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FACTOR ENDOWMENTS, INSTITUTIONS, AND THE RULE OF LAW

By

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ABSTRACT: The analysis shows that factor endowments — natural and human — completely shape the aggregate allocation of talent between production and appropriation and the quality of property rights institutions. More effectual human capital generation, a smaller stock of natural resources and a more favorable climate cause a shift of talent away from appropriation. They also facilitate the establishment of stronger property rights institutions. As human capital accumulates through time, an economy exhibits a continuously more constructive allocation of talent. After a time threshold is reached, society switches from a predatory to a productive equilibrium, exhibiting a drastic institutional improvement.

Key Words: Appropriation, Production, Institutions, Human Capital, Natural Resources.

JEL Classification Codes: P48, O1.

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1. INTRODUCTION

It is well-known that the allocation of society's talent between constructive production and wasteful appropriation — closely related to the quality of its property rights institutions — is an important indicator of economic prosperity. An emphasis on production and a strong protection of property rights tend to be associated with high levels of income (Acemoglu, Johnson and Robinson [2005]). As a result, several economists argue that weak institutions and an unfavorable allocation of talent are fundamental causes of underdevelopment (North and Thomas [1973]).[1] For example, weak institutions may stem from a historical accident at a critical juncture (Glaeser and Shleifer [2002]). Weak institutions may also be the outcome of social conflict; when the political elite have different interests than the rest of the population, they may self-servingly establish extractive institutions, encouraging appropriation and retarding development (Aghion, Alesina and Trebbi [2004], Acemoglu [2005, 2008], Acemoglu and Robinson [2006, 2008]).

A different school of thought, however, states that society's allocation of talent between production and appropriation, as well as society's property rights institutions, may not constitute an independent parameter, but may instead stem from factor endowments — both natural and human. According to this view, factor endowments are primary, while talent allocation and institutions are secondary. Factor endowments shape both the economic and institutional development of a country, which explains the correlation between economic well-being and property rights institutions or the rule of law.

For example, North and Thomas [1973] note that natural resource endowments — especially gold and silver — in the Spanish colonies in the New World encouraged rent seeking and caused an institutional malaise in 17th-century Spain. Furthermore, Lipset [1959] focuses on human capital endowments and informally stresses the role of education in promoting institutional improvement; an increase in human capital leads to stronger institutions. Support for a link between natural and human endowments and the rule of law or institutions also comes from empirical research (e.g., Barro [1999], Hall

[1] Murphy, Shleifer and Vishny [1991, 1993] and Acemoglu [1995], among others, examine the detrimental effects of appropriation and rent seeking on economic prosperity.

and Jones [1999], Przeworski *et al.* [2000], Treisman [2000], Acemoglu, Johnson and Robinson [2001], Easterly and Levine [2003], Glaeser *et al.* [2004]).

However, although the factor endowments view is supported by substantial anecdotal and empirical evidence, it has received relatively little attention in formal economic theory. Many of the existing theoretical discussions are informal and do not explain in a concrete way the mechanisms through which factor endowments may affect institutions and the rule of law. Because of the relative lack of formal theoretical analyses, the factor endowments view of development is often overlooked in mainstream economics.

I provide a formal model of the factor endowments view. The model borrows from a more specialized literature — the natural resource curse literature (e.g., Torvik [2002], Mehlum *et al.* [2006], Robinson, Torvik and Verdier [2006]) — which shows that natural resource booms may enhance rent seeking.[2] This literature examines agent interaction in the presence of exogenous institutions; it assumes that rent seekers are able to capture most of the profit from natural resource enterprises. Then, natural resource booms may encourage rent seeking and reduce output.[3] I extend this literature in three main ways. First, I endogenize institutions, bringing out the mechanisms through which they may emerge. Second, I provide microfoundations for the distinct differences between natural resources and other types of wealth, endogenously showing why natural resources may favor rent seekers. Third, and perhaps more importantly, I incorporate other factor endowments — effective labor and human capital — into the analysis, bringing out the crucial interplay between the various endowments.

These extensions allow us to perform a complete analysis of the factor endowments view. It is shown that the role of factor endowments in a country's institutional and economic development may be far more pervasive than in the literature; in all periods, society's property rights institutions and talent allocation can be completely shaped by such endowments. Overall, in the analysis, factor endowments

[2] Furthermore, Tornell and Lane [1999] show that any boom — natural-resource-based or technological — may encourage rent seeking; this is the so-called "voracity effect."
[3] For example, natural resources may be owned by the government. Since the government is often controlled by rent seekers, it may transfer most of the profits from natural resource enterprises to rent seekers and cronies.

constitute a fundamental parameter that may fully determine a country's developmental and institutional path through time.

In the model, there are two types of agents in the population, producers and predators. Producers have developed the ability to produce output, while predators are skilled in appropriation, trying to expropriate some of the economy's output. An agent makes his aptitude choice — i.e., whether to become a producer or a predator — with rational expectations and aimed at maximizing his payoff. Manufacturing of output entails two inputs, a natural resource and effective labor.

Effective labor depends on the level of human capital — taken to be the professional know-how of producers. Natural resources, on the other hand, are granted by nature, instead of being created by agents. Natural resources initially have no owners, and ownership titles are assigned to agents according to the rule of first possession, i.e., on a first come, first served basis.[4] No productive skills are necessary for claiming ownership of resources through the rule of first possession, which depends to a large extent on luck and coincidence. Both producers and predators are able to take first possession of natural resources and generate revenues from them; producers utilize the resources in their own manufacturing operations, while predators sell the resources to producers.

In each period, the game has a unique — productive or predatory — coalition-proof subgame-perfect equilibrium. If the equilibrium is productive, the proportion of producers in the population is high, allowing producers to prevail politically and establish strong property rights institutions. If the equilibrium is predatory, on the other hand, predators prevail politically and choose weak institutions. The analysis shows that the type of the equilibrium (productive or predatory) and the quality of institutions (strong or weak) do not constitute independent parameters; they are completely determined by society's factor endowments.

In particular, factor endowments — natural resources and human capital — affect the aggregate allocation of talent between production and appropriation. In an economy without natural resources, the proportion of the economy's output that is allocated to

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[4] According to the law literature, the rule of first possession is the most common method of distributing ownership titles to previously unowned goods or assets (Epstein [1979]).

predators is the appropriable fraction of output — the proportion of output that is unprotected by property rights institutions. The presence of natural resources, however, allows predators to earn an extra payoff. In addition to expropriating the appropriable fraction of the economy's output, — which output already encompasses the economy's inputs (including natural resources), — predators can also earn an extra income by taking first possession of a strictly positive quantity of natural resources and by selling these resources to producers. In this way, the existence of natural resources shifts the distribution of the economy's wealth toward predators and encourages more agents to become predators, rather than producers.

When an economy's stock of human capital is small relative to the amount of natural resources, manufacturing of output is more natural-resource-intensive. Then, the shift in the distribution of wealth that is caused by the existence of natural resources is more pronounced, encouraging more agents to become predators, rather than producers. Producers may thus be unable to reach critical mass and prevail politically in a coalition-proof equilibrium, leading to a Pareto inferior predatory equilibrium with weak institutions. Overall, the stock of natural resources, the effectiveness in human capital generation and the climate (which impacts human work efforts) completely determine the allocation of talent between production and appropriation, as well as the quality of property rights institutions.

Society's human capital is a dynamic, rather than a static, parameter and as it accumulates through time, the proportion of producers in the population increases. Thus, the coalition-proof equilibrium is predatory — and marked by weak property rights institutions — in the early phase of development when the stock of human capital is small relative to the amount of natural resources. After, however, a time threshold is reached, the stock of human capital becomes sufficiently large for agents to coordinate towards a Pareto dominant productive equilibrium; then society exhibits a drastic institutional improvement. Weak institutions persist in the early phase of society's development, while strong institutions persist afterwards.

In addition to shaping institutions and the rule of law, factor endowments determine a country's level and growth rate of output. Furthermore, in the very long run, the growth rate of an economy's output is increasing in time. Economic growth is increasing in time — for example, it is higher in advanced than in pre-industrial societies — because as time progresses, the growing input — human capital — accounts for a larger fraction of economic activity relative to the non-growing input — natural resources.[5]

The paper consists of seven sections. Section 2 describes the model, and section 3 solves for the equilibrium. Section 4 shows how factor endowments may affect society's talent allocation and institutions. Section 5 focuses on the effects of endowments on output. Section 6 discusses empirical implications. Section 7 suggests some conclusions.

