Endogenous Strength of Intellectual Property Rights: Implications for Economic Development and Growth*

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Abstract: In recent empirical work, institutions have been shown to explain a significant share of the differences in cross-country accumulation, productivity, and output levels. The key institution that determines sustained development in R&D based growth models is the strength of intellectual property rights, which have thus far been assumed to be exogenous. In this paper we endogenize the strength of the intellectual property rights institutions to study how incentives to protect and exploit property rights affect economic growth.

Our model explains endogenous differences in the strength of intellectual property rights across countries and highlights development thresholds that are related to the quality of such property rights. We show that market size is a crucial determinant of the existence and high quality of such institutions. In addition we find that the endogenous determination of the strength of intellectual property rights generates multiple equilibria and an institutional development threshold that must be overcome if an economy is to have strong institutions and rapid growth in the long run. This result is in line with the observed transition of early/small economic communities with common property laws to mature nation states with large institution-based societies.

Key words: Endogenous institutional change; intellectual property rights; Technological Change

JEL Classification: O3, O1

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1. Introduction

In contrast to the voluminous descriptive and empirical literature on the endogeneity of institutions, the theoretical growth literature has traditionally taken institutions or the quality of their enforcement as exogenous. This paper integrates endogenous institutions into an R&D based model of economic growth, to understand economic agents' incentives to engage in institutional improvements or to exploit institutional imperfections. The goal is to provide theoretical foundations for the importance of institutions documented by cross-country empirical analyses.

Two major events have brought about a rising interest on the role of institutions, so much so that the World Bank devoted its entire 2002 World Development Report to analyzing appropriate institutions for market economies. First is the realization that economic and institutional development must occur simultaneously. Evidence from transition economies suggests that the liberalization of prices and production do not lead to immediate, unqualified economic success. Instead, the absence of institutions is the most commonly cited reason for the failure of transition economies to grow. In a similar vein, financial liberalization in the absence of suitable supervisory institutions has been argued to be a cause of the recent Asian financial crisis.

The second cause for the surge of interest in the effects of institutions on economic performance lies in the cross-country data. Years of modeling endogenous knowledge to augment the basic Solow growth model have generated a wealth of theoretical predications. Growth accounting exercises show, however, that these predictions have not led to satisfactory explanations for the large and persistent variations in Solow residuals across countries (e.g., Hall and Jones, 1999).

The growth experience of transition economies and the large remaining cross-country variations in the Solow residual have led economists to approach institutions as possible explanatory variables of last resort. Hall and Jones (1999), for example, document that cross-country differences in capital accumulation, productivity, and output per worker are driven not only by differences in government policies, but also by institutions. Similar studies have been conducted for transition economies with similar results (e.g., Grigorian and Martinez, 2002). Acemoglu et al (2001, 2002) also document the long run impact of institutions as it relates to a countries colonial history

While the empirics of property rights and growth are extensive, the theoretical literature is scarce. This is largely due to the difficulty in defining institutions. North and Thomas (1973) developed the notion that "social infrastructure" (interpreted as "government institutions" in Hall and Jones, 1999) or "social technology" ("patterned human interaction", see Nelson and Sampat, 2001) reduces uncertainty and transaction costs to allow agents to capture the full social returns to their actions.[1] For all practical matters, Rodrik (1995) argues that institutions encompass property rights, regulatory institutions, macroeconomic stability, social insurance, and conflict management.

Any theoretical analysis of institutions will necessarily adopt a particular interpretation of this broad term. The existing theoretical literature on institutions and growth has focused on the protection of property rights, and in particular of property rights over physical capital. In contrast, in this paper we examine the role of intellectual property rights (IPRs). This is an important distinction for two reasons; first the non-exclusivity IPR makes them particularly vulnerable to misappropriation. Secondly, R&D based growth models rely on private innovative activity to drive growth, implying that

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[1] Other contributors to the voluminous descriptive literature on institutions are, among others, Olson (1965, 1982), Baumol (1990), North (1990). Below we focus only on the link between institutions and growth and within that context only on intellectual property rights and growth.

only those institutions that protect the rewards to innovation are the ultimate determinants of sustained growth.

The focus on IPRs also implies that *private* investment in the quality of intellectual property right protection becomes crucial. For an institutional framework to be successful at protecting individuals, both the written law (formal institutions) and the *implementation* of the law (informal institutions), have to ensure this protection. Although the written law is (often) the result of some collective decision-making process, its implementation may require significant private investment. The patent literature, for example, considers patent infringement suits a necessary step to establish the value of a patent (Lanjouw and Schankerman 2001). Differences in implementations of formal institutions can have significant impact on the effective institutional framework, as illustrated by the fact that the US and Liberia share the same Constitution, but differ markedly in their enforcement.[2] In her description of the early British patent system Khan (2003) argues that "potential patentees were well advised to obtain the help of a patent agent to aid in negotiating the numerous steps [...] required for pursuit of the application in London", and that even after the patent had been awarded "patent rights could not be regarded as settled unless the patent had been contested in court with a favorable outcome". Our approach below concentrates on the role of individual decisions to invest in the *effectiveness* of the institution system.

We present two models. First agents are assumed to take the strength of property rights as given, in an effort to derive the basic intuition that relates IPR institutions and R&D based growth. As in Magee, Brock and Young (1989) and Murphy Shleifer and Vishny (1991), we find that a fraction of the population ("predatory agents") engages in rent seeking ("parasitical litigation" in the Magee et al. setup). This simple model of institutions highlights three effects of misappropriation due to imperfect property rights, all of which reduce the growth rate. First, as researchers cannot capture the full value of their patents, research becomes less attractive. Second, as rent seeking increases, manufacturing employment and output decline. Lastly, as manufacturing output falls, demand for new technologies erodes and the value of new technologies is reduced. As in previous (static) models, the equilibrium growth rate declines in the share of predatory agents.

