration (either human or divine) but of the collective experience of the human race" (Rosenberg, 186-87) or $T(t) = \chi \int_{-\infty}^{t} H(s) e^{\eta s} ds$.

This equation implies that the current institutional arrangement is a function of current and past human capital stocks, colonial legacy and geography. For simplicity's sake, assume that the stock of human capital is constant over time, that is, $H(t)=H_0$, so equation 2.20 can be easily solved:

$$T(t) = \frac{\chi H_0 e^{\eta t}}{\eta} \qquad (2.21)$$

[34] To conform to the literature (e.g. La Porta *et al.*, 1999; Acemoglu *et al.*, 2001 and 2004), χ can be specified as a function of geographically related variables and the colonial legacy (e.g. origin of the legal system, colonization type, etc).

$$g_T = \frac{\dot{T}}{T} = \eta \tag{2.22}$$

Equation 2.21 captures the idea that initial conditions are important for explaining the current state of institutions. First, the 'other' exogenous determinants of institutions (χ) accounts for the historical factors that may have had influence on current institutions. In addition, by controlling for 'other' exogenous determinants of institutions (χ), this equation states that a country that started with a larger stock of human capital would be able to develop better 'early' institutional arrangements, which ultimately reflects in the quality of current institutions because of the *persistence effect*. The *persistence effect* is the idea that once institutions are built, economic and political mechanisms generated as a byproduct of those institutions will set constraints on future institutional changes and those early institutional arrangements will persist over time (Engerman and Sokoloff, 1997; La Porta, *et al.*, 1999; Acemoglu *et al.*, 2000).[35]

Equation 2.22 implies that the growth rate of institutions depends on the weight that historical determinants and previously accumulated human capital have in determining current institutions. Specifically, a larger η will lead to a greater impact of the historical legacy on current institutions. For instance, a large η implies that a country's initial stock of human capital would have a significant impact on current institutions. Therefore, this model makes the case that the growth rate of current institutions depends on the weight that historical determinants and previously accumulated human capital have on current institutions.

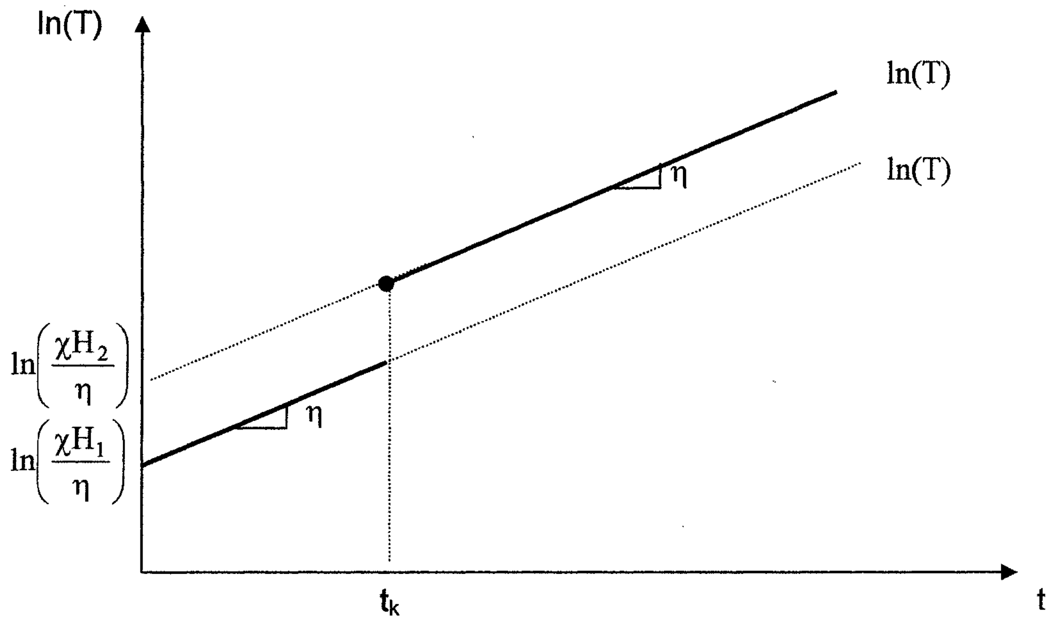
[35] For a detailed discussion of this subject, see Acemoglu *et al.* (2000).

While this formulation is simplistic and ignores much of the dynamics between institutional change and human capital accumulation, it allows us to evaluate the effects of a change on human capital accumulation patterns on both institutions and economic growth. For instance, consider the case where institutions bind the adoption of new technologies (i.e., $A \geq \psi T$). The impact of a once-for-all increase in H at time t_k on the time paths of g and Z is similar to that found in the previous sections. According to equations 2.21 and 2.22, an increase in the stock of human capital from H_1 to H_2, at time t_k will discontinuously shift the level of institutions (see Figure 2.3), but will have no effect on the growth rate of institutions. Because the growth rate of institutions is the deepest determinant of the growth rate of output, a once-and-for-all increase in H will have no long-run effect on the growth rate of output. Therefore, incorporating the idea that human capital is positively related to institutional changes does not affect the main result found in the previous sections that discrete changes in the stock of human capital will affect the short-run run growth of output, but have no steady state effect on growth. Only a sustainable increase in the stock of human capital will affect the steady state growth rate of output.

2.5. Discussion

The analysis above shows that the long-run growth of the economy is intrinsically linked to the growth rate of institutions. This is a direct implication of the specification of the knowledge production function because high-quality institutions boost innovation, but innovation changes the institutional arrangements necessary for keeping the growth rate of innovation constant, that is; innovation causes current institutions to become obsolete.

Figure 2.5: Current Institutions and Initial Conditions



The implications of the assumption that institutional arrangements bind the utilization of new technologies are not straightforward. The model suggests that this assumption will not affect the long-run growth of the economy. In either case, whether institutions bind or whether institutions do not bind the adoption of technologies, the long-run growth of output is determined by the long-run growth rate of innovation, which is equal to the growth rate of institutions. However, the short-run growth rate of the economy as well as the *level* of output are affected only if institutional arrangements constrain the adoption of new technologies. In the short-run, an economy whose institutional arrangements are not changing at the rate needed to follow the path of technological change will experience a slowdown in its rate of innovation and consequently a slowdown in its growth rate of output. In addition, the lack of proper institutions will retard or prevent the utilization of newly invented inputs in the productive process, leading to relatively lower levels of output. Therefore, controlling for all other determinants of income, countries or regions that experience institutional constraints on the adoption of newly invented technologies are expected to have lower levels of output compared to countries where institutions do not constrain the adoption of new technologies.

The model also predicts that human capital is an important determinant of both institutions and output. Despite the fact that human capital does not affect the long-run growth rate of the economy, it directly influences the level of output. Therefore, differences in the stock of human capital are expected to explain income level differentials across countries, but not growth differentials across countries. This is broadly consistent with the predictions of the Uzawa (1965), Lucas (1988) and Jones (1995) theoretical models, which suggest that the growth rate of output is proportional to the growth rate of human capital. However, it contradicts the predictions of the Romer (1990) and Rebelo (1991) models, which suggest that the level of human capital is associated with the growth rate of the economy.

2.6 Conclusion

This chapter evaluates the influence of institutions on economic performance by extending a standard growth model. Specifically, this chapter presents a formal model that explicitly examines how institutions affect technical innovation and economic growth. While the model is simplistic, makes strong assumptions about the way that an economy works and certainly is not a complete theory of growth and institutions, it is important because it contributes to fill a gap in the growth literature and provides valuable insights concerning the dynamics and the interactions among institutions, innovation, income levels and income growth.

A major prediction of the theoretical model is that innovation depends on a country's ability to improve its institutional arrangements as new technologies become available. The logic behind this is that innovation may change the society's production structure, causing current institutions to become relatively obsolete. In addition, the model posits that the long-run growth rate of output is determined by the growth rate of innovation, which is ultimately a function of a society's institutions. Therefore, a testable implication of this model is that better institutional arrangements boost innovation and thus economic growth.

The model also makes the case that the lack of proper institutions will retard or prevent the utilization of newly invented inputs in the productive process, leading to relatively lower levels of output. Therefore, controlling for all other determinants of income, countries or regions that experience institutional constraints on the adoption of newly invented technologies will be expected to lag behind in terms of growth and levels of output per capita and this gap will not vanish over time.

The model also supports the argument that human capital is an important input for shaping institutions and promoting innovation. However, it suggests that human capital has no *growth effect*, that is; an increase in the stock of human capital will not affect the long-run growth rate of the economy. Only sustainable growth in human capital generates growth effects in output. In other words, this model predicts that in the steady state the stock of human capital should not be associated with the growth rate of output; rather the *growth* rate of human capital should be associated with the *growth* rate of output.

CHAPTER 3

INNOVATION AND INSTITUTIONS: AN EMPIRICAL APPRAISAL

3.1 Introduction

This chapter presents an econometric model for technical innovation derived from the theoretical model developed in chapter 2, which gives simple testable predictions about how institutions influence technical innovation. Specifically, I test the prediction that institutions boost technical innovation (patent production) and also assess how different kinds of institutions (Control of Corruption, Rule of Law, Regulatory Quality and Risk of Expropriation) affect the production of patents. The empirical strategy consists of using cross-country data and the instrumental variable approach in order to investigate these questions.

The publication of the breakthrough paper of Kormendi and Meguire (1985) and the availability of datasets on institutional quality[36] greatly contributed to the opening of a new front of empirical research aimed at evaluating the influences of institutional-related variables on the levels and growth rates of output per capita (e.g. Barro, 1991; Knack and Keefer, 1995; Mauro, 1995; Hall and Jones, 1999; Acemoglu *et al.* 2001 and 2004; and McArthur and Sachs, 2001). Even so, very little has been done in terms of evaluating empirically the influences of institutional quality

[36] For example, datasets from Gastil (1979), the International Country Risk Guide (ICRG), the Transparency International (TI), Business Environmental Risk Intelligence (BERI) and Kaufmann, Kraay and Mastruzzi (2003) are now available.

on technical innovation. This study endeavors to contribute to this literature by examining in more detail the links between institutions and technical innovation.

This chapter also presents a brief discussion of the challenges and limitations inherent in research that attempts to examine empirically the association between innovation and institutions. A workable way to proxy for knowledge creation is suggested and implemented in our empirical analysis. Moreover, while I acknowledge that the data used to conduct this analysis is subject to imperfections (e.g. measurement error); this study contributes to the literature by conducting an empirical examination on the links between innovation and institutions. In addition, follow-up discussions of the formulation of the empirical model and discussions on the results of the empirical analysis may stimulate a debate on an important question in the growth literature: which is the most favorable institutional arrangement to enhance innovation and economic growth? (Sala-I-Martin, 2002; Rodrik 2000; Huang and Xu, 1999; Dawson, 1998).

The rest of the chapter is organized as follows: Section 2 briefly revisits the discussion initiated in chapter 1 about the intrinsic challenges in conducting empirical evaluation on institutions and outlines the difficulties in measuring innovation. Section 2 also presents a workable way to proxy for knowledge creation. Section 3 presents the data. Section 4 evaluates the empirical model and discusses the estimates. Section 5 reports the conclusion and suggestions for improving this empirical analysis.

3.2 Background

As shown in chapter 1, it is standard procedure in empirical growth literature to include institutions in the growth regressions as an ordinary explanatory variable of steady state per capita output (e.g. Barro, 1991; Mauro, 1995; Knack and Keefer, 1995 and 1997; Oliva and Rivera-Batiz, 2002; Esfahani and Ramirez, 2003; Dollar and Kraay; 2003). This approach implicitly assumes that institutions affect the productivity of factors of production and implies that countries with better institutional arrangements will experience faster growth rates of per capita output.

Despite the appeal of this argument, most of the empirical analyses (see Table B.1) report only weak evidence that better institutional arrangement leads to faster growth (e.g. Levine and Renelt, 1992; Esfahani and Ramirez, 2003). Moreover, there is a fundamental problem in this analysis. Kormendi and Meguire (1985) regression-type cannot provide evidence that institutions affect long-run growth rates of the economy. The dependent variable (growth rates of output per capita) only accounts for the transitional dynamics of per capita income over a specific period of time and cannot be interpreted as steady state growth rate of per capita income. In other words, a statistically significant coefficient on an institutional measure supports the argument that institutions have a positive effect on steady state levels of per capita income and on transitional growth rates of output per capita, but one cannot jump to the conclusion that this implies steady-state growth effects. In addition, the studies cited above provide no formal theoretical model or empirical analysis that explains the mechanisms by which better institutions translate into faster growth rates of per capita output.

Furthermore, economists are increasingly aware that institutions affect the process of knowledge accumulation (e.g. Rodrik, 2000; Sala-I-Martin, 2002; Gradstein, 2004) and consequently that institutions affect the long-run growth of output. Therefore, if one wants not only to diagnose the problem of growth, but also search for ways to stimulate growth, it is very important to understand how institutions and innovation are linked. To my knowledge, just a few growth models *explicitly* address this issue (e.g. Huang and Xu, 1999; Fedderke, 2001; Gradstein, 2004) and no empirical cross-country analysis directly exploits such a link.

3.2.1 An Empirical Model of Innovation

The model developed in chapter 2 yields a dynamic equation (equation 2.10) that suggests that changes in technology are associated with institutional arrangements. However, the knowledge production function is a nonlinear differential equation and cannot be directly estimated. One can overcome this obstacle by rewriting it as a discrete equation:

$$\Delta A_t = A_t - A_{t-1} = \delta A_{t-1}^{1-a} H_{At-1} T^a \qquad (3.1)$$

where ΔA measures innovation, H_A is personnel engaged in R&D, T is institutions and δ and *a* are parameters. Equation 3.1 can be transformed to linearity by taking logarithms of both sides. Adding an error term and reparametrizing the model generates:

$$\ln(\Delta A_t) = \beta_0 + \beta_1 \ln(H_{Ait-1}) + \beta_2 \ln(A_{it-1}) + \beta_3 \hat{T} + v_{it} \qquad (3.2)$$

where t represents time, i indexes observations, $\hat{T}$ denotes the logarithmic transformation of T and v is random disturbance. This empirical equation is specified in terms of $\hat{T}$ rather than ln(T) because i) this study uses standardized measures of institutions, which have zero mean and may assume negative values, preventing the use of logarithmic transformations and ii) the true measure of institutions is not known, so $\hat{T}$ is used as a proxy for ln(T)[37]. This procedure has become standard in the literature (e.g. Dollar and Kraay, 2003; Acemoglu *et al.*, 2000 and 2004; La Porta *et al.,* 1999; Hall and Jones, 1999). Despite the apparent simplicity of equation 3.2, its estimation may be very difficult due to endogeneity and the difficulties in measuring A and T. These issues are examined below.

i) Measuring Institutions and Innovation

This study follows a growing branch of the growth literature that suggests subjective institutional measures provide relevant information about growth-promoting institutional arrangements and thus can be used as proxies for institutions (e.g. Kormendi and Meguire, 1985; Mauro, 1995; Moers, 1999; Hall and Jones, 1999; McArthur and Sachs, 2001; Acemoglu *et al.*, 2001; Dollar and Kraay, 2003). Specifically, this study uses four subjective measures of institutions: i) Rule of Law (RL), ii) Control of Corruption (C), iii) Regulatory Quality (RQ) and iv) Risk of Expropriation. Section 3 provides more details about these variables.

While innovation can be incorporated into theoretical models and is widely acknowledged as a key determinant of economic growth, difficulties in finding its empirical counterpart has limited empirical examinations (Romer, 2002). However, recent studies suggest that one can use "patents to create systematic measures of intangibles [innovation/knowledge] that drive economic growth" (Romer, 2002: ix, Foreword).

Schmookler (1966), Griliches (1979) and Griliches (1984) are the pioneers in using patent count as a measure of innovation. These authors also provide the

[37] See the next section for a detailed discussion about measurement error in T and the econometric strategy used to address this problem.

foundations for the specification of a production function of knowledge as a function of R&D expenditure and the existing stock of knowledge. These contributions have opened a new and promising front of research, allowing researchers to use "patent data to get an empirical handle on quantifying the 'importance' or 'value' of innovations, measuring flows of technological knowledge and characterizing the technological development and impact of particular institutions and countries" (Jaffe and Trajtenberg, 2002:2).

The use of patent count as a measure of innovation has three main limitations: i) not all inventions are patented because some do not meet certain criteria necessary for an invention to be patentable, even though they increase the stock of knowledge; ii) patentable innovations may not be patented because economic agents may strategically "rely on secrecy or other means of appropriability" (Jaffe and Trajtenberg (2002: 4) and iii) not all patents have the same *quality*. If the first and second limitations were present, the use of patents would underestimate the actual production of knowledge/innovation. In addition, the second problem may be aggravated in countries with poor protection of private property rights and fragile legal systems. In this case, it may be optimal for innovators to choose to rely on secrecy to protect their inventions. However, "it is widely believed that these limitations [i and ii] are not too severe, but that remains an open empirical issue" (Jaffe and Trajtenberg, 2002: 56). In addition, one could invoke the 'law of large number" and argue that the third limitation will not play any role given a significantly large sample size (Griliches, 1990).

Despite these drawbacks the most influential writers in the field of economic growth and innovation have supported the use of patent counts to measure innovation [or change in the stock of knowledge] (e.g. Griliches, 1979, 1990, 1994;

Aghion and Howitt, 1998; Paul Romer, 2002 and Jaffe and Trajtenberg, 2002). This has influenced other researchers to utilize patents to evaluate economic growth issues (e.g. Sedgley and Elmslie, 2004; Sedgley, 2004). This study follows this approach and, albeit imperfect, patent counts are utilized as a measure for innovation (A). Specifically, the accumulated number of patents granted over a period is utilized as a proxy for knowledge production/innovation, that is:

$$\Delta A_{iT} = A_{iT} - A_{i0} = \sum_{t=0}^{T} p_{it} = P_{iT}$$

where p denotes the number of patents granted to country *i* and *t* indexes time.

Substituting the equation above into equation 3.2 generates:

$$\ln(P_{iT}) = \beta_0 + \beta_1 \ln(H_{Ai0}) + \beta_2 \ln(A_{i0}) + \beta_3 \hat{T}_i + \nu_{it} \qquad (3.3)$$

It is worth noticing that equation 3.3 differs from the empirical specification of previous studies that estimate a production function for patents. For instance, Griliches (1990) and Jaffe and Lerner (2002) specify an equation for patents as a function of R&D expenditure by different economic agents (universities, firms and government) using the previous production of patents as a proxy for existing stock of knowledge. The use of personnel engaged in R&D instead of R&D expenditure represents a change of the focus (from input costs to the input itself), but as shown by Griliches (1994), these variables are highly correlated and should contain comparable information about the production process. Moreover, equation 3.3 is an expanded version of the Romer (1990) and Jones (1995) knowledge production functions. More precisely, it explicitly highlights the significant role that institutional arrangements have in the process of knowledge production. To my knowledge, no cross-country study has evaluated the effect of institutions on the production of patents.

ii) Measuring the Stock of Knowledge (A)

The estimation of the patent production equation 3.3 requires an objective measure of the stock of knowledge. While patent production can be used to measure innovation from time t to T, one cannot create a measure of the stock of knowledge by using just data on patent production. Sedgley (2004) proposes to estimate the initial stock of knowledge by utilizing the ratio of total patents issued during a specific period over the growth of the number of volumes in the collection of the national library during the same period. Sedgley (2004) applies this method to conduct a time-series evaluation of innovation in the U.S. However, data limitation prevents the use of this procedure here. Moreover, in this study the key role of the stock of knowledge (A) is to measure a country's share of world knowledge and determine its position on a hypothetical world knowledge frontier. I propose to build a proxy for the stock of knowledge based on a relative measure of book production. The rational for using this method is discussed below.

For simplicity's sake, it is useful to distinguish two kinds of knowledge: *explicit* knowledge and *tacit* knowledge. Explicit knowledge refers to knowledge that can be easily systematized and stored in printed material or multimedia so that it can be easily transmitted across individuals and the scholarly community. Tacit knowledge is knowledge internalized by individuals and rooted in individual experience, personal beliefs, perspectives and values[38]. This kind of knowledge is hard to

[38] "Tacit knowledge is not available as a text. . . .It involves intangible factors embedded in personal beliefs, experiences and values." Pan and Scarbrough (1999:362).

formalize and convert into media (words or models) that can be easily shared and understood by other individuals (Polanyi, 1966, Zoltan and Perner, 1999; Clark, 2000).

While tacit knowledge can be very important at the firm level, since it may translate into competitive advantage (Laszlo and Laszlo, 2002), explicit knowledge, whether privately acquired and/or public knowledge, is the key force in the innovation process and also seems to be a closer parallel to the concept of knowledge found in the endogenous growth literature. For example, the idea that knowledge production in a region may spillover into neighboring regions can only be supported if the new knowledge is made available to economic agents in neighboring areas.

