The Legacy of Colonialism: A Model of Africa's Underdevelopment

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Abstract

Despite the existence of empirical studies linking Africa's current underdevelopment to its colonial history, a formal theoretical explanation of this link has yet to be made. How could colonialism have had apparently lasting impacts? I provide a game-theoretic model that explains how extraction, taking the form of the slave trade and colonial control, resulted in a permanent increase in rent-seeking behavior and a permanent decrease in the security of private property, both of which have helped foster Africa's current underdevelopment.

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1 Introduction

The poor economic performance of Africa remains one of the biggest puzzles facing development and growth economists today. During the 1980s annual per capita GDP growth was -1.3%, while between 1990 and 1994, the decline accelerated to -1.8%.[1] Weak property rights and high levels of corruption and rent-seeking behavior provide little hope for sustained economic development in the near future. In a survey reported in the World Bank's *World Development Report 1997*, firms ranked corruption as the number one obstacle to doing business in sub-Saharan Africa.[2] Further, corruption and other forms of rent-seeking show no signs of subsiding, but instead, continue to increase.[3]

One common explanation for the continent's current state is its colonial history of exploitation and extraction. For example, in his book *Economics and World History*, economic historian Paul Bairoch indicates that "there is no doubt that a large number of structural features of the process of economic underdevelopment have historical roots going back to European colonization."[4] Empirical work also confirms the existence of a link between a country's past colonial experience and its current level of economic development. Bertocchi and Canova (2002) find that within Africa colonization exerted a direct impact on the post-colonial patterns of growth and human and physical capital accumulation. Grier (1999) also finds that among former colonies there is a link between a country's colonial experience and subsequent post-colonial growth. Englebert (2000) claims to have solved the mystery of Africa's underdevelopment, attributing Africa's poor performance to its weak, arbitrarily imposed post-colonial institutions. Most recently, Acemoglu et al. (2001, 2002) document that in former colonies, where the colonizer's focus was on extraction (e.g. Africa), weak institutions of private property were established and these poor institutions persist today.

Despite these empirical findings, no theoretical work formally links a country's colonial history with its current level of development.[5] Specifi-

[1] Collier and Gunning (1999).

[2] World Bank (1997), p. 42.

[3] See the *Global Corruption Report 2001*, p. 309. Here, of seven countries surveyed, the majority of the respondents in only two countries felt that there was less corruption under the current government's regime than under the previous one.

[4] Bairoch (1993), p. 88.

[5] The one exception is Bertocchi (1994). However, in Bertocchi's model the lasting

cally, a formal answer to the question of how and why these historical events continue to influence African economic performance today has not yet been put forth. In an attempt to fill this void, I develop a game-theoretic model that illustrates how the extraction and exploitation that occurred in most of Africa from the late 15th to the mid 20th century is responsible for current underdevelopment. The model shows why high level levels of rent-seeking behavior, insecure property rights, and economic stagnation persist decades after the end of colonial control.[6]

The model developed is a two stage game. In the first stage, a colonizer chooses a policy that has two instruments: a tax rate on production, and the amount of resources to devote towards the protection of private property. In the second stage, a Hobbesian world is modelled, where the security of private property is endogenously determined. A distinction is made between productive activities, which create value, and appropriative activities, which simply redistribute value.[7] It is assumed that individuals choose either to become an entrepreneur and produce, or to become a rent-seeker and steal the production of others.

In the absence of a colonizer, the second stage subgame always has an equilibrium with zero rent-seeking behavior. It may also have high rent-seeking equilibria. It is shown that when a colonizer is present and chooses a high enough level of extraction/taxation, then the zero rent-seeking equilibrium disappears, leaving a unique high rent-seeking equilibrium. Thus the introduction of the colonizer moves a society initially in the zero rent-seeking equilibrium to the high rent-seeking equilibrium. After colonial independence, the zero rent-seeking equilibrium returns, but because of the stability of the high rent-seeking equilibrium the society is trapped in this equilibrium.

This outcome describes one of two possible equilibria of the game. I call equilibria of this type 'underdevelopment equilibria'. There also exist 'development equilibria', in which the optimal colonial policy is one of low

distortions from colonialism are assumed rather than derived within the model. See Section 9 for more discussion.

[6]The model not only applies to the period of official colonial rule (roughly 1885 to 1960), but also applies to the period prior to this, characterized primarily by the trans-Atlantic slave trade. Because of this, I use the term 'colonialism' very broadly; from roughly the early 16th century to the mid 20th century. This broader time frame is the same as that considered in Acemoglu et al. (2002).

[7]A number of other studies have also made this same distinction. Examples include Acemoglu (1995), Baumol (1990), Grossman and Kim (2002), Murphy et al. (1991), and Skaperdas (1992).

rates of extraction and high levels of protection of private property. In these equilibria, a society initially in the zero rent-seeking equilibrium remains in this equilibrium during and after colonial rule. I argue that underdevelopment equilibria describe the history of former African colonies, while development equilibria describe the history of the neo-European colonies: Australia, Canada, New Zealand, and the United States.

In this paper, my focus is on underdevelopment equilibria, and their ability to explain the historical underdevelopment of Africa. Combining the model with the known history of Africa, I provide the following account of the historical origins of Africa's underdevelopment:

- Prior to European contact, African societies are located in the zero rent-seeking equilibrium.
- After contact, the colonial policy chosen lowers the relative return to production and raises the relative return to rent-seeking. This causes the zero rent-seeking equilibrium to disappear, leaving a unique high rent-seeking equilibrium.
- Individuals switch from production to rent-seeking, as the society moves to the new equilibrium.
- Following independence, the society is free from the colonial policy and a zero rent-seeking equilibrium again exists. However, the society is now trapped in a high rent-seeking equilibrium. The stability of this suboptimal equilibrium makes moving to the more efficient zero rent-seeking equilibrium difficult. This is the state of Africa today.