It is important to recognize, however, that not all agents who do not work in manufacturing engage in parasitical litigation. Indeed Magee (1992) estimates significant benefits to the effectiveness of a legal system. His empirical approach implicitly assumes an endogenous institutions model similar to the one we propose below, where a fraction of the population is hired to explicitly build and maintain institutions. In our second model we thus follow Acemoglu and Verdier (1998), who model "bureaucrats" as both enforcers of property rights and rent-seekers, to examine endogenous institutional quality, focusing not only on the prevention of predatory activities, but also on the determinants that foster the strength of intellectual property enforcement.

Once we allow for endogenous IPR protection multiple equilibria appear. Two equilibria exhibit positive growth, and there is the possibility of a poverty trap. A high growth equilibrium is characterized by high quality institutions, extensive R&D, and a high ratio of researcher to predators. Manufacturing employment is comparatively small in this equilibrium, and rapid growth is sustained through fast technological change. In contrast, a low growth equilibrium features weak institutions, little research, a low ratio of researcher to predators, and a large share of the population engaged in manufacturing. Lastly, we find a poverty trap where neither institutions nor innovation exists. Because of

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[2] IPRs are often part of the constitutional framework. Indeed, the US Constitution provides protection to

the lack of investment in property rights protection, all research activity ceases, resulting in a pure manufacturing economy without technical progress or growth.

Two crucial results emerge. First, market size, and hence population, is a crucial determinant of whether or not an equilibrium with any type of property rights even exists. This feature of our model is consistent with North's (1990) notion that early human settlements existed without property rights and that population growth and the larger scale required by agriculture and animal husbandry led to the evolution of property rights.[3] Second, in the presence of multiple equilibria, we find an institutional-quality threshold. Policy can move a country to the high-growth equilibrium only if it establishes a sufficiently high level of intellectual property right protection. Strong IPR protection will generates enough research activity to provide the incentives to maintain the institutional quality. Otherwise, insufficient investment in the maintenance of property rights eventually leads to large-scale misappropriation of the returns to innovation and a fall in R&D activity as the economy reverts to the low-growth equilibrium. This result sheds light on the evidence provided by Acemoglu et al (2001) on the importance of the *type* of colonial influence. They show that strong institutions in settlement colonies have had a positive impact on long-run economic performance, while weak institutions in extractionary colonies have not.

Our paper relates to a number of different literatures. The positive correlation between intellectual property rights and growth in our model is strongly supported by the empirical literature on innovation. Khan and Sokoloff (2001) provide extensive evidence that the early development of broad access to IPR institutions with strict enforcement was

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inventors.

[3] There also exists evidence that institutions can be "imported" (with mixed success) however, and that participatory regimes (i.e., democracy) are conducive to institution-building (e.g., Rodrik 2000). Another branch of the literature examines endogenous formal institutions such as political institutions and cconstitutions to optimize tension between the state, the rulers/enforcers and economic agents (Aghion, Alesina and Trebbi 2002, and Barzel 2002).

crucial to the US moving from being a net importer to becoming a net exporter of patents. Gould and Gruben (1996) and Kanwar and Evenson (2001) document a positive relation between property rights and growth or innovation. Moreover, Ginarte and Park (1997) find, in a study of over 120 countries, that the relation between IPR strength and innovation exhibits threshold effects: the research sector has to attain a minimum size before increased property rights improve economic performance.

There exists an established literature with a broad vision of institutions that pertains to crime/expropriation and corruption starting with Grossman and Kim (1995, 1996), and Mauro (1995) (see Bardhan, 1997, for a survey). However, these models share a focus on the analysis of crime and corruption in the absence of institutions, rather than on the incentives for institution-building. Within that literature, our set up is most closely related to the theory of property rights security by Grossmann and Kim (1995), where agents accumulate defensive and offensive weapons to prevent or foster predation. In our dynamic model, as in the static analysis of Acemoglu and Verdier (1998), property rights are never perfect because the cost of establishing such high quality institutions is prohibitive.

The literature on rent-seeking and talent allocation has addressed related issues. In their seminal paper, Murphy Shleifer and Vishny (1991) explicitly indicate how talent misallocation due to rent seeking reduces growth. Rent seeking returns are shown to rise with market size and returns to scale in each sector, as in our model. However, the endogeneity of the strength of institutions in our model generates a counterbalancing effect: the incentives to invest in high quality property rights to protect innovators from predation itself increases market size to and returns to scale. Multiple equilibria are ubiquitous in the talent and rent seeking literature, where the low-growth/high-rent-seeking equilibrium is stable the absence of policy intervention. In contrast, in our model, the endogeneity of institutions implies that the stability of the high or low quality institution equilibrium depends on country characteristics. Acemoglu's (1995) analysis of the allocation of talent allows for endogenous reward structures, which are determined by the proportion of agents engaged in each type of activity. Our paper takes this approach one step further by arguing that the rewards structure, but also the exact institutional arrangement that ultimately determines the nature of the rewards structure, is the result of agents profit maximization.

A recent literature has started to develop growth models with endogenous institutions. Tornell (1997) and Zak (2002) examine crime and expropriation in the context of an investment-driven growth model, and identify savings as the key determinant of institutional quality. Our focus on patents rather than physical capital, allows us to link institutions directly to sustained growth. It also highlights the role of monopoly power, research efficiency, and market size. The paper closest to ours is Acemoglu, Aghion and Zilibotti (2003), which also addresses the relationship between institutions and the incentives to innovate. Their concept of institution is the type of "contracts" rather than the degree of property right protection. The implications are consequently very different. In particular, understanding institutions as contracts implies that there are no growth enabling or growth reducing institutions; rather the notion is that different types of institutions are more suitable at different stages of development. Furthermore, in their setup the adoption of different institutions involves a (political) fixed cost that may trap countries in the "wrong" institutional framework. In contrast, our emphasis is not on the costs of establishing institutions, but rather on the cost of *enforcing and maintaining* them. Both aspects are clearly important and complementary. Our approach to endogenous institutions highlights the importance of ongoing maintenance costs involved in quality institutions, and the role that *private* expenditures play in determining the *effective* institutional framework.

The paper is organized as follows. Section 2 introduces the model, taking institutions as given. Section 3 is the core of the paper; it endogenizes institutions and examines the resulting equilibria. We conclude in section 4.