Because there are a variety of modes for communicating and exchanging knowledge across individuals, such as books, reference material, television, internet, etc., there exist several difficulties in moving from a theoretical definition of knowledge to a quantitative measure of knowledge even if we restrict our attention to explicit knowledge. However, it seems plausible to assume that much of the explicit knowledge available to a society is contained in its literary production. As a result of the book production revolution in the middle of the fifteenth century, a "much greater proportion of the population has the chance to acquire education, culture and information" (Kipphan, 2001; 5). Moreover, Cochran (2001) argues that the "epoch of printing ... transmuted and magnified the inscribing powers of writing, creating previously unimaginable possibilities to organize and institutionalize *secular knowledge*" (Cochran, 2001: 3, emphasis added).

These thoughts support the idea that the stock of knowledge can be proxied by the country's share of world book production (new titles). The logic behind this formulation is that a significant share of a society's knowledge is transmitted across individuals and from generation to generation through books. While a patent is a tangible measure of innovation, book production is used a concrete measure of the current knowledge stock. In other words, a highly knowledgeable society is expected to produce a large number of book titles and consequently should have a larger share of world book production. A country's share of world book production will be used as a proxy for the starting stock of knowledge in the regression analysis. For robustness' purposes, I use two measures: the share of applied and pure sciences book production and the share of all new titles.

iii) Endogeneity

Another problem in estimating equation 3.3 is the potential endogeneity of the right-hand variables. In a cross-section of countries one can address that by using the initial values of H and A, which are predetermined and uncorrelated with the error term. However, T is measured contemporaneously and is likely to be endogenous. This undermines the reliability of estimates obtained by Ordinary Least Squares (OLS). To eliminate this problem, a set of instruments for institutions, which needs to be correlated with current institutions but uncorrelated with innovation should be used.

The empirical literature on institutions suggests that much of the variation in current institutions can be explained by geography-related variables and historically determined factors such as colonial status and origin of the legal system (Hall and Jones, 1999; La Porta *et al.,* 1999; McArthur and Sachs, 2001; Acemoglu *et al.,* 2001 and 2004). Following this approach and considering the theoretical model developed in chapter 2 (see equation 2.21), current institutions are modeled as follows:

$$\hat{T}_i = \delta_1 + \delta_2 H_{it0} + \delta_3 G_i + \delta_3 R + \eta_i \tag{3.4}$$

where $\hat{T}$ denotes institutions, H_{it0} denotes the initial endowment of human capital, G is a matrix of geographical variables, R is a matrix of "other" exogenous determinants of institutions (e.g., colonial status or legal origin) and η is a random disturbance.

Equation 3.4 is very similar to the empirical specification for institutions found in La Porta *et al.* (1999), McArthur and Sachs (2001) and Acemoglu *et al.* (2000, 2001 and 2004). However, this study proposes to add previously accumulated human capital as a determinant of current institutions. More specifically, this equation states that the initial level of human capital is an important input in the shaping of early institutional arrangements. This proposition is motivated by the work of Bernard Mandeville (early 1700), who argues that the development of institutions is an evolutionary process depending on generations of accumulated knowledge[39].

Acemoglu *et al.* (2000, 2001 and 2004) argue that early institutions were affected by geography because the colonization process endogenously responded to certain environment conditions, creating institutions specific to the colony's geography. Specifically, colonies characterized by a heavy burden of infectious disease (e.g. malaria and yellow fever) discouraged the formation of European-type settlements. In these non-settler colonies "... colonial powers set-up authoritarian and absolutist states, with the purpose of solidifying their control and facilitating the extraction of resources" (Acemoglu *et al.*, 2000:10). As a result, this form of

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[39] See Rosenberg (1963) for a detailed discussion on Bernard Mandeville's ideas.

colonization "... did not introduce much protection for private property, nor did they provide checks and balances against government expropriation" (Acemoglu *et al.*, 2000:2).

On the other hand, geographically advantaged settlement colonies were relatively free to engage in processes that replicated in some way European social arrangements, which ultimately helped to develop better institutions and generate a system that protected private property rights in these colonies (Denoon, 1983; Acemoglu *et al.*, 2000). Denoon (1983) argues that many settler colonies (e.g. US, Canada, Australia and New Zealand) had representative institutions during the colonial period and that those institutions constituted the basis of the modern institutions that emerged in those countries. Engerman and Sokoloff (2003), Gallup *et al.*, (1999) and Sachs (2000) also support the view that adverse geography negatively affects the development of growth-promoting institutions. The influences of geography on institutions have been tested by including variables such as absolute latitude, mean temperature and proportion of land near a seacoast in the regressions used to explain current institutions.

It has also been argued that the historically predetermined origin of the legal system may have had a very important role in determining a country's current institutional arrangements. According to La Porta *et al.* (1999), "[a] civil legal tradition, then, can be taken as a proxy for an intent to build institutions to further the power of the State" (p.232). The different civil law systems were spread throughout "the world through conquest, colonization, imitation and voluntary adoption" (La Porta *et al.*, 1999:231). La Porta *et al.* (1999) suggest categorizing the legal systems into 5 groups: common law (British), French civil law (France), German civil law (German), Scandinavian civil law (Scandinavia) and socialist law (Soviet Union).

Each of these legal systems is based on a set of principles that demarcate the role of the government in protecting property rights, defining regulatory systems and instituting political freedom. For instance, from a theoretical viewpoint, countries whose legal systems are based on the common law tradition are expected to be less interventionist and favor political and economic freedom when compared to countries whose legal system is based on one of the other legal traditions. Countries with socialist laws tend to have protectionist governments and limited political freedom (La Porta *et al.,* 1999).

Therefore, considering that equation 3.4 well explains current institutions, then equations 3.3 and 3.4 form a system of equations - where T and P are endogenous - that links patent production (innovation) to institutions. This specification implies that the origin of the legal system, geographically related variables and the initial human capital endowment determine current institutions, but are uncorrelated with current production of patents (innovation). This setup may be contentious because one could argue that these variables are directly correlated with the production of patents even after controlling for institutions. This would imply that the system is not properly identified. However, it seems to be reasonable to presuppose that the colonial legacy directly influences current institutions, but has no direct effect on current innovation (patent production). The colonial legacy variables should not be correlated with equation 3.3's error term. In other words, the innovation effect from the colonial legacy is felt through the impact on current institutions rather than directly influencing current innovation. Additionally, as argued previously, the initial human capital endowment may have affected early institutions, which ultimately shaped current institutions. Because current innovation is a function of contemporary institutions this variable should have an indirect effect on current patent production via current institutions. Finally, geography-related variables may have a direct effect on current institutions as well as a direct effect on innovation. Because this is an empirical question, it is examined together with the estimation of the model. These observations constitute, in fact, an empirical issue that can be evaluated by testing if such variables satisfy the requirements for valid instruments. This study uses the Hansen's J test to examine this issue.

3.3 Data and Measurement Error

The empirical analysis is conducted using four different measures of institutions. Rule of Law (RL), Control of Corruption (C) and Regulatory Quality (RQ) are calculated as the average index through the time periods 1996, 1998, 2000 and 2002. These variables are from a recent dataset developed by Kaufmann *et al.* (2003), which covers 199 countries. These measures of institutions "are based on several hundred variables measuring perceptions of governance, drawn from 25 separate data sources constructed by 18 different organizations". Specifically, Regulatory Quality "includes measures of the incidence of market-unfriendly policies such as price controls or inadequate bank supervision, as well as perceptions of the burdens imposed by excessive regulation in areas such as foreign trade and business development" (Kaufmann *et al.,* 2003:3). Rule of Law includes "several indicators which measure the extent to which agents have confidence in and abide by the rules of society. These include perceptions of the incidence of crime, the effectiveness and predictability of the judiciary and the enforceability of contracts. Together, these indicators measure the success of a society in developing an environment in which fair and predictable rules form the basis for economic and social interactions and importantly, the extent to which property rights are protected"

(Kaufmann *et al.*, 2003:3). Control of Corruption "measures perceptions of corruption, conventionally defined as the exercise of public power for private gain.... The presence of corruption is often a manifestation of a lack of respect of both the corrupter (typically a private citizen or firm) and the corrupted (typically a public official or politician) for the rules which govern their interactions and hence represents a failure of governance according to our definition" (Kaufmann *et al.*, 2003:4).

The Rule of Law, Control of Corruption and Regulatory Quality indexes range between -2.5 and 2.5, with higher scores indicating better institutional arrangements.

The fourth measure of institutional quality, EXPRO, is a proxy for market institutions and measures the risk of confiscation and forced nationalization. It is calculated as the average value for each country over the period 1985-1995 and rages between 0 and 10 with higher scores representing better institutions and thus lower risk of confiscation or forced nationalization. This variable is originally from Political Risk Services, but it was taken from McArthur and Sachs (2001).

The data on patents is from the World Bank and the United States Patent and Trademark Office (USPTO). The USPTO provides information about the numbers of patents granted to non-residents back to the 1970s, that is, inventions created in countries other than the US whose inventors wish to patent their ideas in the US market. Non-resident patenting suggests that those inventions have some non-negligible economic value and may embody a valuable contribution to the stock of knowledge. Therefore, a proxy for innovation using USPTO data can be defined as follows:

$$\Delta A_i^{USPTO} = A_{i2003} - A_{i1970} = \sum_{t=1970}^{2003} p_{it}^{USPTO} = P_i^{USPTO}$$

where p denotes the number of patents granted to country *i* and *t* indexes times.

The World Bank makes available data on patents granted by each country's patent office to residents from 1995 to 2001. This data is used to generate another proxy for innovation between 1995 and 2001.

$$\Delta A_i^{WB} = A_{i2001} - A_{i1995} = \sum_{t=1995}^{2001} p_{it}^{WB} = P_i^{WB}$$

Despite the fact that patent counts greatly differ across these datasets; there is a 0.81 correlation between the natural logarithms of P_i^{USPTO} and P_i^{WB} for the period 1995-2001 and a 0.79 correlation between these measures using all available data (USPTO: 1970-2003 and World Bank: 1995-2001). The model is estimated using both the USPTO and World Bank datasets in order to make the results more robust. This requires running regressions for each dataset, which demands collecting data that match the time periods for which the statistics on patents are available.

As previously discussed, equation 3.3 can be only estimated if an objective measure of the initial stock of knowledge is provided and this study proposes a proxy for the stock of knowledge based on book production. Data on book production are from several years of the UNESCO Statistical Yearbook and defined as the number of book titles produced (non-periodical publications) by each country. The statistics include book production in applied sciences, pure sciences, social sciences, philosophy, arts, geography, history and generalities. In a cross-section analysis such as the one undertaken in this study, the initial values play a key role in determining the parameter estimates. In order to minimize noise from a single year data the calculations are made using the average number of books produced over a five years period. In a few cases, the statistics are not available for all five years during the time period considered and the average is calculated using the available information. Specifically, A_0 is calculated as follows:

$$A_{0,i} = \frac{\sum_{t=1968}^{1972} B_{t,i} \Big/ n_i}{\sum_{t=1968}^{1972} B_{t,US} \Big/ n_{US}}$$

where B denotes yearly book title production, i indexes countries, t indexes time and n denotes the number of years for which the data is available. This variable can be interpreted as the share of average yearly book production relative to book production in the United States. As previously discussed, this variable is intended to proxy the initial stock of knowledge. To conform to the availability of the patent data, this variable is measured over 1968 to 1972 (bookshare6872) and over 1995 to 1999 (bookshare9599). Moreover, two alternative measures are utilized: the share of all new titles produced and the share of applied and pure sciences book production.

Personnel engaged in R&D is measured as the total number of scientists, engineers, technicians and supporting staff engaged in research and development. The data on personnel is expressed as a full-time equivalent. This variable is from several years of the UNESCO Statistical Yearbook. The data is not comprehensive in the sense that it does not provide a large cross-section of countries for the same year. In numerous cases, the statistics are available just for a few years during the time period considered. Averages over a five years period are utilized to maximize the sample size. Specifically,

$$H_{A0,i} = \sum_{t=1968}^{1972} L_{t,i} \Big/ n_i$$

where L denotes labor force engaged in R&D, i indexes countries, t indexes time and $n \leq 5$ denotes the number of years for which the data is available. This variable is measured over 1968 to 1972 (rdperso68) and over 1995 to 2001 (rdperson95).

The idea that the development of institutions is an evolutionary process depending on previously accumulated knowledge is accounted for in the empirical model by including a variable that measures human capital accumulation in the early 20th century. This variable is calculated as the number of students in school in 1920 per squared kilometer. Data on students enrolled in primary and secondary schools in early 20th century is from Mitchell (2003a, 2003b, 2003c). Mitchell provides these statistics back to the eighteenth century only for a few countries. A representative cross-country sample can be only collected around 1920. Mitchell reports the number of children enrolled in primary and secondary schools for 68 countries in 1920 and statistics for 52 countries around the 1930s, which allows us to estimate the number of children in schools in 1920[40]. Therefore, the full sample has 120 countries. The country area, which is needed to calculate the schooling density variable, is from the United Nations and based upon the current geopolitical arrangement. Countries that experienced changes in their boundaries, such as the former URSS republics, Paraguay, Peru, Bolivia, India, Ivory Coast, Mali, Mauritania, Algeria and Zaire were not included in the regression analysis[41].

The geographic variables are taken from McArthur and Sachs (2001) and La Porta *et al. (1999).* It is used i) mean temperature (Meantemp), which measure the

[40] I use the geometric growth rates in the estimations. For instance, if a country has data on enrollment between 1930 and 1940, the geometric growth rate between these periods is utilized to estimate enrollment back to 1920.

[41] In fact, these countries were not included in our analysis because of missing data or simply because they did not exist back to the beginning of the 20 century.

1987 mean annual temperature in degrees Celsius; ii) coastal land (lt 100 km), which quantifies the proportion of land area within 100 km of the coast and iii) latitude, which quantifies the absolute value of the latitude, is scaled to take values between 0 and 1. This variable is taken from La Porta *et al.* (1999).

The colonial legacy is measured by a set of dummy variables that identify the origin of a country's legal system. Specifically, these dummies identify if the origin of the legal system is English, French, German, Scandinavian, or Socialist. These variables were taken from La Porta *et al.* (1999)[42].

Measurement error

Almost all economic variables are measured with error and this problem is augmented in this study due to the nature of the variables been studied. If an explanatory variable is measured with error, it is necessarily correlated with the error term. In the presence of measurement error OLS estimates will be biased and inconsistent (Davidson and MacKinnon, 1993). According to Hall and Jones (1999), this problem can be addressed together with the endogeneity issue by using the IV estimator. Consider that institutions are measured with an error, such that:

$$\hat{\mathrm{T}} = \overline{\mathrm{T}} + \mu \tag{3.5}$$

where $\hat{\mathrm{T}}$ is unobserved institutions, $\overline{\mathrm{T}}$ is measured institutions and μ is the measurement error. Substituting equation 3.5 into equation 3.4 gives:

$$\ln(\mathrm{P}_{\mathrm{iT}}) = \beta_0 + \beta_1 \ln(\mathrm{H}_{\mathrm{Ai0}}) + \beta_2 \ln(\mathrm{A}_{\mathrm{i0}}) + \beta_3 \overline{\mathrm{T}}_{\mathrm{i}} + \beta_3 \mu + v_{\mathrm{it}} \tag{3.6}$$

[42] According to La Porta *et al.* (1999), this variable is a more direct measure of the colonial status of a country and overcomes difficulties in identifying the colonial status of particular countries. "For example, Barro (1996b) does not classify Hungary, Czechoslovakia, or Italy as former colonies, even though each was at time (at least partially) controlled by the Habsburg empire and the former two were arguably colonized by the Soviet Union as well." (La Porta *et al.*, 1999:265).

The explanatory variables from equation 3.3 and 3.4 can be stacked in matrices $Z=[H_{A0} \quad A_0]$ and $X=[H_0 \quad G \quad R]$ respectively. If X is a valid instrument for $\overline{T}$ then $E[X'v]=0$. Assuming that μ is uncorrelated with v, Z and X; β_3 is identified by the orthogonality conditions and both the measurement error and the endogeneity concerns are addressed.

3.4 Regression Analysis

Table F.1 presents descriptive statistics for the variables utilized in this study. The differences in the sample size reported in this table are the result of missing data. While we have data on institutional measures for about 200 countries, we only have data on patent count (USPTO) for about 100 countries. The regressions were run using all available data.

Table F.2 and Figures G.1-G.4 show that patent production is strongly correlated with all four institutional measures. For example, Figure G.1 plots patent production using the USPTO data between 1970 and 2003 and the rule of law index. It shows that the countries with the highest measures of rule of law are the USA, Germany and Japan, which are among the countries with the highest levels of patent production. On the other hand, Liberia, Democratic Republic of Congo and Iraq have the lowest measures of rule of law and are also among the countries with lowest patent production. This positive association between Rule of Law and patent production is also found when we use other measures of institutions, such as control of corruption, regulatory quality and the risk of expropriation index (see Figures G.2, G.3 and G.4 in Appendix G).

We use regression analysis to test if the positive relationship between institutions and patent production holds as we account for other factors that influence patent production. Several alternative specifications and different methods of estimation are utilized to evaluate the robustness of the results. We follow Acemoglu *et al.* (2001 and 2004) and La Porta *et al.* (1999) and estimate equation 3.4 using OLS. Subsequently, equation 3.5 is estimated using OLS and the 2SLS-IV methods.

3.4.1 Determinants of Institutions

Despite the fact that appraising the determinants of institutions is not the primary goal of this study, our model of patent production requires finding suitable instruments for institutions. This necessitates at least some evaluation of the determinants of institutions[43].

Tables F.3 and F.4 provide the estimates of equation 3.4 using the different four institutional measures. The dependent variable in models 1 thru 4, 5 thru 8, 9 thru 12 and 13 thru 16 are Control of Corruption, Rule of Law, Regulatory Quality and Risk of Expropriation, respectively. The adjusted R-squared indicates that over 60 percent of the variation in Control of Corruption and Rule of Law can be explained by the set of explanatory variables included in the estimates. The model explains about 50 percent of the variation in Regulatory Quality and Risk of Expropriation. The overall fit of the model is in accordance with previous studies in the field (e.g. Acemoglu *et al.,* 2001 and 2004; La Porta *et al.,* 1999). It is worth noticing that mean temperature and latitude are highly correlated (-0.85) and provide comparable information about climate conditions. Including these two variables simultaneously

[43] A detailed discussion on the determinants of institutions can be found in Acemoglu *et al.* (2000, 2001 and 2004) and La Porta *et al.* (1999).

may cause severe multicollinearity but not improve the model's fit. The best parsimonious specification seems to include only mean temperature and the share of land in the coast as controls for geographic influences.

Table F.4 reports OLS regressions using Regulatory Quality (RQ) as the dependent variable. The geographic-related variables have the expected sign and are statistically significant. This suggests that countries with lower mean temperature (or ones further away from the Equator) and with relatively more coastland tend to have better regulatory systems. In all four regressions, while controlling for geographically related variables and legal origin, human capital density in the early 20th century has a positive and statistically significant influence on regulatory quality, that is, countries that accumulated relatively more human capital in the early 20th century turned out to have more market-friendly policies. In addition, as expected, socialist legal origin is associated with relatively more market-unfriendly policies such as price controls, inadequate bank supervision and excessive regulation in foreign trade and business development. The regressions also suggest that the Scandinavian, French, German and British legal systems perform similarly in terms of affecting the Regulatory Quality, once we account for geographically related influences and initial human capital accumulation.

Table F.4 also reports the OLS regressions using Risk of Expropriation as the dependent variable. The results are similar to those found in the model for Regulatory Quality. Specifically, adverse geography dampens the development of institutions and increases the risk of expropriation. The regressions also support that initial level of human capital contributes to the reduction of the risk of expropriation and that socialist origin of the legal system increases the risk of expropriation. The coefficients of French legal origin are negative and significant at the 10% level, which suggests that countries with French origin may have a higher risk of expropriation.

Table F.3 shows the results using Control of Corruption and Rule of Law as the dependent variables. In all regressions, Socialist and French legal origins serve to increase the perception of corruption (decrease the index of corruption control) and deteriorate agents' perceptions of the incidence of crime, the effectiveness and predictability of the judiciary and the enforceability of contracts. Despite a few coefficients of initial level of human capital that are only marginally significant, the estimates do show a consistently positive coefficient for human accumulation in the early 20th century. This supports the idea that countries that accumulated relatively more human capital in the early 20th century tend to have institutional arrangements that control corruption and improved enforceability of contracts and effectiveness and predictability of the judiciary.

The estimates also provide evidence that, controlling for initial human capital and legal origin, geographically related variables are important in explaining institutions. Finally, controlling for geographical related variables, legal origin and initial human capital, all of the tested regressions suggest that population density in the early 20th century has no effect on current institutions[44].

