Do Institutions Impact Innovation?

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by

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Abstract

This paper contributes to the literature on institutions and economic growth by conducting an empirical examination on the links between innovation and institutions. Using cross-country data and the instrumental variable method, this study finds that institutional arrangements explain much of the variation on patent production across countries. We find evidence that control of corruption, market-friendly policies, protection of property rights and a more effective judiciary system boost an economy's rate of innovation. Most of the previous literature on institutional and economic performance finds a positive association between institutions and levels of income and between institutions and the *transitional* growth rates of per capita income; however an unambiguous empirical association between institutions and the *steady state growth* has not yet been established. Based on the theoretical model developed by Tebaldi and Elmslie (2006), which shows that the impacts of institutions on innovation spillover to the growth rate of GDP per capita, this paper shows evidence of a *growth effect* through innovation, i.e., institutions have a growth effect on income because institutional quality affects an economy's rate of innovation, the engine of economic growth. Moreover, this study finds that controlling for institutional quality; geographic-related variables are not significant in explaining patent production. This paper also finds evidence to support the idea that in the long-run human capital accumulation is an important variable in shaping institutions.

JEL code: O3 - Technological Change; Research and Development
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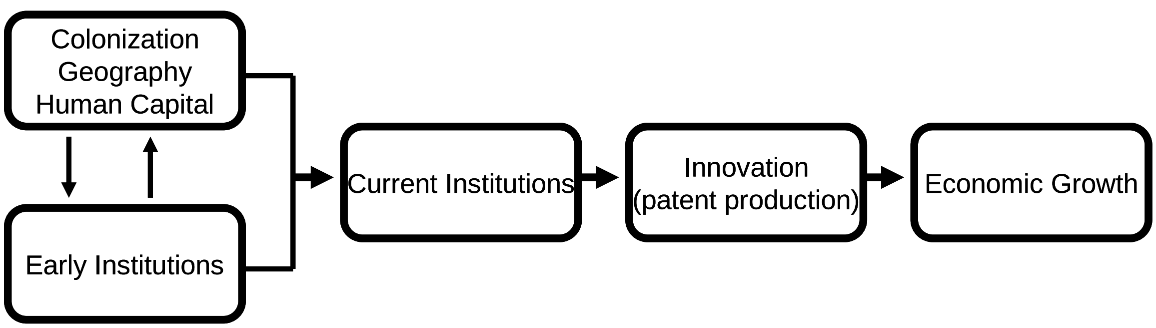
1. Introduction

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. Fundamentally, growth economists are still struggling to understand the linkages between institutional quality and innovation and to incorporate institutions into the standard theoretical framework of economic growth (Sala-i-Martin, 2002; Huang and Xu, 1999). The publication of the breakthrough paper of Kormendi and Meguire (1985) and the availability of datasets on institutional quality[1] greatly contributed to the opening of a new front for empirical research aimed at evaluating the influences of institutional-related variables on economic performance [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; McArthur and Sachs, 2001; Acemoglu and Johnson, 2005; Alcala and Ciccone, 2004; Easterly and Levine, 2003). Most of the previous literature on institutional and economic performance finds a positive association between institutions and levels of income (e. g Hall and Jones, 1999; Acemoglu *et al.* 2001 and 2004; Alcala and Ciccone, 2004; Easterly and Levine, 2003) and between institutions and the *transitional* growth rates of per capita income (e.g. Barro, 1991; Mauro, 1995). However, an unambiguous empirical association between institutions and the *steady state growth* has not yet been established and the question whether institutions affect the *steady-state growth rate* of income is still open. In addition, very little has been done in terms of evaluating empirically the influences of institutional quality on technical innovation. This study contributes to this literature by examining empirically the links between technical innovation and the quality of institutional arrangements.

[1] 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.