The remainder of the paper is structured as follows. In the next section I describe the game. In the following sections I look more closely at the second (Sections 3 and 4) and first (Section 5) stages of the game, characterizing the player's optimal strategies. In Section 6 the game's set of equilibria are described. In Section 7 I turn to the historical evidence and argue that the historical facts support the model's explanation for Africa's underdevelopment. In Section 8 I discuss the relationship between the model and the recent empirical evidence on colonialism that has been put forth in Acemoglu et al. (2001). Section 9 describes the model's relationship with the existing theoretical literature, and Section 10 concludes.

2 The Model

The players of the game consist of a continuum of members of an African society and one foreign colonizer.

In the first stage, the colonizer moves, choosing a policy which consists of two policy instruments. The first is the tax rate τ. This is the fraction of each entrepreneur's production that is extracted. The second instrument is the amount of resources to devote towards enforcing the security of private property in the colony.These resources determine the proportion $q \in (0, 1)$ of an entrepreneur's output that a rent-seeker can steal in the second stage. The cost to the colonizer of a policy that generates q is $c(q)$, where $c'(q) < 0$ and $\lim_{q \to 0} c'(q) = \infty$.

In the second stage, each member of the society chooses whether to become and entrepreneur and produce, or to become a rent-seeker and appropriate resources from others; these decisions are made simultaneously. Each entrepreneur produces the output A, and a rent-seeker, when successful, obtains the proportion q of the output of an entrepreneur. Search is costless and rent-seekers can perfectly identify entrepreneurs. Given these assumptions, the probability of a rent-seeker's success depends on the division of the population between entrepreneurs and rent-seekers. Denote the fraction of rent-seekers by P. If there are fewer rent-seekers in the society than entrepreneurs ($P < 1 - P$), then each rent-seeker finds an entrepreneur to rob with certainty; otherwise, the probability of a rent-seeker's finding an entrepreneur to rob is $\frac{1-P}{P}$. Thus, the probability of a rent-seeker's finding an entrepreneur to rob is

$$\Pr(\text{successful theft}) = \begin{cases} 1 & \text{if} \quad P \leq .5 \\ \frac{1-P}{P} & \text{if} \quad P \geq .5 \end{cases} \tag{1}$$

or alternatively

$$\Pr(\text{successful theft}) = \min \left\{ \frac{1-P}{P}, 1 \right\} \tag{2}$$

By a similar logic, the probability of an entrepreneur's losing the fraction q of her output is

$$\Pr(\text{stolen from}) = \min \left\{ \frac{P}{1-P}, 1 \right\} \tag{3}$$

Expected payoffs depend on the proportion of rent-seekers in the society, P, and on the policy chosen by the colonizer in the first stage, (τ, q). An entrepreneur's expected payoff is equal to the net return when robbed, $(1-\tau)(1-q)A$, multiplied by the probability of being robbed, Pr(stolen from), plus the return when not robbed, $(1-\tau)A$, multiplied by the probability of not being robbed, $1 - \Pr(\text{stolen from})$. That is,

$$\begin{aligned}\pi_E(P,\tau,q) &= \min\left\{\frac{P}{1-P},1\right\}(1-\tau)(1-q)A \\ &\quad + \left(1-\min\left\{\frac{P}{1-P},1\right\}\right)(1-\tau)A \end{aligned} \tag{4}$$

The expected payoff of a rent-seeker is equal to the return to successful theft, qA, multiplied by the probability of successful theft, Pr(successful theft). When unsuccessful, a rent-seeker receives a payoff of zero. Thus, the expected payoff to a rent-seeker is

$$\pi_R(P,\tau,q) = \min\left\{\frac{1-P}{P},1\right\}qA \tag{5}$$

Because the colonizer is unable to tax rent-seekers, τ does not directly enter a rent-seeker's expected payoff.[8]

The colonizer receives revenues from taxes on producers and incurs the cost $c(q)$ to maintain q. Thus, the colonizer's payoff is

$$\begin{aligned}\pi_C(P,\tau,q) &= \tau\left[\min\left\{\frac{P}{1-P},1\right\}(1-q)\,A\right. \\ &\quad \left. + \left(1-\min\left\{\frac{P}{1-P},1\right\}\right)A\right](1-P) - c(q) \end{aligned} \tag{6}$$

[8]The assumption that the colonizer is unable to tax rent-seekers is consistent with the historical evidence. During the slave trade and colonial rule, domestic rent-seeking and foreign extraction went hand-in-hand. If one engaged in rent-seeking, one was exempt from foreign extraction. For example, if an African worked with European slavers as a slave raider, this exempted him from being caught as a slave. Or if an African worked as part of the colonial army, bureaucracy, or police force, this exempted him from the taxation, forced labor, and general coercion that was inflicted upon the general population. The assumption also holds in today's environment. Governments have a very difficult time controlling, or even recognizing rent-seeking activities, let alone being able to set up institutions to tax the returns from these activities. This assumption is also common in similar models that have a population of potential rent-seekers and a government. For a recent example see Grossman (2002).