As stated before, appraising the determinants of institutions is not the primary goal of this study. However, the estimates above contribute to this debate because the regression analysis is conducted using a recent dataset on institutional quality and a measure of human capital accumulation in the early 20th century. Furthermore,

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[44] This was tested using both a linear and a quadratic specification for population density. In addition, there is a strong correlation between schooling density and population density, which suggests that a potential impact of agglomeration on institutions may have already been accounted for by including the schooling density variable.

the results discussed above are in accordance with previous findings in this field. For instance, La Porta *et al.* (1999) and Acemoglu *et al.* (2001) find that French and Socialist legal [only la Porta] origins have negative effects on the measures of governance, i.e., a property rights index, a business regulation index and a corruption index. Hall and Jones (1999), La Porta *et al.* (1999), Acemoglu *et al.* (2001), McArthur and Sachs (2001) also find that geographically related variables affect current institutions. While we are able to replicate the findings of previous empirical examinations, this study adds a new finding that schooling density in the early 1900's also helps to explain current institutions. In addition, we also find no significant effect of the French legal system on Regulatory Quality. This result casts some doubt on previous findings that the French legal system contributes to worsen current institutions compared to, for instance, the Common Law system.

3.4.2 Institutions and Innovation: 2SLS-IV Estimates

The results from regressions 1 thru 16 suggest that the dummy variables for the origin of the legal system, geographically related variables and schooling density in the early 1900's explain much of the variation in current institutions, implying that these variables are potentially good candidates to instrument institutions. I examine this hypothesis using the Hansen's J overidentification test.

Tables F.5 thru F.9 report the regressions of the determinants of innovation using different measures of institutions and patent counts from both the USPTO and the World Bank. In these four tables, the dependent variable in models 1 thru 5 is the USPTO patent count between 1970 and 2003 and the dependent variable in models 6 thru 10 is the World Bank patent count between 1995 and 2001. Models 1, 2, 6 and 7 only include variables suggested by the theoretical model developed in chapter 2. The other models are augmented to evaluate the model's robustness. Models 1 and 6 are OLS estimates and all of the other models are 2SLS-IV estimates.

The results reported in Tables F.5 thru F.9 show that the OLS estimates underestimate the impact of institutions on innovation. In all forty regressions the 2SLS-IV estimates of the coefficients on institutions are larger than the corresponding coefficients generated by OLS. This clearly indicates that there exists significant measurement error in the institutional variables, which is not accounted for in the OLS regressions, thus generating significant bias in the OLS estimates.[45]

In all of the regressions presented in Tables F.5 thru F.9 the coefficients on personnel engaged in R&D and share of book production have the expected signs and are statistically significant[46]. While these variables are not our key interest, they control for the size of an economy and the position of a country on the world knowledge frontier, allowing us to evaluate the 'net' influences of institutions on patents production.[47]

The estimates provide evidence that institutions have a strong positive effect on innovation. Specifically, the coefficients on institutional measures are positive and statistically significant in all of the regressions reported in Tables F.5 thru F.9. This suggests that economies that have market-friendly policies, lower perception of

[45] This finding is consistent with Acemoglu *et al.* (2001).

[46] In Table F.8, models 7 thru 10, the coefficients on book production are only marginally significant.

[47] In a set of regressions not reported, we tested an alternative measure of book production. More precisely, I use the share of applied and pure science book production instead of the share of all new titles produced. There are no significant quantitative differences compared to those results reported in Tables F.5 – F.7, which corroborates the model's specification. However, the coefficient on applied and pure science book production is found to be positive but insignificant at the 5 % significance levels in the regressions for the Risk of Expropriation. The significance and sign of the other coefficients in these regressions are not affected.

corruption, or whose judiciary systems are more effective and predictable will gave faster rates of innovation. For example, the estimates suggest that if Brazil had the same market regulatory system as that of the U.S. (the difference in the regulatory quality index between these two countries is about 1.2), 257% more patents would have been granted between 1970 and 2003. The model also suggests that controlling for the differences between the Brazilian and the American indexes of control of corruption or rule of law, Brazilian patent production, between 1970 and 2003, would be approximately four times bigger that it actually was. The presence of measurement errors in quantifying institutions implies that interpretation of the coefficients of the model may be imprecise. However, the impacts of improving institutions on patent production seem to be reasonable.

The specification above implicitly assumes that adverse geography affects innovation through an indirect effect from institutions. This specification is similar to those used by Acemoglu *et al.* (2001 and 2004) and Hall and Jones (1999). However, Gallup *et al.* (1999), Sachs (2000) and McArthur and Sachs (2001) argue that geography may have a direct effect on production as well as an indirect effect from institutions. The argument could be made that spatial location contributes directly to innovation. For instance, mean temperature (climate) may affect the health of the personnel engaged in R&D[48]. Sachs (2000) argues that the burden of malaria – a disease specific to tropical climates - is necessarily lower in temperate zones. Models 3 and 8 in Tables F.5-F.9, report the estimates of the basic model augmented with mean temperature and the share of land in the coast. The regressions provide no support to the claim that geographically related variables

[48] McArthur and Sachs (2001) refer to this effect as "disease ecology".

have direct effects on innovation. Specifically, once we have controlled for institutions, the coefficients of mean temperature and share of land in the coast are insignificant at the standard levels of significance in all regressions [49].

Endogenous growth theory suggests that the size of population may affect innovation (e.g. Kremer, 1993). Specifically, innovation may be more likely to occur in regions with a large population because of the potential for increasing returns to scale and lower transactions costs. However, inefficiencies due, for example, to pollution and crime and resource diversion due to, for example, increased cost of commuting and real estate, may be generated as population density grows (Sedgley and Elmslie, 2004). Models 9 and 10 in Tables 3-5 thru 3.8 test the hypothesis that agglomeration and congestion might be important forces in the economics of innovation. Controlling for institutions, personnel engaged in R&D and initial stock of knowledge; the results suggest that population density has no direct linear effect on patent production. A quadratic specification, allowing us to test the agglomeration and congestion effects also provides no evidence that population density affects patent production[50]. However, we were able to find a positive association between population size (population density and absolute population) in a set of regressions (not reported) that excludes personnel engaged in R&D and adds population size. This is not surprising because there is a positive correlation between population size and personnel engaged in R&D. The size of the economy is accounted for in the original model by the inclusion of personnel engaged in R&D.

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[49] In a set of regressions not reported, mean temperature was substituted for absolute latitude. The results are similar, that is, the coefficients of absolute latitude turned out to be insignificant in all regressions.

[50] We also tested the natural logarithm of the population aged 15-64 instead of population density. The results are similar.

3.4.3 Robustness

Although the results detailed in the presentation seem reasonable, the estimates are subject to several assumptions. Specifically, the results above depend on data quality, model specification and econometric postulates. While statistical tests will not provide definitive answers concerning the validity of the model, complementary estimates and statistical tests will increase our confidence in the model's predictions.

3.4.3.1 Overidentification Test.

The validity of the 2SLS-IV results depends on the assumption that the model can be properly identified by the set of proposed instruments. In other words, the 2SLS-IV estimator requires that the set of instruments for institutions (geographically related variables, dummies for the origin of the legal system and schooling density in the 1900's) is uncorrelated with the error term of the patent production equation.

One can assess this issue by using overidentification tests. In this study, we use the Hansen's J statistic[51] to evaluate the overidentifying restrictions in the 2SLS-IV regressions. This test evaluates the joint null-hypothesis that the instruments are valid instruments, i.e., uncorrelated with the error term. Under the null, the test statistic is distributed as chi-squared in the number of overidentifying restrictions and is consistent in the presence of heteroskedasticity (Hayashi, 2000). While this approach is useful to corroborate the validity of the instruments, the test needs to be interpreted cautiously because of the "... usual problems of power associated with overidentification tests" (Acemoglu *et al.*, 2001:1393).

[51] See Hansen (1982) for details about this test.

Tables F.5 thru F.9 report the Hansen's J statistic for all of the estimated models. This test supports the overidentifying restrictions present in our model for Control of Corruption, Rule of Law and Regulatory Quality because the null-assumption cannot be rejected at the standard levels of significance. Keeping the caveat above in mind, the overidentification test results give more confidence in the validity and robustness of the estimates. However, at the 10% level of significance, the overidentification test statistics reject the null-hypothesis in models 1 thru 5, in Table F.8. This casts some doubt that the model for risk of expropriation is correctly identified.

3.4.3.2 Model's Specification.

Equation 3.22 is derived from a theoretical model, but the functional form chosen is subject to imperfections. Despite the fact that the theoretical equation is nonlinear, it can be transformed to linearity by taking logarithms. However, a log-linear form may not be the best specification for the relationship between institutions and innovation, so alternative specifications can be used to check the robustness of the results. This section examines this issue by testing if the influences of institutions on patent production vanish when institutional arrangements reach some specific level. It may be the case that there are no substantial effects from institutions on patent production across OECD countries because most of these countries have reached an "institutional quality threshold" that puts no restrictions to innovation. If this were the case, institutional differences across these countries may not have any affect on innovation. This issue is evaluated by using two approaches: the first strategy consists of specifying an equation using a quadratic form for institutions. The second approach uses dummy variables and interaction terms to test if there is a differentiated effect of institutions on innovation across OECD countries and non-OECD countries

i) Quadratic form

A special nonlinear specification for modeling the relationship between institutions and innovation can be written as follows:

$$\ln(P_{iT}) = \beta_0 + \beta_1 \ln(H_{Ai0}) + \beta_2 \ln(A_{i0}) + \beta_3 \hat{T}_i + \beta_3 \hat{T}_i^2 + \nu_{it} \qquad (3.7)$$

This equation is linear in parameters but the econometric techniques needed to estimate this quadratic equation are not straightforward because of the nonlinearity in one of the endogenous variables ($\hat{T}$). According to Wooldridge (2002), this creates a system *nonlinear in endogenous variables* and the identification of any such model "...needs to be treated differently" (p. 231)[52]. It is necessary to find a set of instruments suitable to explain $\hat{T}^2$ that is not identical to the set used to instrument $\hat{T}$. This implies that one needs to extend the system by adding an equation for $\hat{T}^2$. Wooldridge (2002) argues that the squared values of the original set of instruments plus their cross-terms are natural instruments for $\hat{T}^2$. The new equation should also contain the linear values of the set of instruments. Accordingly, we augment the system by adding the following equation:

$$\hat{T}^2 = \delta_1 + \delta_2 H_{it0} + \delta_3 G_i + \delta_3 R + \delta_2 H_{it,0}^2 + \delta_3 G_i^2 + \delta_3 R^2 + \phi C + \tau_i \qquad (3.8)$$

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[52] One may be tempted to instrument, for instance, $\hat{T}^2$, by calculating the squared value of predicted $\hat{T}$, which is estimated using a specific set of exogenous variables (instruments). However, this procedure will produce inconsistent estimators and is called "forbidden regression" (Wooldridge, 2002:236). Precisely, the term *forbidden regression* "describes replacing a nonlinear function of an endogenous explanatory variable with the same nonlinear function of fitted values from a first-stage [linear] estimation" (Wooldridge, 2002:236).

where C denotes the cross products between H, G and R, τ is a error term and all other variables are defined as before.

The system of equations is now the collection of equations 3.4, 3.6 and 3.8. Table F.9 provides the 2SLS-IV estimates of this model. The basic results still hold in this specification and the coefficient on the quadratic term is insignificant in the model whose institutional measures are Control of Corruption, Rule of Law and Risk of Expropriation. This suggests that in a cross-sectional of countries the positive effects of institutions on innovation do not vanish when T increases. In addition, the coefficient of the quadratic term on Regulatory quality is found to be positive and statistically significant at the 5% level. This suggests that there is a nonlinear relationship between regulatory quality and patent production. This implies that patent production increases at increasing rates as a result of improvements in the regulatory system.

ii) Dummy variable approach

We use the dummy variable approach to examine if institutions differently affect patent production across OECD and non-OECD countries. Specifically, we test whether the slope and intercept of the model change for countries with relatively good institutional arrangements vis-à-vis countries with poor institutional arrangements. In order to conduct this test, equation 3.5 is augmented as follows:

$$\ln(\mathrm{P_{iT}}) = \beta_0 + \beta_1 \ln(\mathrm{H_{Ai0}}) + \beta_2 \ln(\mathrm{A_{i0}}) + \beta_3 \hat{\mathrm{T}}_\mathrm{i} + \beta_4 \mathrm{OECD} + \beta_5 \hat{\mathrm{T}}_\mathrm{i} * \mathrm{OECD} + \nu_\mathrm{it} \qquad (3.9)$$

where OECD is a dummy variable that assumes value 1 for countries that are member of the OECD and zero for all other countries[53]. All other variables are defined as before.

The modified model, given by equations 3.9 and 3.4, has the same properties of the original model, does not add an extra burden to the estimation process and the 2SLS-IV method can still be used to estimate the model. Table F.9 provides the estimates of this *spline* function. We find that all coefficients of the OECD dummy variable and all the coefficients of the interaction term (OECD*Institution) are statistically insignificant at standard levels. This suggests that the hypothesized threshold for the OECD countries may not exist and that the marginal effect of institutions on patent production is similar for OECD and non-OECD countries[54].

3.4.3.3 Institutions as the Fundamental Determinant of Innovation.

Even though the empirical equation used to estimate the influences of institutions on innovation was derived directly from the theoretical model, the empirical strategy used here may be controversial because it differs from the standard approach. Specifically, institutions are assumed to be the fundamental engine of long-run economic performance, so institutions solely are expected to explain much of the variations, for instance, in income levels (e.g. Hall and Jones, 1999; Acemoglu *et al.*, 2000, 2001; and 2004; Rodrik, 2000). In this literature, income levels are regressed against only institutional measures and geographically

[53] This equation is known as *spline* function (Greene, 2000:324).

[54] It was tested if the coefficients on institutions are still significant if potential outliers are excluded/controlled in the regression analysis. I created a dummy variable with values 1 for USA, JPN, FRA, DEU, UK (top innovator), BGD, CMR, GHA, LBY and MWI (bottom innovators) and zero otherwise. The coefficient on this dummy variable turned out to be insignificant. In addition, this did not affect the significance or the size of the coefficients on institutions. Moreover, excluding the countries above from the regression analysis did not change the results.

related variables. For robustness purposes and to conform to this strategy, we re-estimate the model for patent production (equation 3.6) excluding all variables other than the institutional measure. Specifically, we estimate:

$$\ln(P_{iT}) = \beta_0 + \beta_1 \overline{T}_i + \beta_1 \mu + v_{it} \qquad (3.6B)$$

where $\overline{T}$ is measured institutions, μ is the measurement error and v is a white noise. The dependent variable is redefined in terms of patent production per workforce (in the initial period).

$$P_{iT} = \frac{\sum_{t=0}^{T} p_{it}}{N_0}$$

where p denotes the number of patents granted to country i, t indexes time and N_0 denotes total population aged 15-64 in 1970[55].

Table F.10 provides the 2SLS-IV estimates of equation 3.6B. The coefficient estimates on institutions are positive and statistically significant in all regressions. Table F.10 also shows the estimates of equation 3.6 augmented by geographical controls. The coefficients of mean temperature and proportion of land within the 100 km of the seacoast are not significant at 5 percent significance levels in all the regressions[56]. In addition, the models for Control of Corruption, Rule of Law and Regulatory Quality 'survive' the overidentification tests. However, the overidentification test casts doubt about the validity of the identification of the model for Risk of Expropriation.

[55] It was also tested a model using the average size of workforce between 1970 and 2003. The results are very similar and no significant quantitative differences are found. It is worth noticing that this specification implicitly assumes that the labor force participation is constant over time and so, the estimates will be biased if this assumption does not hold.

[56] In the equation for regulatory quality, the coefficient of mean temperature is significant at the 10% level.

These results corroborate our previous findings that i) institutions are key determinants of innovation and, once controlled for the effects of geography on institutions, geographically related variables have no effect on innovation. Geography affects innovation, but only through institutions.

3.5 Conclusion

This study contributes to the literature of institutions and economic growth by conducting an exploratory empirical examination on the links between innovation and institutions. Using cross-country data and the instrumental variable method, we construct an econometric model that evaluates the influences of institutions on technical innovation (patent production). For robustness' purposes, several alternative specifications are estimated and an overidentification test is used to evaluate the validity of the set of variables utilized to instrument institutions.

The estimates obtained show that institutional arrangements positively contribute to explain much of the variation on patent production across-countries. While most of the previous literature on institutional and economic performance is able to show a positive association between institutions and levels of income, but fails to show a positive association between institutions and levels the growth rate of income; this study provides evidence that institutions have a growth effect on income because institutional quality affects an economy's rate of innovation, the engine of economic growth. This research also finds that geography, *per se,* cannot explain differences in innovation across-countries. Geography affects innovation, but only through institutions.

CHAPTER 4

SUMMARY AND CONCLUSIONS

This study endeavors to incorporate institutions in the standard growth theoretical framework and examines the links between institutions and technical innovation by developing a theoretical model that explicitly accounts for the effects of institutions on economic performance. Furthermore, this study assesses empirically the influences of institutional quality on patent production, which is a tangible measure of technical innovation. This chapter provides a broad view of the major theoretical and empirical findings from this study.

Chapter 1 reviews both the theoretical and empirical literature on institutions and economic performance and discusses the challenges faced in attempting to empirically evaluate the influences of institutions on economic performance as well as to modeling institutions in a formal growth framework. A major finding from this literature review is that it is difficult to provide conclusive empirical evidence to support the idea that institutions matter for economic growth. Although several studies have attempted to demonstrate that institutions affect the transitional growth rate of output per capita, there is still no empirical evidence that institutions operate to determine the steady-state growth of GDP per capita. In addition, the review of the literature shows that the evaluations of the impacts of institutions on technical innovation are generally disregarded in both empirical investigations of cross-country economic performance and formalized growth models. The survey of the literature also puts forward the *ad hoc* nature of the econometric specification found in studies that evaluate the links between institutions and economic performance. These findings suggest that a current important task in economists' agenda is to address the effects of institutions on innovation. This motivates the analysis developed in chapters 2 and 3.

Chapter 2 evaluates the influence of institutions on economic performance by developing a model that explicitly examines how institutions affect technical innovation and economic growth. A major prediction of the theoretical model is that better institutional arrangements boost innovation and thus economic growth. For instance, the lack of proper institutions will retard or prevent the utilization of newly invented inputs in the productive process, leading to relatively lower levels of output. Therefore, controlling for all other determinants of income, countries or regions that experience institutional constraints to adopt newly invented technologies are expected to lag behind in terms of growth and levels of output per capita and this gap does not vanish over time. The model also predicts that, at the steady state, the stock of human capital should not be associated with the growth rate of output; rather the *growth* rate of human capital should be associated with the *growth* rate of output.

Chapter 3 presents the empirical analysis - which uses cross-country data and the instrumental variable method - of the influences of institutions on technical innovation. The results support the hypothesis that institutions explain a significant portion of the variation in patent production across-countries and provide evidence that control of corruption, market-friendly policies, protection of private propriety and a more effective judiciary systems have a growth effect on income because institutional quality affects an economy's rate of innovation, the engine of economic growth. This analysis also finds evidence that geography, *per se,* cannot explain innovation across-countries.

Future research in this area might want to refine the measure of innovation utilized in this study or look for alternative ways to measure technical innovation. One possible approach would be calculating total factor productivity and regressing it against institutional measures. There is much to do in terms of modeling institutions and institutional effects in growth models. The model developed in this study shows that some predictions from well-known growth models may not hold under a framework that explicitly accounts for institutional quality. Therefore, there is much more to be learned from incorporating institutions in the standard economic growth framework.

BIBLIOGRAPHY

Acemoglu, Daron, Simon Johnson and James A. Robinson (2000). "The Colonial Origins of Comparative Development: An Empirical investigation," *NBER Working Paper 7771.*

Acemoglu, Daron, Simon Johnson and James A. Robinson (2001). "The Colonial Origins of Comparative Development: An Empirical investigation," *American Economic Review*, 91(5): 1367-1401.

Acemoglu, Daron, Simon Johnson and James A. Robinson (2004). "Institutions as the Fundamental Cause of Long-Run Growth," *NBER*, Working Paper 10481.

Aghion, Philippe and Peter Howitt (1992). "A Model of Growth through Creative Destruction," *Econometrica*, 60(2): 323-351.

Ali, Abdiweli M. and W. Mark Crain (2001). "Political Regimes, Economic Freedom, Institutions and Growth", *Journal of Public Finance and Public Choice*, XIX(1): 3-21.

Atkinson, Glen (1998). "The Evolutionary Theory of the Development of Property and the State," In: **The Foundation of Institutional Economics**, edited by Warren Samuels. New York, Routledge.

Baldwin, John and Zhengxi Lin (2002). "Impediments to Advanced Technology Adoption for Canadian Manufacturers," *Research Policy*, 31(1): 1-18.

Barro, Robert (1991). "Economic Growth in a Cross Section of Countries," *Quarterly Journal of Economics*, 106(2): 407-43.

Barro, Robert (1996). "Institutions and Growth, an Introductory Essay," *Journal of Economic Growth*, 1: 145-148.