2. A Simple Model of IPR Protection and Growth

We introduce imperfectly protected intellectual property rights into Romer's (1990) model of R&D-based endogenous growth, and interpret the strength of IPR protection as a measure of institutional quality. It is thus the *quality* of institutions, not their very existence that is captured by our model and the strength of these institutions pertains only to the ability of patent holders to protect their property rights. We first examine an economy with exogenous institutional quality, in order to highlight who are the winners and looser when property rights are strengthened. In the second part of the paper we use these insights to understand the incentives of agents to maintain and improve intellectual property right protection.

2.1. Research and Production

Consider an economy that is populated by a continuum of identical individuals, who supply *L* units of labor inelastically.[4] Each individual maximizes her utility across time.

$$U = \int_t^\infty \frac{c(\tau)^{1-\sigma} - 1}{1-\sigma} e^{-\rho(\tau - t)} d\tau \tag{1}$$

where *c* is per capita consumption, σ the inverse of the elasticity of substitution, and ρ the discount rate.

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[4] The production structure follows Jones (1995) and Arnold (2000) who abstract, without loss of generality, from different types of labor.

There are two types of goods in the economy: a single final good, which is the numeraire, and a continuum of intermediate capital goods. Final output, *Y*, is produced in a competitive sector with a technology that exhibits constant returns at each point in time, according to

$$Y = L_Y^{1-\alpha} \int_0^A x(j)^{\alpha} \, dj \tag{2}$$

where *A* is the number of different intermediate inputs used in production, *x* represents the amount of each intermediate used, and L_Y is the amount of labor employed in the manufacturing sector. Different types of intermediate goods are imperfect substitutes in the production of the final good.

Each intermediate is produced using a different blueprint, A_j, and one unit of capital, *K*. The aggregate capital stock thus satisfies $K = \int_0^A x(j) dj$. In the symmetric equilibrium, equal quantities of all intermediates are used in production, hence the aggregate capital constraint simplifies to $K = Ax$. This allows us to express the production function as

$$Y = (AL_Y)^{1-\alpha} K^{\alpha} \tag{2'}$$

The reformulated production function highlights that technological change, taking the form of increasing product variety, is labor augmenting.

There are two sources of accumulation in the economy, physical capital and knowledge. Assuming no depreciation of capital goods, capital accumulates according to

$$\dot{K} = Y - C \, . \tag{3}$$

The state of knowledge is parameterized by the number of existing blueprints for intermediate goods. New blueprints are generated in a research sector according to Romer’s (1990) R&D function:

$$\dot{A} = \frac{L_R}{a} A , \qquad (4)$$

where L_R are the number of workers employed in research, $1/a$ the productivity of researchers, and it is assumed that there is an intertemporal spillover of knowledge.

Under perfect property rights, once a blueprint is invented, it becomes the property of innovators, who sell it to a single intermediate goods producer at a price P_A. Since intermediates are imperfect substitutes, there is monopolistic competition in the intermediate goods sector. Each producer faces a downwards-slopping demand function,

$$p_{x_i} = \alpha L_Y^{1-\alpha} x_i^{\alpha-1} \quad \forall i \qquad (5)$$

and charges a monopoly price $p_i = r / \alpha$, where r is the interest rate. In equilibrium this price will be the same for all varieties. The resulting instantaneous profits obtained by each intermediate producer are

$$\pi = (1-\alpha) px , \qquad (6)$$

Note that the demand for intermediaries, and consequently profits, are higher the larger manufacturing employment is.

The innovator that holds the patent for a particular variety chooses the price of the blueprint, P_A, so as to extract the entire stream of monopoly profits generated by the good. Hence the value of the blueprint is given by the profit condition

$$P_A = \int_t^{\infty} e^{-\int_t^{\tau} r(s) ds} \pi(\tau) d\tau , \qquad (7)$$

which we can differentiate with respect to time to find the familiar arbitrage equation

$$\frac{\dot{P}_A}{P_A} = r - \frac{\pi}{P_A} . \qquad (8)$$

Arbitrage determines the evolution of the price of technology as a function of the rate of interest and profits over time. In steady state, $P_A = \pi / r$, implying that the price of new technology increases in the expected profit stream. Larger manufacturing sectors increase the rental rate on intermediate goods, (see 5), generating not only higher profits, but also higher prices for the technology blueprints.

2.2. Exogenous Institutions

The strength of intellectual property rights in the model determines how much of the value of innovations can actually be captured by inventors. In particular, the weakness intellectual property right institutions lead to extralegal misappropriations undertaken by agents who exploit imperfect property rights. In a world with imperfect property rights, inventors reap only a fraction $q(t) \in [0,1]$ of the total value of any given invention, P_A. Then, q represents the quality of intellectual property right protection. For now, we take this fraction as given, to highlight the impact of institutions on the rate of innovation.

As a result of imperfect patent property right protection, an inventor can obtain only a fraction of the value of the patent, qP_A, while $(1-q)P_A$ of the value of inventions is misappropriated by other individuals.[5] Workers in the research sector are paid their marginal product, which is now a function of the quality of institutions $w_R = qP_A A / a$. Akin to Krueger's (1974) approach to rent seeking, it is in the economic interest of agents to leave their productive activities in either research or manufacturing and attempt to expropriate imperfectly protected property.

At any point in time, an amount $(1-q)P_A \dot{A}$ can be misappropriated. Following Brock, Magee and Young (1989), we label agents who exploit weak property rights

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[5] As will become apparent later on, we are not assuming that the absence of property rights renders blueprints freely available. Rather we assume that those who misappropriate reap the same profits that the innovator would have received. In essence the predator gets to sell the blueprint to intermediate goods produces without having to have worked for it.