3 Second Stage - Pre-Contact Africa

The second stage of the game, without colonial extraction ($\tau = 0$) and with the security of property, q, determined exogenously, models pre-contact Africa. In this simplified version of the second-stage subgame, payoffs are written as functions of P only: $\pi_E(P)$ and $\pi_R(P)$. Despite the simplicity of the subgame, its set of Nash equilibria have interesting properties. A strategy profile in the second stage is a Nash equilibrium of the subgame if and only if the following condition holds:

$$\begin{aligned} &\text{either } P = 0 \text{ and } \pi_R(P) \leq \pi_E(P) \\ &\text{or } 0 < P < 1 \text{ and } \pi_R(P) = \pi_E(P) \\ &\text{or } P = 1 \text{ and } \pi_R(P) \geq \pi_E(P) \end{aligned} \tag{7}$$

The set of possible Nash equilibria is most easily seen by graphing $\pi_E(P)$ and $\pi_R(P)$ against P for differing efficiencies of theft, q, as in Figure 1. From the figure it is apparent that the slopes of the two value functions switch their relative sizes before and after $P = .5$. That is,

$$\frac{\partial \pi_R(P)}{\partial P} > \frac{\partial \pi_E(P)}{\partial P} \quad \text{if} \quad 0 \leq P \leq .5 \tag{8}$$

$$\frac{\partial \pi_R(P)}{\partial P} < \frac{\pi_E(P)}{\partial P} \quad \text{if} \quad .5 \leq P \leq 1 \tag{9}$$

This feature of the payoff functions is significant because it is the source of the potential existence of multiple equilibria. The feature is a result of the differing effects that an increase in P has on the returns to both strategies. When the number of rent-seekers is less than the number of producers ($P < 1 - P$), an increase in P has no effect on the payoffs to rent-seekers, since each rent-seeker can still find an entrepreneur to rob with certainty. However, an increase in P increases each entrepreneur's probability of being robbed, and thus decreases the expected payoff to each entrepreneur. If $P > 1 - P$, then all entrepreneurs are stolen from with certainty and an increase in P no longer decreases an entrepreneur's expected payoff. However, now the expected payoff to a rent-seeker is strictly decreasing in P. This is because there is crowding out among the rent-seekers and an increase in P decreases each rent-seeker's probability of finding an entrepreneur to steal from.

From Figure 1 it is also apparent that there always exists an equilibrium in which $P = 0$. For low values of q this equilibrium is unique. However,

as q increases eventually other equilibria arise. In these equilibria both rent-seeking and productive activities are chosen. A description of the set of Nash equilibria is provided in Proposition 1. The proof of this proposition, along with all other proofs, is reported in the appendix.

Proposition 1. *For all values of q and A, the second-stage subgame has a Nash equilibrium in which every person chooses to be a producer, $P^\star = 0$. If $q < .5$, this equilibrium is unique. If $q = .5$, the subgame has one additional equilibrium with $P^\star = .5$, and if $.5 < q < 1$, it has two additional equilibria; one with $P^\star = 1 - q < .5$ and the other with $P^\star = q > .5$.*

Proposition 1 paints a relatively optimistic picture for early African societies. A zero rent-seeking equilibrium always exists. Further, if a society is able to develop customs and institutions that keep q low, then this equilibrium is unique. As the next section shows, the situation is not as bright once the colonizer is introduced.

4 Second Stage - Post-Contact Africa

To analyze the changes that occur following European expansion, I consider the model in a dynamic environment. To do this, I use the two-player version of the standard replicator dynamic

$$\frac{P_{t+1} - P_t}{P_t} = \gamma \left[\pi_R(P_t, \tau, q) - \overline{\pi}(P_t, \tau, q)\right] \tag{10}$$

if $P_t > 0$, where $\overline{\pi}$ is the average payoff of the full population,

$$\overline{\pi}(P_t, \tau, q) = P_t \pi_R(P_t, \tau, q) + (1 - P_t)\pi_E(P_t, \tau, q) \tag{11}$$

Although the original interpretation of the dynamic is biological, the dynamic is also consistent with models of local information or social evolution.[9] Specifically, assume that each period, with probability $\gamma > 0$, a player compares her payoff in the previous period to that of another randomly selected player. If the other player's payoff was higher, then she switches. If not, the player maintains her original strategy. Given these assumptions the replicator dynamic (10) can be derived.[10]

[9] See Gintis (2000) and Weibull (1995) for references and examples.

[10] Gintis (1997), p. 28.

When $P_t = 0$, I assume that if $\pi_R(0, \tau, q) - \pi_E(0, \tau, q) \leq 0$, then $P_{t+1} = 0$, and if $\pi_R(0, \tau, q) - \pi_E(0, \tau, q) > 0$, then

$$P_{t+1} = \varepsilon \tag{12}$$

for some small $\varepsilon > 0$. The motivation for this assumption is that a very small proportion of the population ε is fully informed about the game,[11] and therefore, these individuals choose in each period the strategy that yields the highest payoff.[12]

Combining (10), (11) and (12), we have

$$P_{t+1} - P_t = \begin{cases} \varepsilon & \text{if } P_t = 0 \text{ and } \pi_R(0, \tau, q) > \pi_E(0, \tau, q) \\ F(P_t) & \text{otherwise} \end{cases} \tag{13}$$

where

$$F(P_t) = P_t(1 - P_t)\gamma \left[\pi_R(P_t, \tau, q) - \pi_E(P_t, \tau, q)\right] \tag{14}$$

A Nash equilibrium $P^\star$ is stable if

$$F'(P^\star) < 0 \tag{15}$$

This condition ensures that a small perturbation of P above $P^\star$ results in a subsequent decrease in P back to $P^\star$, and that a small perturbation of P below $P^\star$ results in an increase in P back to $P^\star$. It is useful to define the *basin of attraction* of a stable equilibrium $P^\star$. The basin of attraction of $P^\star$ is the set of points P_0 such that a trajectory through P_0 converges over time to $P^\star$. That is, it is the set of initial population proportions that converge to $P^\star$.