Barro, Robert (1999). "Determinants of Democracy," *Journal of Political Economy*, 107(6): S158-S183.

Barro, Robert and Xavier Sala-I-Martin (1995). **Economic Growth**. Cambridge-MA: The MIT Press.

Bliss, Christopher (1999). "Galton's Fallacy and Economic Convergence," *Oxford Economic Papers*, 51(4): 4-14.

Bliss, Christopher (2000). "Galton's Fallacy and Economic Convergence: A Reply to Cannon and Duck," *Oxford Economic Papers*, 52(2): 420-422.

Bloom, David E., Jeffrey D. Sachs, Paul Collier, and Christopher Udry (1998). "Geography, Demography and Economic Growth in Africa," *Brookings Papers on Economic Activity*, 1998(2): 207-295.

Bosworth, Barry P. and Susan M. Collins (2003). "The Empirics of Growth: An Update," *Brooking Papers on Economic Activity*, 2.

Cannon, ES and NW Duck (2000). "Galton's Fallacy and Economic Convergence," *Oxford Economic Papers*, 52(2): 415-419.

Clark, Donald (2004). *Knowledge*. From http://www.nwlink.com/~donclark/knowledge/knowledge.html. Downloaded in 01/25/05

Cochran, Terry (2001). **Twilight of the Literacy: Figures of Thought in the Age of Print**. Cambridge, MA: Harvard.

Davidson, Russell and James G. MacKinnon. (1993). **Estimation and Inference in Econometrics**. New York: Oxford University Press.

Dawson, John W. (1998). "Institutions, Investment and Growth: New Cross-Country and Panel Data Evidence," *Economic Inquiry*, XXXVI: 603-619.

Denoon, Donald (1983). **Settler Capitalism: The Dynamics of Dependent Development in the Southern Hemisphere.** Oxford: Clarendon Press.

Diamond, Jared (1999). **Guns, Germs and Steel. The Fates of Human Societies.** New York: W.W. Norton.

Dollar, David and Aart Kraay (2003). "Institutions, Trade and Growth," *Journal of Monetary Economics*, 50: 133-162.

Easterly, William and Levine, Ross (1997). "Africa's Growth Tragedy: Policies and Ethnic Divisions," *Quarterly Journal of Economics*, 112(4): 1203-1250.

Engerman, Stanley L. and Kenneth L. Sokoloff (1997). "Factor Endowments, Institutions and Differential Paths of Growth Among New World Economies: A View from Economic Historians of the United States." In Stephen Haber (ed.). **How Latin America Fell Behind**. Stanford.

Engerman, Stanley L. and Kenneth L. Sokoloff (2003). "Institutions and Non-Institutional Explanations of Economic Differences," *NBER Working Paper* 9989.

Esfahani, Hadi Salehi and María Tereza Ramírez (2003). "Institutions, Infrastructure and Economic Growth," *Journal of Economic Development,* 70: 443-447.

Fedderke, Johannes (2001). "Growth and Institutions," *Journal of International Development*, 13: 645-670.

Freeman, Christopher (1987). **Technology Policy and Economic Performance: Lessons from Japan.** London: Pinter Publishers.

Gallup, John Luke and Jeffrey D. Sachs, with Andrew D. Mellinger (1999). "Geography and Economic Development," *CID Working Paper, No. 1.*

Gastil, Raymond D. (1979). **Freedom in the World: Political Rights and Civil Liberties.** New York : Freedom House.

Glaeser, Edward L., Rafael La Porta, Florencio Lopes-de-Silanes and Andrei Shleifer (2004). "Do Institutions Cause Growth?," *NBER Working paper 10568.*

Gradstein, Mark (2002). "Rules, Stability and Growth," *Journal of Economic Development*, 67: 471-484.

Gradstein, Mark (2004). "Governance and Growth," *Journal of Development Economics,* 73: 505– 518.

Greene, Willian H. (2000). **Econometric Analysis.** New Jersey: Prentice Hall. Fourth Edition.

Griliches, Zvi (1979). "Issues in Assessing the Contribution of R&D to Productivity Growth," *Bell Journal of Economics,* 10(1): 92-116.

Griliches, Zvi (1990). "Patent Statistics as Economic Indicators: A Survey," *Journal of Economic Literature,* 28(4): 1661-1770.

Griliches, Zvi (1994). "Productivity, R&D and the Data Constraint," *American Economic Review*, 84(1): 1-23.

Griliches, Zvi (ed) (1984). **R&D, Patents and Productivity**. Chicago: University of Chicago Press.

Grossman, Gene M. and Elhanan Helpman (2001 [1991]). **Innovation and Growth in the Global Economy.** Cambridge, MA: The MIT Press. Seventh printing. (First Printing 1991)

Gurr, Ted Robert, Keith Jaggers, and Will Moore (1990). "The Transformation of the Western State: The Growth of Democracy, Autocracy, and State Power Since 1800," *Studies in Comparative International Development,* 25 (1): 73-108.

Hall, Robert E. and Charles Jones (1999). "Why Do Some Countries Produce So Much More Output Per Worker Than Others?," *Quarterly Journal of Economics*, 114(1): 83-116.

Hansen, L. (1982). "Large Sample Properties of Generalized Method of Moments Estimators," *Econometrica*, 50, 1029-1054.

Haucap, Justus and Christian Wey (2004). "Unionisation Structures and Innovation Incentives," *Economic Journal*, 114(494): C149-65.

Hayashi, Fumio. (2000). **Econometrics**. Princeton: Princeton University Press.

Hsiao, Cheng and Yan Shen (2003). "Foreign Direct Investment and Economic Growth: The Importance of Institutions and Urbanization," *Economic Development and Cultural Change," 51: 883-896.*

Huang, Haizhou and Chenggang Xu (1999). "Institutions, Innovations and Growth," *American Economic Review*, 89(2): 438-443.

Jaffe, Adam B. and Manuel Trajtenberg (2002). **Patents, Citations & Innovations.** Cambridge-MA, The MIT Press.

Jaffe, Adam B. and Josh Lerner (2002). "Reinventing Public R&D: Patent Citations on the Impact of NASA and other Federal Las on Commercial Innovation." In: Jaffe Adam B. and Manuel Trajtenberg. (2002). **Patents, Citations & Innovations.** Cambridge-MA, The MIT Press. pp. 287-335.

Jones, Charles (1995). "R&D-Based Models of Economic Growth," *Journal of Political Economy*, 103:4: 759-784.

Kaufmann, Daniel , Aart Kraay and Massimo Mastruzzi (2003). "Governance Matters III: Governance Indicators for 1996–2002," *Policy Research Working Paper No. 3106.*

Kipphan, Helmut. (2001). **Handbook of Print Media: Technologies and Production Methods**. Berlin: Springer-Verlag Berlin Heidelberg.

Knack, Stephen and Philip Keefer (1995). "Institutions and Economic Performance: Cross-Country Tests Using Alternative Institutional Measures," *Economics and Politics*, 7(3): 207-227.

Knack, Stephen and Philip Keefer (1997). "Does Social Capital Have an Economic Payoff? A Cross-Country Investigation," *Quarterly Journal of Economics,* 112(4): 1251-*1288.*

Kormendi, Roger C. and Philip G. Meguire (1985). "Macroeconomic Determinants of Growth," *Journal of Monetary Economics*, 16: 141-163.

Kremer, Michael (1993). "Population Growth and Technological Change: One Million B.C. to 1990," *Quarterly Journal of Economics*, 108(3): 681- 716.

La Porta, Rafael, Florencio Lopes-de-Silanes, Andrei Shleifer and Robert Vishny (1999). "The Quality of Government," *Journal of Law, Economics, & Organization,* 15(1): 222-279.

Lambsdorff , Johann Graf (2004). "Background Paper to the 2004 Corruption Perceptions Index," Transparency International (TI). Available at: http://www.transparency.org/cpi/2004/dnld/framework_en.pdf . Downloaded in 01/26/05

Laszlo, Kathia C. and Alexander Laszlo (2002). "Evolving Knowledge for Development: The Role of Knowledge Management in a Changing World," *Journal of Knowledge Management*, 6(4): 400-412.

Levine, Ross and David Renelt (1992). "A Sensitivity Analysis of Cross-Country Growth Regressions," *American Economic Review*, 82(4): 942-963.

Lucas, Robert (1988). "On the Mechanisms of Development Planning," *Journal of Monetary Economics*, 22(1): 3-42.

Lundvall, Bengt-Ake (1992). **National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning.** London: Pinter Publishers.

Marinho, Emerson, Flávio Ataliba and Edinaldo Tebaldi (2003). "Efeitos da Integração Nacional e Difusão de Conhecimento sobre a Trajetória de Crescimento Econômico", *Estudos Economicos,* 33(3).

Matthews, R.C.O. (1986). "The Economics of Institutions and the Sources of Growth," *Economic Journal*, 96: 903-918.

Mauro, Paola (1995). "Corruption and Growth," *Quarterly Journal of Economics*, 110(3): 681-712.

McArthur, John W. and Jeffrey D. Sachs (2001). "Institutions and Geography: Comment on Acemoglu, Johnson and Robinson (2000)," *NBER*, Working Paper 8114.

Merriam-Webster (1993). **Webster's Third New International Dictionary of the English Language**. (1993). Springfield, MA: Merriam Webster Inc.

Mitchell, Brian R. (2003a). **International Historical Statistics: Africa, Asia & Oceania, 1750-2001.** New York: Palgrave Macmillan, fourth Edition, 1144 pp.

Mitchell, Brian R. (2003b). **International Historical Statistics Europe 1754-2000: Europe, 1750-2000.** New York: Palgrave Macmillan, fifth Edition, 960 pp.

Mitchell, Brian R. (2003c). **International Historical Statistics: The Americas 1750-2000**. New York: Palgrave Macmillan, fifth Edition, 856 pp.

Moers, Luc (1999). "Growth Empirics with Institutional Measures and its Application to Transition Countries: A survey." Manuscript

North, Douglass Cecil and Robert Paul Thomas (1973). **The Rise of the Western World; a New Economic History.** Cambridge University Press.

Oliva, Maria-Angels and Luis A. Rivera-Batiz (2002). "Political Institutions, Capital Flows and Developing Country Growth: An Empirical Investigation," R*eview of Development Economics*, 6(2): 248-262.

Pan, S. Ling and Scarbrough, H. (1999). "Knowledge Management in Practice: An Exploratory Case Study of Buckman Labs," *Technology Analysis and Strategic Management,* 11(3): 359-74.

Polanyi, Michael (1966). **The Tacit Dimension**. Garden City, NY: Doubleday, 1966.

Rebelo, Sergio (1991). "Long-Run Policy Analysis and Long-Run Growth," *Journal of Political Economy*, 99(3): 500-521.

Rischel, T.D. and O.M. Burns (1997). "The Impact of Technology on Small Manufacturing Firms," *Journal of Small Business Management,* 35: 2-10.

Rodrik, Dani (2000). "Institutions for High-Quality Growth: What They Are and How to Acquire Them," *NBER Working Paper 7540.*

Rodrik, Dani (2003). **In Search of Prosperity. Analytic Narratives on Economic Growth.** New Jersey: Princeton University Press.

Romer, Paul (1986). "Increasing Returns and Long-Run Growth," *Journal of Political Economy,* 94: 1002-1037.

Romer, Paul (1990). "Endogenous Technological Change," *Journal of Political Economy*, 98: S71-S102.

Romer, Paul (2002). *Preface.* In: Jaffe Adam B. and ManuelTrajtenberg. (2002). **Patents, Citations & Innovations.** Cambridge: The MIT Press.

Rosenberg, Nathan (1963). “Mandeville and Laissez-Faire,” *Journal of the History of Ideas*, 24 (2): 183-196.

Sachs, Jeffrey D. (2000). **Tropical Underdevelopment.** Center for International Development, Harvard University.

Sala-I-Martin, Xavier X. (1997). “I just Ran Two Million Regressions,” *American Economic Review*, 87(2): 178-183.

Sala-I-Martin, Xavier X. (2002). “15 Years of New Growth Economics: What Have We Learnt?” *Central Bank of Chile,* Working Paper 172, 22p.

Sala-I-Martin, Xavier X., Gernot Doppelhofer and Donald I. Miller (2004). “Determinants of Long-Term Growth; A Bayesian Averaging of Classical Estimates (BACE) Approach,” *American Economic Review*, 94(4): 813-835.

Schmoolkler, Jacob (1966). **Invention and Economic Growth**. Harvard University Press.

Sedgley, Norman (2004). “A Time Series Test of Innovation Driven Endogenous Growth,” Manuscript.

Sedgley, Norman and Bruce Elmslie (2004). “The Geographic Concentration of Knowledge: Scale, Agglomeration and Congestion in Innovation across US States,” *International Regional Science Review,* 22(2), 111-137.

Segerstrom, Paul S. (1998). “Endogenous Growth Without Scale Effects,” *American Economic Review*, 88(5): 1290-1310.

Small, M. H. (1998). “Objectives for Adopting Advanced Manufacturing Systems: Promise and Performance,” *Industrial Management and Data Systems,* 98: 129-37.

Solow, Robert (1956). “A Contribution to the Theory of Economic Growth,” *Quarterly Journal of Economics,* 70: 65-94.

The World Bank (2003). World Development Indicators. CD-ROM. Washington-DC.

Toye, J. (1993). "Is There a New Political Economy of Development?," In: Christopher Colclough and Manor (eds) **States or Markets? New-Liberalism and the Development Policy Debate,** Oxford: Clarendon Press.

UNESCO Statistical Yearbook . United Nations. Several Volumes

Uzawa, Hirofumi (1965). "Optimal Technical Change in an Aggregative Model of Economic Growth," *International Economic Review*, 6: 18-31.

Wooldridge, Jeffrey M. (2002). **Econometric Analysis of Cross Section and panel Data.** Cambridge: The MIT Press.

Young, Alwyn (1998). "Growth Without Scale Effects," *Journal of Political Economy*, 106(1): 41-63.

Zoltan, Dienes and Perner Josef (1999). "A Theory of Implicit and Explicit Knowledge," *Behavioral and Brain Sciences*, 22(5), 735-808.

APPENDICES

Appendix A: Measuring Institutions

Table A.1: Measures of Institutions

Institution	Organization	Variables	Range (higher ratings = better institutions)	Availability (# countries)
Law Enforcement	• International Country Risk Guide (ICRG)	• Rule of Law • Contract enforcement • Expropriation Risk	• 0-6 • 0-10 • 0-10	• 1984-2003 (~100)
	• Kaufmann, Kraay and Mastruzzi, (2003)	• Rule of Law	• -2.5 – 2.5	• 1996-2002 (~200)
	• Business Environmental Risk Intelligence (BERI)	• Expropriation Risk • Contract enforcement	• 0-4 • 0-4	• 1980-2003 (~53)
Political Institutions	• Polity III dataset (Inter-University Consortium for Political and Social Research)	• Executive Constraints	• 1 -7	• 1800-1994 (~100)
		• Democracy	• 0 -10	
	• Kaufmann, Kraay and Mastruzzi, (2003)	• Political Stability • Voice and Accountability	• -2.5 – 2.5 • -2.5 – 2.5	• 1996-2002 (~200)
	Barro (1991)	• Number of Revolutions and Coups • Number of assassinations	• Absolute number	• 1960-1985
	Freedom House/Gastil	• Political Freedom Index • Civil Liberty Index	• 1972-2002	• 1974-1989
	• ICRG	• Political Risk index • Democracy	• 0-100 • 0-6	• 1984-2003 (~100)
Public Administration:	• ICRG	• Quality of Bureaucracy	• 0 -6	• 1984-2003 (~100)
		• Corruption	• 0 - 6	
	• Kaufmann, Kraay and Mastruzzi, (2003)	• Government Effectiveness	• -2.5 – 2.5	• 1996-2002 (~200)
		• Corruption	• -2.5 – 2.5	
	• Transparency International	• Corruption	• 0-10	• 1996-2003(+100)
	• BERI	• Bureaucratic delays	• 0-4	• 1980-2003 (~53)

Continued: Table A.1: Measures of Institutions

Institution	Organization	Variables	Range (higher ratings=better institutions)	Availability (# countries)
Market Structure:	• Kaufmann, Kraay and Mastruzzi, (2003)	• Regulatory Quality	• -2.5 – 2.5	• 1996-2002 (~200)
	• ICRG	• Expropriation Risk • Financial Risk • Economic Risk	• 0-10 • 0-50 • 0-50	• 1984-2003 (~100)
	World Bank, IMF	• Black Market foreign exchange premium	• -	-
	Heritage Foundation	• Economic Freedom Index	• 1-5 (lower ratings indicate improved institutional configuration)	• 2000-2004 (+100)
	Gwartney *et al.* (1996)	• Economic Freedom Index	• 0-10	1970, 1975, 1980, 1985, 1990,1995, 1997-2004 (~100)
Social Interaction	• Easterly and Levine, 1997	• Ethnolinguistic heterogeneity	•	•
	• Knack and Keefer, 1997	• Trust	• Percentage of respondents in each nation replying "most people can be trusted"	• 1990(26)
		• Civic Cooperation	• 0-10	
		• Putnam's social capital	• Density of associational activity	
	• ICRG	• Ethnic Tensions	• 0-6	• 1984-2003 (~100)
Global Measures	• BERI	• BERI Composite Score	• 0-16	• 1980-2003 (~53)
	• ICRG	• ICRG Composite Index	• 0-100	• 1984-2003 (~100)

Source: Author's compilation

Appendix B: The Empirics of Institutions and Economic Performance

Table B.1: Institutions and Growth of GDP Per Capita: Main Empirical Studies

Study	Number of countries/period	Institutional measures (relationship with growth/investment)*	Other main explanatory variables	Econometric Method	Instrument for institutions
Dollar and Kraay, 2003	~100 1970-1990	• Change Contract-intensive money (NR) • Change Frequency of Revolutions and coups (NR) • Change ICRG index (NR) • Change Freedom House Index (NR) • Change Wars deaths (NR) • Significance depends on 4 outliers (US, CA, Australia, New Zealand)	• Average real per capita GDP growth in previous decade • Trade/gdp	Panel data OLS/IV	• Initial Level of institutional variables
Esfahani and Ramirez, 2003	75 1965-1995	• Democracy (- NA) • Contract enforcement (+ NA) • Ethnolinguistic heterogeneity (- NA) • Black Market foreign exchange premium (- NA)	• Population density • Share of industry GDP • Investment, • schooling	Panel data (1965-1975; 1975-1985; 1985-1995) IV/2SLS	none
Hsiao and Shen, 2003	23 developing countries 1976-1997	• Corruption (NA +FDI)	• urbanization • schooling • telephone	VEC	none
Oliva and Rivera-Batiz, 2002	121 1970-1994	• Democracy (+ NA) • Rule of Law (NA +FDI)	• Initial GDP • Gov't consumption • Investment, • schooling	OLS/3SLS	none
Ali and Crain, 2001	74/91 1975-1994	• Economic freedom index (+ +NR) • Civil liberty Index (I I) • Political Freedom Index (I I)	• Initial GDP • Investment, • Population growth • schooling	OLS	none
Dawson, 1998	85 1975-1990	• Economic freedom index (+ +NR) • Civil liberty Index (I I) • Political Freedom Index (I I)	• Initial GDP • Investment, • Population growth • schooling	Panel OLS	none

Continued: Table B.1: Institutions and Growth of GDP Per Capita: Main Empirical Studies

Study	Number of countries/period	Institutional measures (relationship with growth/investment)*	Other main explanatory variables	Econometric Method	Instrument for institutions
Knack and Keefer, 1997	29 1980-1992	• Trust (+NR +NR) • Civic cooperation (+NR +) • Putnam's social capital (I I)	• Initial GDP • Schooling • Investment price	OLS/2SLS	law students/ post secondary students and ethnolinguistic heterogeneity
Mauro, 1995	57 1960-1985	• Corruption (-NR -) • Freq. of coups/revolutions (I I) • Political assassinations (- I) • Policy volatility (- -NR) • Bureaucratic efficiency (+NR +NR)	• Initial GDP • Gov't. consumption • Investment • Schooling	OLS/2SLS	Ethnolinguistic heterogeneity
Knack and Keefer, 1995	97 1974-1989	• ICRG index (+ +) • BERI index (+ +) • Freq. of coups/ revolutions (- -) • Political assassinations (- -)	• Initial GDP • Government consumption • Investment price (IP) • Deviation from IP • schooling	OLS	None
Levine and Renelt, 1992	119 1974-1989	• Democracy (NR NR) • Policy volatility (NR NR) • Freq. of coups/revolutions (NR -)	• Initial GDP • Gov't consumption • Investment • Schooling • Inflation, trade	OLS/ Sensitivity test	none
Barro, 1991	98 1960-1985	• Freq. of coups/revolutions (- -) • Political assassinations (- -)	• Initial GDP • Investment, • Investment price (IP) • Deviation fromIP • schooling	OLS	None
Kormendi and Meguire, 1985	47 1950-1977	• Democracy (I +) • Policy Volatility (- -)	• Initial GDP • Population growth • Investment • Inflation, export growth	OLS	none