This paper develops an econometric model for technical innovation derived from a theoretical model developed in Tebaldi and Elmslie (2006), which gives simple testable predictions regarding the mechanism by which institutions[2] influence technical innovation. Specifically, we test the prediction that institutions boost technical innovation (patent production) and also examine 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 used to assess the questions posed above is derived from Figure 1, which presupposes that early institutions are associated with the colonization process, geography and early accumulated human capital; and the interaction of these factors determine current institutions (Rule of law, Control of Corruption, Regulatory Quality and the Risk of Expropriation). Furthermore, current institutions affect technical innovation (measured by patent production), which ultimately affects a country's economic performance. The econometric analysis conducted in this paper consists of estimating OLS and instrumental variable (IV) cross-country regressions, where the dependent variable is the number of patents (a measure of innovation).

Figure 1: Institutions and Economic Growth



This paper provides evidence that control of corruption, market-friendly policies, protection of property rights and a more effective judiciary system boost an economy's rate of innovation. In addition, it

[2] This study follows Sala-i-Martin (2002) and the word *institutions* (or institutional arrangements) refers to a hypothetical variable that accounts for:
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.

also shows a *growth effect* through innovation, i.e., institutions have a growth effect on income because institutional quality affects an economy's rate of innovation, the engine of economic growth. This paper also finds empirical evidence to support Lipset's (1960) theoretical arguments that in the long-run human capital accumulation is a key variable in shaping institutions.

The rest of the paper is organized as follows: Section 2 briefly discusses the intrinsic challenges in conducting empirical evaluation on institutions and outlines the difficulties in measuring innovation. Section 3 presents the data. Section 4 evaluates the empirical model and discusses the estimates. Section 5 summarizes the paper's findings.

2. Background

It is standard procedure in the empirical growth literature to include institutions in growth regressions as an ordinary explanatory variable of steady state per capita output (e.g. Kormendi and Meguire, 1985; 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 report only weak evidence that better institutional arrangement leads to faster growth (see Levine and Renelt, 1992; Esfahani and Ramirez, 2003). Moreover, there is a fundamental problem in this analysis. Regression analysis based on Kormendi and Meguire (1985) 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 transitional growth rates of output per capita, but one cannot jump to the conclusion that this implies steady-state growth effects.

Furthermore, economists are increasingly aware that institutional arrangements affect knowledge accumulation (e.g. Rodrik, 2000; Sala-i-Martin, 2002; Gradstein, 2004) and consequently, institutional arrangements 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. Few growth models *explicitly* address this issue (e.g. Huang and Xu, 1999; Fedderke, 2001; Gradstein, 2004; Tebaldi and Elmslie, 2006) and no empirical cross-country analysis directly exploits such a link.

2.1 An Empirical Model of Innovation

The model developed by Tebaldi and Elmslie (2006) suggests that changes in technology are associated with the quality of institutional arrangements. Specifically, a variable that accounts for institutional quality 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 as given. Consider the equation:[3]

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

where A measures technical knowledge, H_A is human capital engaged in R&D, and Z denotes the quality of the institutional structure, which depends on both the set of institutions in place (T) and the state-of-art technology.

It is assumed that Z increases as the institutional arrangements (T) improve $\left(\frac{\partial Z}{\partial T} > 0\right)$. It is also assumed that improvements in technology make existing institutions relatively obsolete,[4] which implies that $\frac{\partial Z}{\partial A} = \frac{\partial Z}{\partial T}\frac{\partial T}{\partial A} < 0$. To make this specification workable, Z is defined as $Z = (T/A)^a$, where $0 < a < 1$. Accordingly, the production function of new technologies is given by:

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

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

[4] Tebaldi and Elmslie (2006) provide the rationale for this specification/argument.

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. Therefore, in this theoretical formulation, *ceteris paribus*, good institutions are expected to impact positively in the rate of technical innovation. In addition, the model developed by Tebaldi and Elmslie (2006) also shows that the impact of institutions on innovation spillovers to income such that, at the steady state, the growth rate of output increases as the institutional quality improves. More specifically, the model implies that in the steady state the growth rate of GDP per capita is equal to the growth rate of technology. Therefore, from a theoretical standpoint, showing that institutions impact the rate of innovation implies that institutions impact the growth rate of GDP per capita.