2. THE MODEL

In each period t ($t \in \mathbb{Z}^+$) the economy is populated by L agents, who live for one period only. At the end of t, each agent exits the game and is replaced by a new agent. Then, in period $t + 1$ the game repeats with the new agents; we have an infinitely repeated game. An agent chooses to be either a producer (P) or a predator (R). Although both producers and predators aim at maximizing their personal payoff, they build up different skills and thus pursue payoff maximization in different ways. Producers develop the ability to create output, but do not have appropriation skills. Predators, on the other hand, lack the ability to produce; instead, they develop an aptitude for appropriation, attempting to expropriate the economy's output.[6]

Appropriation may take several forms (Olson [2000]). For example, it may happen through brute force, theft or coercive encroachment. Predators may also use the government as a means of appropriation; the government may seize output through extractive taxation or regulation and redistribute it to predators (who may be government cronies). The proportion of producers and predators in the population in period t is θ_t^P and $\theta_t^R = 1 - \theta_t^P$, respectively. Our results would be qualitatively similar if each producer also had some appropriation skills and each predator also had some productive skills as long as producers had better productive and worse appropriation skills than predators.

[5] Kremer [1993] and Maddison [2003] empirically show that in the very long run, society's rate of economic growth tends to be increasing in time.
[6] Murphy, Shleifer and Vishny [1993], Acemoglu [1995] and Grossman and Kim [2000], among others, also construct models where there are both producers and predators in the population.

Each producer manufactures a homogeneous output. Manufacturing entails two inputs, namely a natural resource and effective labor. The natural resource and effective labor can substitute for each other; abundance of effective labor can compensate for scarcity of the natural resource, and vice versa. Therefore, as in Dasgupta and Heal [1974], I make the standard assumption of a constant elasticity of substitution (CES) production function. Furthermore, for simplicity, I assume that the elasticity of substitution in the CES function is infinite, i.e., the function is linear. As will be explained in section 4.4, our basic results are qualitatively unchanged for almost any elasticity of substitution. We have

$$q(\omega, \chi) = \omega + \chi \, , \tag{1}$$

where q is the amount of output that is manufactured by a producer and ω and χ are the amounts of the natural resource and effective labor that are used.

Each producer provides effective labor for his own manufacturing operations. In period t, the amount of effective labor χ_t^i that a producer i can provide is a function of first, the time s^M ($s^M \in [0,1]$) that the producer spends on manufacturing and second, the level of human capital H_t^i — i.e., the level of professional know-how — that the producer has. It follows that

$$\chi_t^i(s^M, H_t^i) = f(s^M) H_t^i \, . \tag{2}$$

I make the standard assumption that output is increasing in time at a decreasing rate (concave function), i.e., $\partial f(s^M)/\partial s^M > 0$ and $\partial^2 f(s^M)/\partial s^{M^2} < 0$.

In period t, a producer randomly chooses to observe a producer that operated in the previous period t – 1. The contemporary producer adopts all the know-how of the randomly selected producer from the previous period. For simplicity, I assume that such adoption is costless; our results, however, would be similar if the adoption entailed a fixed cost (as long as it was not prohibitively large). A producer may also generate new human capital by improving upon the skills he adopts. The new human capital ΔH_t^i that is generated by a producer *i* is a function of the time s^H ($s^H \in [0,1]$) that the producer spends on human capital accumulation and the level of human capital $\widetilde{H}_{t-1}$ of the previous period producer that has been randomly selected for observation. We have

$$\Delta H_t^i(s^H, \widetilde{H}_{t-1}) = ae(s^H)\widetilde{H}_{t-1}, \tag{3}$$

where $a > 0$. I make the standard assumption that human capital generation is an increasing and concave function of time, i.e., $\partial e(s^H)/\partial s^H > 0$ and $\partial^2 e(s^H)/\partial s^{H^2} < 0$.[7]

Each agent has one unit of time available. A predator spends his entire time on appropriation. On the other hand, as in Lucas [1988], a producer allocates his one unit of time between manufacturing and human capital accumulation, i.e., $s^M + s^H = 1$. The total level of human capital H_t^i of producer *i* is equal to $\widetilde{H}_{t-1} + \Delta H_t^i$, i.e., equal to the sum of the human capital that the producer adopts and the new human capital that he generates. In period 1, producers adopt an initial stock of human capital $H_0 > 0$.

In each period *t*, the total amount of natural resources in the economy is Ω. Natural resources are renewable and do not become depleted in time; our results would also be similar with gradual depletion of resources.[8] Natural resources are different from the other input to manufacturing — effective labor — in that they are not created by agents, but are instead granted by nature. At the beginning of period *t*, natural resources have no owner; ownership titles are awarded to agents according to the rule of first possession, i.e., on a first come, first served basis. As the law literature points out, this is usually the dominant method of establishing ownership of previously unowned goods or

[7] According to endogenous growth theory (Romer [1986], Lucas [1988]), an economy can grow consistently when the input that can be augmented — human capital in our model — exhibits non-diminishing marginal productivity in its accumulation and in manufacturing. For this reason, in expression (3) human capital accumulation $\Delta H_t^i(s^H, \widetilde{H}_{t-1})$ is linear in existing human capital $\widetilde{H}_{t-1}$, and in expression (2) the amount of effective labor $\chi_t^i(s^M, H_t^i)$ is linear in a producer's human capital H_t^i. Our results would be similar for other (non-linear) forms of non-diminishing marginal productivity of human capital.

[8] In practice, some natural resources — such as arable land — are renewable and may not become depleted through time. Others — such as oil — may be gradually depleted.

assets (Epstein [1979]).[9] In this way, success in taking first possession of natural resources depends to a large extent on luck and coincidence — some agents are randomly located closer to natural resources than others when they enter the game. Claiming ownership of natural resources through the rule of first possession requires no productive skills, and thus both producers and predators are able to take first possession of resources. For simplicity, it is assumed that all agents have the same degree of luck, thereby taking first possession of an equal amount Ω / L of natural resources.[10]

A producer utilizes the amount of natural resources of which he takes first possession in his manufacturing operations. A predator, on the other hand, does not have the productive capabilities to transform natural resources into output. He thus auctions any natural resources he takes first possession of, selling them to the producer that makes the highest bid; bids are in terms of a specified amount of output in the future.

In each period *t*, society establishes laws and institutions that fix the strength of property rights to output. Stronger property rights institutions offer greater protection to agents that acquire output through their activities in the supply chain of production — i.e., through manufacturing (producers) or through the sale of natural resources (predators). The strength of property rights is d_t, which denotes that each agent is guaranteed legal rights to a fraction d_t of the final output he possesses. The law, on the other hand, does not offer protection to the remaining share $1-d_t$ of an agent's final output, which is expropriated by predators. An agent's appropriable property is equally distributed among all predators.[11]

We have $d_t \in [0,\bar{d}]$ and $0.5 < \bar{d} < 1$; the upper bound $\bar{d}$ is determined by technological constraints in the enforcement of property rights. The assumption $\bar{d} > 0.5$ ensures that in at least one period, it is feasible for producers to prevail politically. In

[9] Other methods of allocating ownership titles to goods or assets that initially have no owner are the uniform allocation rule (equal distribution among all agents) and the lottery. Our results would be similar if these methods, rather than the first possession rule, were used as long as predators acquired a strictly positive quantity of natural resources.

[10] Our results would be similar for any other distribution of luck parameters as long as predators attained first possession of a strictly positive quantity of natural resources. Furthermore, our results would be similar if agents could also exert an active effort in taking first possession of natural resources as long as taking first possession also depended on luck and coincidence. The role of luck prevents the dissipation of reserve ownership gains by a race among agents (Johnson and Libecap [1982]).

[11] This is a standard assumption (Murphy, Shleifer and Vishny [1993], Grossman and Kim [2000]).

each period t agents engage in a political battle to establish rules for the strength of property rights d_t. In this political contest strength lies in numbers. Each agent chooses a level of property rights in the interval $[0, \overline{d}]$ and votes for this level. Society adopts the strength of property rights with the most votes. Such a voting process can be interpreted either literally, — for example, as each agent voting in a democratic election, — or metaphorically — for example, as each agent supporting an alliance in an armed struggle. Overall, this method of determining property rights is in the spirit of the social conflict literature (Acemoglu [2005, 2008], Acemoglu and Robinson [2006, 2008]), which stresses that an economy's institutional structure is shaped by the prevalent social group.

As in Murphy, Shleifer and Vishny [1993] and Tornell and Lane [1999], each producer has the opportunity to drop out of the formal economy and operate in the shadow economy. Shadow output, as well as any payment in shadow output that is made to third parties, cannot be detected by predators and is thus immune from appropriation. Operating in the shadow economy, however, is costly for a producer because a fraction $1-b$ of his output is dissipated; the producer's output is then only a fraction $b<1$ of the output that he would otherwise manufacture. It is assumed that formal property rights protection is technologically superior to private shadow-economy protection (or hiding), i.e., $\overline{d} > b$; otherwise, there would be no scope for an institutional framework in society.

An agent chooses his aptitude type — producer or predator — at the beginning of a period, aiming at maximizing his expected payoff. In the spirit of Stigler and Becker [1977], the acquisition of skills constitutes a long-term training process that can only start early. An agent's aptitude choice at the beginning of a period is thus irreversible and his particular type characterizes him for the entire period. Because of the long-term nature of aptitude choices, decisions about the legal system are made after agents have chosen their aptitude types.

We have a seven-stage game:

Stage 1: Period t starts. Each agent chooses his aptitude type — producer or predator — and begins acquiring the skills relevant for his type.