* (+)=positive relationship; (-) negative relationship; I=Insignificant; NR=not robust ; NA=Not evaluated; FDI=Foreign Direct Investment
Source: Original Studies

Table B.2: Institutions and Levels of GDP Per Capita: Main Empirical Studies

Study	Number of countries/period	Institutional measures (relationship with levels of output)*	Other main explanatory variables	Econometric Method	Instrument for institutions
Acemoglu, Johnson and Robinson, 2004	64/1995	• Risk of expropriation (+) • Constraint on executive (+)	• Latitude • Continent • Mean temperature • Humidity • Soil quality • Value for resources • Landocked • Dummies for colonizer	IV	• Settler mortality
Dollar and Kraay, 2003	121-154 (* sample size depends on specification) 1995	• Contract-intensive money (NR) • Frequency of Revolutions and coups (NR) • ICRG index (NR) • Freedom House (NR) • Wars deaths (NR) • Rule of Law (NR) Significance depends on 4 outliers (US, Canada, Australia, New Zealand)	• Population • Trade/gdp • Distance from equator • Landlocked	IV	• Distance from the equator • Frankel-Romer Instrument • Fraction population speaking English at birth • Fraction population speaking a western language at birth • Landlocked
Acemoglu, Johnson and Robinson, 2002	~64 1995	• Risk of expropriation (+) • Constraint on executive (+)	• Latitude • Continent • Mean temperature • Humidity • Soil quality • Value for resources • Landocked • Dummies for colonizer	OLS/2SLS	• Settler mortality • Urbanization in 1500 • Population density in 1500

Continued: Table B.2: Institutions and Levels of GDP Per Capita: Main Empirical Studies

Study	Number of countries/period	Institutional measures (relationship with levels of output)*	Other main explanatory variables	Econometric Method	Instrument for institutions
McArthur and Sachs, 2001	118 1995	• Risk of expropriation (+) (ranges 0-10 – higher score means more protection against risk of expropriation)	• Infant mortality rate • Life expectancy • Malaria Index	OLS/IV	• Adult mortality rates in the 19th century • Mean temperature • Proportion of land within 100km of the sea coast • Latitude • Hydrocarbon production per capita • War during 1960s to 1980s • National independence after 1914
Acemoglu, Johnson and Robinson, 2000 and 2001	64 1995	• Risk of expropriation (+) (ranges 0-10 – higher score means more protection against risk of expropriation) • Constraint on executive • Democracy	• Latitude • Continent dummies • Mean temperature	2SLS/IV	• Settler mortality rates
Hall and Jones, 1999	127 1988	• Government antidiversion policies (GADP) (+) (this index is a weighted average of he following indicators: Law and order; bureaucratic quality, corruption, risk of expropriation, government repudiation of contracts)	• none	IV	• Distance from the equator • Frankel-Romer Instrument • Fraction population speaking English at birth • Fraction population speaking a western language at birth

* (+)=positive relationship; (-) negative relationship; I=Insignificant; NR=not robust ; NA=Not evaluated; FDI=Foreign Direct Investment
Source: Original Studies

Appendix C: Variables Definitions

Table C.1: List of Variables

Variable	Definition
Y	Output
H_Y	Human capital employed in the manufacturing sector
H_A	Human capital engaged in R&D
H	$=H_Y+H_A$
K	Stock of physical capital
x	Intermediate inputs
A	Knowledge (innovation)
T	Institutions
Z	Institutional structure controlling for the level of technology (defined as $Z=T/A$
r	Interest rate
p	Input price
P_A	Price of a patent
W_Y	Wages in the final good sector
W_A	Wages in the R&D sector
C	Consumption
g_A	Growth rate of innovation
g_T	Rate of Institutional changes

Appendix D: Institutions Binding the Adoption of New Technologies: The Case of Genetically Modified Crops

The first genetically modified seeds were produced and planted in the U.S. during the early 1970s. The development of the hybrid corn seeds (cytoplasmic male sterility - CMS) systematically changed the production of corn in the U.S. and provided the basis for significant improvements in the productivity of U.S. agriculture (Weingartner, 2002; Larson and Cardwell, *2004)*. According to Larson and Cardwell *(2004),* in the U.S. "[a]t the present time hybrid seed is used on essentially all land planted to corn" (p.1). Moreover, transgenic seeds have spread throughout the world during the 1990s. According to a worldwide study conducted by James (2004), "approximately 8.25 million farmers in 17 countries planted biotech crops [e.g. corn, soybean, cotton, tomato, canola and potato] in 2004" (p.1). However, the production of genetically modified crops is highly concentrated in a few countries. The U.S. is the leading transgenic producer and accounts for 59 percent of the total global transgenic crop area. Argentina (20 percent), Brazil (6 percent), Canada (6 percent) and China (5 percent) complete the list of the other major producers of transgenic crops (James, 2004)[57].

The noticeable concentration of the production of transgenic crops in only a few countries and the fact that transgenic seeds have been widely available for

[57] These numbers are calculated considering only countries growing 50,000 hectares or more of genetically modified crops.

commercialization since 1996[58] posits a fundamental question: why are only a few countries engaged in the production of such crops and why does the U.S. alone account for the majority of the total global transgenic crop area?

Institutions certainly explain much of this observable fact. First, innovating countries may be afraid of delivering new technologies to countries with a poor system of property rights protection (Krattiger, 1997). In this case, institutionally backward countries are not able to learn and adapt the new technologies because they have no access to the technology needed to manipulate the genetically altered seeds. This may lessen the benefits of using transgenic seeds in institutionally backward countries. However, these countries would still be able to buy transgenic seeds from the leading innovating countries.

The second and perhaps the most important institutional constraint to the use of genetically altered seeds are the biosafety regulatory laws (Krattiger, 1997, James, 2004). While planting genetically modified crops began in the early 1970s and extensive research on this matter was conducted during the 1980s and 1990s, concerns about biosafety prevented the commercialization of genetically modified crops until the early 1990s. According to James and Krattiger (1996), "China was the first country to commercialize transgenics [tobacco and tomatoes] in the early 1990s"(p.7). In 1994 the U.S. government authorized the commercialization of transgenic tomatoes and by 1996 the list of authorized genetically modified products included corn, soybeans, cotton, canola, potatoes and squash. In 1995 these crops were also commercialized in six other countries (e.g. China and Canada) plus the members of the European Union (James and Krattiger, 1996).

[58] The U.S., Canada and other 'transgenic' countries started to commercialize transgenic crops in 1996. (James and Krattiger, 1996).

While all OECD countries have regulations concerning the commercialization of genetically modified crops and by products from these crops, the process for approving the commercialization of genetically modified crops in developing countries progressed very slowly.[59] Institutional constraints have prevented these countries from using transgenic crops. Specifically, a group of developing countries completely lacks regulation for this sector and another group of developing countries has only embryonic regulatory systems (e.g. Brazil and Argentina), which in general create difficulties hindering the planting and commercialization of genetically modified crops and the byproducts from genetically modified crops (James and Krattiger, 1996). However, "[f]ailure to do so [regulate the use of genetically modified crops] will result in delayed access to transgenic crops that will directly impact on their ability to increase crop productivity and their competitive advantage in terms of crop production in the domestic and international market place" (James and Krattiger, 1996:1).

[59] "Genetic engineering of crops has been a controversial subject since 1971 when the first genetically modified organisms were developed. Concern about biosafety has led to Government regulation of transgenic crops in contained and field experiments to assess potential risk before the genetically engineered crops are approved for commercialization. The first field trials of transgenic crops featured herbicide resistance, used as a marker gene in tobacco in the USA and France in 1986. In the interim period, more than 3,500 field trials of transgenic crops have been conducted on more than 15,000 individual sites, in 34 countries with at least 56 crops, mostly in North America and the European Union. 91% of the trials have been conducted in industrialized countries, 1% in Eastern Europe and Russia and the balance of 8% in the developing countries with most in Latin America and the Caribbean, only 2% in the developing countries of Asia, almost exclusively in China and very few in Africa, almost all in South Africa." (James and Krattiger, 1996:7).

REFERENCES
(Only articles referenced in Appendix D)

Cortright, Joseph and Heike Mayer (2002). "Signs of Life: The Growth of Biotechnology Centers in the U.S.," The Brookings Institution Center on Urban and Metropolitan Policy, Washington http://www.brookings.edu/es/urban/publications/biotech.pdf

James, Clive. and A.F. Krattiger (1996). "Global Review of the Field Testing and Commercialization of Transgenic Plants, 1986 to 1995: The First Decade of Crop Biotechnology." ISAAA Briefs No. 1. ISAAA: Ithaca, NY. pp. 31.

James, Clive (2004). "Global Status of Commercialized Biotech/GM Crops: 2004." ISAAA Briefs No. 32. ISAAA: Ithaca, NY

Krattiger, A.F. (1997). "Insect Resistance in Crops: A Case Study of Bacillus thuringiensis (Bt) and its Transfer to Developing Countries." ISAAA Briefs No. 2. ISAAA: Ithaca, NY. pp. 42.

W.E. Larson and V.B. Cardwell (2004). "History of U.S. Corn Production." University of Minnesota. http://citv.unl.edu/cornpro/html/history/history.html downloaded in 02/01/2005.

Weingartner, Urs. (2002). **Combined Effect of Male Sterility and Xenia on Grain Yield and Yield Components in Maize (Zea Mays L.).** Swiss Federal Institute of Technology Zurich. PhD dissertation.

Appendix E: Institutions and the Use of Genetically Modified Crops: The Case of Brazil

Brazilian regulations of biogenetic activities are very recent. The *LEI N° 8.974/1995* was the first legal arrangement created for the regulation of biogenetic activities in that country. While this law allowed field tests with genetically modified crops, it did not allow for planting or commercialization of transgenic crops. The Brazilian government approved the planting of transgenic soybean for the first time and under numerous limitations in late 2003, 8 years after the decision of the OECD countries to liberalize transgenic crops. This authorization was given to producers that were already raising transgenic soybeans (illegally) and had existing stocks of transgenic seeds from the 2003 harvest. The producers of transgenic soybeans could plant, in 2004, seeds from the 2003 harvest, but they were not allowed to sell the 2003 harvest to other producers that could potentially use the transgenic soybean as seed. All seeds not used or sold by December 31 of 2003 were supposed to be destroyed and any places where the seed had been stored cleaned. In addition, the 2004 harvest was not to be used as seed in the future and all products made from transgenic soybean were to be properly labeled, so that consumers could easily identify that they were transgenic. Except for the condition described above, this law prohibited the planting and commercialization of transgenic seeds.

In October of 2004 the government signed a decree (*Medida Provisória N° 223*) that allowed producers of transgenic soybeans to plant in 2005 their own transgenic seeds from the 2004 harvest. All other producers were prohibited from planting or commercializing transgenic crops. In addition, except for the soybean case discussed above, all other transgenic crops are still forbidden from being planted and commercialized in Brazil.

The Brazilian institutional arrangement on transgenic crops is still embryonic and the government has yet to create legislation that effectively regulates the production and commercialization of transgenic crops. While this productivity-increasing technology is widely utilized in countries such as the U.S. (world's leading producer of corn) and Argentina, Brazil lags behind in the use of this technology due to institutional constraints.

The Brazilian *transgenic* experience well supports the argument that an economy will not operate at its production possibility frontier production when restrictive legislation prevents the use of new technologies and removes the benefits from introducing new technologies that are productivity-increasing. "It is obvious that consumers want their food to be safeguarded by rules that are rigorous enough to prevent any loopholes. But the legislation must not be so restrictive that it removes any incentive for introducing new food products that are potentially beneficial to society" (ISAAA, 2002:14).[60]

[60] ISAAA -International Service for the Acquisition of Agri-biotech Applications (2002). "Biotechnology: Myths & Facts." SEAsiaCenter, Manila. http://www.isaaa.org/kc/Publications/pdfs/myths/Myths%20_english.pdf downloaded in 01/31/05.

Appendix F: Data Analysis

Table F.1 – Descriptive Statistics

Variable	Number of Countries	Mean	Standard Deviation
Control of Corruption	104(1)	0.038	1.082
Rule of Law	110(1)	-0.003	1.064
Regulatory Quality	109(1)	0.070	0.979
Expropriation Risk	101(1)	6.976	1.881
ln Human Capital Density in the early 20th century	110(1)	-1.481	3.159
ln Population Density in the early 20th century (1,000 inhabitants)	106(1)	2.532	1.673
Legal Origin - Socialist	110(1)	0.100	0.301
Legal Origin - French	110(1)	0.545	0.500
Legal Origin - German	110(1)	0.045	0.209
Legal Origin - Scandinavian	110(1)	0.036	0.188
Prop. land within 100km of the sea coast	110(1)	0.375	0.357
Absolute Latitude	110(1)	0.268	0.184
Mean Temperature	110(1)	20.075	7.331
ln Patent Count, 1970-2003 - USPTO	76(2)	5.6060	3.4343
ln Personnel engaged in R&D	76(2)	8.5276	2.0099
ln Share of book production	76(2)	-4.1496	1.9265
ln Patent Count, 1995-2001-World Bank	55(3)	7.9426	3.1122
ln Personnel engaged in R&D	55(3)	10.322	1.7942
ln Share of book production	55(3)	-2.4941	1.8325

Source: Author's compilation

(1) sample utilized in the analysis of the determinants of institutions, (2) sample used in the IV regressions with patent data from the USPTO; (3) sample utilized in the IV regressions with patent data from the World Bank.

Table F.2: Simple Correlation of Institutional Measures and Patent Count

Institutional Measure	Patent Count 1970-2003 USPTO	Patent Count, 1995-2001 World Bank
Regulatory Quality*	0.60	0.42
Rule of Law*	0.68	0.58
Control of Corruption*	0.69	0.56
Risk of Expropriation**	0.80	0.76

Source: Author's calculations; * number of countries=133; ** number of countries =85

Table F.3: OLS Regressions of the Determinants of Institutions (Control of Corruption and Rule of Law)

Explanatory Variables	Control of Corruption				Rule of law			
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
ln Human Capital Density in the early 20th century	0.044	0.033	0.090[a]	0.042	0.055[c]	0.060	0.094[a]	0.050[c]
	(1.33)	(0.76)	(2.90)	(1.27)	(1.89)	(1.56)	(3.60)	(1.73)
Legal Origin – Socialist	-0.983[a]	-0.997[a]	-0.957[a]	-0.950[a]	-1.027[a]	-1.003[a]	-0.971[a]	-0.991[a]
	(-4.37)	(-4.15)	(-4.26)	(-4.21)	(-4.53)	(-4.15)	(-4.39)	(-4.35)
Legal Origin – French	-0.356[b]	-0.329[b]	-0.351[b]	-0.337[b]	-0.387[a]	-0.376[a]	-0.380[a]	-0.371[a]
	(-2.50)	(-2.24)	(-2.34)	(-2.36)	(-2.74)	(-2.57)	(-2.62)	(-2.61)
Legal Origin – German	0.089	0.056	0.326	0.086	0.277	0.303	0.473	0.275
	(0.27)	(0.16)	(0.97)	(0.26)	(0.84)	(0.87)	(1.43)	(0.83)
Legal Origin – Scandinavian	0.221	0.202	0.677[c]	0.263	0.031	0.019	0.407	0.069
	(0.57)	(0.51)	(1.72)	(0.67)	(0.08)	(0.05)	(1.06)	(0.18)
Prop. land within 100 km of the sea coast	0.620[a]	0.657[a]	0.315	0.660[a]	0.544[b]	0.600[a]	0.265	0.601[a]
	(2.73)	(2.75)	(1.44)	(2.90)	(2.46)	(2.57)	(1.29)	(2.73)
Absolute Latitude	1.010	1.012	2.770[a]		1.069[c]	1.069[c]	2.638[a]	
	(1.61)	(1.60)	(6.35)		(1.72)	(1.69)	(6.54)	
Mean Temperature	-0.071[a]	-0.073[a]		-0.093[a]	-0.061[a]	-0.061[a]		-0.085[a]
	(-3.82)	(-3.86)		(-7.54)	(-3.32)	(-3.26)		(-7.13)
ln Population Density in the early 20th century		0.022				-0.017		
		(0.31)				(-0.25)		
Constant	1.244[b]	1.349[b]	-0.505[b]	1.938[a]	1.112[b]	1.022[c]	-0.406[b]	1.849[a]
	(2.47)	(2.18)	(-2.39)	(7.37)	(2.22)	(1.70)	(-2.10)	(7.06)
Sample size	104	104	104	104	110	106	110	110
Adjusted R-squared	0.67	0.67	0.52	0.67	0.66	0.65	0.62	0.65

Notes: The dependent variable in models 1-4 is control of corruption and the dependent variable in models 5-8 is Rule of Law; a, b and c denote that the coefficients are statistically significant at 99%, 95% and 90% of confidence, respectively; t-ratios are reported between parentheses; all regressions were ran with standard errors robust to arbitrary heteroskedasticity.

Table F.4: OLS Regressions of the Determinants of Institutions (Regulatory Quality and Risk of Expropriation)

Explanatory Variables	Regulatory Quality				Risk of Expropriation			
	Model 9	Model 10	Model 11	Model 12	Model 13	Model 14	Model 15	Model 16
ln Human Capital Density in the early 20th century	0.078[b]	0.080[c]	0.129[a]	0.082[b]	0.164[b]	0.147[c]	0.272[a]	0.165[b]
	(2.30)	(1.73)	(4.22)	(2.41)	(2.30)	(1.60)	(4.01)	(2.31)
Legal Origin – Socialist	-0.853[a]	-0.841[a]	-0.724[a]	-0.881[a]	-1.064[b]	-1.109[b]	-0.713	-1.069[b]
	(-3.27)	(-2.99)	(-2.82)	(-3.39)	(-2.04)	(-2.00)	(-1.35)	(-2.06)
Legal Origin - French	-0.097	-0.084	-0.116	-0.110	-0.562[c]	-0.519[c]	-0.555[c]	-0.566[c]
	(-0.60)	(-0.50)	(-0.69)	(-0.68)	(-1.86)	(-1.68)	(-1.75)	(-1.89)
Legal Origin - German	-0.091	-0.081	0.126	-0.090	0.262	0.181	0.679	0.264
	(-0.24)	(-0.20)	(0.33)	(-0.24)	(0.38)	(0.25)	(0.95)	(0.38)
Legal Origin - Scandinavian	-0.017	-0.025	0.406	-0.047	-0.251	-0.361	0.634	-0.259
	(-0.04)	(-0.05)	(0.91)	(-0.10)	(-0.30)	(-0.43)	(0.76)	(-0.32)
Prop. land within 100 km of the sea coast	0.521[b]	0.558[b]	0.197	0.475[c]	0.258	0.400	-0.429	0.251
	(2.05)	(2.07)	(0.82)	(1.89)	(0.54)	(0.80)	(-0.92)	(0.53)
Absolute Latitude	-0.839	-0.838	1.273[c]		-0.200	-0.130	3.346	
	(-1.18)	(-1.15)	(2.68)		(-0.15)	(-0.10)	(3.60)	
Mean Temperature	-0.078[a]	-0.078[a]		-0.059	-0.142[a]	-0.148[a]		-0.138[a]
	(-3.66)	(-3.56)		(-4.25)	(-3.60)	(-3.68)		(-5.26)
ln Population Density in the early 20th century		-0.006				0.028		
		(-0.08)				(0.19)		
Constant	1.928[a]	1.890[a]	-0.045	1.350[a]	10.302[a]	10.439[a]	6.839[a]	10.164[a]
	(3.34)	(2.66)	(-0.20)	(4.47)	(9.61)	(7.96)	(15.28)	(18.19)
Sample size	109	105	109	109	101	97	101	101
Adjusted R-squared	0.46	0.46	0.40	0.46	0.52	0.53	0.47	0.52

Notes: The dependent variable in models 9-12 is Regulatory Quality and the dependent variable in models 13-16 is Risk of Expropriation; a, b and c denote that the coefficients are statistically significant at 99%, 95% and 90% of confidence, respectively; t-ratios are reported between parentheses; all regressions were ran with standard errors robust to arbitrary heteroskedasticity.