Although equation (1) intuitively associates changes in technology to institutional arrangements, it is a nonlinear differential equation and cannot be directly estimated. One can overcome this obstacle by rewriting it as a discrete equation:

$$\Delta \mathrm{A}_{\mathrm{t}} = \mathrm{A}_{\mathrm{t}} - \mathrm{A}_{\mathrm{t-1}} = \delta \mathrm{A}_{\mathrm{t-1}}^{1-\mathrm{a}} \mathrm{H}_{\mathrm{At-1}} \mathrm{T}^{\mathrm{a}} \tag{1A}$$

Equation 1A can be transformed to linearity by taking logarithms of both sides. Adding an error term and reparametrizing the model generates:

$$\ln(\Delta A_{i,t}) = \beta_0 + \beta_1 \ln(H_{Ai,t-1}) + \beta_2 \ln(A_{i,t-1}) + \beta_3 \hat{T}_i + \nu_{i,t} \tag{2}$$

where t represents time, i indexes observations, $\hat{\mathrm{T}}$ denotes the logarithmic transformation of T and v is random disturbance. This empirical equation is specified in terms of $\hat{\mathrm{T}}$ rather than ln(T) because i) this study uses standardized measures of institutions, which have zero mean and assume negative values, preventing the use of logarithmic transformations and ii) the true measure of institutions is not known, so $\hat{\mathrm{T}}$ is used as a proxy for ln(T).[5] This procedure has become standard in the literature (e.g. Dollar and Kraay, 2003; Acemoglu *et al.,* 2001; La Porta *et al.,* 1999; Hall and Jones, 1999). Despite the apparent

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

simplicity of equation 2, its estimation is difficult due to endogeneity and the difficulties in measuring A and T.

i) Measuring Institutions and Innovation

We follow a growing branch of the growth literature that suggests that 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; Acemoglu *et al.*, 2005a and 2005b). Specifically, this study uses four subjective measures of institutions: i) Rule of Law, ii) Control of Corruption, iii) Regulatory Quality and iv) Risk of Expropriation. Section 3 provides more details about these variables.

There is no problem incorporating technical innovation into theoretical economic models. However, there are serious limitations to most methods aimed at developing a proxy for quantifying innovation. In fact, difficulties in finding an empirical counterpart for technical innovation have limited empirical studies on technical innovation and economic performance (Romer, 2002). Albeit imperfect, we develop a proxy for innovation using the sum of patents registered over a specific period. This approach follows recent studies that 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 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 for 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).

Three main concerns regards the reliability of patent count as a measure of innovation can be raised: 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 and other[6] well known drawbacks the use of patent counts to measure innovation [or change in the stock of knowledge] is now widely supported (e.g. Griliches, 1979, 1990 and 1994; Aghion and Howitt, 1992; Paul Romer, 2002; and Jaffe and Trajtenberg, 2002). According to Griliches (1990), "[I]n spite of all the difficulties, patents statistics remain a unique resource for the analysis of the process of technical change" (Griliches, 1990:1702). This study follows this approach and uses patent counts as a measure for innovation. Specifically, the accumulated number of patents granted over a period is utilized as a proxy for knowledge production/innovation, that is:

$$\Delta A_{i,T} = A_{i,T} - A_{i,0} = \sum_{t=0}^{T} p_{i,t} = P_{i,T}$$

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

Substituting the equation above into equation (2) generates:

$$\ln(P_{i,T}) = \beta_0 + \beta_1 \ln(H_{Ai,0}) + \beta_2 \ln(A_{i,0}) + \beta_3 \hat{T}_i + \nu_{i,T} \tag{3}$$

It is worth noticing that equation 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

[6] In addition to the problems discussed above, the reliability of the proxy for innovation based on sum of patents also depends on i) the cross-country similarly in standards to register a patent; ii) measurement precision, and iii) target of the market.

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 is an expanded version of the Romer (1990) and Jones (1995) knowledge production functions. More precisely, it highlights the significant role that institutional arrangements have in the process of knowledge production.

ii) Measuring the Stock of Knowledge

Sedgley (2005) 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 (2005) 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. So, this study utilizes two alternative proxies for the initial stock of knowledge: patent flow in the initial period and a relative measure of book production. The rational for using these proxies 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. This kind of knowledge is difficult to 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, 2004).