Stage 2: Voting for property rights occurs. The population sets up laws that determine the strength of property rights d_t.

Stage 3: Agents have the opportunity to take first possession of natural resources. Producers decide whether to operate in the formal or the shadow economy.

Stage 4: Predators have the opportunity to sell their natural resources.

Stage 5: Manufacturing of output takes place. Producers compensate the predators from whom they purchased natural resources in stage 4.

Stage 6: Predators appropriate a fraction $1-d_t$ of the output that each agent (producer or predator) possesses after his activities in stage 5.

Stage 7: Period *t* ends. Each agent exits the game and is replaced by a new agent. The game goes back to stage 1 and repeats for period $t+1$.

Overall, our model follows the standard game theory methodology of rational expectations and subgame perfection. With rational expectations about the simultaneous decisions of other agents and the future effects of these decisions on his payoff, an agent chooses his strategy in each stage of the game. Furthermore, our model follows the standard game theory approach of coalition-proofness. As, for example, in Bernheim, Peleg and Whinston [1987], in each stage agents can coordinate by freely discussing their strategies and engaging in pre-play communication.[12] Our analysis thus seeks coalition-proof equilibria in each subgame. In such equilibria, there exists no proper subset (or coalition) of agents that can agree to deviate in a way which makes all its members better off taking the actions of the other agents (non-members) as fixed. Similarly, a deviation is valid only if there exists no proper sub-coalition that can reach a mutually beneficial agreement to deviate from the deviation.[13]

For simplicity, I adopt the tie-breaking convention that in the case of a tie in stage 4, a predator divides his natural resources equally among the highest bidders. Furthermore, in the case of a tie in the stage 2 voting outcome, the strongest property rights (among the tied outcomes) are chosen, and in the case of a tie in an agent's voting choices — i.e., in the case an agent expects his vote to be non-pivotal (and thus indifferent) — the agent votes for his most preferred property rights. In stage 1, if an agent is indifferent between becoming a producer and a predator, he becomes a predator.

[12] As, however, Bernheim, Peleg and Whinston [1987] note, agents are unable to make binding and enforceable agreements about their strategies (although they can engage in pre-play communication). Thus any meaningful agreement about strategies must be self-enforcing, i.e., coalition-proof.

[13] A coalition-proof equilibrium is always a Nash equilibrium, while the reverse is not true.

3. EQUILIBRIUM OF THE MODEL

To solve for the coalition-proof subgame-perfect equilibrium, I proceed by backward induction. In stage 5, if a producer spends a time s^H on human capital accumulation, he utilizes his remaining time $s^M = 1 - s^H$ for manufacturing. In each period *t* a producer maximizes his effective labor $f(1-s^H)[1+ae(s^H)]\widetilde{H}_{t-1}$ by spending the following time on human capital accumulation:

$$\widehat{s^H} = \underset{s^H \in [0,1]}{\arg\max} \; f(1-s^H)[1+ae(s^H)]. \tag{4}$$

The argument of the maximum in condition (4) exists and is unique (see the proof of proposition 1 in the appendix).

The amount of effective labor χ_t^i that a producer *i* provides for his manufacturing in period *t* is $f(1-\widehat{s^H})[1+ae(\widehat{s^H})]\widetilde{H}_{t-1}$. In each period $t \in \mathbb{Z}^+$ all producers spend a time $\widehat{s^H}$ on human capital accumulation, and in period 1 all producers adopt an initial level of human capital H_0. Thus in a period *t* all producers provide the same amount of effective labor χ_t, i.e., $\chi_t^i = \chi_t$. We have

$$\chi_t = f(1-\widehat{s^H})[1+ae(\widehat{s^H})]^t H_0. \tag{5}$$

In each period *t*, since all agents (producers or predators) have the same degree of luck, in stage 3 an agent takes first possession of a resources size Ω / L. When a predator auctions an amount Ω / L of the natural resource in stage 4, competition among producers drives the price of the resource to Ω / L; all producers are willing to pay a price Ω / L (in terms of output) to buy the natural resource. The predator thus divides the amount of his natural resource equally among all producers.[14]

[14] When a predator auctions his natural resources (as in the model), he is able to capture the entire surplus that is created by his natural resources because producers bid against each other. Our results would be

In stage 2, expected producer payoff is maximized when society chooses the strongest possible protection of property rights $\overline{d}$, minimizing appropriation. Predators, on the other hand, expect to expropriate producer output in stage 6; also, a fraction $1-d_t$ of each predator's proceeds from selling his natural resources is appropriable. Since, however, predators prey upon each other's sales proceeds, internal appropriation within the group of predators does not affect a predator's payoff; the amount that a predator expropriates from other predators is equal to the amount that is expropriated from him. Thus in stage 2, expected predator payoff is maximized when society chooses a strength of property rights b — i.e., the weakest protection of property rights that prevents producers from resorting to the shadow economy (in which case producer output would be immune from appropriation). In the stage 2 equilibrium, all producers vote for $\overline{d}$ while all predators vote for b. If producers are the majority in the population ($\theta_t^P \geq 0.5$), they prevail politically, establishing property rights $\overline{d}$. Similarly, if predators are the majority in the population ($\theta_t^P < 0.5$), they establish a strength of property rights b.

In stage 1, in period t, the expected payoff of a producer is equal to $E\{d_t[\Omega/L+\chi_t]\}$. The expected payoff of a predator is $E\{(1-d_t)\theta_t^P/(1-\theta_t^P)[\Omega/L+\chi_t]+\Omega/L\}$, i.e., the sum of the output that he expects to appropriate and the output that he expects to generate from selling the natural resources he takes first possession of. In a subgame-perfect equilibrium, no agent has an incentive to deviate from his aptitude choice given that the other agents do not deviate. Thus, in stage 1 the equilibrium expected payoff of a producer is equal to the equilibrium expected payoff of a predator; otherwise, agents would have an incentive to deviate. It follows that in equilibrium, the proportion θ_t^P of producers in the population is equal to $E(d_t)-[1-E(d_t)]\Omega/(L\chi_t)$. The expected payoff of an agent ─ producer or predator ─ is $E(d_t)(\Omega/L+\chi_t)$.

In stage 2 there are two possible levels — $\overline{d}$ and b — of property protection. There may thus be two subgame-perfect equilibria in the game. When agents expect that

qualitatively similar if producers were able to capture a strictly positive fraction of this surplus as long as predators were also in a position to capture a strictly positive fraction.

the majority of the population will choose to become producers ($\theta_t^P \geq 0.5$), — so that the strength of property rights will be set equal to $\bar{d}$ in stage 2, — we have a productive equilibrium. In this equilibrium, the proportion of producers in the population is $\theta_t^P *$, which is equal to $\bar{d} - (1-\bar{d})\Omega/(L\chi_t)$. When, on the other hand, agents expect that the majority of the population will choose to become predators ($\theta_t^P < 0.5$), — so that the strength of property rights will be set equal to *b*, — we have a predatory equilibrium. In this equilibrium, the proportion of producers in the population is $\theta_t^P **$, which is equal to $b - (1-b)\Omega/(L\chi_t)$. A productive equilibrium exists in period *t* as long as $\theta_t^P * \geq 0.5$, i.e., as long as producers are indeed the majority in the population (fulfilling agent expectations) when agents expect strong property rights $\bar{d}$. A predatory equilibrium exists as long as $\theta_t^P ** < 0.5$.

Since $\bar{d} > b$, the proportion of producers in the population is higher in a productive than in a predatory equilibrium in all periods $t \in \mathbb{Z}^+$, i.e., $\theta_t^P * > \theta_t^P **$. Furthermore, in a period *t*, the expected payoff of an agent — producer or predator — is $\bar{d}(\Omega / L + \chi_t)$ in a productive and $b(\Omega / L + \chi_t)$ in a predatory equilibrium; the expected payoff of an agent is higher in a productive equilibrium. A productive equilibrium thus Pareto dominates a predatory equilibrium. Intuitively, the skills of producers are more conducive to economic prosperity than the skills of predators. The proportion of producers is higher in a productive than in a predatory equilibrium, which enhances social welfare.

In the analysis, agents can engage in pre-play communication and coordinate (a la Bernheim, Peleg and Whinston [1987]). Then, there exists a unique coalition-proof subgame-perfect equilibrium. If $\Omega / (L\chi_t) < (\bar{d} + b - 1) / (2 - \bar{d} - b)$, only the productive subgame-perfect equilibrium (which always exists in this range) is coalition-proof. If, on the other hand, $\Omega / (L\chi_t) \geq (\bar{d} + b - 1) / (2 - \bar{d} - b)$, only the predatory subgame-perfect equilibrium (which always exists in this range) is coalition-proof. Proposition 1 follows.

Proposition 1: In a period $t \in \mathbb{Z}^+$, there exists a unique coalition-proof subgame-perfect equilibrium. The equilibrium is either productive or predatory:

(a) If $\Omega / (L\chi_t) < (\overline{d} + b - 1) / (2 - \overline{d} - b)$, the equilibrium is productive. The proportion of producers in the population is $\theta_t^P * = \overline{d} - (1 - \overline{d})\Omega / (L\chi_t)$ and the strength of property rights is set equal to $\overline{d}$.