The dynamics of the subgame are illustrated in Figure 2, the dynamic analogue of Figure 1. Looking at Figure 2, we see that the zero rent-seeking equilibrium is stable, and that of the two equilibria that exist when $q > .5$, one is stable and the other is unstable. The following proposition more completely states the dynamic properties of the subgame's equilibria.

[11] It is assumed that ε is sufficiently small that the actions of this fraction of the population can be ignored in expression (10).

[12] Without this modification, members from a population of only entrepreneurs ($P = 0$), would never switch to rent-seeking. This is true even when $\pi_R(0, \tau, q) > \pi_E(0, \tau, q)$. Intuitively, because only entrepreneurs exist in the population, a rent-seeker's payoff is never observed and therefore, members of the population never switch to rent-seeking. This is a general feature (and short-coming) of the standard replicator dynamic. See Gintis (2000), pp. 191–192 for a brief discussion of this issue.

Proposition 2. *For all values of q and A, the second-stage subgame has a stable Nash equilibrium with $P^\star = 0$. If $q = .5$, the subgame has one additional unstable equilibrium with $P^\star = .5$. If $.5 < q < 1$, the subgame has one additional stable equilibrium, with $P^\star = q > .5$, and one unstable equilibrium, with $P^\star = 1-q < .5$. The unstable equilibrium defines the border of the basins of attraction of the two stable equilibria.*

I now consider the impact that colonial extraction has on the African society. Without taxation ($\tau = 0$) there always exists a stable zero rent-seeking equilibrium (Proposition 2). However, if extraction is severe enough, then the zero rent-seeking equilibrium disappears, leaving a unique stable high rent-seeking equilibrium.

Proposition 3. *If $\tau > 1 - q$, then the game has a unique, stable Nash equilibrium with $P^\star = \frac{q}{q+(1-\tau)(1-q)} > .5$.*

The rationale behind Proposition 3 is illustrated in Figure 3. As shown, increases in τ have an asymmetric effect on the payoff to each strategy. Increases in τ decrease the payoff to production, while leaving the payoff to rent-seeking unchanged. Therefore, as τ is increased, eventually at $P = 0$ the payoff to rent-seeking becomes larger than the payoff to entrepreneurship, and this leaves a unique high rent-seeking equilibrium.

4.0.1 An Explanation of Africa's Underdevelopment

Given the properties of the model developed to this point, an account of the historical origins of Africa's underdevelopment can now be given. This is done graphically in Figures 4 and 5. The top graph of Figure 4 illustrates the situation in Africa prior to European contact. It is assumed that initially q was low and societies were located in the zero rent-seeking equilibrium $P_0^\star$. After contact, because of the introduction of new production and rent-seeking technologies, A and q both increase. The increase in A shifts the payoffs to rent-seeking and entrepreneurship proportionately, and therefore does not affect the equilibria. If the increase in q is modest, then the zero rent-seeking equilibrium remains. However, if the increase in q is large enough, a stable high rent-seeking equilibrium emerges. This case is shown in the lower graph if Figure 4, where the high rent-seeking equilibrium is labelled $P_{h_1}^\star$. Because of the stability of $P_0^\star$, the society does not converge to $P_{h_1}^\star$, but remains in the zero rent-seeking equilibrium.

Next, consider what occurs if the colonizer begins to extract a large proportion of African production, i.e. $\tau > 1 - q$. This is illustrated in the top graph of Figure 5. Colonial extraction distorts the relative returns of the two activities enough to cause the zero rent-seeking equilibrium, $P_0^\star$, to disappear. This leaves a unique stable high rent-seeking equilibrium, $P_{h_2}^\star$. Each period, individuals who were previously entrepreneurs switch to rent-seeking, causing P to increase over time. This continues until $P_{h_2}^\star$ is reached. In reality, families, tribes, and entire regions that had been cultivators and hunter-gatherers, began buying guns and engaging in slave raiding, theft, and other forms of predatory behavior. I discuss these historic changes in more detail in Section 7.

The situation in Africa following independence is illustrated in the lower graph of Figure 5. After independence, the colonizer leaves and τ returns to zero. If the period of European extraction was long enough, then P will have increased sufficiently such that at independence P will be within the basin of attraction of the high rent-seeking equilibrium, $P_{h_3}^\star$. If P has increased such that $P > P^B$ by independence, then after independence, P will continue to increase until $P_{h_3}^\star$ is reached. Therefore, even after independence rent-seeking may continue to increase, with property right becoming more insecure.

In the end, colonialism has permanently moved the society from its initial zero rent-seeking equilibrium, $P_0^\star$, to a high rent-seeking equilibrium, $P_{h_3}^\star$, characterized by insecure property rights and high levels of rent-seeking behavior.

5 First Stage - The Colonizer's Strategy

The model's explanation for the historical origins of Africa's current underdevelopment relies on the assumption that it is optimal, at least under some conditions, for the colonizer to choose values of τ and q that satisfy $\tau > 1 - q$ (Proposition 3). I now consider the first stage of the game to show that there are two possible optimal strategies for the colonizer, and that under one of the two strategies $\tau > 1 - q$.

In choosing the tax rate τ and the protection of private property, which determines q, the colonizer is effectively choosing what institutions to implement in the colony. Because in reality it is difficult to adjust these institutions each period, I assume that the colonizer's choice of (τ, q) is made once-and-for-all.