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 arguments 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, so that 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. So, a country's share of world book production is used as a proxy for the starting stock of knowledge (concrete measure of the current knowledge stock) in the regression analysis. For robustness purposes, we use two measures: the share of applied and pure sciences book production, and the share of all new titles. In addition, we also use the initial flow of patents to approximate the stock of knowledge.

iii) Endogeneity

Another problem in estimating equation 3 is the potential endogeneity of the right-hand variables. In a cross-section of countries one can address the issue 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; Acemoglu and Johnson, 2005). Following this approach, current institutions are modeled as follows:

$$\hat{T}_i = \delta_1 + \delta_2 H_{0,i} + \delta_3 G_i + \delta_3 R_i + \eta_i \qquad (4)$$

where $\hat{T}$ denotes institutions, H_0 denotes the initial endowment of human capital, G is a vector of geographical variables, R is a vector of "other" exogenous determinants of institutions (e.g., colonial status or legal origin) and η is a vector of random disturbances.

Equation 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.* (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.[7]

Acemoglu *et al.* (2001 and 2004) argue that early institutions were affected by geography because the colonization process endogenously responded to certain environmental 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 ´extractive states´…. These institutions did not introduce much protection for private property, nor did they provide checks and balances against government expropriation" (Acemoglu *et al.*, 2001:1370). On the other hand, geographically advantaged settlement colonies were relatively free to engage in processes that replicated in some way European social

[7] 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 (Rosenberg, 1963). In addition, a recent article by Glaeser *at al*. (2004) also shows that human capital positively impacts institutions, "even over a relatively short horizon of 5 years" (p. 296).

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.*, 2001). 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.

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, that is, "[a] civil legal tradition, then, can be taken as a proxy for an intent to build institutions to further the power of the State" (La Porta *et al.*, 1999:.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, equations 3 and 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), so the colonial legacy variables should not be correlated with equation 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 could 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. The concerns regarding the identification of the model constitute, in fact, an empirical issue that can be evaluated by testing if the instruments are correlated with the equation 3' error term. Following Acemoglu *et al.* (2001 and 2004) and Acemoglu *et al.* (2005a), this study uses the Hansen's J test to examine whether the variables listed above satisfy the requirements for valid instruments.

3. Data and Measurement Error

There are several cross-country measures of institutional quality available for conducting empirical research. The most common measures used in the growth and institutions literature include autocracy, government effectiveness, executive constraints, risk of expropriation, and (control of) corruption. However, many of these proxies for institutions are highly correlated (see La Porta *et at.*, 1999; Glaeser *et al*., 2004) and the choice of the institutional measure for conducting empirical work is, in general, *ad hoc*.

This study uses four different measures of institutions. Three of these measures are from a dataset developed by Kaufmann *et al.* (2003), which covers 199 countries. Specifically, it utilizes an average index through the time periods 1996, 1998, 2000 and 2002 of Rule of Law, Control of Corruption and Regulatory Quality. 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" (Kaufmann *et al.*, 2003:3). The Rule of Law, Control of Corruption and Regulatory Quality variables range between -2.5 and 2.5, with higher scores indicating better institutional arrangements.[8]

The fourth measure of institutional quality is a proxy for market institutions and measures the risk of confiscation and forced nationalization. This variable is used with the purpose to conform to other studies in the growth and institutions literature. It is calculated as the average value for each country over the period 1985-1995 and ranges 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).[9]

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 U.S. 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. A proxy for innovation using USPTO data can be defined as follows:

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

[8]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).

[9] Glaeser *at al.* (2004) argue that these measures of institutions (Risk of Expropriation, Control of Corruption, Rule of Law and Regulatory Quality (the last three are labeled as "government effectiveness") are actually *outcome* measures rather than ´deep´ measures of institutions. While this argument is correct, that is, the institutional measures used in this paper are outcome measures, if this were not so; we would not be concerned about finding instruments for these measures (see Acemoglu *et al.* 2005a and 2005b for a detailed discussion on this issue).

where p denotes the number of patents granted to country *i*.[10]

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.[11]

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

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. This necessitates 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 can be estimated only if an objective measure of the initial stock of knowledge is provided. This study uses the initial flow of patents and a share of book production to approximate the stock of knowledge. 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's data the calculations are made using the average number of books produced over a five year 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, for the regressions using patent data from the USPTO, A_0 is calculated as follows:

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[10] This proxy for innovation may be biased against countries whose inventors do not target the U.S. market or due to high transaction costs due to distance for example, which may affect an inventor's decision to patent a new invention in the U.S.