(b) If $\Omega / (L\chi_t) \geq (\overline{d} + b - 1) / (2 - \overline{d} - b)$, the equilibrium is predatory. The proportion of producers in the population is $\theta_t^P ** = b - (1 - b)\Omega / (L\chi_t)$ and the strength of property rights is set equal to *b*.

Proof: The proof is in the appendix.

For simplicity, to bring out the role of factor endowments in a clear and straightforward manner, I assume that the equilibrium in proposition 1 is interior, rather than corner. In particular, it is assumed that even in period 1, the proportion $\theta_t^P **$ of producers in a predatory equilibrium has an interior solution, i.e., we have $b - (1 - b)\Omega / (L\chi_1) > 0$ or $b - (1 - b)\Omega / \{Lf(1 - \widehat{s^H})[1 + ae(\widehat{s^H})]H_0\} > 0$.[15] Furthermore, $\widehat{s^H}$ has an interior solution, i.e., $\widehat{s^H} \in (0,1)$.

4. FACTOR ENDOWMENTS AND THE RULE OF LAW

So far we have seen that the coalition-proof subgame-perfect equilibrium is productive — with strong property rights institutions and a majority of producers in the population — if $\Omega / (L\chi_t) < (\overline{d} + b - 1) / (2 - \overline{d} - b)$. Otherwise, the equilibrium is predatory — with weak institutions and a majority of predators in the population. I will show in this section that an economy's aggregate allocation of talent between production and appropriation is completely determined by factor endowments — natural resources

[15] When $[b - (1 - b)\Omega / (L\chi_t)] \in (-\infty, 0]$, we have a corner predatory equilibrium in which exactly one agent becomes a producer while all other agents become predators. The producer cannot deviate and become a predator (although the payoff of predators is greater) because such a deviation would drive the payoff of all agents to zero (by driving production to zero).

and effective labor or human capital — regardless of whether the equilibrium is productive or predatory. Furthermore, factor endowments determine the type of the equilibrium, productive or predatory. Thus the fundamental cause of society's talent allocation and institutions is factor endowments; the rule of law constitutes a by-product of factor endowments, rather than an independent developmental parameter.

In a given institutional regime, — productive ($d_t = \overline{d}$) or predatory ($d_t = b$), — the proportion of producers in the population is $d_t - (1-d_t)\Omega/(L\chi_t)$. The proportion of producers is thus completely shaped by factor endowments, i.e., by the average amount $\omega = \Omega / L$ of natural resources per agent and by the expected amount χ_t of effective labor per producer. A smaller amount ω of natural resources per agent or a greater amount χ_t of effective labor per producer leads to an aggregate shift of talent toward production. Proposition 2 follows.

Proposition 2: In a coalition-proof subgame perfect equilibrium in either the productive ($\Omega / (L\chi_t) < (\overline{d} + b - 1) / (2 - \overline{d} - b)$) or the predatory ($\Omega / (L\chi_t) \geq (\overline{d} + b - 1) / (2 - \overline{d} - b)$) range, the proportion of producers in the population is:

(a) Decreasing in the average amount $\omega = \Omega / L$ of natural resources per agent, i.e., $\partial\theta_t^P * / \partial\omega < 0$ and $\partial\theta_t^P ** / \partial\omega < 0$, $\forall t \in \mathbb{Z}^+$.

(b) Increasing in the expected amount χ_t of effective labor per producer, i.e., $\partial\theta_t^P * / \partial\chi_t > 0$ and $\partial\theta_t^P ** / \partial\chi_t > 0$, $\forall t \in \mathbb{Z}^+$.

Proof: The proof is in the appendix.

Intuitively, predators appropriate a fraction $1-d_t$ of the economy's total output — the fraction of output that is not protected by property rights institutions. In an economy without natural resources, a proportion d_t of total output is allocated to producers, while the remaining proportion $1-d_t$ is allocated to predators. The presence of natural resources, however, changes the distribution of wealth. A crucial difference between natural resources and the other input — effective labor — is that natural resources are granted by nature, instead of being created by agents. Natural resources have no owner at the beginning of a period t, and ownership titles are assigned to agents according to the rule of first possession, i.e., on a first come, first served basis. No productive skills whatsoever are necessary for claiming ownership of natural resources through the rule of first possession, which depends to a large extent on luck and coincidence; both producers and predators are able to take first possession of resources.

For this reason, in addition to expropriating a fraction $1-d_t$ of the economy's output, — in which output the economy's inputs (including natural resources) are already embedded, — predators can also earn a supplemental payoff by taking first possession of a strictly positive quantity of natural resources and by selling these resources to producers. It follows that the existence of natural resources shifts the distribution of the economy's wealth toward predators. The proportion of the economy's total output that is allocated to predators is higher than the appropriable fraction of output $1-d_t$ because predators also earn an extra payoff by taking first possession of a strictly positive quantity of natural resources. A greater amount of natural resources encourages more agents to become predators, rather than producers.

Furthermore, a greater expected amount of effective labor per producer implies that the manufacturing of output becomes more effective-labor-intensive and less natural-resource-intensive. The shift in the distribution of wealth toward predators that is caused by natural resources is thus less pronounced. This encourages more agents to become producers, rather than predators, leading to a more favorable allocation of talent in the economy.

Effective labor depends on human capital (condition (5)). Thus more effectual human capital generation a leads to a higher proportion of producers in the population. Furthermore, as human capital accumulates through time, the proportion of producers in the population increases. Proposition 3 follows.

<u>Proposition 3:</u> In a coalition-proof subgame perfect equilibrium in either the productive ($\Omega/(L\chi_t) < (\bar{d}+b-1)/(2-\bar{d}-b)$) or the predatory ($\Omega/(L\chi_t) \geq (\bar{d}+b-1)/(2-\bar{d}-b)$) range, the proportion of producers in the population:

(a) Increases when human capital generation is more effectual, i.e., $\partial\theta_t^P{*}/\partial a > 0$ and $\partial\theta_t^P{**}/\partial a > 0$, $\forall t \in \mathbb{Z}^+$.

(b) Is increasing in time, i.e., $\partial\theta_t^P{*}/\partial t > 0$ and $\partial\theta_t^P{**}/\partial t > 0$.

Proof: The proof is in the appendix.

Intuitively, more effectual human capital generation — for example, a better educational infrastructure — increases the expected amount of effective labor per producer in all periods *t*. Thus, as proposition 2 implies, it makes manufacturing less natural-resource-intensive, causing an aggregate shift of talent toward production and away from appropriation. Furthermore, since human capital accumulates through time, the natural resource (whose quantity remains constant) continuously becomes a less important input to the manufacturing of output relative to effective labor. It thus follows that the proportion of producers in the population is increasing in time. As time approaches infinity, the proportion of producers in the population tends to $\bar{d}$ and b in a productive and predatory subgame-perfect equilibrium, respectively, i.e., $\lim_{t\to\infty}\theta_t^P{*} = \bar{d}$ and $\lim_{t\to\infty}\theta_t^P{**} = b$.

The coalition-proof subgame-perfect equilibrium is productive — with strong property rights institutions and a majority of producers in the population — if $\Omega/(L\chi_t) < (\bar{d}+b-1)/(2-\bar{d}-b)$ (proposition 1); otherwise, it is predatory — with weak institutions and a majority of predators. It follows that society's property rights institutions — strong ($d_t = \bar{d}$) or weak ($d_t = b$) — are determined by factor endowments — the average amount $\omega = \Omega/L$ of natural resources per agent and the expected amount χ_t of effective labor per producer (which depends on human capital). Institutions do not constitute an independent parameter.

In particular, society is characterized by a predatory equilibrium and weak institutions in the early phases of development when the amount χ_t of effective labor is small (and thus $\Omega / (L\chi_t)$ is low). Society switches to a productive equilibrium and strong property rights institutions after a time threshold $\overline{T}$ is reached, arriving at a productive equilibrium in all periods afterwards, i.e., in all periods $t > \overline{T}$. The time threshold $\overline{T}$ equalizes $\Omega / (L\chi_t)$ and $(\overline{d} + b - 1) / (2 - \overline{d} - b)$. We have

$$\overline{T} = \frac{ln[\frac{(2-\overline{d}-b)\Omega}{Lf(1-\widehat{s^H})H_0(\overline{d}+b-1)}]}{ln[1+ae(\widehat{s^H})]}. \tag{6}$$

When $t < \overline{T}$, the economy has not yet accumulated a large amount of human capital; production of output is too natural-resource-intensive — which disproportionately shifts the distribution of wealth toward predators — for producers to attain critical mass and prevail politically in a coalition-proof equilibrium. When $t \geq \overline{T}$, on the other hand, the stock of human capital — or the amount of effective labor per producer — in the economy is sufficiently large for agents to coordinate (a la Bernheim, Peleg and Whinston [1987]) toward a Pareto dominant productive equilibrium. An economy switches sooner from a predatory to a productive equilibrium — the time threshold $\overline{T}$ is lower — when the amount of natural resources per agent is lower and the generation of human capital is more effectual. Proposition 4 follows.