"predatory agents." Predatory agents, L_P each obtain an income w_L such that the entire value of unprotected innovations is exhausted,

$$L_P w_P = (1-q) P_A A L_R / a \tag{9}$$

With exogenous institutions, the model remains exceedingly simple and the steady state implications are easily attained. Labor market equilibrium requires all wages to be the same. Equating the wage in research to that in manufacturing, we have

$$q \frac{A P_A}{a} = (1-\alpha) \frac{Y}{L_Y}. \tag{10}$$

Using equations (5), (6), and (8), we can rewrite equation (10) as

$$L_Y = \frac{a}{\alpha q}\left(r - \frac{\dot{P}_A}{P_A} \right) \tag{11}$$

The level of employment in production depends on the productivity of researchers, the level of institutional quality, the share of intermediate goods in output, and the change in the price of innovations. The faster the price of innovations grows, the larger the productivity in research, and the stronger institutions are the greater the incentives to engage in research, and hence the lower production employment will be.

Equality between the wage in research and the wage of predatory agents renders

$$\frac{1-q}{q} = \frac{L_P}{L_R}, \tag{12}$$

implying that weaker institutions attract relatively more predators. The labor market equilibrium requires that predators, manufacturing workers, and researchers exhaust the fixed supply of labor in the economy, *L,* so that

$$L = L_P + L_Y + L_R. \tag{13}$$

Equation (12), together with the labor constraint (13), imply that the number of innovators is given by

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$$L_R = q\left(L - L_Y\right). \tag{14}$$

The balanced growth rate can now be derived. In steady state, the stationarity of price of innovations, $\dot{P}_A / P_A = 0$, implies $L_Y = ar/\alpha q$ and, by (14), $L_R = qL - ar/\alpha$. Since the amount of each intermediate good produced is constant, output growth is given by $\dot{A}/A = L_R / a$, while utility maximization implies, $\dot{C}/C = \left(r - \rho\right)/\sigma$. These two equations together can be solved for the equilibrium interest rate and the balanced growth rate, $g*$,

$$g* = \frac{q\alpha\, L/a - \rho}{\alpha + \sigma}. \tag{15}$$

Equation (15) implies that growth increases in the efficiency of researchers and in the strength of institutions.

Three reasons induce a lower growth rate under weaker intellectual property rights. First, the smaller *q*, the larger the fraction of the population that engages in unproductive rent seeking. Lowering the quality of property rights protection thus diminishes the labor supply available for research and final goods production. Second, a lower *q* decreases the incentives to invest in research for a given level of profits. The indirect and third effect is that the lack of manufacturing workers reduces the demand for intermediate goods and hence the profitability of an innovation, thus reducing the value of blueprints and further diminishing the incentives to engage in R&D.

3. Endogenous Intellectual Property Rights Protection

In this section we allow institutional quality to be determined by economic incentives. Agents, aware of the rents lost due to predation, possess incentives to improve intellectual property right protection. The strength of these incentives depends on the magnitude of potential rents. Second laws exist to protect property rights, and in addition ever better case law is created through a legal system by *institution-building* agents (see Magee, 1992 and Olsen 1992). While the formal institution of a court is taken as given, the quality of the enforcement is now chosen endogenously. We alter the model by introducing a fraction of the population that has the capacity to generate improvements in intellectual property rights protection.

The efforts of institution-building agents must be compensated. We follow the lead of the political economy literature and stipulate that profit-maximizing agents find it in their interest to expend resources to protect their own property rights. In our case, innovators realize that part of the value of innovations is misappropriated, and hence it is in their interest to hire institution-building, property rights protecting agents. To approximate institution-building we introduce an institution "production function"

$$q_t = F[L_B, L], \text{ with } F_{L_B} > 0, F_{L_B L_B} < 0, F_L < 0. \qquad (16)$$

This function stipulates that the quality of institutions depends positively on the number of institution-building agents, L_B, and negatively on the size of the economy as measured by its population, *L*. This last assumption implies that the strength of institutions depends on the size of the population relative to a given number of institution builders that enforce property rights. To simplify the analysis, we assume that the elasticity of institutional quality with respect to institution-building agents is constant, and that in the absence of institution-building agents there is no protection of intellectual property rights whatsoever, $F(0, L) = 0$.

3.1. The Instantaneous Equilibrium

Innovators are assumed to hire agents in order to protect their property rights over new technologies. They then choose the number of institution-building agents so as to maximize their net income, that is

$$\max_{L_B} L_R F[L_B, L] P_A A / a - w_B L_B . \tag{17}$$

The optimality condition following from the innovators choice of investment in institutional quality stipulates that the marginal cost of hiring another institution-building agent (her wage) must equal the marginal benefit embodied in the change of the innovators return due to improved institutions,

$$L_R \beta \frac{qAP_A}{aL_B} = w_B , \tag{18}$$

where β is the elasticity of institutional quality with respect to institution-building agents. Free entry into the research sector implies that wage payments to researchers and to institution-building agents must exhaust the return from innovation. That is,

$$w_R L_R + w_B L_B = L_R q P_A A / a \tag{19}$$

Equations (18) and (19) together yield the research wage $w_R = (1-\beta) q P_A A / a$.

In equilibrium all workers must receive the same wage. The first equilibrium condition, $w_R = w_B$, yields a relationship between researchers and institution-building agents,

$$\frac{L_B}{L_R} = \frac{\beta}{1-\beta} . \tag{20}$$

The second labor market equilibrium condition, $w_R = w_P$, implies

$$\frac{L_P}{L_R} = \frac{1}{1-\beta} \frac{1-q}{q} . \tag{21}$$

Note that both expressions require the elasticity of institutions with respect to L_B not to exceed unity to insure the existence of an equilibrium with institutions. Equality between wages in the research and the production sectors, $w_R = w_Y$, renders the equilibrium price of blueprints,

$$P_A = \frac{1-\alpha}{1-\beta}\frac{aY}{qAL_Y}. \tag{22}$$

Equations (16), (20), (21), and (23), together with the labor market constraint

$$L = L_L + L_R + L_B + L_Y, \tag{23}$$

yield the instantaneous labor market equilibrium of the economy,

$$q = F[\beta(L - L_Y)q, L]. \tag{24}$$

$$L_B = \beta(L - L_Y)q \tag{25}$$

$$L_R = (1-\beta)(L - L_Y)q \tag{26}$$

$$L_P = (L - L_Y)(1-q) \tag{27}$$

Equations (24)-(27) determine L_B, L_R, L_P and q as a function of manufacturing employment. Given the level of manufacturing employment, the first equation implicitly defines the instantaneous level of institutions. Once *q* is known, we immediately obtain the allocation of workers (not employed in production) to each activity: a fraction (1-*q)* engages in predation, while a fraction *q* is employed by the research sector. Among the latter, a fraction β works to protect property rights, and the rest in research (1-β).