[11] This proxy for innovation may suffer from comparability issues due to cross-country dissimilarly in standards to register a patent;

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

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 and over 1995 to 1999. Moreover, two alternative measures are utilized: the share of all new titles produced and the share of applied and pure sciences book production.

The second approximation of the stock of knowledge is built as follows:

$$A_{o,i}^{p} = \sum_{t=1970}^{1963} p_{t,i}$$

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

Figure 1 shows that the two measures of the initial stock of knowledge are highly correlated, so the model's estimates should not differ significantly when using either of these proxies. In addition, the high correlation between the share of book production and the initial stock of patents also suggests that knowledgeable societies are more innovative. Therefore, our strategy of using the share of book production to proxy initial knowledge seems to be reasonable.

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 and over 1995 to 2001.

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 square kilometer.

$$H_{0,i} = h_{0,i} / \text{area}_i$$

where h_0 denotes the number of students in school in 1920, *area* denotes the country land area and *i* indexes countries.

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. Therefore, combining the actual 1920 data with estimates of the number of students enrolled in 1920 based upon the 1930 numbers allows one to get a sample comprised of 120 countries.[12] 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 USSR republics, Paraguay, Peru, Bolivia, India, Ivory Coast, Mali, Mauritania, Algeria and Zaire were not included in the regression analysis.[13]

The geographic variables are taken from McArthur and Sachs (2001) and La Porta *et al. (1999).* We use i) mean temperature, which measures the 1987 mean annual temperature in Celsius; ii) coastal land, which quantifies the proportion of land area within 100 km of the coast and iii) latitude, which

[12] We 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.

[13] 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 20th century.

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).

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 being 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:

$$\hat{T}_i = \overline{T}_i + \mu_i \tag{5}$$

where $\hat{T}$ is unobserved institutions, $\overline{T}$ is measured institutions and μ is the measurement error. Substituting equation 5 into equation 3 gives:

$$\ln(P_{i,T}) = \beta_0 + \beta_1 \ln(H_{Ai,0}) + \beta_2 \ln(A_{i,0}) + \beta_3 \overline{T}_i + \beta_3 \mu_i + \nu_{i,t} \tag{6}$$

The explanatory variables from equation 3 and 4 can be stacked in matrices Z=[H_{A0} A_0] and X=[H_0 G 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. Therefore, it is crucial for the reliability of estimates to select variables to instrument institutions that are uncorrelated with the error term of the second-stage regressions.

4 Regression Analysis

Table 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. Table 2 and Figure 2 show that patent production is strongly correlated with all four measures of institutions. 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 4 using OLS. Subsequently, equation 5 is estimated using OLS and the IV methods.[14]

4.1 The 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.[15] Our empirical strategy closely follows the literature by instrumenting institutions with legal origins (La Porta et al. 1999), geography (Acemoglu, 2001; Rodrik, 2000) and historical levels of human capital. Our estimates of the first stage regressions for the four measures of institutions considered in the paper conform to most of the results previously found in the literature.

Tables 3 and 4 provide the estimates of equation 4 using the four different institutional measures. 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 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.

[14] We also estimated the model using the GMM estimator. The sizes of the GMM and 2SLS coefficients were very similar and the qualitative conclusions identical. The GMM estimates are not reported in the paper and can be provided upon request.

[15] A detailed discussion of the determinants of institutions can be found in Acemoglu *et al.* (2001 and 2004), Acemoglu and Johnson (2005) and La Porta *et al.* (1999).