Proposition 4: The type of the coalition-proof subgame-perfect equilibrium changes through time:

(a) The equilibrium is predatory with weak property rights institutions ($d_t = b$) in all early periods $t \leq \overline{T}$, while it is productive with strong institutions ($d_t = \overline{d}$) in all late periods $t > \overline{T}$.

(b) Less natural resources per agent and more effectual human capital generation lead to a lower time threshold $\overline{T}$, i.e., $\partial\overline{T} / \partial\omega > 0$ and $\partial\overline{T} / \partial a < 0$.

Proof: The proof is in the appendix.

Proposition 4 implies that property rights institutions tend to persist; weak institutions ($d_t = b$) persist in the early developmental phase $t \le \overline{T}$, while strong institutions ($d_t = \overline{d}$) persist afterwards ($t > \overline{T}$). Institutional persistence stems from factor endowments; the factor endowment that can be augmented — human capital — increases only gradually. As a result, weak institutions persist as long as society's stock of human capital is not sufficiently large to support a productive equilibrium. Once human capital reaches a threshold level at time $\overline{T}$, society switches to strong institutions that persist afterwards.[16]

4.1. Climate and Geography

It is well-known that a country's climate may be an important determinant of human vitality and work effort. In hot and humid climates, — for example, in countries that are closer to the equator, — it is often harder for people to remain vigorous and work at full capacity (Landes [1998], Acemoglu, Johnson and Robinson [2005]).[17] In addition, in such climates people may be more vulnerable to diseases; such a disease burden further reduces human energy and vitality (Acemoglu, Johnson and Robinson [2005]).

To examine the effects of climate, I introduce parameter ϕ ($\phi > 0$). ϕ stands for the vigor of a producer's efforts to provide effective labor — i.e., for the vigor of his efforts in manufacturing and in human capital generation. The effective labor $\chi_t^i(s^M, H_t^i)$ of a producer is now equal to $\phi f(s^M) H_t^i$, while the human capital $\Delta H_t^i(s^H, \widetilde{H}_{t-1})$ that is generated by a producer is now equal to $\phi a e(s^H) \widetilde{H}_{t-1}$. A higher ϕ

[16] In Acemoglu and Robinson [2006, 2008], on the other hand, property rights institutions persist for a different reason; the political elite uses a combination of *de facto* and *de jure* political power to maintain institutions that serve its interests. Furthermore, in Glaeser and Shleifer [2002], institutions persist because they are the outcome of a historical accident.
[17] For example, Landes [1998], p. 15, quotes a diplomat as saying, "in countries like India, Pakistan, Indonesia, Nigeria, and Ghana I have always felt enervated by the slightest physical or mental exertion, whereas in the UK, France, Germany, or the US I have always felt reinforced and stimulated by the temperate climate."

implies that the country's climate is more favorable, allowing producers to be more energetic in their work efforts.

When the climate is more favorable, producers have more effective labor χ_t in all periods *t*; producers are more vigorous in both human capital generation and manufacturing. This makes manufacturing less natural-resource-intensive (and more effective-labor-intensive), reducing the shift in the distribution of wealth toward predators that is caused by natural resources. Thus a more favorable climate — for example, a geographical location further from the tropics — leads to a higher proportion of producers in the population regardless of whether the equilibrium is in the productive or the predatory range. In addition, it reduces the time threshold $\overline{T}$, allowing an economy to switch from a predatory to a productive equilibrium sooner. Proposition 5 follows.

Proposition 5: A more favorable climate leads to:

(a) A higher proportion of producers in a coalition-proof subgame-perfect equilibrium in either the productive $(\Omega/(L\chi_t) < (\overline{d}+b-1)/(2-\overline{d}-b))$ or the predatory $(\Omega/(L\chi_t) \geq (\overline{d}+b-1)/(2-\overline{d}-b))$ range, i.e., $\partial\theta_t^P{}^*/\partial\phi > 0$ and $\partial\theta_t^P{}^{**}/\partial\phi > 0$, $\forall t \in \mathbb{Z}^+$.

(b) A lower time threshold $\overline{T}$, i.e., $\partial\overline{T}/\partial\phi < 0$.

Proof: The proof is in the appendix.

4.2. Multiple Institutional Changes

In the analysis, society transforms its institutional framework only once; there is a switch from weak institutions ($d_t = b$) to strong institutions ($d_t = \overline{d}$) at time $\overline{T}$. It is straightforward to extend the model to allow for multiple institutional changes through time. In particular, an overwhelming majority — a supermajority — may be necessary for a coalition to establish especially strong property rights. For example, let us assume that although $d_t \in [0, \overline{d}]$ (as in the basic model), the level of property rights cannot be set strictly higher than $\overline{d^1}$, where $b < \overline{d^1} < \overline{d}$ and $\overline{d^1} > 0.5$, unless the number of votes for such a high level of property rights is at least $\overline{\theta}L$, where $0.5 < \overline{\theta} < \overline{d}$. Then, there may be two time thresholds, $\overline{T^1}$ and $\overline{T^2}$. Society may switch from weak ($d_t = b$) to moderate ($d_t = \overline{d^1}$) institutions at time $\overline{T^1}$, and from moderate to strong ($d_t = \overline{d}$) institutions at time $\overline{T^2}$. Weak, moderate and strong institutions may persist in the early ($t \leq \overline{T^1}$), intermediate ($\overline{T^1} < t \leq \overline{T^2}$) and late ($t > \overline{T^2}$) phases of development, respectively. In a similar manner, we can have more than two institutional changes through time.

4.3. Natural Resource Bequests

In the model, natural resources have no owner at the beginning of each period because their previous owners have exited the game; they are thus allocated among contemporary agents according to the rule of first possession. Our results would be the same if each agent made a bequest before exiting the game, randomly transferring his natural resources to a next period agent. In particular, although agents consume their entire output in their lifespan, they have ownership titles to renewable (or non-depleted) natural resources that can be reused in future periods; they could thus transfer these resources to the next period agents. For simplicity, to maintain symmetry, we might assume that an agent could not receive more than one bequest. Then, taking first possession of natural resources would only occur at the beginning of the game (when resources have no owner); afterwards, natural resources would be transferred — in the form of bequests — from one generation to the next. Our results would be unchanged. In particular, both producers and predators would be able to take first possession of natural resources at the beginning of the game. Furthermore, afterwards, both producers and predators would be able to receive natural resource bequests. In the same way as before, the existence of natural resources would shift the distribution of the economy's wealth toward predators.

4.4. Other CES Production Functions

For simplicity, the model adopts a CES production function with an infinite elasticity of substitution between the natural resource and effective labor — i.e., a linear function. It is straightforward to see that our results remain qualitatively unchanged for almost any CES function.[18] Let us assume that the manufacturing of output entails a general CES function $[\omega^{\rho} + \chi^{\rho}]^{1/\rho}$, where $\rho \in (-\infty, 1]$ and the elasticity of substitution is $1/(1-\rho)$. In period *t*, the total amount of output that predators receive from selling their natural resources is $L\theta_t^P\{[(\Omega/(L\theta_t^P))^{\rho} + \chi_t{}^{\rho}]^{1/\rho} - [(\Omega/L)^{\rho} + \chi_t{}^{\rho}]^{1/\rho}\}$. Total output in the economy is $L\theta_t^P\{[(\Omega/(L\theta_t^P))^{\rho} + \chi_t{}^{\rho}]^{1/\rho}$. The ratio of predators' proceeds from selling natural resources to total output is $1 - \{[(\Omega/L)^{\rho} + \chi_t{}^{\rho}]/[(\Omega/(L\theta_t^P))^{\rho} + \chi_t{}^{\rho}]\}^{1/\rho}$, which is decreasing in χ_t and increasing in ω for all $\rho \neq 0$. The only exception is the CES function where $\rho = 0$, i.e., the Cobb-Douglas function.[19]

It follows that for $\rho \neq 0$ and for a given allocation of talent, when the amount ω of natural resources per agent becomes larger or the amount χ_t of effective labor per producer becomes smaller, predators' proceeds from selling natural resources account for a larger fraction of wealth in the economy. As in the basic model, this leads to a shift of talent towards appropriation. Thus our results on the link between factor endowments and the rule of law remain qualitatively similar.

5. FACTOR ENDOWMENTS AND OUTPUT

Section 4 showed that factor endowments completely shape society's institutional framework and the rule of law. I will now examine the impact of factor endowments on an economy's level and growth rate of output. Such impact may be two-fold; direct — through the utilization of endowments in manufacturing — and indirect — through the effect of endowments on the aggregate allocation of talent between production and appropriation.

In a period *t*, the total amount of final output that is produced if the coalition-proof subgame-perfect equilibrium is productive is $Y_t{}^* = L\bar{d}(\Omega/L + \chi_t)$. The total amount of final output that is produced if the equilibrium is predatory is

[18] The CES production function was introduced by Arrow *et al.* [1961].