Given our assumption of diminishing returns to institution-building, we can use the implicit function theorem to show that institutional quality increases in the productivity of institution-building agents, β, and decreases in manufacturing employment, $dq/dL_Y < 0$ and $dq/d\beta > 0$. Increasing the productivity of institution builders lowers the marginal costs to inventors, which leads to better institutions. Increases in manufacturing employment, in contrast, lower the profitability of a new technologies, which reduces the size of the innovation sector and hence the funds available for institution-building.

Note that, equation (26) implies that for a given *q*, the number of researchers declines with β. This can be explained by the fact that a higher productivity of institution builders makes it profitable to switch workers from research to institution-building. This reallocation of the workforce reduces the number of innovations, although it raises the fraction of the patent value that the innovator can obtain.

3.2. The Intertemporal Equilibrium

The intertemporal general equilibrium requires the analysis of the evolution of manufacturing employment over time. Along the balanced growth path, all variables grow at a constant rate. Hence, we follow Arnold (2000) and normalize key variables to attain stationarity, using $\chi \equiv C/K, z \equiv Y/K$. The dynamic system governing the evolution of the economy over time is then given by (see appendix):

$$\frac{\dot{\chi}}{\chi} = \frac{\alpha^2 z - \rho}{\sigma} - z + \chi \,. \tag{28}$$

$$\frac{\dot{L}_Y}{L_Y} = \frac{\dot{z}/z}{1-\alpha} - \frac{(1-\beta)(L-L_Y)q}{a} + z - \chi \,. \tag{29}$$

$$\frac{\dot{z}}{z} = (1-\alpha)\left((1-\beta)q\frac{L_Y}{a} - \alpha z - \alpha\frac{\dot{q}}{q}\right) \tag{30}$$

$$\frac{\dot{q}}{q} = -\frac{\beta}{1-\beta}\frac{\dot{L}_Y/L_Y}{(L/L_Y - 1)} \,. \tag{31}$$

The first equation is simply the consumer's optimal consumption growth decision, where $\alpha^2 z$ is the equilibrium interest rate obtained from the equality between the marginal product of capital, αz, and the monopoly price for intermediate goods, $p = \alpha / r$. The second equation is obtained by differentiating the production function with respect to time. The third one is a combination of the labor market equilibrium equation (equation (23)) and the arbitrage equation (11), and expresses the evolution of the capital output ratio as a function of manufacturing employment and the evolution of institutions. Differentiating (24) we obtain the evolution of institutions over time as stated in (31).

Equations (28) to (31) fully characterize the dynamics of the economy. This system can be solved for its steady state, $\dot{z} = \dot{\chi} = \dot{L}_Y = \dot{q} = 0$ (see appendix), yielding the steady state relationship between manufacturing employment and institutional quality

$$q = \frac{a\rho}{(1-\beta)\left(L_Y(\alpha+\sigma) - L\sigma\right)}, \tag{32}$$

We can now obtain the growth rate of output. In steady state, employment in all sectors is constant, hence the only input in final goods production that grows over time is the number of intermediate goods available. The growth rate of the economy is then $g \equiv \dot{A}/A = L_R/a$. Using (26) and (32) we can express it as

$$g = \frac{\rho(L - L_Y)}{L_Y(\alpha+\sigma) - L\sigma}, \tag{33}$$

which shows that the growth rate is a decreasing function of the level of manufacturing employment.

3.3. Characterization of the Equilibria

3.3.1 Multiplicity

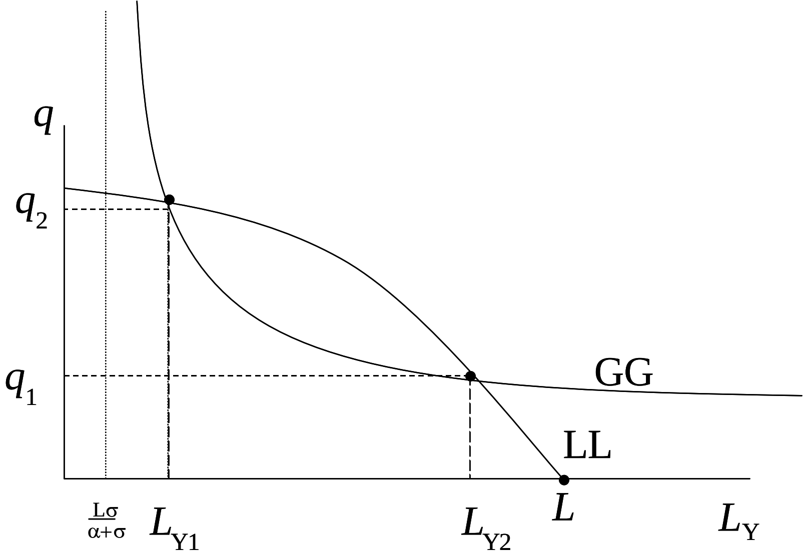
The steady state levels of manufacturing employment and institutions are determined by the dynamic equilibrium and the instantaneous equilibrium conditions, (24) and (32), respectively. That is, by the system

$$q = F\left[\beta(L - L_Y)q, L\right] \tag{LL}$$

$$q = \frac{a\rho}{(1-\beta)\left(L_Y(\alpha+\sigma) - L\sigma\right)}. \tag{GG}$$

The first equation, (LL), is simply the instantaneous labor market equilibrium condition that holds at any point in time. The level of institutions is decreasing in L_Y because greater production employment reduces the size of the labor force available for research and institution-building. The second equation, (GG), is the $\dot{L}_Y = 0$ schedule, which represents the steady state combinations of institutions and production employment that ensure goods market equilibrium. The relationship is negative because in order to maintain the equilibrium level of research, a deterioration of institutional quality has to be offset by an increase in the value of the patent, which in turn requires more manufacturing employment.