To sum up, the estimates provide evidence that historical levels of human capital, legal origins, and geographically related variables are important in explaining institutions. In addition, controlling for the variables mentioned above, all of the tested regressions suggest that historical levels of population density has no effect on shaping current institutions.[16]

Our estimates of the first stage regressions contribute to the literature 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, the results discussed above are in accordance with previous findings in this field. For instance, La Porta *et al.* (1999) find that French and Socialist legal 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) and Acemoglu and Johnson (2005) 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. This finding is consistent with the reasoning of Lipset (1960), which argues that human capital accumulation contributes to shape more benign politics, less violence and more political stability. As noticed by Glaeser *et al*. (2004), "[t]he key human capital externality is not technological but political: courts and legislatures replace guns. These improvements in turn bring about greater security of property and economic growth." (p. 282).

4.2 Institutions and Innovation: IV Estimates

Tables 5 through 8 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. The other models are augmented to

[16] 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.

evaluate the model's robustness. Models 1 and 6 are OLS estimates and all of the other models are IV estimates.

The results show that the OLS estimates underestimate the impact of institutions on innovation. In all regressions the 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.[17]

In all of the regressions the coefficients on personnel engaged in R&D and share of book production have the expected signs and are statistically significant.[18] 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.[19] It is important to emphasize that countries that are far from the technological frontier do not patent as much as the others. Therefore, failure to control for the distance from the technological frontier may bias the estimates of the impact of institutions on innovation. In this study the share of book production (and initial flow of patents) supposedly controls for a country's distance from the technological frontier (level of development).

The results do not support the presence of scale effect from personnel engaged in R&D on patent production. In all of the regressions, the null hypothesis that the coefficient on personnel engaged in R&D is equal to one is rejected (at the 1% and 5% levels of significance) in favor of the alternative hypothesis that the coefficients are less than one. This implies that long-run growth of technology (patent production)

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

[18] In Table 7, models 7 through 10, the coefficients on book production are only marginally significant.

[19] In a set of regressions not reported in the paper, we tested an alternative measure of book production. More precisely, we 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 5-7, 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. In addition, the model's estimates using the initial flow of patents rather than the share of book production show no significant differences compared to the results reported in tables 5 through 8. To save space, the results using the initial flow of patents are not reported.

cannot be sustained only with the increase of the workforce engaged in P&D. This finding contradicts the predictions from Romer (1990)'s model, but is in accordance with the findings reported by Jones (1995).

The estimates provide evidence that, controlling for the size of an economy and the position of a country on the world knowledge frontier, 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 5 through 8. This suggests that economies that have market-friendly policies, lower perception of corruption, or whose judiciary systems are more effective and predictable will experience higher rates of innovation (patent production). 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), Brazilian residents would have produced about 2.5 times more patents than what they actually produced between 1970 and 2003. The model also suggests that controlling for the differences between the Brazilian and the U.S. indexes of control of corruption or rule of law, Brazilian patent production, between 1970 and 2003, would be approximately four times larger than it actually was. The presence of measurement errors in quantifying institutions implies that interpretation of the coefficients (marginal effects) of the model may be imprecise. However, the impacts of improving institutions on patent production seem to be quite large and have the right direction.

It is worth noticing that the estimated size of the coefficients on institutions is larger than what was hypothesized by Tebaldi and Elmslie (2006). More specifically, the model developed by Tebaldi and Elmslie (2006) assumes that the coefficient on institutions should rage between 0 and 1, but our estimates provide evidence that the coefficient on institution is greater than one. This result may be generated due to the presence of measurement errors in quantifying institutions or imprecise model specification.

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[20]. Models 3 and 8 in Tables 5 through 8, 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 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.[21]

4.3 Robustness

Although the results detailed in the presentation seem reasonable, the estimates are subject to the validity of the IV estimates, which ultimately depends on the assumption that the model is properly identified by the set of proposed instruments. Of course, we recognize that the instruments are not perfect and that the exclusivity assumption may be violated. For instance, although initial human capital is expected to not be correlated with current innovation (patent production), there are channels (e.g. omitted variables, measurement error) by which initial human capital may be correlated with the error term of the second-stage regressions. To alleviate concerns about the validity of the instruments, we follow Acemoglu *et al.* (2005a) and Alcala and Ciccone (2004) and use the Hansen's J statistic (Hansen, 1982) to evaluate the overidentifying restrictions in the IV regressions. In general, the overidentification tests suggest that the correlation between the instruments proposed and the error term is not significant. The results give more confidence in the validity and robustness of the estimates. However, the test does cast some doubt that the model for risk of expropriation is correctly identified.