[19] In the CES function where ρ = 0 (Cobb-Douglas function), the ratio of predators' proceeds from selling natural resources to total output does not depend on χ_t or ω.

$Y_t ** = Lb(\Omega / L + \chi_t)$. It is straightforward to see that regardless of whether the equilibrium is productive and a predatory, total output Y_t is increasing in the amount χ_t of effective labor per producer, i.e., $\partial Y_t / \partial \chi_t = Ld_t > 0$. In addition to improving productivity in manufacturing, a greater amount of effective labor leads to an aggregate shift of talent towards production. Thus when the generation of human capital is more effectual or the climate is more favorable, total output increases in all periods *t*.

A greater amount $\omega = \Omega / L$ of natural resources per agent, on the other hand, causes two opposing effects on total output; more natural resources can be used in the production of output, but there is also a shift of talent away from production and toward appropriation. Overall, despite their unfavorable side effects, natural resources increase total output in a given institutional regime, productive or predatory. In particular, a greater amount ω of natural resources per agent leads to a higher payoff for each producer ($d_t[\Omega / L + f(1 - \widehat{s^H})[1 + ae(\widehat{s^H})]^t H_0]$) by increasing the amount of natural resources the producer can take first possession of. Furthermore, since in equilibrium the expected payoffs of all agents — producers and predators — are equal, a larger stock of natural resources raises the expected payoff of each agent and the total amount of output Y_t in both a productive and a predatory institutional regime.

Another effect of a greater amount ω of natural resources per agent is that the initial developmental phase in which the coalition-proof subgame-perfect equilibrium is predatory is prolonged (proposition 4). A marginal increase $\Delta\omega$ in the amount of natural resources per agent leads to a new time threshold $\overline{T} + \Delta\overline{T}$, where $\Delta\overline{T} = \Delta\omega / \{\omega \ln[1 + ae(\widehat{s^H})]\}$. Thus for all $t \in (\overline{T}, \overline{T} + \Delta\omega / \{\omega \ln[1 + ae(\widehat{s^H})]\}]$ a marginal increase $\Delta\omega$ reduces the total amount of output Y_t (and each agent's payoff) because it prevents the economy from reaching a Pareto dominant productive equilibrium. In all other periods, a marginal increase $\Delta\omega$ does not affect the type of the institutional regime; then, as the previous paragraph explained, it increases the total amount of output Y_t and each agent's payoff.

Proposition 6: A marginal increase $\Delta\omega$ in the amount of natural resources per agent increases the economy's equilibrium total output in all periods $t \leq \overline{T}$ and $t > \overline{T} + \Delta\omega / \{\omega \ln[1 + ae(\widehat{s^H})]\})$, while it decreases the economy's equilibrium total output in all periods $\overline{T} < t \leq \overline{T} + \Delta\omega / \{\omega \ln[1 + ae(\widehat{s^H})]\})$.

Proof: The proof is in the appendix.

The growth rate of the economy's total output from period *t* – 1 to period *t* is $Y_t / Y_{t-1} - 1$.[20] In the early periods $t < \overline{T}$ the coalition-proof subgame-perfect equilibrium is predatory in both *t* – 1 and *t*, and the growth rate of total output from *t* – 1 to *t* is $g_t{**}$. In the late periods $t > \overline{T}$ the equilibrium is productive in both *t* – 1 and *t*, and the growth rate of total output from *t* – 1 to *t* is $g_t{*}$. We have

$$G_t = g_t{*} = g_t{**} = \frac{Lae(\widehat{s^H})\chi_t}{L\chi_t + [1 + ae(\widehat{s^H})]\Omega}. \tag{7}$$

Condition (7) implies that the growth rate of an economy's total output does not depend on the institutional regime — strong ($d_t = \overline{d}$) or weak ($d_t = b$). The growth rate in a period *t* is equal to G_t regardless of whether the coalition-proof subgame-perfect equilibrium is productive or predatory, i.e., $g_t{*} = g_t{**} = G_t$.

Furthermore, after the economy reaches a time threshold $\overline{T}$, it switches from a predatory to a productive equilibrium and exhibits a discontinuous jump in the level of output. This sudden increase in the level of output from $Lb(\Omega / L + \chi_{\overline{T}})$ to $L\overline{d}(\Omega / L + \chi_{\overline{T}})$ — which is a pronounced economic take-off — stems a drastic institutional improvement that alters the aggregate allocation of talent between production and appropriation. Such a jump, however, constitutes a level, rather than a

[20] In equilibrium, an economy's total output is equally distributed among all agents. Thus the growth rate of total output is equal to the growth rate of each agent's payoff.

growth effect; the institutional improvement is a one-time event that cannot be repeated. The growth rate of (the now higher level of) output is not affected by the discontinuous jump. The model thus interprets the extraordinarily high growth rates of output that several countries experience in the early stages of industrialization as a possible level effect — which is caused by one-time institutional changes — rather than as a growth effect. [21]

According to condition (7), the growth rate G_t of total output depends on an economy's factor endowments. More effectual human capital generation, a more favorable climate and a smaller amount of natural resources per agent lead to a higher growth rate G_t. Furthermore, growth rate G_t is increasing in time. Proposition 7 follows.

Proposition 7: The equilibrium growth rate G_t of the economy's total output:

(a) Increases when human capital generation is more effectual, the country's climate is more favorable, and the amount of natural resources per agent is smaller, i.e., $\partial G_t / \partial a > 0$, $\partial G_t / \partial \phi > 0$ and $\partial G_t / \partial \omega < 0$, $\forall t \in \mathbb{Z}^+$.

(b) Is increasing in time, i.e., $\partial G_t / \partial t > 0$, $\forall t \in \mathbb{Z}^+$.

Proof: The proof is in the appendix.

Intuitively, the engine of economic growth is human capital accumulation; more effectual human capital generation thus leads to a higher rate of economic growth. Similarly, a more favorable climate enhances the vigor of a producer's work efforts in human capital generation (as well as in manufacturing), increasing the rate of economic growth. Furthermore, the amount of natural resources remains in fixed supply through time; a larger amount of natural resources per agent implies that the non-growing input

[21] The same reasoning applies when an economy exhibits multiple discontinuous jumps in institutional quality and output (as in section 4.2).

— natural resources — accounts for a larger fraction of economic activity. As a result, the growth rate of total output decreases.[22]

Society's rate of economic growth is increasing in time. As time progresses, human capital accumulates and accounts for an increasingly larger fraction of the production of output. It follows that the growth rate of the economy's total output accelerates through time because the growing input — i.e., effective labor (or human capital) — continuously accounts for a higher proportion of economic activity. As time approaches infinity, we have $\lim_{t\to\infty} G_t = ae(\widehat{s^H})$.

6. EMPIRICAL IMPLICATIONS

In our model, more effectual human capital generation leads to an aggregate shift of talent away from appropriation; it also allows an economy to switch sooner from weak to strong property rights institutions. If we adopt the view that an important channel of human capital generation may be educational attainment, our model is consistent with the empirical findings of Barro [1999], Przeworski et al. [2000], Glaeser et al. [2004] and Glaeser and Saks [2006] that education subsequently improves institutions and decreases corruption.[23] Furthermore, our analysis suggests that a more favorable climate — for example, a geographical location further from the equator and a less severe disease burden — leads to a shift of talent away from appropriation and to a more rapid switch from weak to strong institutions. This is in harmony with the empirical results of Hall and Jones [1999], Acemoglu, Johnson and Robinson [2001] and Easterly and Levine [2003]. In addition, in our model, a larger natural resource endowment encourages appropriation and delays society's switch from weak to strong institutions. This is consistent with the empirical finding of Treisman [2000] that a greater stock of natural resources increases corruption.

In our model, more effectual human capital generation, a more favorable climate and a smaller endowment of natural resources lead to a higher growth rate of output in a country. This is consistent with the empirical results of Hall and Jones [1999], Barro

[22] However, although a larger amount of natural resources per agent reduces the rate of economic growth, it leads to a higher level of output in most periods (proposition 6).

[2001] and Sachs and Warner [2001] about the effects of climate, human capital and natural resources. Our analysis also suggests that in the very long run, — abstracting from technological cycles, business cycles, wars, etc, — a society's rate of economic growth increases in time; a developed economy, for example, tends to exhibit a higher growth rate than a pre-industrial economy. The implication that the rate of economic growth tends to be increasing in time is consistent with the empirical findings of Kremer [1993] and Maddison [2003].[24]

In addition, our analysis has some as yet untested implications. The model implies that society's aggregate allocation of talent continuously becomes more favorable over time, shifting towards production and away from appropriation. Furthermore, society's property rights institutions become stronger over time; an economy exhibits drastic institutional improvements when certain time thresholds are reached. These implications are supported by historical evidence; for example, appropriation tends to be more intense and institutions tend to be weaker in the pre-industrial than in the advanced phases of a country's history (e.g., North and Thomas [1973], Acemoglu, Johnson and Robinson [2005]). However, these implications have not been tested in the formal empirical literature as yet.