I also assume that after each period of play, the colonizer loses control of the colony with positive probability. This assumption allows me to study how differences in the strength of the colonizer's hold on a colony influences the equilibrium. Let the probability that the colonizer maintains control and continues the game next period be given by $\delta \in (0,1)$. The colonizer's payoff over the infinite horizon is then

$$\Pi_C(\tau, q) = (1-\delta)\sum_{t=0}^{\infty} \delta^t \pi_C(P_t, \tau, q) \tag{16}$$

My explanation for Africa's underdevelopment begins with the assumption that prior to European contact (call this period $t = 0$), African societies are located in the zero rent-seeking equilibrium; that is, $P_0 = 0$. Given this initial population distribution, I argue that the colonizer's optimal choice of (τ, q) must satisfy $\tau \geq 1 - q$. This can be seen as follows. If $\tau \leq 1 - q$, then $P_t = 0$ for all t, and from (6), the colonizer's payoff is

$$\Pi_C(\tau, q) = \pi_C(0, \tau, q) = \tau A - c(q) \tag{17}$$

which is strictly increasing in τ. Any strategy (τ, q), with $\tau < 1-q$, is strictly dominated by the strategy (τ', q) with $\tau' = 1 - q$. Therefore, any strategy with $\tau < 1 - q$ is not optimal.

Among the strategies that satisfy $\tau \geq 1 - q$, I consider two types:

1. Strategies with $\tau > 1 - q$, which I call short-run strategies (SR). As shown in Proposition 3, these strategies cause P_t to converge to $P^\star = \frac{q}{q+(1-\tau)(1-q)} > .5$.

2. Strategies with $\tau = 1 - q$, which I call long-run strategies (LR). These maintain the initial equilibrium, with $P^\star = 0$.

I argue that both LR and SR strategies can be optimal, and that which is optimal depends on the colonizer's control over the colony, δ. The first step of this argument is the following result.

Lemma 1. *For every LR strategy, there are SR strategies that yield a higher payoff in at least the first period.*

To prove this, consider the colonizer's payoff in the first period,

$$\pi_C(0, \tau, q) = \tau A - c(q) \tag{18}$$

which is increasing in both τ and q. Given any LR strategy (τ, q), SR strategies can always be found that yield a higher payoff. Under each LR strategy, $\tau = 1 - q$. Therefore, SR strategies (τ', q), with $\tau' > \tau$, and SR strategies (τ, q'), with $q' > q$ (recall $c'(q) < 0$), all yield a higher payoff in the first period.

The second part of the argument is given in Lemma 2.

Lemma 2. *There exists $\bar{t}$ sufficiently large, such that the best LR strategy yields higher payoffs in each period $t \geq \bar{t}$ than do all SR strategies.*

To prove this, fix any SR strategy $(\hat{\tau}, \hat{q})$. Under this strategy, over time P_t increases from $P_0 = 0$ to $P^\star = \frac{\hat{q}}{\hat{q}+(1-\hat{\tau})(1-\hat{q})} > .5$. Consider a period t large enough that under $(\hat{\tau}, \hat{q})$, $P_t \geq .5$. From (6), the colonizer's payoff in this period is

$$\pi_C(P_t, \hat{\tau}, \hat{q}) = \hat{\tau}(1 - \hat{q})A(1 - P_t) - c(\hat{q}) \tag{19}$$

Next, consider the best LR strategy. Under any LR strategy $P_t = 0$, $\tau = 1-q$, and the colonizer's payoff each period is given by

$$\pi_C(0, \tau, q) = (1 - q)A - c(q) \tag{20}$$

Denote the value of (τ, q) that maximizes (20) by $(\tau^\star, q^\star)$. This is the best LR strategy. Then, using (19) and (20), we have the following result

$$\begin{aligned} \pi_C(0, \tau^\star, q^\star) &= (1 - q^\star)A - c(q^\star) \\ &\geq (1 - \hat{q})A - c(\hat{q}) \\ &> \hat{\tau}(1 - \hat{q})A(1 - P_t) - c(\hat{q}) \\ &= \pi_C(P_t, \hat{\tau}, \hat{q}) \end{aligned} \tag{21}$$

That is, for t large enough that $P_t \geq .5$ under the SR strategy, the best LR strategy yields higher payoffs than any SR strategy.

Lemmas 1 and 2 illustrate that the choice between the two types of strategies involves a trade-off between larger payoffs in early periods and larger payoffs in later periods. This is shown clearly in Figure 6, which illustrates the payoffs over time to both types of strategies. The figure illustrates the results of Lemmas 1 and 2: in (at least) the initial period the SR strategy yields a higher payoff, but in later periods the LR strategy yields higher payoffs. The figure also shows that payoffs under an SR strategy are monotonically

decreasing over time. This follows from the fact $\pi_C(P_t, \tau, q)$ is decreasing in P_t. Therefore, over time, as P_t monotonically increases under any SR strategy, $\pi_C(P_t, \tau, q)$ monotonically decreases. The figure also shows that under any LR strategy $P_t = 0$ for all t and thus $\pi_C(0, \tau, q)$ remains constant.

From Lemmas 1 and 2, and Figure 6, it follows that which of the two types of strategies is optimal depends on the government's preference over the infinite horizon, which is determined by δ. More precisely, we have the following result.

Proposition 4. *For any γ and A, there exists $\bar{\delta} \in (0, 1)$ such that the colonizer's optimal strategy is an LR strategy if $\delta > \bar{\delta}$ and an SR strategy if $\delta < \bar{\delta}$.*

If the colonizer has a secure hold on the colony (δ is large), then an LR strategy will be optimal. However, if the colonizer has a sufficiently tenuous grip on the colony (δ is low), then an SR strategy will be optimal.

6 Equilibria

Putting together both stages of the game, the two types of equilibria of the game can be described.