The functional form chosen for the empirical model is also subject to imperfections, so alternative specifications can be used to check the robustness of the results. A key concern regarding the validity of the specification is motivated by the idea that countries that are far from the technological frontier do not patent as much as the others, independently from the quality of institutions. Another concern originates

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

[21] 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.

from the idea that developed and developing countries may respond differently to changes in institutional quality. We address these concerns by estimating three alternative models, whose estimates are shown in Table 9. Models 1 and 3 test if innovation in OECD and non-OECD countries responds differently to the quality of institutions. The estimates show no differential effect for countries in the technological frontier (OECD) and countries far from the technological frontier (non-OECD countries). In addition, a quadratic model on institutions (Model 2) also shows no differential effect. These results suggest that the impact of institutional quality on innovation is important for countries in the technological frontier as well as for countries far from the technological frontier. This finding also refutes the idea that the link between institutions and patenting found in this study could be by showing a relationship between the level of development and a country's distance from the technological frontier.[22]

5 Final Remarks

Recently researchers have turned to study the impacts of institutions on economic performance. However, one can identify the following important gaps in the empirical 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; and iii) there is no clear empirical evidence supporting the claim that institutions affect an economy’s steady state growth rate of per capita income. This study contributes to the literature by conducting an empirical examination on the links between innovation and institutions that addresses the points raised above.

The estimates obtained show that institutional arrangements positively contribute to explain much of the variations on patent production across countries. Specifically, we find evidence that control of corruption, market-friendly policies, protection of property rights and a more effective judiciary system boost an economy’s rate of innovation (patent production).

[22] We also tested if, controlling for institutional quality, the initial level of GDP per capita, a measure of economic development (and a measure of the distance from the technological frontier), affects innovation. The coefficients on initial level of GDP per capita turned out insignificant at the standard levels of confidence. The authors would gladly provide these results upon request.

While most of the previous literature on institutional and economic performance is able to show a positive association between institutions and *levels* of income and between institutions and the *transitional* growth rates of per capita income, an unambiguous empirical link between institutions and the *steady state growth* has not yet been established. Based on the theoretical model developed by Tebaldi and Elmslie (2006), which shows that the impacts of institutions on innovation spillover to the growth rate of GDP per capita, this paper shows evidence of a *growth effect* through innovation, i.e., institutions have a growth effect on income because institutional quality affects an economy's rate of innovation, the engine of economic growth.

The econometric estimates also provide evidence that the impact of institutional quality on innovation is important for countries in the technological frontier as well as for countries far from the technological frontier. This result is important because it refutes the idea that countries that are far from the technological frontier do not patent as much as the others, independently from the quality of institutions. This research also finds that geography, *per se,* cannot explain differences in innovation across countries. Geography affects innovation, but only through institutions. This paper also provides empirical evidence that in the long-run human capital accumulation is an important variable in shaping institutions.

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APPENDIX

Table 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 (average 1968-1972)	76[(2)]	8.5276	2.0099
ln Share of book production, (average 1968-1972)	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, (average 1995-2001)	55[(3)]	10.322	1.7942
ln Share of book production(average 1995-1999)	55[(3)]	-2.4941	1.8325