Figure 1
Institutional Equilibria



The two schedules are depicted in Figure 1 in (q, L_Y) space. The (GG) schedule is decreasing and convex, and has an asymptote at $L_Y = \sigma L/(\alpha+\sigma)$. The (LL) schedule is also decreasing, concave for $\beta \geq 1/2$, and otherwise convex.[6] The instantaneous labor market equilibrium (LL) lies below the (GG) schedule both at $L_Y = \sigma L/(\alpha+\sigma)$ and $L_Y = L$. Hence, there are either two intersections between (LL) and (GG), or none.

The graph indicates the existence of two internal equilibria that exhibit positive growth, which can be characterized as follows. Equilibrium 1 exhibits strong intellectual

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[6] The LL schedule will always be less convex than the GG schedule, hence its curvature is irrelevant for the equilibrium discussions below.

property rights, high research, and a relatively small employment level in manufacturing. In contrast, equilibrium 2 features weak property rights, little research, and large manufacturing sector employment. Since the growth rate depends on research employment, which declines in manufacturing employment (see equation 34), the growth rate will be greater in the strong institutions equilibrium.

The model's third equilibrium at $L_Y = L, q = 0$ is a poverty trap where innovation simply does not pay. The intuition that innovations cease in a country without property rights is readily established: in the absence of institutions all research outlays are fully misappropriated, research ceases (equation (30) does not hold), and the economy degenerates to the Solow model without technical change.

3.3.2 Institutions and scale effects

An equilibrium with institutions exists only if the (GG) and (LL) schedules intersect. A crucial factor in determining the relative position of the two schedules is population size, or the scale of the economy. Scale has two opposing effects on growth: larger populations constitute larger markets for technologies, which increase intermediate good production and the profitability of research. This in turn provides greater incentives to invest in institution builders. At the same time, large populations have a negative direct effect since larger countries require more institutional maintenance, as $F_L < 0$. The net of these two effects, which depends on the specific institution function, determines whether size is positively or negatively related to economic growth.

As an example, let us consider an institution function of the form $q = \sqrt{L_B/L}$, so that $\beta = 1/2$. Then, the two internal equilibria are given by

$$L_{Y1,2} = L\left[\frac{\alpha + 2\sigma}{2(\alpha + \sigma)} \pm \frac{\sqrt{\alpha^2 - 16a\rho(\alpha + \sigma)/L}}{2(\alpha + \sigma)}\right], \qquad (33)$$

with $L_{Y1} < L_{Y2}$.

Here growth and institutions deteriorate in the low institution equilibrium as scale increases, while the effect for the high institution equilibrium depends on the remaining parameters that determine market size. If the R&D sector is productive, the country is patient, and the return to innovation high (the very virtues that will be shown below to lead countries to the high growth equilibrium in the first place) then larger scale is positively related to economic growth. Population growth can then be a source of divergence between countries: in economies that already have strong institutions, population growth can further strengthen them as incentives to invest in research and protection expand. In countries with weak intellectual property rights, population growth simply increases the extent of misappropriation and reduces innovative efforts.

In our example, there is an explicit population threshold, $\overline{L} \equiv 16a\rho(\alpha+\sigma)/\alpha^2$, such that if L is below $\overline{L}$ no equilibrium with institutions can exist.[7] As a result, if the population is too small, the economy will be in a poverty trap with no innovation. This feature of the model is consistent with North's (1990) notion that early human settlements existed without property rights, and that population growth led to the evolution of property rights. Furthermore, if sharing the same law or language increase the population reach of any given innovation, our approach provides some foundation for the finding by Hall and Jones (1999) that common country characteristics, such as common law or language, are important institutional determinants.

Market size is also affected by technological parameters. Production functions with small shares of technology (low α) generate little demand for new intermediate goods, lowering the demand for innovation and intellectual property right protection. The remaining comparative statics are straightforward. Low researcher productivity ($1/a$)

shifts the GG curve upwards, and a low productivity of institution builders (β) increases the convexity of the instantaneous labor market equilibrium schedule, LL, both of which make an equilibrium with institutions less likely. As in Tornell (1997), preference parameters also matter: a high discount rate (high ρ) and low intertemporal elasticities of substitution (high σ) increase the likelihood of a poverty trap.

The fundamental reason for the importance of market size is the prominence of scale effects present in endogenous growth models, where larger economies generate high benefits to innovation, as the value of the patent is large. Countries whose markets for technology are small, either because population is small or because the production technology implies a low productivity of new technologies, are likely to exhibit weak or even no institutions. Low returns to investment in technological change render research less profitable. With fewer funds to hire institution-building agents, property rights are weak, reinforcing the lack of incentives to invest in R&D.

3.3.3 Growth, Institutional Quality, and the Service Sector

The two internal equilibria constitute a novel interpretation of why manufacturing employment has been falling in industrialized countries. Let us define the service sector employment as $L_P + L_B$, that is, those agents not engaged in research or manufacturing production. It can be shown that $d\left(L_P + L_B\right)/dL_Y < 0$ (see appendix). Countries with large shares of employment in manufacturing do not have the capacity to maintain a large service sector that ensures high institutional quality. As a result, institutional quality and smaller manufacturing sectors correlate not only with higher growth rates, but also with larger service sectors.

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[7] Equation (33) has real roots only if $\alpha^2 - 16a\rho(\alpha + \sigma)/L \geq 0$.

At the same time, it is possible to use equations (25)-(27) to show that the ratio of service sector relative to research activity declines in institutional quality, $d\left(\left(L_P + L_B\right)/ L_R\right)/ dq < 0$. Intuitively, the rewards taken away from predatory agents are divided between researchers and institution-builders, implying that the incentives to become a predatory agent fall faster than the rewards to institution-building increase.