1. **Development Equilibria**. The colonizer chooses an LR strategy, with $\tau = 1 - q$. In the second stage, every period each African chooses to become an entrepreneur and produce, and the economy remains in the zero rent-seeking equilibrium, with $P^\star = 0$. After the colonizer exits the country and τ returns to zero, the society remains in the zero rent-seeking equilibrium. Development equilibria describe the successful colonial experiences of Australia, Canada, New Zealand, and the United States.

2. **Underdevelopment Equilibria**. The colonizer chooses an SR strategy, with $\tau > 1 - q$. Over time, individuals switch from production to rent-seeking. This continues until the society converges to a high rent-seeking equilibrium. If this convergence has sufficiently progressed by independence, the society will be located within the basin of attraction of the post-colonial high rent-seeking equilibrium. Therefore, even after colonialism, the society will remain in a stable high rent-seeking equilibrium. Underdevelopment equilibria describe the history of countries within Africa.

7 Historical Evidence

The known history of Africa is consistent with the model's explanation of Africa's underdevelopment. In this section, I make four observations based on the writings of historians and anthropologists regarding Africa's history. These four observations provide evidence in support of the explanation suggested by the model: initially African societies were located in the zero rent-seeking equilibria. After contact, the productivity of production and rent-seeking both increase, extraction occurs, and African societies permanently move from the zero rent-seeking equilibrium to a high rent-seeking equilibrium.

Observation 1. *Prior to European contact, q was low and African societies tended to be located in zero rent-seeking equilibria: $P_0 = 0$.*

In pre-colonial African societies, well-established customs, laws, conventions, ethics and rituals had evolved, which were effective in resolving conflicts and enforcing order, both within and between communities. These institutions were successful in suppressing various forms of predatory or rent-seeking behavior. Anthropologist Robert Edgerton writes that "in general it is accurate to say that these societies emphasized cooperation among family members, kinsmen, lineage mates and neighbors ... [and that] harmony was important and was almost always maintained."[13]

Among hunter and gatherer societies, organized warfare was rare if it occurred at all. In pastoral societies and larger kingdoms, wars did occur, although various forms of diplomacy were widely practiced to minimize the frequency of warfare between societies.[14] Diplomacy took the form of marriages, alliances, the swearing of oaths, and the exchange of citizens. Arbitrators, resident representatives and other diplomats also existed to resolve conflicts and disputes between groups peacefully.[15] When conflicts between groups did escalate, traditional rules of limited warfare kept casualties to a minimum. Wars were formally declared in advance, with an invitation (that could be declined), sent to the other group. This custom eliminated the large number of casualties that result from surprise attacks.[16]

[13]Edgerton (2002), p. 7.
[14]Edgerton (2002), pp. 16–17.
[15]Smith (1989), pp. 7–27.
[16]Kouassi (2000), pp. 67–72.

Within societies, political and legal systems that were able to effectively govern the people and control rent-seeking behavior had been well established. Some societies were centralized with a formal political system and advanced legal institutions that resemble modern day courts. Other societies did not have a centralized government, but rather maintained order through kinship ties or a lineage system. In these groups a council of elders typically existed to resolve any disputes or disagreements that could not be resolved by consensus or compromise. Both types of institutions were very successful in maintaining peace and order within the society.[17]

In the parts of Africa that were unaffected by the trans-Saharan slave trade, domestic slavery, another form of rent-seeking behavior, was not commonly practiced before European contact.[18] A number of studies have shown that before the arrival of the Portuguese in the Kongo Kingdom, there was no slave class present. Before the rise of the Atlantic slave trade, the people of this region did not have words for 'slave' or 'slavery'. In these areas, other words, which originally meant 'servant', 'prisoner' or 'captive', took on new meaning and were applied to describe slaves and slavery.[19] For example, in the Kongo Kingdom the word *pika* originally meant servant. After the expansion of the slave trade the word took on the meaning of a traded slave, and the use of the word spread throughout West-Central Africa.[20]

Observation 2. *Following contact there was an increase in the productivity of entrepreneurship (A) and rent-seeking (q).*

Early contact with Europeans did have benefits. It led to increased opportunities for trade and consumption, and to the introduction of new technologies and more efficient modes of production. During official colonial rule, colonizers invested resources towards the provision of an infrastructure of roads, railways, harbors, the telegraph and the telephone, and this too increased the efficiency of production. In the model, all of these benefits are captured by increases in A. From Propositions 2 and 3 we know that changes in A do not affect the equilibria of the game. That is, the long-run security of private property and amount of rent-seeking behavior in the economy are unaffected by increases A following European contact.

[17] Bohannan and Curtin (1998), pp. 147–167, Adejumobi (2000).
[18] Inikori (2000), Rodney (1966).
[19] Hilton (1985), Vansina (1989, 1990).
[20] Vansina (1989), p. 352, Vansina (1990), p. 278.

Contact with Europeans also resulted in a natural increase in q, as it became easier and more profitable to engage in rent-seeking behavior. Because of contact with Europeans, Africans were introduced to more sophisticated weaponry, most notably firearms. Guns first appeared in Western Africa around 1591 and quickly spread throughout the continent. Within the same century guns were being used in wars, and by the late 1690s the musket had replaced the bow and arrow, the spear and shield, and the battle-axe as the primary military weapons of warfare.[21] By 1730, 180,000 guns per year were being imported into the Gold and Slave Coasts, and by the late 18th century imports reached 394,000 guns per year.[22] Imports were also significant in other areas of Africa. Over 50,000 guns per year were imported into the Congo-Loango area during this same time period,[23] and by the late 19th century the import of firearms into East Africa ranged from 80,000 to 100,000 guns per year.[24] At the same time that firearms became available to Africans, an export market for slaves was developing. The combination of more efficient weaponry and a market for the sale of slaves allowed Africans to engage in rent-seeking with unprecedented ease.