Table F.5: IV Regressions of accumulated Patent Counts on Control of Corruption

Explanatory Variables	Patent count 1970-2003- USPTO					Patent count 1995-2001- World Bank				
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
Control of Corruption	1.53 [a]	1.79 [a]	2.16 [a]	1.78 [a]	1.79 [a]	0.85 [a]	1.06 [a]	1.21 [a]	1.03 [a]	0.99 [a]
	(11.62)	(9.45)	(5.06)	(9.70)	(9.78)	(5.57)	(5.67)	(3.33)	(5.97)	(5.86)
ln Personnel engaged in R&D	0.49 [a]	0.49 [a]	0.51 [a]	0.49 [a]	0.49 [a]	0.68 [a]	0.69 [a]	0.68 [a]	0.68 [a]	0.68 [a]
	(4.89)	(5.19)	(5.10)	(5.20)	(4.90)	(4.59)	(4.96)	(5.25)	(4.84)	(4.86)
ln Share of book production	0.55 [a]	0.46 [a]	0.44 [a]	0.46 [a]	0.46 [a]	0.67 [a]	0.60 [a]	0.56 [a]	0.61 [a]	0.63 [a]
	(4.96)	(4.23)	(3.48)	(4.15)	(4.19)	(4.17)	(3.60)	(3.62)	(3.77)	(3.58)
Prop. land within 100 km of the sea coast	-	-	-0.32	-	-	-	-	-0.87	-	-
	-	-	(-0.58)	-	-	-	-	(-1.56)	-	-
Mean Temperature	-	-	0.05	-	-	-	-	0.01	-	-
	-	-	(1.06)	-	-	-	-	(0.21)	-	-
ln population (aged 15-64) density	-	-	-	0.01	-	-	-	-	0.04	-
	-	-	-	(0.09)	-	-	-	-	(0.29)	-
Population (aged 15-64) density	-	-	-	-	0.000	-	-	-	-	-0.001
	-	-	-	-	(0.07)	-	-	-	-	(-0.20)
Population (aged 15-64) density Squared	-	-	-	-	0.000	-	-	-	-	0.000
	-	-	-	-	(-0.06)	-	-	-	-	(0.38)
Constant	3.29 [a]	2.78	1.61	2.75	2.76 [b]	2.09	1.71	1.82	1.69	1.88
	(2.69)	(2.41)	(1.01)	(2.27)	(2.34)	(1.21)	(1.01)	(0.98)	(0.97)	(1.11)
Method	OLS	2SLS-IV	2SLS-IV	2SLS-IV	2SLS-IV	OLS	2SLS-IV	2SLS-IV	2SLS-IV	2SLS-IV
Sample Size	76	76	76	76	76	76	76	76	76	76
Centered R-Squared	0.86	0.85	0.84	0.85	0.85	0.84	0.84	0.84	0.84	0.84
Overidentification test (Hansen J statistic)	-	3.03	5.31	5.26	5.25	-	2.01	4.87	5.80	4.34
[P-Value]	-	[0.22]	[0.26]	[0.26]	[0.26]	-	[0.37]	[0.30]	[0.22]	[0.36]

Notes: The dependent variable in models 1-5 is the natural logarithm of the USPTO patent count between 1970-2003 and the dependent variable in models 6-10 is the natural logarithm of the World Bank patent count between 1995-2001; a, b and c denote that the coefficients are statistically significant at 99%, 95% and 90% of confidence, respectively; t-ratios are reported between parentheses; all regressions were ran with standard errors robust to arbitrary heteroskedasticity. All 2SLS-IV regressions are estimated using the following set of instruments: ln human capital density in the early 20th century, dummies for the origin of the legal system, mean temperature, and proportion of land within 100 km of the seacoast.

Table F.6: IV Regressions of accumulated Patent Counts on Rule of Law

Explanatory Variables	Patent count 1970-2003- USPTO					Patent count 1995-2001- World Bank				
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
Rule of Law	1.64^{b}	1.91^{b}	2.17^{b}	1.92^{b}	1.94^{b}	0.99^{b}	1.16^{b}	1.19^{b}	1.14^{b}	1.13^{b}
	(11.62)	(10.36)	(5.34)	(10.52)	(10.63)	(5.82)	(5.68)	(3.72)	(5.95)	(5.84)
ln Personnel engaged in R&D	0.41^{b}	0.40^{b}	0.41^{b}	0.40^{b}	0.41^{b}	0.67^{b}	0.68^{b}	0.67^{b}	0.68^{b}	0.68^{b}
	(4.36)	(4.45)	(4.36)	(4.38)	(4.25)	(4.59)	(4.89)	(5.10)	(4.91)	(4.88)
ln Share of book production	0.60^{b}	0.52^{b}	0.52^{b}	0.53^{b}	0.52^{b}	0.65^{b}	0.59^{b}	0.55^{b}	0.60^{b}	0.61^{b}
	(5.37)	(4.55)	(4.00)	(4.52)	(4.52)	(3.94)	(3.48)	(3.54)	(3.61)	(3.42)
Prop. land within 100 km of the sea coast	-	-	-0.21	-	-	-	-	-0.74	-	-
	-	-	(-0.39)	-	-	-	-	(-1.41)	-	-
Mean Temperature	-	-	0.03	-	-	-	-	-0.01	-	-
	-	-	(0.75)	-	-	-	-	(-0.25)	-	-
ln population (aged 15-64) density	-	-	-	-0.05	-	-	-	-	-0.04	-
	-	-	-	(-0.54)	-	-	-	-	(-0.30)	-
Population (aged 15-64) density	-	-	-	-	0.00	-	-	-	-	0.00
	-	-	-	-	(-0.45)	-	-	-	-	(-0.33)
Population (aged 15-64) density Squared	-	-	-	-	0.00	-	-	-	-	0.00
	-	-	-	-	(0.48)	-	-	-	-	(0.30)
Constant	4.02^{b}	3.67^{b}	3.01^{b}	3.87^{b}	3.65^{b}	2.01	1.74	2.11	1.83	1.79
	(3.42)	(3.19)	(2.05)	(3.20)	(3.09)	(1.16)	(1.02)	(1.20)	(1.06)	(1.05)
Method	OLS	2SLS-IV	2SLS-IV	2SLS-IV	2SLS-IV	OLS	2SLS-IV	2SLS-IV	2SLS-IV	2SLS-IV
Sample Size	76	76	76	76	76	55	55	55	55	55
Centered R-Squared	0.86	0.86	0.85	0.86	0.86	0.85	0.85	0.85	0.85	0.85
Overidentification test (Hansen J statistic)	-	2.76	4.06	4.23	4.30	-	0.96	3.54	4.17	3.20
[P-Value]	-	[0.25]	[0.40]	[0.38]	[0.37]	-	[0.62]	[0.47]	[0.38]	[0.52]

Notes: The dependent variable in models 1-5 is the natural logarithm of the USPTO patent count between 1970-2003 and the dependent variable in models 6-10 is the natural logarithm of the World Bank patent count between 1995-2001; a, b and c denote that the coefficients are statistically significant at 99%, 95% and 90% of confidence, respectively; t-ratios are reported between parentheses; all regressions were ran with standard errors robust to arbitrary heteroskedasticity. All 2SLS-IV regressions are estimated using the following set of instruments: ln human capital density in the early 20th century, dummies for the origin of the legal system, mean temperature, and proportion of land within 100 km of the seacoast.

Table F.7: IV Regressions of Accumulated Patent Counts on Regulatory Quality

Explanatory Variables	Patent count 1970-2003- USPTO					Patent count 1995-2001- World Bank				
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
Regulatory Quality	1.61[a]	2.14[a]	2.49[a]	2.25[a]	2.07[a]	0.86[a]	1.58[a]	1.60[a]	1.53[a]	1.48[a]
	(6.65)	(9.12)	(3.56)	(9.88)	(8.98)	(2.98)	(5.25)	(3.51)	(5.65)	(5.50)
ln Personnel engaged in R&D	0.42[a]	0.41[a]	0.40[a]	0.40[a]	0.42[a]	0.76[a]	0.86[a]	0.86[a]	0.86[a]	0.86[a]
	(3.73)	(3.56)	(3.32)	(3.63)	(3.62)	(4.36)	(5.22)	(5.10)	(5.18)	(5.18)
ln Share of book production	0.79[a]	0.69[a]	0.66[a]	0.71[a]	0.71[a]	0.69[a]	0.48[b]	0.43[b]	0.49[b]	0.52[b]
	(6.46)	(5.83)	(5.11)	(6.18)	(6.03)	(3.76)	(2.22)	(2.09)	(2.41)	(2.34)
Prop. land within 100km of the sea coast	-	-	-0.70	-	-	-	-	-0.80	-	-
	-	-	(-0.87)	-	-	-	-	(-1.16)	-	-
Mean Temperature	-	-	0.02	-	-	-	-	-0.02	-	-
	-	-	(0.26)	-	-	-	-	(-0.50)	-	-
ln population (aged 15-64) density	-	-	-	-0.18	-	-	-	-	-0.03	-
	-	-	-	(-1.55)	-	-	-	-	(-0.22)	-
Population (aged 15-64) density	-	-	-	-	-0.001	-	-	-	-	-0.004
	-	-	-	-	(-0.32)	-	-	-	-	(-0.58)
Population (aged 15-64) density Squared	-	-	-	-	0.0000	-	-	-	-	0.0000
	-	-	-	-	(0.38)	-	-	-	-	(0.66)
Constant	4.72[a]	4.23[a]	4.07[b]	4.86[a]	4.26[a]	1.29	-0.67	-	-	-0.34
	(3.33)	(2.92)	(2.14)	(3.26)	(2.94)	(0.60)	(-0.33)	(-0.08)	(-0.23)	(-0.17)
Method	OLS	2SLS-IV	2SLS-IV	2SLS-IV	2SLS-IV	OLS	2SLS-IV	2SLS-IV	2SLS-IV	2SLS-IV
Sample Size	76	76	76	76	76	55	55	55	55	55
Centered R-Squared	0.84	0.83	0.81	0.83	0.83	0.81	0.79	0.80	0.79	0.80
Overidentification test (Hansen J statistic)	-	3.47	4.28	5.47	6.27	-	1.86	4.26	4.90	3.99
[P-Value]	-	[0.18]	[0.37]	[0.24]	[0.18]	-	[0.40]	[0.37]	[0.30]	[0.41]

Notes: The dependent variable in models 1-5 is the natural logarithm of the USPTO patent count between 1970-2003 and the dependent variable in models 6-10 is the natural logarithm of the World Bank patent count between 1995-2001; a, b and c denote that the coefficients are statistically significant at 99%, 95% and 90% of confidence, respectively; t-ratios are reported between parentheses; all regressions were ran with standard errors robust to arbitrary heteroskedasticity. All 2SLS-IV regressions are estimated using the following set of instruments: ln human capital density in the early 20th century, dummies for the origin of the legal system, mean temperature, and proportion of land within 100 km of the seacoast.

Table F.8: IV Regressions of Accumulated Patent Counts on Expropriation Risk

Explanatory Variables	Patent count 1970-2003- USPTO					Patent count 1995-2001- World Bank				
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
Expropriation Risk	0.97[a]	1.45[a]	1.42[a]	1.45[a]	1.45[a]	0.69[a]	1.07[a]	1.30[a]	1.02[a]	0.98[a]
	(6.38)	(7.43)	(3.63)	(7.56)	(7.68)	(5.03)	(4.83)	(3.10)	(5.01)	(5.17)
ln Personnel engaged in R&D	0.31[a]	0.24[b]	0.25[b]	0.24[b]	0.23[c]	0.58[a]	0.54[a]	0.50[b]	0.55[a]	0.58[a]
	(2.86)	(2.03)	(2.32)	(2.00)	(1.87)	(3.10)	(2.81)	(2.40)	(2.91)	(3.18)
ln Share of book production	0.60[a]	0.36[b]	0.39[b]	0.37[b]	0.35[b]	0.54[b]	0.31	0.23	0.34	0.30
	(4.31)	(2.19)	(2.14)	(2.22)	(2.15)	(2.31)	(1.35)	(0.91)	(1.54)	(1.41)
Prop. land within 100km of the sea coast	-	-	0.42	-	-	-	-	-0.85	-	-
	-	-	(0.68)	-	-	-	-	(-1.39)	-	-
Mean Temperature	-	-	0.01	-	-	-	-	0.02	-	-
	-	-	(0.15)	-	-	-	-	(0.55)	-	-
ln population (aged 15-64) density	-	-	-	-0.06	-	-	-	-	-0.04	-
	-	-	-	(-0.52)	-	-	-	-	(-0.26)	-
Population (aged 15-64) density	-	-	-	-	0.00	-	-	-	-	-0.01[b]
	-	-	-	-	(0.25)	-	-	-	-	(-2.37)
Population (aged 15-64) density Squared	-	-	-	-	0.00	-	-	-	-	0.0001[a]
	-	-	-	-	(-0.23)	-	-	-	-	(3.41)
Constant	-1.71	-5.63[b]	-5.69	-5.45[b]	-5.71[b]	-2.14	-5.33[b]	-6.90	-4.81[c]	-4.71[b]
	(-0.89)	(-2.41)	(-1.35)	(-2.31)	(-2.52)	(-0.82)	(-2.08)	(-1.69)	(-1.87)	(-2.02)
Method	OLS	2SLS-IV	2SLS-IV	2SLS-IV	2SLS-IV	OLS	2SLS-IV	2SLS-IV	2SLS-IV	2SLS-IV
Sample Size	75	75	75	75	75	54	54	54	54	54
Centered R-Squared	0.83	0.79	0.80	0.79	0.79	0.83	0.81	0.79	0.81	0.84
	Results from Overidentification Test									
Overidentification test (Hansen J statistic)	-	8.94[c]	7.93[b]	9.67[b]	8.90[c]	-	2.86	0.40	3.72	4.49
[P-value]	-	[0.06]	[0.02]	[0.05]	[0.06]	-	[0.58]	[0.82]	[0.45]	[0.34]

Notes: The dependent variable in models 1-5 is the natural logarithm of the USPTO patent count between 1970-2003 and the dependent variable in models 6-10 is the natural logarithm of the World Bank patent count between 1995-2001; a, b and c denote that the coefficients are statistically significant at 99%, 95% and 90% of confidence, respectively; t-ratios are reported between parentheses; *all regressions were ran with standard errors robust to arbitrary heteroskedasticity*. All 2SLS-IV regressions are estimated using the following set of instruments: ln human capital density in the early 20th century, dummies for the origin of the legal system, mean temperature, and proportion of land within 100 km of the seacoast.

Table F.9: IV Regressions of Accumulated Patent Counts -USPTO

Explanatory Variables	T=Risk of Expropriation		T=Regulatory Quality		T=Control of Corruption		T=Rule of Law	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Institution (T)	1.34[a]	2.11[c]	2.05[a]	1.95[a]	2.00[a]	2.02[a]	2.03[a]	2.08[a]
	(4.54)	(1.82)	(5.59)	(7.93)	(6.74)	(5.39)	(6.53)	(5.58)
Institution Squared (T^2)	-	-0.04	-	0.80[b]	-	-0.16		-0.15
	-	(-0.57)	-	(2.25)	-	(-0.70)		(-0.54)
OECD * Institution (T)	0.00	-	-0.18	-	-0.59	-	-0.43	
	(-0.02)	-	(-0.32)	-	(-1.54)	-	(-1.08)	
OECD	0.55	-	0.70	-	0.69	-	0.63	
	(0.25)	-	(1.18)	-	(1.28)	-	(1.18)	
ln Personnel engaged in R&D	0.23[c]	0.22	0.39[a]	0.56[a]	0.50[a]	0.49[a]	0.40[a]	0.39[a]
	(1.80)	(1.61)	(2.84)	(4.05)	(4.07)	(4.05)	(3.31)	(3.14)
ln Share of book production	0.35[b]	0.37[b]	0.65[a]	0.48[a]	0.42[a]	0.45[a]	0.50[a]	0.53[a]
	(2.33)	(2.44)	(4.87)	(3.47)	(3.41)	(3.59)	(4.05)	(4.21)
Constant	-5.03	-7.85	4.09[b]	1.35	2.55[c]	2.90[a]	3.53[a]	3.92[a]
	(-2.00)[b]	(-1.92)[c]	(2.51)	(0.73)	(1.77)	(2.01)	(2.46)	(2.52)
Method	2SLS-IV	2SLS-IV	2SLS-IV	2SLS-IV	2SLS-IV	2SLS-IV	2SLS-IV	2SLS-IV
Sample Size	75	75	76	76	76.00	76.00		
Centered R-Squared	0.82	0.82	0.83	0.84	0.84	0.84	0.84	0.84

Notes: The dependent variable in all models is the natural logarithm of the USPTO patent count between 1970-2003; a, b and c denote that the coefficients are statistically significant at 99%, 95% and 90% of confidence, respectively; t-ratios are reported between parentheses; all regressions were ran with standard errors robust to arbitrary heteroskedasticity. *The 2SLS-IV regressions are estimated using the following set of instruments:* ln human capital density in the early 20th century, dummies for the origin of the legal system, mean temperature, and proportion of land within 100km of the seacoast. For models 2, 4 ,6 and 8, the squared measure of institutions are instrumented by using the set of instruments listed above plus the squared values of the following variables. ln human capital density in the early 20th century, mean temperature, and proportion of land within 100 km of the seacoast.

Table F.10: IV Regressions of Accumulated Patent Counts -USPTO

Explanatory Variables	Institutional Measure							
	Control of Corruption		Rule of Law		Regulatory Quality		Risk of Expropriation	
Institution	2.75[a]	2.92[a]	2.87[a]	2.75[a]	3.64[a]	3.03[a]	1.77[a]	1.78[a]
	(16.26)	(6.00)	(19.79)	(6.29)	(11.96)	(5.31)	(14.82)	(4.37)
Proportion of land within 100 km of the sea coast		-0.05		0.30		-0.03		1.04
		(-0.08)		(0.52)		(-0.03)		(1.51)
Mean Temperature		0.02		-0.01		-0.08[c]		0.01
		(0.39)		(-0.22)		(-1.81)		(0.19)
Constant	-4.01[a]	-4.46[a]	-4.10[a]	-3.98[a]	-4.39[a]	-2.77[a]	-16.17[a]	-16.98[a]
	(-23.96)	(-4.27)	(-24.65)	(-4.53)	(-17.06)	(-3.86)	(-16.51)	(-4.15)
Method	2SLS-IV	2SLS-IV	2SLS-IV	2SLS-IV	2SLS-IV	2SLS-IV	2SLS-IV	2SLS-IV
Sample Size	93	93	95	95	95	95	92	92
Centered R-Squared	0.73	0.72	0.74	0.75	0.47	0.61	0.60	0.61
Overidentification test (Hansen J statistic)	2.27	1.92	1.78	1.42	7.51	1.12	10.65	7.38
[p-value]	[0.69]	[0.38]	[0.78]	[0.49]	[0.11]	[0.57]	[0.03]	[0.02]

Notes: The dependent variable in all models is the natural logarithm of the USPTO patent count between 1970-2003 divided by population aged 15-64 years; a, b and c denote that the coefficients are statistically significant at 99%, 95% and 90% of confidence, respectively; t-ratios are reported between parentheses; all regressions were ran with standard errors robust to arbitrary heteroskedasticity. All 2SLS-IV regressions are estimated using the following set of instruments: ln Human Capital Density in the early 20th century, dummies for the origin of the legal system, mean temperature, and proportion of land within 100 km of the seacoast.