7. CONCLUSION

Although the view of factor endowments — natural and human — as important determinants of property rights institutions and of the rule of law is common in informal discussions, it is insufficiently understood in formal economic theory. This paper has formulated a theoretical model to examine the factor endowments view of development. It has been shown that factor endowments may completely shape the rule of law and the institutional framework. More effectual human capital generation, a smaller stock of natural resources and a more favorable climate cause a shift of talent toward production and away from appropriation; they also facilitate the emergence of a productive

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[23] According to the empirical results of Acemoglu, Johnson, Robinson and Yared [2005], on the other hand, there is no causal relationship between education and democratic institutions.

[24] Furthermore, our analysis offers a new explanation for the reason economic growth may be increasing in time; as human capital accumulates, the growing input — human capital and effective labor — accounts for a larger fraction of economic activity compared with the non-growing input — natural resources. Kremer

equilibrium with strong property rights institutions. As human capital accumulates through time, there is a continuously more constructive allocation of talent. Thus after a time threshold is reached, society switches from a predatory to a productive equilibrium, exhibiting a drastic institutional improvement.

Society's institutions and rule of law are very complex features and are likely to have several different causes. In this paper, I analyze one commonly discussed explanation — factor endowments — and explore its role in the evolution of a society's institutional framework and allocation of talent.

[1993], on the other hand, argues that population size drives economic growth (through economies of scale); as population increases in time, economic growth accelerates.

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APPENDIX

Proof of Proposition 1

The first-order condition of expression (4) is:

$$-\frac{\partial f(s^M / s^M = 1 - s^H)}{\partial s^M}[1 + ae(s^H)] + \frac{\partial e(s^H)}{\partial s^H} af(1 - s^H) = 0 . \quad \text{(A1)}$$

The second-order condition is

$$\frac{\partial f^2(s^M / s^M = 1 - s^H)}{\partial s^{M^2}}[1 + ae(s^H)] - 2a\frac{\partial f(s^M / s^M = 1 - s^H)}{\partial s^M}\frac{\partial e(s^H)}{\partial s^H} + \frac{\partial^2 e(s^H)}{\partial s^{H^2}} af(1 - s^H) < 0. \quad \text{(A2)}$$

It follows that a producer's payoff function in stage 5, $f(1 - s^H)[1 + ae(s^H)]\widetilde{H}_{t-1}$, is continuous and concave in the closed interval $s^H \in [0,1]$. As a result, there exists a unique argument of the maximum $\widehat{s^H}$ on $s^H \in [0,1]$.

In stage 1, as section 3 explained, there are two possible subgame-perfect equilibria, namely a productive and a predatory equilibrium. A productive equilibrium exists if and only if $[\overline{d} - (1-\overline{d})\Omega / (L\chi_t)] \geq 0.5$ or $\Omega / (L\chi_t) \leq (2\overline{d} - 1) / [2(1-\overline{d})]$, i.e., if and only if producers are the majority in the population when agents expect strong property rights protection $\overline{d}$ (fulfilling agent expectations). A predatory equilibrium exists if and only if $[b - (1-b)\Omega / (L\chi_t)] < 0.5$ or $\Omega / (L\chi_t) > (2b-1) / [2(1-b)]$ i.e., if and only if predators are the majority in the population when agents expect weak property rights protection *b*.

A productive equilibrium is coalition-proof if and only if $\Omega / (L\chi_t) < (\overline{d} + b - 1) / (2 - \overline{d} - b)$. Then, no coalition of producers can increase their payoff by switching to being predators. In particular, assume that a coalition of at most $(\theta_t^P * - 0.5)L$ producers (so that the institutional regime does not change) deviate and become predators. Their payoff becomes lower than the equilibrium payoff $\overline{d}(\Omega / L + \chi_t)$ of agents (producers or predators) because the payoff of predators is increasing in the proportion of producers (upon whom they prey). Thus such a deviation will not occur. Assume now that a coalition of more than $(\theta_t^P * - 0.5)L$ producers deviate and become predators so that they are in a position to impose weak property rights *b*. Their equilibrium payoff cannot be higher than $\Omega / L + (1-b)(\Omega / L + \chi_t)$, i.e., than a predator's payoff when the proportion of producers approaches 0.5 (the maximum proportion subject to the constraint that predators prevail politically). This payoff is lower than their equilibrium payoff $(\Omega / L + (1-b)(\Omega / L + \chi_t) < \overline{d}(\Omega / L + \chi_t))$ if and only if $\Omega / (L\chi_t) < (\overline{d} + b - 1) / (2 - \overline{d} - b)$; then such a deviation will not occur. Furthermore, no coalition of predators have an incentive to deviate and become producers because their payoff will not increase.

Similarly, a predatory equilibrium is coalition-proof if and only if $\Omega/(L\chi_t) \geq (\overline{d}+b-1)/(2-\overline{d}-b)$. Then, no self-enforcing coalition of predators can increase their payoff by switching to being producers. In particular, a coalition of less than $(0.5-\theta_t^P{**})L$ predators (so that the institutional regime does not change) have no incentive to deviate and become producers because the deviation will not increase their payoff. Assume now that a coalition of at least $(0.5-\theta_t^P{**})L$ predators deviate and become producers so that they are in a position to impose strong property rights $\overline{d}$; their payoff will become $\overline{d}(\Omega/L+\chi_t)$ which is higher than the equilibrium payoff $b(\Omega/L+\chi_t)$. However, such a deviation is valid only when there exist no sub-coalitions that can reach mutually beneficial agreements to deviate from the deviation.

The payoff from deviating from the deviation (returning to being a predator) so that the expected strength of property rights returns to being b can be as high as $\Omega/L+(1-b)(\Omega/L+\chi_t)$ (a predator's payoff when the proportion of producers approaches 0.5). This payoff is higher than the payoff from the deviation $(\Omega/L+(1-b)(\Omega/L+\chi_t) \geq \overline{d}(\Omega/L+\chi_t))$ if and only if $\Omega/(L\chi_t) \geq (\overline{d}+b-1)/(2-\overline{d}-b)$. Then such a deviation from the predatory equilibrium will not occur because there are sub-coalitions that can profitably deviate from the deviation.

Furthermore, we have $(2b-1)/[2(1-b)] < (\overline{d}+b-1)/(2-\overline{d}-b) < (2\overline{d}-1)/[2(\overline{d}-1)]$. This implies that when $\Omega/(L\chi_t) < (\overline{d}+b-1)/(2-\overline{d}-b)$ a productive subgame-perfect equilibrium always exists and is coalition-proof. When $\Omega/(L\chi_t) \geq (\overline{d}+b-1)/(2-\overline{d}-b)$ a predatory subgame-perfect equilibrium always exists and is coalition-proof.

Proof of Proposition 2

In all periods $t \in \mathbb{Z}^+$ we have

$$\frac{\partial \theta_t^P{*}}{\partial \omega} = -\frac{(1-\overline{d})}{\chi_t} < 0, \tag{A3a}$$

$$\frac{\partial \theta_t^P{**}}{\partial \omega} = -\frac{(1-b)}{\chi_t} < 0, \tag{A3b}$$

$$\frac{\partial \theta_t^P{*}}{\partial \chi_t} = \frac{(1-\overline{d})\omega}{\chi_t^2} > 0, \tag{A3c}$$

$$\frac{\partial \theta_t^P{**}}{\partial \chi_t} = \frac{(1-b)\omega}{\chi_t^2} > 0. \tag{A3d}$$

Proof of Proposition 3

Implicit differentiation of first-order condition (A1) leads to

$$\frac{\partial \widehat{s^H}}{\partial a} =$$

$$\frac{e(s^H)\frac{\partial f(s^M / s^M = 1-s^H)}{\partial s^M} - \frac{\partial e(s^H)}{\partial s^H} f(1-s^H)}{\frac{\partial^2 f(s^M / s^M = 1-s^H)}{\partial s^{M2}}[1+ae(s^H)] - 2a\frac{\partial f(s^M / s^M = 1-s^H)}{\partial s^M}\frac{\partial e(s^H)}{\partial s^H} + af(1-s^H)\frac{\partial^2 e(s^H)}{\partial s^{H2}}}. \tag{A4}$$

Since first-order condition (A1) is equal to zero, the numerator of condition (A4) is strictly negative. Condition (A4) is thus strictly positive, i.e., $\partial \widehat{s^H} / \partial a > 0$.