During this time, q also increased because African societies witnessed an erosion of previously existing indigenous institutions. "The European demand for more and more captives soon gave rise to the formation of groups of bandits all over western Africa. In places where the foundations already laid had not yet given rise to firmly established large political organization, the process was hijacked by these bandits ... Overall, the conditions created by the large-scale European demand for captives over a period of more than three hundred year severely retarded the long-term process of socio-economic development in western Africa."[25] Following the slave trade, colonial rule further weakened domestic institutions by undermining the legitimacy and power of African leaders. "The particular mechanisms by which effective civil societies were developing among African polities were destroyed, as the chief was no longer answerable to local precolonial check structures or ideologies."[26] No longer was the king or chief accountable to the tribe. Instead, the leader was accountable to, and often chosen by, the colonial government.

[21] Kea (1971), pp. 185, 187, 207–208.
[22] Richards (1980), p. 46.
[23] Inikori (1977), pp. 348-349.
[24] Beachey (1962), p. 453.
[25] Inikori (2000), pp. 393–394.
[26] Kolapo (2002), p. 99.

Colonial chiefs lacked the legitimacy and authority to effectively control, police, and govern members of their tribe. This erosion of domestic forms of governance resulted in an increased ability for individuals to engage in appropriative activities.[27]

Observation 3. *Following European contact, there was extraction from Africans by Europeans:* $\tau > 0$.

Prior to the period of official colonialism, extraction in Africa took the form of the trans-Atlantic slave trade. Domestic African slave traders benefitted from the slave trade, a fact captured by q in the model. Europeans also received some of the surplus from the trade, which is captured by the colonizer's rate of extraction τ. The amount of extraction that occurred through the slave trade was significant. Between the 15th and 19th centuries approximately 12 million slaves were exported from Africa during the Atlantic slave trade.[28] These figures do not include Africans that died during the long, arduous trek to the coast. These losses are estimated to be between 20 and 40 % of the number exported.[29] Therefore, in total, as many as 16.8 million Africans were enslaved during the Atlantic slave trade.

Between 1880 and 1900 the slave trade was brought to an end. This was the result of the European conquest of the African continent, which began with the Berlin Conference of 1885 and its laying down of the ground rules for the partition of Africa. However, with the abolition of the slave trade, European extraction did not end. Rather, it simply changed forms, switching from slavery to forced labor and taxation. Because of the exploitative nature of the relations between European employers and African employees, colonial rulers found that unless some form of force and coercion was employed, Africans would choose not to work. The tactics used to force native Africans to enter the labor force included land expropriation, taxation, and forced labor.

The classic example of land expropriation comes from the Belgian Congo. In 1885, King Leopold II proclaimed that all *free land* in the Congo was the property of Belgium. Because most peasants lived by gathering the fruits of wild plants and performed little cultivation of land, virtually all of the land at the time could be classified as *free land*. It was declared that the state

[27] Ayittey (1991), ch. 9.
[28] Lovejoy (2000), Table 1.1.
[29] Lovejoy (2000), pp. 63–64.

had exclusive rights to the ownership of the land and its fruits, and that any person gathering fruits or purchasing gathered fruits would be punished.[30] In South Africa, by 1925 over 90% of the land had been expropriated and was controlled by European settlers.[31] Generally, when land was not taken directly by the colonial government, it was sold to European settlers by native chiefs in violation of native law or without the chiefs full understanding of the nature of the transaction.[32]

The poll, head and hut taxes were the primary tools used to extract resources from Africans. As well as being a direct tool to raise revenues, taxes were also used as an indirect tool to exploit Africans by forcing them into extractive employment relations. Generally, the amount of the taxes was equivalent to 30 days of work and could only be paid in the official colonial currency (not in-kind).[33] As a result, natives were forced to sign restrictive labor contracts, lasting up to two years, in order to obtain the necessary currency to pay the taxes.[34] Once signed, these contracts could not be broken by the native without severe punishment. In Uganda, according to the Master and Servant Ordinance of 1913, a laborer could be jailed for up to 6 months or fined up to 150 shillings (well over 1 year's wages) if he left employment in the middle of a contract.[35] In Tanganyika, in accordance with the Whipping Regulations, a native boy who was guilty of "neglect of duty" or "desertion" could be whipped up to 12 strokes.[36]

More direct policies of forced labor were also used by the colonial governments. All Africans were required to perform annual amounts of compulsory labor, usually on public works projects. The labor was usually provided without compensation. When compensation was provided, it was well below the market rate. The required amount of compulsory labor varied by colony, but in all cases the required time was significant. In the Belgian Congo, natives were required to spend 40 hours each month gathering rubber for the colony.[37] In Uganda natives were obliged to provide 30 days of free labor a

[30]Nzula et al. (1979), pp. 61–62.

[31]Buell (1928a), p. 513.

[32]Buell (1928a), p. 307.

[33]For tax rates in Northern and Southern Rhodesia, the Union of South Africa, Sierra Leone, Togo, the Cameroons, Kenya, Uganda and Tanganyika see Buell (1928a, 1928b). For tax rates in Gambia see Nzula et al. (1979).

[34]Buell (1928a), p. 498.

[35]Buell (1928a), p. 629.

[36]Buell (1928a), p. 500.

[37]In actuality, the amount of time required was much higher. This is because private

year on the roads.[38] In Kenya, in addition to an unpaid obligation to work 24 days a year, natives were also required to provide up to 60 days a year of compulsory, compensated labor.[39]

Observation 4. *Following European contact, there was an increase in rent-seeking behavior over time:* $P_t \to P^\star = \frac{q}{q+(1-\tau)(1-q)} > .5$.