Appendix G: Figures

Figure G.1: Rule of Law and Patent Production, 1970-2003

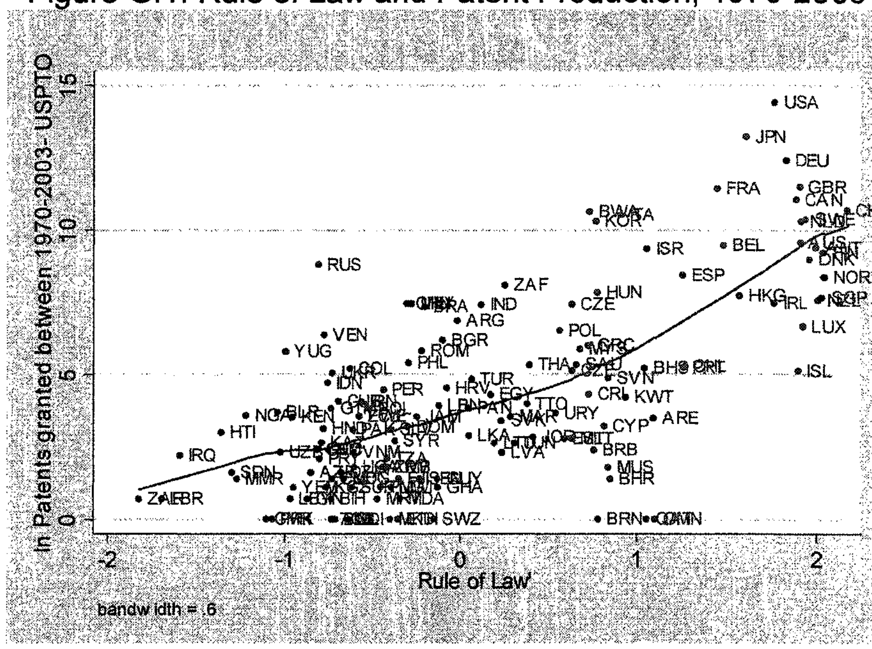


Figure G.2: Regulatory Quality and Patent Production, 1970-2003

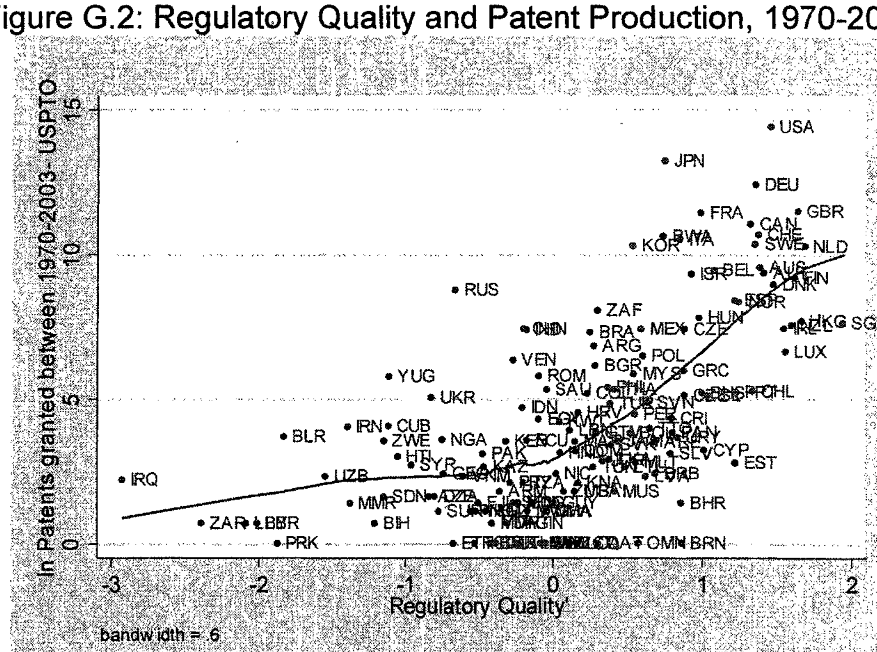


Figure G.3: Control of Corruption and Patent Production, 1970-2003

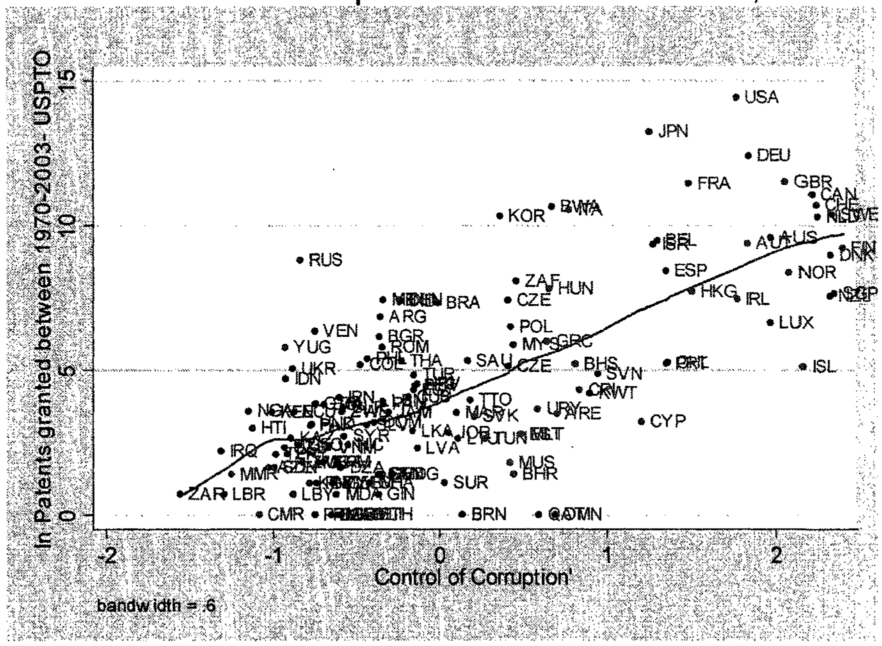
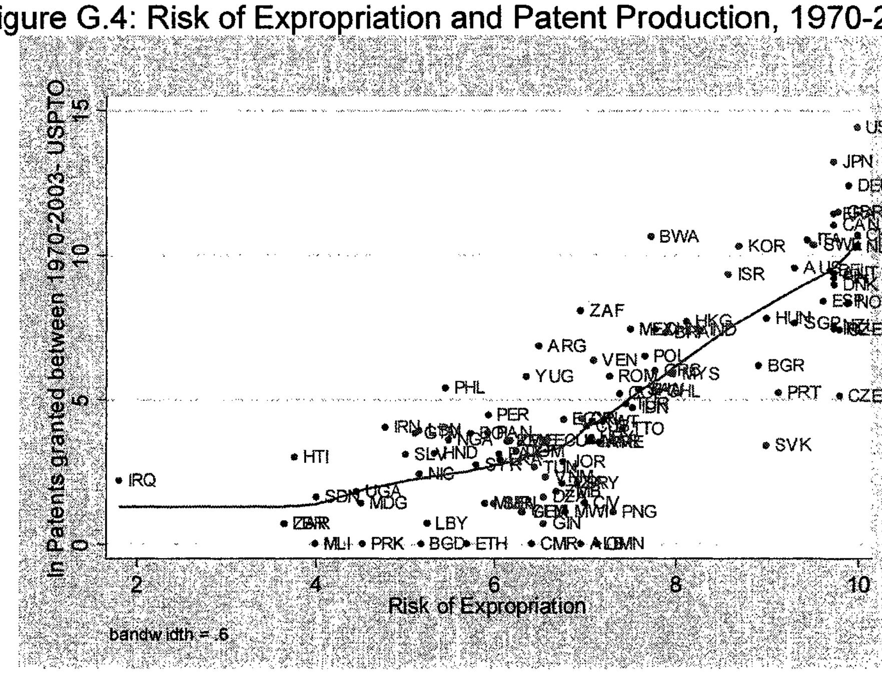


Figure G.4: Risk of Expropriation and Patent Production, 1970-2003



Appendix H: Dataset

Table H.1 – List of Variables

Variable	Definition
Country	Country's name
ISO3	ISO
C	Control of Corruption, Average 1996-2002
RL	Rule of Law, Average 1996-2002
RQ	Regulatory Quality, Average 1996-2002
Exprop	Risk of Expropriation, average 1985-1995
lnptuspto	Natural logarithm of the USPTO patent count between 1970-2003
lnpt_wb	Natural logarithm of the World Bank patent count between 1995-2001
lnscien70	Natural logarithm of Personnel engaged in R&D, average 1968-1972
lnscien95	Natural logarithm of Personnel engaged in R&D, average 1995-1999
Sample A	Observation included in the regression analysis - USPTO Patent data
Sample B	Observation Included in the regression analysis - World Bank Patent data
lnbkshare70	Natural logarithm of Share of book production, average 1968-1972
lnbkshare95	Natural logarithm of Share of book production, average 1995-1999
lnpop70	Natural logarithm of population (aged 15-64) density, 1970
lnpop95	Natural logarithm of population (aged 15-64) density, 1995
Socialist	Socialist Legal Origin
French	French Legal System
English	Common Law Legal System
German	German Legal System
Scandin	Scandinavian Legal System
lt100km	Proportion of land within 100 km of the seacoast
meantemp	Mean Temperature
latabs	Absolute Latitude
lnschool20	Natural logarithm of Schooling Density in the early 20th century (1920)

Table H.2: Dataset

Country	ISO3	C	RL	RQ	Exprop	lnptuspto	lnpt_wb	lnscien70	lnscien95	Sample A	Sample B
Afghanistan	AFG		-1.5450								
Algeria	DZA	-0.5900	-0.6775	-0.7975	6.5500	1.6094	5.5910	5.8348		Yes	
Angola	AGO	-1.1200	-1.4350	-1.4825	5.3700						
Argentina	ARG	-0.3525	-0.0100	0.2825	6.5000	6.8427	7.8571	9.7172	10.3428	Yes	Yes
Australia	AUS	1.9725	1.9075	1.3875	9.3200	9.5417	11.1080	10.6674	11.4358	Yes	Yes
Austria	AUT	1.8375	1.9975	1.4125	9.7400	9.3524	9.9123	8.4399	10.3516	Yes	Yes
Bangladesh	BGD	-0.6475	-0.7075	-0.4200	5.1800	0.0000	4.6250	7.7882	9.7189	Yes	
Belgium	BEL	1.3025	1.4875	1.0800	9.6900	9.4398	9.3910	10.0399	10.7454	Yes	Yes
Benin	BEN		-0.3225	-0.0975							
Bolivia	BOL	-0.6900	-0.5150	0.5250	5.7400	3.8067	2.8332	7.0901	6.5985	Yes	
Brazil	BRA	-0.0075	-0.1950	0.2600	7.9000	7.3139	9.7224	8.9522	10.9743	Yes	Yes
Bulgaria	BGR	-0.3600	-0.0925	0.2950	8.9200	6.1633	7.7039	10.4090	9.8548	Yes	Yes
Burkina Faso	BFA	-0.3900	-0.5800	-0.1925	4.5000				6.6320		
Burundi	BDI		-0.8675	-1.1225			0.0000		7.2513		
Cambodia	KHM	-0.9025	-0.7975	-0.2275							
Cameroon	CMR	-1.0825	-1.1000	-0.4200	6.4200	0.0000		5.6168	5.3083	Yes	
Canada	CAN	2.2075	1.8875	1.3225	9.7400	11.0321	10.3685	10.4502	11.8512	Yes	Yes
Central African Republic	CAF		-0.6375	-0.5725				4.8520	6.9717		
Chad	TCD		-0.7275	-0.5250		0.0000		4.9127			
Chile	CHL	1.3650	1.2700	1.3375	7.8200	5.2730	6.4151	8.7376	9.4430	Yes	Yes
China	CHN	-0.2400	-0.2975	-0.1950	7.7900	7.4260	11.5581		13.6169		Yes
Colombia	COL	-0.4725	-0.6250	0.2400	7.3900	5.1874	6.2305	7.0388	8.5980	Yes	Yes
Congo	COG	-0.9050	-1.1950	-0.9200	4.6300				5.4972		
Congo, Democratic Republic (zaire)	ZAR	-1.5625	-1.8200	-2.3875	3.6600	0.6931	1.6094				
Costa Rica	CRI	0.8400	0.7375	0.7950	6.9700	4.3175		5.7683	7.5316	Yes	
Cuba	CUB	-0.1875	-0.6900	-1.1150	7.0200	4.0604	6.0210	8.9449	11.0190	Yes	Yes
Ivory Cost	CIV	-0.3650	-0.7275	-0.1375	7.0000	1.3863		6.2934		Yes	
Denmark	DNK	2.3200	1.9625	1.4750	9.7400	8.9461	9.9447	9.4122	10.4058	Yes	Yes
Dominican Republic	DOM	-0.3900	-0.2925	0.1600	6.2500	3.1781		8.9666		Yes	
Ecuador	ECU	-0.8700	-0.5725	-0.1750	6.5600	3.5553	3.6376	8.3795	8.0430	Yes	Yes
Egypt	EGY	-0.1550	0.1775	-0.0925	6.7700	4.3041	7.8368	9.0588	12.0857	Yes	Yes

Continued: Table H.2: Dataset

Country	ISO3	C	RL	RQ	Exprop	lnptuspto	lnpt_wb	lnscien70	lnscien95	Sample A	Sample B
El Salvador	SLV	-0.4350	-0.3875	0.7900	5.0100	3.0910	1.0986	7.1861	7.9983	Yes	Yes
Finland	FIN	2.3900	2.0375	1.6175	9.7400	9.1926	10.0718	9.1378	10.7437	Yes	Yes
France	FRA	1.4900	1.4550	0.9925	9.7400	11.4260	11.8238	11.8524	12.6528	Yes	Yes
Gabon	GAB	-0.8275	-0.3950	-0.1800	7.8100			3.3322			
Germany	DEU	1.8450	1.8325	1.3575	9.9100	12.3947	13.0642	12.3305	13.0633	Yes	Yes
Greece	GRC	0.6450	0.7350	0.8800	7.7800	5.9687	7.1033	8.3729	10.0577	Yes	Yes
Guatemala	GTM	-0.7450	-0.7300	0.2950	5.1200	3.8286	3.8501	6.7370		Yes	
Guinea	GIN	-0.3675	-0.8700	-0.1750	6.5500	0.6931					
Haiti	HTI	-1.1225	-1.3525	-1.0500	3.7700	2.9957	1.3863				
Honduras	HND	-0.7675	-0.7750	0.0550	5.3300	3.1355	3.5835	6.6187	7.6811	Yes	
Hungary	HUN	0.6600	0.7875	0.9800	9.0100	7.8099	8.5260	10.6941	9.9607	Yes	Yes
India	IND	-0.2300	0.1250	-0.1775	8.2800	7.3790	9.5655	11.5165	12.7152	Yes	Yes
Indonesia	IDN	-0.9200	-0.7525	-0.2050	7.5300	4.6913	3.6889	9.8699	11.8164	Yes	Yes
Iran	IRN	-0.6000	-0.5575	-1.3950	4.7800	4.0431	7.5022	8.4384	10.8263	Yes	Yes
Iraq	IRQ	-1.3150	-1.5875	-2.9225	1.8100	2.1972	4.2195	6.9108		Yes	
Ireland	IRL	1.7725	1.7650	1.5450	9.7400	7.4372	8.6841	7.9899	9.3667	Yes	
Israel	ISR	1.2775	1.0625	0.9300	8.5900	9.3136	9.4921	8.0064	9.4485	Yes	Yes
Italy	ITA	0.7800	0.9175	0.8550	9.4600	10.5003	10.3641	10.8550	11.8696	Yes	Yes
Jamaica	JAM	-0.3075	-0.2400	0.4425	7.0400	3.5264	2.6391	8.6933	6.7020	Yes	
Japan	JPN	1.2600	1.6150	0.7550	9.7400	13.2146	14.5999	12.8891	13.7137	Yes	Yes
Jordan	JOR	0.0600	0.4225	0.3400	6.7600	2.8332		4.9488	10.0836	Yes	
Kenya	KEN	-1.0075	-0.9525	-0.3175	6.1500	3.5264	4.6540	7.3796		Yes	
Korea, Dem. People's Rep. of	PRK	-0.7450	-1.0675	-1.8725	4.5300	0.0000					
Korea, Republic of	KOR	0.3675	0.7800	0.5425	8.7100	10.2897	12.9374	9.1182	11.8525	Yes	Yes
Lao People's Dem. Rep.	LAO	-0.9325	-1.1075	-1.1675				5.8972			
Lebanon	LBN	-0.3400	-0.1150	0.1200	5.1600	3.9120		6.0088		Yes	
Liberia	LBR	-1.2975	-1.6925	-2.0100	3.6500	0.6931					
Libyan Arab Jamahiriya	LBY	-0.8775	-0.9650	-2.0850	5.2500	0.6931	2.4849	5.2575		Yes	
Madagascar	MDG	-0.2800	-0.6625	-0.2325	4.5100	1.3863	3.1355	5.6971	6.9921	Yes	Yes
Malawi	MWI	-0.6375	-0.3875	-0.1675	6.7900	1.0986	2.8904	2.6391		Yes	
Malaysia	MYS	0.4475	0.6875	0.5500	7.9800	5.8608	5.1874	7.2145	8.8609	Yes	Yes
Mali	MLI	-0.4375	-0.6325	-0.0425	4.0000	0.0000					

Continued: Table H.2: Dataset

Country	ISO3	C	RL	RQ	Exprop	lnptuspto	lnpt_wb	lnscien70	lnscien95	Sample A	Sample B
Mauritania	MRT		-0.4675	-0.3150		0.6931					
Mauritius	MUS	0.4250	0.8475	0.4200		1.7918	2.1972	5.0876	7.1869	Yes	Yes
Mexico	MEX	-0.3375	-0.2700	0.5975	7.5100	7.4170	7.9384	8.9534	10.5152	Yes	Yes
Morocco	MAR	0.1075	0.2900	0.1575	7.0900	3.5264	5.2679				
Mozambique	MOZ	-0.6725	-0.8925	-0.4950	6.4900		0.0000				
Myanmar	MMR	-1.2525	-1.2675	-1.3775	5.9000	1.3863		7.7053		Yes	
Netherlands	NLD	2.2400	1.9150	1.6875	10.0000	10.2664	10.5425	10.9130	11.3302	Yes	Yes
New Zealand	NZL	2.3150	2.0100	1.5950	9.7400	7.5401	9.1426	7.4348	9.3697	Yes	Yes
Nicaragua	NIC	-0.5475	-0.7500	0.0275	5.1600	2.3979	3.0445		6.4297		
Niger	NER	-0.7975	-0.8750	-0.5475	5.1000			4.5433			
Nigeria	NGA	-1.1475	-1.2125	-0.7450	5.4900	3.5835		7.9431	9.4852	Yes	
Norway	NOR	2.0825	2.0425	1.2475	9.9000	8.3561	9.2166	9.1484	10.1358	Yes	Yes
Pakistan	PAK	-0.7725	-0.6100	-0.4700	6.0600	3.0910	4.3041	8.5841	10.5107	Yes	Yes
Panama	PAN	-0.3375	0.0500	0.8025	5.9300	3.8286	3.6376	6.2246	7.1997	Yes	
Paraguay	PRY	-0.9150	-0.8000	-0.2875	6.9200	2.0794		4.8978	7.6138		
Peru	PER	-0.1450	-0.4325	0.5550	5.9400	4.4543	4.9972	7.7668	8.6479	Yes	Yes
Philippines	PHL	-0.4325	-0.2875	0.3750	5.4600	5.3936	6.6187	7.8656	9.5873	Yes	Yes
Poland	POL	0.4325	0.5750	0.6100	7.6700	6.4800	9.5573	11.8004	11.3142	Yes	Yes
Portugal	PRT	1.3575	1.2625	1.2275	9.1400	5.2257	6.6386	8.3075	9.8927	Yes	Yes
Romania	ROM	-0.3425	-0.2125	-0.0900	7.2800	5.7900	8.9976	10.4271	10.7415	Yes	Yes
Saudi Arabia	SAU	0.1725	0.6675	-0.0375	7.6000	5.3230	5.5094	10.4156		Yes	
Senegal	SEN	-0.3450	-0.2250	-0.2675	6.0000	1.3863		6.8112	4.2767		
Sierra Leone	SLE	-0.9625	-0.9275	-1.0600	5.8400		0.0000				
Singapore	SGP	2.3400	2.0300	1.9400	9.3200	7.6468	9.1147	5.9135	9.5711	Yes	
Somalia	SOM	-1.4475	-1.7900	-2.3800	3.0000						
South Africa	ZAF	0.4650	0.2600	0.3100	6.9600	8.0618	6.1759		10.4311		Yes
Spain	ESP	1.3550	1.2600	1.2225	9.6200	8.4018	9.8876	8.9049	11.5459	Yes	Yes
Sri Lanka	LKA	-0.1600	0.0550	0.3850	6.0700	2.8904	4.8752	8.9134	8.3619	Yes	Yes
Sudan	SDN	-0.9950	-1.2950	-1.1450	4.0100	1.6094	2.8904	7.8633		Yes	
Sweden	SWE	2.3275	1.9425	1.3550	9.5200	10.3459	10.8220	10.1873	11.1290	Yes	Yes
Switzerland	CHE	2.2350	2.1650	1.3750	10.0000	10.6625	10.4716	9.7036	10.8444	Yes	Yes
Syrian Arab Republic	SYR	-0.5700	-0.3675	-0.9575	5.8000	2.7081	5.5175	10.1074	6.6896	Yes	Yes
Thailand	THA	-0.2275	0.3975	0.4175	7.6100	5.3230	7.6183	8.3357	9.4210	Yes	Yes
Togo	TGO	-0.6775	-0.8650	-0.4275	6.8400			4.9127			
Trinidad and Tobago	TTO	0.1900	0.3850	0.6500	7.4200	3.9703	3.2958	6.3491	7.2563		
Tunisia	TUN	0.2800	0.3125	0.2800	6.4500	2.6391	3.8286	7.2226	8.4530	Yes	Yes

Continued: Table H.2: Dataset

Country	ISO3	C	RL	RQ	Exprop	Inptuspto	Inpt_wb	Inscien70	Inscien95	Sample A	Sample B
Turkey	TUR	-0.1525	0.0700	0.3925	7.4600	4.8203	7.5570	8.8885	10.0086	Yes	Yes
Uganda	UGA	-0.7300	-0.6025	0.1550	4.4600	1.7918	2.1972		6.9373		Yes
United Kingdom	GBR	2.0600	1.9075	1.6375	9.7900	11.4695	12.1020	11.9185	12.5883	Yes	Yes
United Rep. of Tanzania	TZA	-0.9800	-0.4150	-0.1975	6.7500	2.0794	0.6931	9.6173		Yes	
United States of America	USA	1.7725	1.7725	1.4575	10.0000	14.4058	13.7123	13.5312	14.5373	Yes	Yes
Uruguay	URY	0.5900	0.5500	0.8325	7.0700	3.6636	5.0434	7.7337	6.9641	Yes	Yes
Venezuela	VEN	-0.7450	-0.7725	-0.2675	7.1000	6.3439	6.0845	8.0609	8.6646		Yes
Viet Nam	VNM	-0.6625	-0.6025	-0.6050	6.5700	2.3026	4.9345	8.3948	10.5506	Yes	Yes
Zambia	ZMB	-0.8225	-0.4150	0.0825	6.6800	1.7918	3.2581	6.5117	7.6275		
Zimbabwe	ZWE	-0.5850	-0.5700	-1.1475	6.1800	3.5553	3.7842				