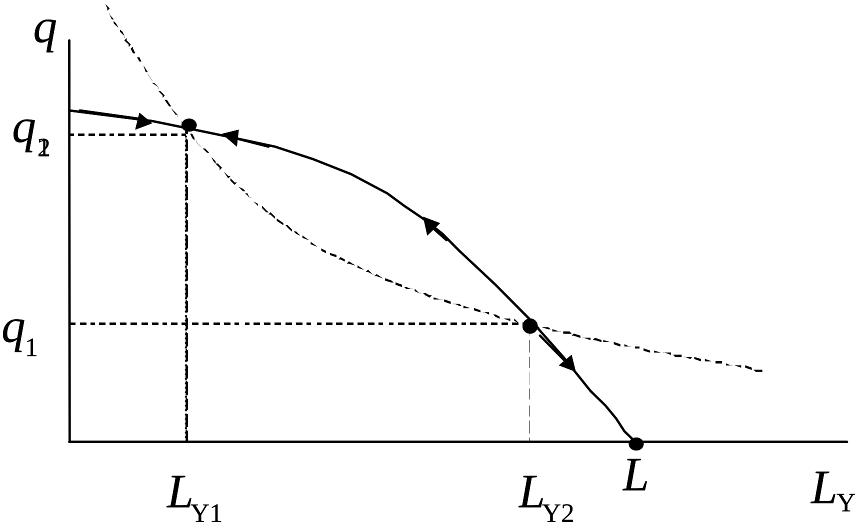
This implication is supported by the evidence in Magee, Brock and Young (1989), who show a negative relationship between researchers/engineers (proxied by physicians) and unproductive predatory agents. In the context of the Magee et al model, such a relationship is not surprising. They only examine the rent-seeking aspect of institutions, hence more predators necessarily imply fewer researchers. Our analysis shows that the negative relationship persists even after introducing “costly institution building”, where both predators and institution builders coexist in a service sector outside manufacturing,

3.4. Stability of the Equilibria

The stability of equilibria provides additional insights into the conditions that render a country in the high or low institution equilibrium. Focusing on the two dimensions in Figure 1, we analyze the autonomous differential equation system around the stationary state, $\dot{L}_Y = f\left(L_Y, q, \chi^*, z^*\right)$ and $\dot{q} = g\left(L_Y, q, \chi^*, z^*\right)$, where starred variables represent steady state values. The instantaneous labor market equilibrium requires that the economy always satisfies (LL), which implies it is always on the solid line in Figure 3. The dynamics around the $\dot{L}_Y = 0$ line depend on the sign of $\partial\dot{L}_Y / \partial L_Y$, which can be shown to depend on whether L_Y^* is greater or lower than certain level $\overline{L}_Y$, where $\overline{L}_Y \equiv L/\left(1+\beta/(1-\beta)\sigma\right)$.

Figure 2

Stable Equilibria with Institutions $q^* > \overline{q}$



$\overline{L}_Y$ is in fact a crucial threshold level of manufacturing employment. The stability condition defines an institutional development threshold $\overline{q} = F\left[\beta(L - \overline{L}_Y)\overline{q}, L\right]$, so that if the equilibria of the economy are such that $q_1^*, q_2^* > \overline{q}$, then $\partial \dot{L}_Y / \partial L_Y < 0$ and the strong intellectual property rights equilibrium is stable. This case is depicted in Figure 2. Countries with initial levels of institutions above those given by L_{Y2}, q_2 will converge to the strong-institutions equilibrium. As intellectual property rights are progressively better protected and growth increases, the service sector expands in ever-richer countries where high rates of innovation afford an ever-larger stock of institution builders to further protect property rights. Those economies starting below this point converge to the poverty trap: the return to research does not cover the cost of establishing sufficient intellectual property rights quality to provide adequate returns to innovators, hence innovators leave the research sector, which reduces institution-building funds further until the no-research, no-institutions equilibrium is attained. If the equilibria are such that $q_1^*, q_2^* < \overline{q}$, then $\partial \dot{L}_Y / \partial L_Y > 0$, and the weak-institutions equilibrium is instead the only stable one.

The exact stability condition depends on the functional form of the institution-building function, as this determines L_Y^*. However, we can establish intuition from the general condition $L_Y / L \left(1 + \beta / (1-\beta)\sigma\right) - 1 < 0$, implies that the high-growth equilibrium is stable only in economies where this equilibrium is characterized by a comparatively small manufacturing sector. In our example in (33), inspection of the solutions indicates that this occurs in three cases: if research productivity is high, if the productivity of intermediate goods is large, and when a country has a low rate of time preference.

The stability analysis provides some insights as to why initial conditions, such as the type of colonial institutional influence, have been shown to be so influential in the empirical literature. If the strong-institutions equilibrium is stable, then initial conditions are a crucial determinant of the long-run equilibrium. Countries where colonization imposed weak institutions (i.e. the country could not pass the institutional threshold of q_2^*) were not able to sustain such a level of institutions in the long run, and hence eventually reverted to the low-growth equilibrium. For similar reasons, policy may not always be effective in generating strong institutions. Only policies that overcome the institutional threshold can generate fast growth in the long run.

4. Conclusions

We integrate endogenous strength of intellectual property rights into an R&D based growth model to analyze the effects of endogenous institutional quality on the performance of the economy. We find that the growth rate and the strength of institutions move hand-in-hand, and obtain two crucial results. First, market size, and hence population, is a crucial determinant of whether an equilibrium with strong property rights exists. Second, endogenous strength of property rights are shown to generate multiple equilibria and an institutional quality development threshold that must be overcome if an economy is to have strong institutions and rapid growth in the long run. The crucial determinants of the strength of the institutions are shown to be the efficiency of institution-building, and the determinants of patent profitability. The value of patents depends itself on the size of the economy, the productivity in research, and the profitability of new technologies in production.

The model provides theoretical foundations for several regularities that have been discussed in the empirical growth and institutions literature. Institutional development thresholds can explain why it is that not all colonies benefited from colonization equally, and why minimal standards of institutions are now seen as the key to take off in transition economies. In addition, the model provides a novel interpretation for the decline in the manufacturing sector and the rise of the service sector in advanced countries (those with the strongest institutions). The service sector expands naturally in our model as rents from innovations rise with growth and market size; hence more resources are spent on services to protect property rights.