Source: Authors' 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 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 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 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 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	IV	IV	IV	IV	OLS	IV	IV	IV	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 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 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 [a]	1.91 [a]	2.17 [a]	1.92 [a]	1.94 [a]	0.99 [a]	1.16 [a]	1.19 [a]	1.14 [a]	1.13 [a]
	(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 [a]	0.40 [a]	0.41 [a]	0.40 [a]	0.41 [a]	0.67 [a]	0.68 [a]	0.67 [a]	0.68 [a]	0.68 [a]
	(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 [a]	0.52 [a]	0.52 [a]	0.53 [a]	0.52 [a]	0.65 [a]	0.59 [a]	0.55 [a]	0.60 [a]	0.61 [a]
	(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 [a]	3.67 [a]	3.01 [b]	3.87 [a]	3.65 [a]	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	IV	IV	IV	IV	OLS	IV	IV	IV	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 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 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	IV	IV	IV	IV	OLS	IV	IV	IV	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 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 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	IV	IV	IV	IV	OLS	IV	IV	IV	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
					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 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 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	Model 9	Model 10	Model 11	Model 12
Institution (T)	1.34^{a}	2.11^{c}	2.03^{a}	2.05^{a}	1.95^{a}	4.29^{a}	2.00^{a}	2.02^{a}	1.72^{a}	2.03^{a}	2.08^{a}	2.03^{a}
	(4.54)	(1.82)	(4.31)	(5.59)	(7.93)	(4.11)	(6.74)	(5.39)	(4.16)	(6.53)	(5.58)	(4.03)
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	0.88^{a}	0.39^{a}	0.56^{a}	1.37^{a}	0.50^{a}	0.49^{a}	0.98^{a}	0.40^{a}	0.39^{a}	1.01^{a}
	(1.80)	(1.61)	(2.88)	(2.84)	(4.05)	(3.04)	(4.07)	(4.05)	(2.72)	(3.31)	(3.14)	(2.87)
ln Share of book production	0.35^{b}	0.37^{b}	-0.03	0.65^{a}	0.48^{a}	-0.48	0.42^{a}	0.45^{a}	0.23	0.50^{a}	0.53^{a}	0.01
	(2.33)	(2.44)	(-0.07)	(4.87)	(3.47)	(-0.80)	(3.41)	(3.59)	(0.55)	(4.05)	(4.21)	(0.03)
Constant	-5.03	-7.85	-18.61^{b}	4.09^{b}	1.35	-10.81	2.55^{c}	2.90^{b}	-2.79	3.53^{a}	3.92^{a}	-3.97
	$(-2.00)^{b}$	$(-1.92)^{c}$	(-2.33)	(2.51)	(0.73)	(-1.61)	(1.77)	(2.01)	(-0.56)	(2.46)	(2.52)	(-0.78)
Method	IV	IV	IV	IV	IV	IV	IV	IV	IV	IV	IV	IV
Sample Size	75	75	24 (OECD)	76	76	24 (OECD)	76	76	24 (OECD)	76	76	24 (OECD)
Centered R-Squared	0.82	0.82	0,90	0.83	0.84	0.78	0.84	0.84	0.84	0.84	0.84	0.85

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 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, 5 ,8 and 11, 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.

Figure 1: Book Production and Initial Flow of Patents

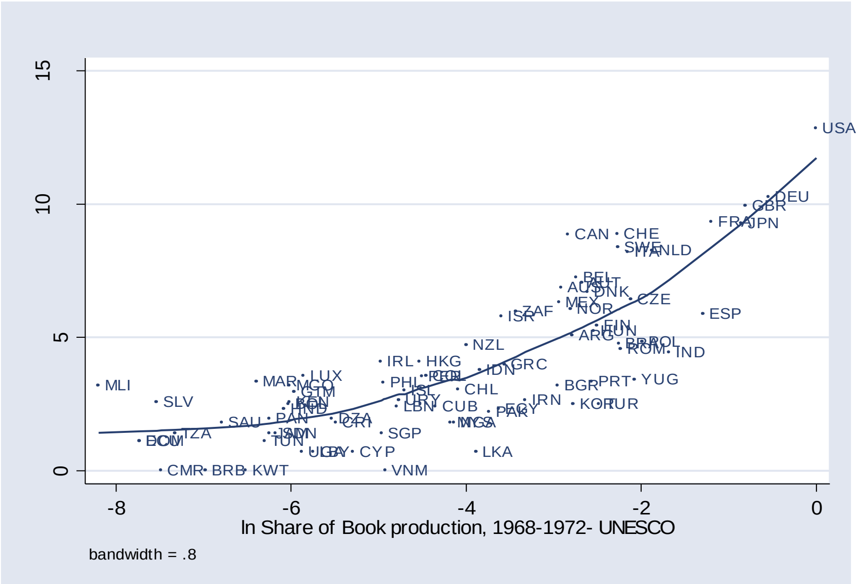

Figure 2: Institutional Quality and Patent Production