Furthermore, in stage 5 each producer maximizes his effective labor. The envelope theorem implies that

$$\frac{\partial \chi_t}{\partial a} =$$

$$f(1-\widehat{s^H})[1+ae(\widehat{s^H})]^{t-1} H_0 \{e(\widehat{s^H}) + (t-1)[a\frac{\partial e(s^H / s^H = \widehat{s^H})}{\partial s^H}\frac{\partial \widehat{s^H}}{\partial a} + e(\widehat{s^H})]\} > 0. \tag{A5}$$

Thus, in all periods $t \in \mathbb{Z}^+$, given that $\partial \theta_t^P * / \partial \chi_t > 0$ and $\partial \theta_t^P ** / \partial \chi_t > 0$ (conditions (A3c), (A3d), we have

$$\frac{\partial \theta_t^P *}{\partial a} = \frac{\partial \theta_t^P *}{\partial \chi_t}\frac{\partial \chi_t}{\partial a} > 0, \tag{A6a}$$

$$\frac{\partial \theta_t^P **}{\partial a} = \frac{\partial \theta_t^P **}{\partial \chi_t}\frac{\partial \chi_t}{\partial a} > 0. \tag{A6b}$$

We also have

$$\frac{\partial \theta_t^P *}{\partial t} = \frac{(1-\overline{d})\omega \ln[1+ae(\widehat{s^H})]}{f(1-\widehat{s^H})[1+ae(\widehat{s^H})]^t H_0} > 0, \tag{A7a}$$

$$\frac{\partial \theta_t^P **}{\partial t} = \frac{(1-b)\omega \ln[1+ae(\widehat{s^H})]}{f(1-\widehat{s^H})[1+ae(\widehat{s^H})]^t H_0} > 0. \tag{A7b}$$

Proof of Proposition 4

We have

$$\frac{\partial \overline{T}}{\partial \omega} = \frac{1}{\omega \ln[1+ae(\widehat{s^H})]} > 0. \tag{A8}$$

The coalition-proof subgame-perfect equilibrium is productive when $\Omega/(L\chi_t) < (\overline{d} + b - 1)/(2 - \overline{d} - b)$ or when $[1 + ae(\widehat{s^H})]^{t-1} > B$, where $B = (2 - \overline{d} - b)\omega / \{(\overline{d} + b - 1)H_0 f(1 - \widehat{s^H})[1 + ae(\widehat{s^H})]\}$. In stage 5 each producer maximizes his effective labor. The envelope theorem implies that $\partial\{f(1 - \widehat{s^H})[1 + ae(\widehat{s^H})]\}/\partial a = e(\widehat{s^H}) f(1 - \widehat{s^H}) > 0$ and thus $\partial B/\partial a < 0$.

Condition $[1 + ae(\widehat{s^H})]^{t-1} > B$ suggests that the time threshold $\overline{T}$ can be expressed as $\overline{T} = 1 + \ln B / \ln[1 + ae(\widehat{s^H})]$. We thus have

$$\frac{\partial \overline{T}}{\partial a} = -\frac{[e(\widehat{s^H}) + a\dfrac{\partial e(s^H / s^H = \widehat{s^H})}{\partial s^H}\dfrac{\partial \widehat{s^H}}{\partial a}]\ln B}{[1 + ae(\widehat{s^H})]\{\ln[1 + ae(\widehat{s^H})]\}^2} + \frac{1}{B\ln[1 + ae(\widehat{s^H})]}\frac{\partial B}{\partial a} < 0. \qquad \text{(A9)}$$

Proof of Proposition 5

By following exactly the same procedure as in the proof of proposition 3, it is straightforward to show that $\partial\widehat{s^H}/\partial\phi > 0$ and $\partial\chi_t/\partial\phi > 0$. Thus in all periods $t \in \mathbb{Z}^+$, we have $\partial\theta_t^P * /\partial\phi > 0$ and $\partial\theta_t^P ** /\partial\phi > 0$.

The coalition-proof subgame-perfect equilibrium is productive when $\Omega/(L\chi_t) < (\overline{d} + b - 1)/(2 - \overline{d} - b)$ or when $[1 + \phi ae(\widehat{s^H})]^{t-1} > B$, where $B = (2 - \overline{d} - b)\omega / \{(\overline{d} - b - 1)H_0 \phi f(1 - \widehat{s^H})[1 + \phi ae(\widehat{s^H})]\}$. In stage 5 each producer maximizes his effective labor. The envelope theorem implies that $\partial\{\phi f(1 - \widehat{s^H})[1 + \phi ae(\widehat{s^H})]\}/\partial\phi = a\phi e(\widehat{s^H}) f(1 - \widehat{s^H}) + f(1 - \widehat{s^H})[1 + \phi ae(\widehat{s^H})] > 0$ and thus $\partial B/\partial\phi < 0$.

Condition $[1 + \phi ae(\widehat{s^H})]^{t-1} > B$ suggests that the time threshold $\overline{T}$ can be expressed as $\overline{T} = 1 + \ln B / \ln[1 + \phi ae(\widehat{s^H})]$. We thus have

$$\frac{\partial \overline{T}}{\partial \phi} = -\frac{[ae(\widehat{s^H}) + \phi a\dfrac{\partial e(s^H / s^H = \widehat{s^H})}{\partial s^H}\dfrac{\partial \widehat{s^H}}{\partial \phi}]\ln B}{[1 + \phi ae(\widehat{s^H})]\{\ln[1 + \phi ae(\widehat{s^H})]\}^2} + \frac{1}{B\ln[1 + \phi ae(\widehat{s^H})]}\frac{\partial B}{\partial \phi} < 0. \qquad \text{(A10)}$$

Proof of Proposition 6

Expression (A8) implies that a marginal increase $\Delta\omega$ in the amount of natural resources per agent leads to a new time threshold $\overline{T} + \Delta\omega / \{\omega\ln[1 + ae(\widehat{s^H})]\}$ at which the economy switches from a predatory to a productive equilibrium. Thus when $t \in (\overline{T}, \overline{T} + \Delta\omega / \{\omega\ln[1 + ae(\widehat{s^H})]\}]$, a marginal increase $\Delta\omega$ reduces total output Y_t by preventing the economy from switching to a Pareto dominant productive equilibrium, i.e., $L(b-\overline{d})[\omega+f(1-\widehat{s^H})[1+ae(\widehat{s^H})]^t H_0]+Lb\Delta\omega<0$.

When $t \le \overline{T}$, on the other hand, the coalition-proof subgame-perfect equilibrium is predatory regardless of whether there is a marginal increase $\Delta\omega$ in the amount of natural resources per agent. Then, marginal increase $\Delta\omega$ increases total output Y_t, i.e., $\partial Y_t / \partial\omega = L\overline{d} > 0$. Furthermore, when $t > \overline{T} + \Delta\omega / \{\omega \ln[1+ae(\widehat{s^H})]\}$, the equilibrium is productive regardless of whether there is a marginal increase $\Delta\omega$ in the amount of natural resources per agent. Then, marginal increase $\Delta\omega$ increases total output Y_t, i.e., $\partial Y_t / \partial\omega = Lb > 0$.

Proof of Proposition 7

The proof of proposition 3 shows that $\partial\chi_t / \partial a > 0$ and $\partial\widehat{s^H} / \partial a > 0$. We thus have

$$\frac{\partial G_t}{\partial a} = \frac{ae(\widehat{s^H})[1+ae(\widehat{s^H})]\omega}{\{[1+ae(\widehat{s^H})]\omega+\chi_t\}^2}\frac{\partial\chi_t}{\partial a} + \frac{\chi_t(\omega+\chi_t)[e(\widehat{s^H})+a\dfrac{\partial e(s^H / s^H=\widehat{s^H})}{\partial s^H}\dfrac{\partial\widehat{s^H}}{\partial a}]}{\{[1+ae(\widehat{s^H})]\omega+\chi_t\}^2} > 0. \tag{A11}$$

If we incorporate the climate parameter ϕ into the model, the growth rate G_t becomes equal to $L\phi ae(\widehat{s^H})\chi_t / \{L\chi_t + [1+\phi ae(\widehat{s^H})]\Omega\}$. The proof of proposition 5 shows that $\partial\chi_t / \partial\phi > 0$ and $\partial\widehat{s^H} / \partial\phi > 0$. We thus have

$$\frac{\partial G_t}{\partial \phi} = \frac{\phi ae(\widehat{s^H})[1+\phi ae(\widehat{s^H})]\omega}{\{[1+\phi ae(\widehat{s^H})]\omega+\chi_t\}^2}\frac{\partial\chi_t}{\partial \phi} + \frac{\chi_t(\omega+\chi_t)[ae(\widehat{s^H})+\phi a\dfrac{\partial e(s^H / s^H=\widehat{s^H})}{\partial s^H}\dfrac{\partial\widehat{s^H}}{\partial \phi}]}{\{[1+\phi ae(\widehat{s^H})]\omega+\chi_t\}^2} > 0. \tag{A12}$$

We also have

$$\frac{\partial G_t}{\partial \omega} = -\frac{ae(\widehat{s^H})[1+ae(\widehat{s^H})]\chi_t}{\{[1+ae(\widehat{s^H})]\omega+\chi_t\}^2} < 0, \tag{A13a}$$

$$\frac{\partial G_t}{\partial t} = \frac{\omega ae(\widehat{s^H})[1+ae(\widehat{s^H})]^{t+1} f(1-\widehat{s^H})H_0 ln[1+ae(\widehat{s^H})]}{\{[1+ae(\widehat{s^H})]^t f(1-\widehat{s^H})H_0+[1+ae(\widehat{s^H})]\omega\}^2} > 0. \tag{A13b}$$