The size of the economy plays a crucial role in our analysis. On the one hand, it determines whether or not an equilibrium with institutions exists. On the other, a larger population will result in faster growth if an economy is in a strong institutions equilibrium, and in slower growth if it finds itself in a weak-institutions equilibrium. A limitation of our analysis is that population size is given, yet when we think about growth over the very long-run population size is clearly endogenous. Our model seems to indicate that population growth can help us understand the advent of events such as the industrial revolution, or the current trend towards income divergence between rich and poor countries. These are important questions that we leave for future research.

Appendix

The intertemporal general equilibrium requires the analysis of the evolution of the manufacturing employment over time. Let $\chi \equiv C/K, z \equiv Y/K$. Utility maximization implies $\dot{C}/C = (r-\rho)/\sigma$, which together with the capital accumulation constraint (3) yields $\dot{\chi}/\chi = (r-\rho)/\sigma - z + \chi$. Since the marginal product of capital in the final good sector, $p = \alpha z$, must be equal to the price of intermediate goods, $p = r/\alpha$, we have

$$\frac{\dot{\chi}}{\chi} = \frac{\alpha^2 z - \rho}{\sigma} - z + \chi \tag{A.1}$$

Wage equalization between the final goods sector and the research sector renders the equilibrium price of blueprints, $P_A = a(1-\alpha)Y/(1-\beta)qAL_Y$, which we can differentiate to find the evolution of the price of technology over time that is compatible with a labor market equilibrium. That is

$$\frac{\dot{P}_A}{P_A} = \frac{\dot{Y}}{Y} - \left(\frac{\dot{A}}{A} + \frac{\dot{L}_Y}{L_Y}\right) - \frac{\dot{q}}{q}. \tag{A.2}$$

Differentiating the production function with respect to time,

$$\frac{\dot{Y}}{Y} - \left(\frac{\dot{A}}{A} + \frac{\dot{L}_Y}{L_Y}\right) = -\frac{\alpha}{1-\alpha}\frac{\dot{z}}{z} \tag{A.3}$$

Using equation (11) and (A.2), we can express (A.3) as

$$\frac{\dot{z}}{z} = (1-\alpha)\left((1-\beta)q\frac{L_Y}{a} - \alpha z - \alpha\frac{\dot{q}}{q}\right) \tag{A.4}$$

We solve for the evolution of L_Y by totally differentiating z and using the production function (2) to find

$$\frac{\dot{L}_Y}{L_Y} = \frac{\dot{z}/z}{1-\alpha} - \frac{(1-\beta)(L-L_Y)q}{a} + z - \chi. \tag{A.5}$$

Differentiating (24) we obtain the evolution of institutions over time,

$$\frac{\dot{q}}{q} = -\frac{\beta}{1-\beta}\frac{\dot{L}_Y/L_Y}{(L/L_Y - 1)}. \tag{A.6}$$

This system formed by (A.1), (A.4), (A.5), and (A.6) can be solved for its steady state $\dot{z} = \dot{\chi} = \dot{L}_Y = \dot{q} = 0$, yielding

$$\chi^* = \frac{\rho(L_Y(1+\alpha) - L\alpha)}{\alpha(L_Y(\alpha+\sigma) - L\sigma)} \tag{A.7}$$

$$z^* = \frac{L_Y\rho}{\alpha(L_Y(\alpha+\sigma) - L\sigma)} \tag{A.8}$$

$$q^* = \frac{a\rho}{(1-\beta)(L_Y(\alpha+\sigma) - L\sigma)} \tag{A.9}$$

The steady state equilibrium levels of institutions and manufacturing employment are then given by

$$q = \frac{a\rho}{(1-\beta)(L_Y(\alpha+\sigma) - L\sigma)}. \tag{GG}$$

$$q = F[\beta(L-L_Y)q, L] \tag{LL}$$

Differentiating the (GG) schedule we have $dq/dL_Y < 0, d^2q/dL_Y^2 > 0$, implying that it is decreasing and convex in L_Y. It has an asymptote at $L_Y = L\sigma/(\alpha+\sigma)$, and takes a strictly positive value at $L_Y = L$. Totally differentiating (LL) we have

$$\frac{dq}{dL_Y} = -\frac{\beta}{1-\beta}\frac{q}{L-L_Y}, \tag{A.10}$$

which implies

$$\frac{d^2q}{dL_Y{}^2} = -\frac{1-2\beta}{(1-\beta)^2}\frac{\beta q}{(L-L_Y)^2}. \tag{A.11}$$

The (LL) schedule is decreasing, concave for $\beta \geq 1/2$ and convex otherwise. Given our assumptions on $F[L_B, L]$, it takes a positive, finite value at $L_Y = \sigma L/(\alpha+\sigma)$, and is 0 at $L_Y = L$.

The (GG) schedule is then above the (LL) one both at $L_Y = \sigma L/(\alpha+\sigma)$ and at $L_Y = L$. Hence, there are either two intersections between the (LL) and the (GG) or none. For $\beta \geq 1/2$, the (LL) schedule is convex and the two equilibria will always exist. For $\beta < 1/2$, no equilibrium with institutions may exist, existence being less likely the smaller β is (the more concave the (LL) schedule is).

We can now examine the variations in the allocation of labor as manufacturing employment changes. From equations (24) to (26), and using (A.10) we have

$$\frac{dL_R}{dL_Y} = \frac{d}{dL_Y}\left((1-\beta)(L-L_Y)q\right) = -q,$$

$$\frac{d(L_P+L_B)}{dL_Y} = \frac{d}{dL_Y}\left((1-q(1-\beta))(L-L_Y)\right) = -(1-q),$$

$$\frac{d((L_P+L_B)/L_R)}{dL_Y} = \frac{d}{dL_Y}\left(\frac{1}{q(1-\beta)}-1\right) = \frac{\beta}{q(1-\beta)^2(L-L_Y)}.$$

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