Continued: Table H.2: Dataset

Country	lnbkshare70	lnbkshare95	lnpop70	lnpop95	Socialist	French	English	German	Scandin	Sample A	Sample B
Afghanistan	-7.1348		2.3350	2.8956	0	1	0	0	0		
Algeria	-5.5288	-5.0873	1.0087	1.9151	0	1	0	0	0	Yes	
Angola	-9.1158	-7.9927	0.8894	1.4605	0	1	0	0	0		
Argentina	-2.7828	-1.8356	1.7074	2.0292	0	1	0	0	0	Yes	Yes
Australia	-2.9085	-1.7829	0.0217	0.4475	0	0	1	0	0	Yes	Yes
Austria	-2.6753	-2.0794	3.9986	4.1557	0	0	0	1	0	Yes	Yes
Bangladesh	-5.0009		5.4648	6.1493	0	0	1	0	0	Yes	
Belgium	-2.7365	-0.9032	5.2937	5.3924	0	1	0	0	0	Yes	Yes
Benin		-8.8866	2.4809	3.1710	0	1	0	0	0		
Bolivia	-6.0248		0.7209	1.3317	0	1	0	0	0	Yes	
Brazil	-2.2494	-1.0829	1.8062	2.4766	0	1	0	0	0	Yes	Yes
Bulgaria	-2.9478	-2.6139	3.9461	3.9270	1	0	0	0	0	Yes	Yes
Burkina Faso		-8.6859	2.3576	2.8690	0	1	0	0	0		
Burundi			4.1870	4.7124	0	1	0	0	0		
Cambodia			3.0295	3.3831	1	0	0	0	0		
Cameroon	-7.4817	-7.1325	2.0267	2.6827	0	1	0	0	0	Yes	
Canada	-2.8303	-1.1479	0.2816	0.6888	0	0	1	0	0	Yes	Yes
Central African Republic			0.5067	1.0448	0	1	0	0	0		
Chad			0.4371	0.9797	0	1	0	0	0		
Chile	-4.0878	-3.5051	1.9439	2.4852	0	1	0	0	0	Yes	Yes
China		0.5209	3.8615	4.4350	1	0	0	0	0		Yes
Colombia	-4.4524	-2.5079	2.3102	3.0290	0	1	0	0	0	Yes	Yes
Congo			0.7205	1.4797	0	1	0	0	0		
Congo, Democratic Republic (zaire)	-8.9980	-6.3653	1.5401	2.2494	0	1	0	0	0		
Costa Rica	-5.4848	-4.0371	2.8473	3.7097	0	1	0	0	0	Yes	
Cuba	-4.3451	-4.4219	3.7776	4.2188	1	0	0	0	0	Yes	Yes
Ivory Cost	-6.8132		2.1836	3.1188	0	1	0	0	0	Yes	
Denmark	-2.6085	-1.5972	4.3000	4.4037	0	0	0	0	1	Yes	Yes
Dominican Republic	-7.7295		3.8090	4.5451	0	1	0	0	0	Yes	
Ecuador	-7.7295	-4.4439	2.3814	3.1703	0	1	0	0	0	Yes	Yes
Egypt	-3.6243	-3.4769	2.8860	3.5127	0	1	0	0	0	Yes	Yes

Continued: Table H.2: Dataset

Country	lnbkshare70	lnbkshare95	lnpop70	lnpop95	Socialist	French	English	German	Scandin	Sample A	Sample B
El Salvador	-7.5317	-5.1358	4.4656	5.0516	0	1	0	0	0	Yes	Yes
Finland	-2.5009	-1.6053	2.2031	2.3140	0	0	0	0	1	Yes	Yes
France	-1.1927	-0.4086	4.0575	4.2362	0	1	0	0	0	Yes	Yes
Gabon			0.1500	0.8351	0	1	0	0	0		
Germany	-0.5413	0.1468	4.9227	5.0511	0	0	0	1	0	Yes	Yes
Greece	-3.5575	-2.7549	3.7528	3.9808	0	1	0	0	0	Yes	Yes
Guatemala	-5.9588		3.2070	3.8554	0	1	0	0	0	Yes	
Guinea			2.1155	2.6417	0	1	0	0	0		
Haiti		-5.2548	4.4831	4.9253	0	1	0	0	0		
Honduras	-6.0773		2.4353	3.2844	0	1	0	0	0	Yes	
Hungary	-2.5345	-1.8833	4.3195	4.3111	1	0	0	0	0	Yes	Yes
India	-1.6763	-1.6576	4.5340	5.1381	0	0	1	0	0	Yes	Yes
Indonesia	-3.8403	-3.6783	3.5131	4.1386	0	1	0	0	0	Yes	Yes
Iran	-3.3186	-1.6062	2.1874	2.9561	0	1	0	0	0	Yes	Yes
Iraq	-4.8237		2.3894	3.2491	0	1	0	0	0	Yes	
Ireland	-4.9707		3.1859	3.4951	0	0	1	0	0	Yes	
Israel	-3.5924	-3.4985	4.4570	5.0912	0	0	1	0	0	Yes	Yes
Italy	-2.1454	-0.6548	4.7476	4.8671	0	1	0	0	0	Yes	Yes
Jamaica	-6.2465		4.3909	4.8892	0	0	1	0	0	Yes	
Japan	-0.8506	-0.1467	5.2485	5.4411	0	0	0	1	0	Yes	Yes
Jordan	-6.2974	-4.8935	2.1541	3.2724	0	1	0	0	0	Yes	
Kenya	-6.0135	-5.1515	2.2440	3.1481	0	0	1	0	0	Yes	
Korea, Dem. People's Rep. of			4.2300	4.7847	1	0	0	0	0		
Korea, Republic of	-2.7722	-0.6742	5.1767	5.7832	0	0	0	1	0	Yes	Yes
Lao People's Dem. Rep.	-6.6955	-6.6065	1.8427	2.3403	1	0	0	0	0		
Lebanon	-4.7867	-5.0849	4.8579	5.4547	0	1	0	0	0	Yes	
Liberia			1.8870	2.4132	0	0	1	0	0		
Libyan Arab Jamahiriya	-5.7442		-0.5268	0.4513	0	1	0	0	0	Yes	
Madagascar	-6.0079	-6.3047	1.8069	2.4710	0	1	0	0	0	Yes	Yes
Malawi	-7.0521	-6.0665	2.9677	3.6710	0	0	1	0	0	Yes	
Malaysia	-4.1733	-2.4178	2.8398	3.6270	0	0	1	0	0	Yes	Yes
Mali	-8.1995	-7.9057	0.8023	1.3620	0	1	0	0	0		

Continued: Table H.2: Dataset

Country	lnbkshare70	lnbkshare95	lnpop70	lnpop95	Socialist	French	English	German	Scandin	Sample A	Sample B
Mauritania			-0.4100	0.1546	0	1	0	0	0		
Mauritius	-7.1177	-6.8941	5.4730	5.9941	0	1	0	0	0	Yes	Yes
Mexico	-2.9319	-2.2938	2.5365	3.3259	0	1	0	0	0	Yes	Yes
Morocco	-6.3912	-4.2870	2.3388	3.0809	0	1	0	0	0		
Mozambique	-6.3912		1.8449	2.3494	0	1	0	0	0		
Myanmar	-3.6594	-3.5745	3.0832	3.6693	1	0	0	0	0	Yes	
Netherlands	-1.8687	-0.6477	5.2801	5.5394	0	1	0	0	0	Yes	Yes
New Zealand	-3.9941	-2.5212	1.8366	2.1897	0	0	1	0	0	Yes	Yes
Nicaragua			2.0862	2.8796	0	1	0	0	0		
Niger	-8.0598		0.4846	1.2342	0	1	0	0	0		
Nigeria	-4.1365	-3.9030	3.4025	4.1204	0	0	1	0	0	Yes	
Norway	-2.8052	-2.3697	2.0134	2.1617	0	0	0	0	1	Yes	Yes
Pakistan	-3.7313	-6.8353	3.7178	4.4057	0	0	1	0	0	Yes	Yes
Panama	-6.2465		2.3000	3.0272	0	1	0	0	0	Yes	
Paraguay			1.0548	1.8458	0	1	0	0	0		
Peru	-4.5019	-3.9014	1.6851	2.4048	0	1	0	0	0	Yes	Yes
Philippines	-4.9395	-4.1681	4.1440	4.8717	0	1	0	0	0	Yes	Yes
Poland	-1.9846	-1.4329	4.2106	4.4018	1	0	0	0	0	Yes	Yes
Portugal	-2.5589	-2.3632	4.1066	4.2880	0	1	0	0	0	Yes	Yes
Romania	-2.2298	-2.2802	4.0223	4.1664	1	0	0	0	0	Yes	Yes
Saudi Arabia	-6.7885	-2.8306	0.4277	1.5853	0	0	1	0	0	Yes	
Senegal			2.4107	3.0975	0	1	0	0	0		
Sierra Leone	-6.8778		3.0145	3.5139	0	0	1	0	0		
Singapore	-4.9609		7.5248	8.2659	0	0	1	0	0	Yes	
Somalia			1.0678	1.7512	0	0	1	0	0		
South Africa	-3.4297	-2.4863	2.2786	2.9696	0	0	1	0	0		Yes
Spain	-1.2880	-0.2307	3.7299	3.9685	0	1	0	0	0	Yes	Yes
Sri Lanka	-3.8820	-2.8199	4.6577	5.1362	0	0	1	0	0	Yes	Yes
Sudan	-6.1714		1.1179	1.8296	0	0	1	0	0	Yes	
Sweden	-2.2611	-1.6118	2.4600	2.5256	0	0	0	0	1	Yes	Yes
Switzerland	-2.2670	-1.4101	4.5898	4.7522	0	0	0	1	0	Yes	Yes
Syrian Arab Republic	-5.0662	-6.8353	2.7590	3.6910	0	1	0	0	0	Yes	Yes
Thailand	-3.5304	-2.0790	3.5907	4.3342	0	0	1	0	0	Yes	Yes
Togo		-9.4743	2.9162	3.5670	0	1	0	0	0		
Trinidad and Tobago			4.6168	5.0457	0	0	1	0	0		
Tunisia	-6.2974	-4.3409	2.7514	3.5009	0	1	0	0	0	Yes	Yes

Continued: Table H.2: Dataset

Country	lnbkshare70	lnbkshare95	lnpop70	lnpop95	Socialist	French	English	German	Scandin	Sample A	Sample B
Turkey	-2.4764	-2.3788	3.2046	3.9038	0	1	0	0	0	Yes	Yes
Uganda	-5.8723	-5.4208	3.0458	3.7372	0	0	1	0	0		Yes
United Kingdom	-0.8044	0.4931	4.9573	5.0356	0	0	1	0	0	Yes	Yes
United Rep. of Tanzania	-7.3241	-5.9363	1.9975	2.7858	0	0	1	0	0	Yes	
United States of America	0.0000	0.0000	2.5775	2.8884	0	0	1	0	0	Yes	Yes
Uruguay	-4.7655	-4.2454	2.3104	2.4376	0	1	0	0	0	Yes	Yes
Venezuela		-2.8285	1.7994	2.6602	0	1	0	0	0		Yes
Viet Nam	-4.9186	-2.1160	4.1916	4.8567	1	0	0	0	0	Yes	Yes
Zambia			1.0487	1.7978	0	0	1	0	0		
Zimbabwe		-5.6371	1.8584	2.7050	0	0	1	0	0		

Continued: Table B3.2 Dataset

Country	Lt100km	Meantemp	Latabs	Inschool20	Sample A	Sample B
Afghanistan	0.0000	16.1000	0.3667	-6.8298		
Algeria	0.0472	19.3000	0.3111	-2.7636	Yes	
Angola	0.1188	22.9413	0.1367	-6.3545		
Argentina	0.1231	17.1000	0.3778	-0.9035	Yes	Yes
Australia	0.1990	20.9000	0.3000	-2.0455	Yes	Yes
Austria	0.0076	6.6000	0.5245	2.3801	Yes	Yes
Bangladesh	0.4016	25.6862	0.2667	2.1865	Yes	
Belgium	0.4893	8.4000	0.5611	3.5083	Yes	Yes
Benin	0.1090	26.8000	0.1033	-2.8036		
Bolivia	0.0000	21.5000	0.1889	-3.0926	Yes	
Brazil	0.0925	23.7000	0.1111	-1.9175	Yes	Yes
Bulgaria	0.2737	10.7000	0.4778	1.8163	Yes	Yes
Burkina Faso	0.0000	28.1000	0.1444	-7.1510		
Burundi	0.0000	23.3900	0.0367	-0.8237		
Cambodia	0.2243	27.2208	0.1445	-3.4749		
Cameroon	0.0982	24.4333	0.0667	-6.5209	Yes	
Canada	0.0212	-0.2000	0.6667	-1.6975	Yes	Yes
Central African Republic	0.0000	25.4649	0.0778	-7.3433		
Chad	0.0000	27.9722	0.1667	-11.6676		
Chile	0.6602	13.4000	0.3333	-0.5112	Yes	Yes
China	0.0517	11.7000	0.3889	-3.9487		Yes
Colombia	0.1597	22.5000	0.0444	-1.2267	Yes	Yes
Congo	0.0479	24.7515	0.0111	-5.2509		
Congo, Democratic Republic (zaire)	0.0040	23.3546	0.0000	-3.9709		
Costa Rica	1.0000	25.1000	0.1111	-0.3447	Yes	
Cuba	1.0000	27.4000	0.2367	1.1723	Yes	Yes
Ivory Cost	0.1711	26.0907	0.0889	-4.7030	Yes	
Denmark	1.0000	6.8000	0.6222	2.4018	Yes	Yes
Dominican Republic	1.0000	25.6000	0.2111	-0.5202	Yes	
Ecuador	0.3684	19.1000	0.0222	-0.9887	Yes	Yes
Egypt	0.2392	22.6000	0.3000	-0.6709	Yes	Yes

Continued: Table B3.2 Dataset

Country	Lt100km	Meantemp	Latabs	Inschool20	Sample A	Sample B
El Salvador	1.0000	23.5710	0.1500	0.8454	Yes	Yes
Finland	0.2833	0.2000	0.7111	-0.1281	Yes	Yes
France	0.3292	11.2000	0.5111	1.9495	Yes	Yes
Gabon	0.2618	24.5000	0.0111	-5.5602		
Germany	0.1861	7.2000	0.5667	3.2374	Yes	Yes
Greece	0.9300	16.9000	0.4333	1.4340	Yes	Yes
Guatemala	0.4255	21.7000	0.1700	-0.6830	Yes	
Guinea	0.1406	24.4389	0.1222	-3.7720		
Haiti	1.0000	26.5803	0.2111	0.8785		
Honduras	0.6686	25.4000	0.1667	-1.1358	Yes	
Hungary	0.0000	9.0000	0.5222	2.2848	Yes	Yes
India	0.1568	25.9000	0.2222	0.8470	Yes	Yes
Indonesia	0.7458	26.8000	0.0556	-0.7927	Yes	Yes
Iran	0.1012	23.3071	0.3556	-3.3820	Yes	Yes
Iraq	0.0150	22.6062	0.3667	-2.7443	Yes	
Ireland	0.9134	9.2000	0.5889	1.9255	Yes	
Israel	0.9332	19.2000	0.3478	2.1650	Yes	Yes
Italy	0.7775	13.4000	0.4722	2.7146	Yes	Yes
Jamaica	1.0000	26.5000	0.2017	2.1248	Yes	
Japan	0.9400	14.6000	0.4000	3.1831	Yes	Yes
Jordan	0.1313	18.1000	0.3445	-1.4958	Yes	
Kenya	0.0825	22.6000	0.0111	-2.0741	Yes	
Korea, Dem. People's Rep. of	0.7420	8.2000	0.4444	0.2826		
Korea, Republic of	0.8912	13.1000	0.4111	0.4847	Yes	Yes
Lao People's Dem. Rep.	0.0766	25.4133	0.2000	-5.9277		
Lebanon	1.0000	17.7616	0.3722	1.6688	Yes	
Liberia	0.5436	26.0000	0.0700	-4.3650		
Libyan Arab Jamahiriya	0.1055	21.3000	0.2778	-8.8511	Yes	
Madagascar	0.5710	23.3000	0.2222	-1.3847	Yes	Yes
Malawi	0.0000	22.0000	0.1478	0.0536	Yes	
Malaysia	0.7944	26.7000	0.0256	-1.6239	Yes	Yes
Mali	0.0000	29.3000	0.1889	-4.9865		

Continued: Table B3.2 Dataset

Country	Lt100km	Meantemp	Latabs	Inschool20	Sample A	Sample B
Mauritania	0.0569	25.3000	0.2222	-10.2348		
Mauritius	1.0000	23.5000	0.2241	2.6900	Yes	Yes
Mexico	0.3726	19.0000	0.2556	-1.2662	Yes	Yes
Morocco	0.3679	18.5000	0.3556	-3.5008		
Mozambique	0.2899	23.6000	0.2017	-3.4972		
Myanmar	0.2609	26.5443	0.2444	-0.2154	Yes	
Netherlands	0.8560	8.6000	0.5811	3.2440	Yes	Yes
New Zealand	0.9595	12.8000	0.4556	-0.1046	Yes	Yes
Nicaragua	0.6327	26.6333	0.1445	-1.4492		
Niger	0.0000	28.4000	0.1778	-7.2814		
Nigeria	0.0978	26.6507	0.1111	-2.0663	Yes	
Norway	0.4769	3.2000	0.6889	0.2420	Yes	Yes
Pakistan	0.0942	23.5000	0.3333	-1.7994	Yes	Yes
Panama	1.0000	27.5000	0.1000	-0.9019	Yes	
Paraguay	0.0000	23.0000	0.2556	-1.7357		
Peru	0.1732	20.5000	0.1111	-1.8460	Yes	Yes
Philippines	0.9986	26.5000	0.1445	1.1346	Yes	Yes
Poland	0.1658	6.4000	0.5778	2.3125	Yes	Yes
Portugal	0.6085	16.0000	0.4367	1.1077	Yes	Yes
Romania	0.0650	8.4000	0.5111	1.2884	Yes	Yes
Saudi Arabia	0.1243	23.7000	0.2778	-8.3773	Yes	
Senegal	0.2448	27.2000	0.1556	-3.4952		
Sierra Leone	0.4662	26.2000	0.0922	-1.8752		
Singapore	1.0000	27.1000	0.0136	-0.0393	Yes	
Somalia	0.4475	27.2364	0.1111	-6.6986		
South Africa	0.1963	17.7000	0.3222	-0.8131		Yes
Spain	0.4103	15.9000	0.4444	1.2718	Yes	Yes
Sri Lanka	0.9936	27.6000	0.0778	1.8002	Yes	Yes
Sudan	0.0232	28.5000	0.1667	-5.0870	Yes	
Sweden	0.3016	2.4000	0.6889	0.5002	Yes	Yes
Switzerland	0.0000	5.9000	0.5222	2.7054	Yes	Yes
Syrian Arab Republic	0.1292	18.4000	0.3889	-1.3484	Yes	Yes
Thailand	0.2726	27.2000	0.1667	-1.0437	Yes	Yes
Togo	0.1677	26.8000	0.0889	-1.6415		
Trinidad and Tobago	1.0000	25.9000	0.1222	2.2789		
Tunisia	0.4797	19.6000	0.3778	-1.4086	Yes	Yes

Continued: Table B3.2 Dataset

Country	Lt100km	Meantemp	Latabs	Inschool20	Sample A	Sample B
Turkey	0.3838	13.2000	0.4333	-1.0108	Yes	Yes
Uganda	0.0000	21.5743	0.0111	-3.3380		Yes
United Kingdom	0.9234	8.8000	0.6000	3.1161	Yes	Yes
United Rep. of Tanzania	0.0882	25.0902	0.0667	-5.6574	Yes	
United States of America	0.1117	11.2000	0.4222	0.7843	Yes	Yes
Uruguay	0.3123	18.4000	0.3667	-0.3042	Yes	Yes
Venezuela	0.2444	24.8000	0.0889	-2.8543		Yes
Viet Nam	0.5703	25.5571	0.1778	-2.1047	Yes	Yes
Zambia	0.0000	21.3000	0.1667	-3.6452		
Zimbabwe	0.0000	19.6000	0.2222	-2.0840		