A vast literature has been written, documenting the increase in predatory behavior within Africa following European contact. European contact, during the trans-Atlantic slave trade and colonial rule, distorted the relative returns towards rent-seeking and away from production, causing a dramatic increase in rent-seeking behavior throughout the continent. John Fage writes that "the slave trade acted generally as a factor retarding orderly progress and development in West Africa. The dominant activity for many peoples became trade, and a peculiar kind of trade which discouraged rather than stimulated agriculture and industrial production, which indeed discouraged constructive work of any kind."[40] William Darity writes that "the most lucrative activity throughout the 18th century for those Africans with the power to enslave rather than be enslaved was procurement of human exports for the slave trade."[41] Entire regions degenerated into robber or predatory societies, with traders and rulers engaged in constant violence and coercion of the local populations. "By the nineteenth century, much of the continent was militarized; great kingdoms and powerful warlords rose and fell, their fates linked to fluctuations in the slave trade ... Even in egalitarian communities, the temptation to profit from the sale of captives or culprits kept the slave trade alive."[42] Robin Law writes that "the effects were seen not only in the increasing level of disorder, but also in the increasing prominence of groups for whom violence was a profession. The emergence of banditry and mercenary soldiering was paralleled by the militarization of existing ruling élites."[43]

agents who profited from the gathering of rubber were left in charge of administering the tax. In reality, "the tax was extended to such an extent that for the majority of natives the majority of their time was spend gathering rubber to pay the tax." Buell (1928b), pp. 429–431.

[38] Buell (1928a), p. 567.

[39] Berman and Lonsdale (1980), p. 68.

[40] Fage (1962), p. 86.

[41] Darity (1992), p. 165.

[42] Manning (1990), p. 147.

[43] Law (1991), p. 346.

Because of this switch from productive to predatory activities, large drops in production were observed. In 1705 the Dutch Director-General described the changes occurring on the Gold Coast, writing that "it has completely changed into a Slave Coast, and the natives nowadays no longer occupy themselves with the search for gold, but rather make war on each other to furnish slaves."[44] This diversion of labor from gold mining and other more productive activities also occurred in other parts of Africa. In Mozambique, between 1806 and 1821, at the same time that slave exports from the port of Quelimane increased by 340%, gold, ivory, rice and wheat exports each fell by proportions ranging from 50 to 95%.[45]

The Atlantic slave trade also led to the establishment and proliferation of domestic slavery in many parts of Africa. The domestic merchants, warlords and monarchs that had emerged during the external slave trade soon made the transition to domestic slave ownership, managing large slave run plantations. An extractive African leisure class developed, which lived off the agricultural and hand-crafted commodities produced by their slaves.[46]

During colonial rule, predatory behavior among the African population continued. In this environment, one form of rent-seeking behavior was to work hand-in-hand with the colonial authorities in the colonial army, police force, native treasury (as a tax collector) or any other part of the colonial bureaucracy. In the Belgian Congo, some of the natives, faced with little return to farming and employment, chose to work for the foreign merchants and help with the taxation of the other natives. These armed native "sentinels" were hired and stationed to ensure that natives gathered their quota of rubber. It was not long before the sentinels began to abuse their authority. They soon established themselves as despots, commanding an army of soldiers, which lived off stolen food, women, and other goods. Those who attempted to resist their demands were either mutilated (often having their hands cut off), kidnapped or killed.[47]

[44]Richards (1980), p. 46.

[45]Austen (1987), pp. 68–71.

[46]Typically, the proportion of the population that were slaves ranged from 10 to 50%. However, in some cases the proportion was as high as 80%, as was the case among the Cowke of Angola. See Lovejoy (1989), p. 392, Manning (1990), pp. 60–85, and Lovejoy (2000), pp. 142–148.

[47]Buell (1928b), pp. 431–432.

8 The Model and Related Empirical Evidence

The model developed here complements the recent empirical work of Acemoglu et al. (2001) (henceforth AJR). In their study AJR document that, among former colonies, the different colonization strategies implemented by Europeans led to very different paths of development. Colonies where the European focus was on extraction subsequently did not develop and stagnated economically. In other colonies, where the focus was not on extraction, the colonizer implemented institutions to enforce the rule of law and protect private property. Today, these colonies are among the most economically advanced countries in the world. The authors find that the disease environment was a primary determinant of which of the two strategies were followed. In areas with a high disease environment, *extractive institutions* were implemented, while in low disease environments, settlement was possible and *institutions of private property* were implemented.

By providing a theoretical framework for their analysis, the model helps to clarify two points from AJR's paper. First, in their explanation it is not made explicit why initially implemented institutions should persist, and why they should continue to matter decades after the end of colonialism. The model clarifies this point. Consider first colonies with a high disease environment. According to AJR, in these colonies the focus was on extraction and domestic institutions to enforce the rule of law and protect private property were not implemented. Within the framework of the model, in these colonies τ and q were both high, as the colonizer pursued an SR strategy, with $\tau > 1 - q$. This led to a permanent movement to a high rent-seeking equilibrium. These colonies remain trapped in this equilibrium today. In colonies with a low disease environment, settlement occurred and the focus was not on extraction (τ was low), and institutions to protect private property were implemented (q was low). In these areas the colonizer pursued an LR strategy with $\tau = 1 - q$, and the colony remained in the zero rent-seeking equilibrium.

The model also helps to clarify the assumption made by AJR that settlement in an area caused a colonizer to focus on implementing good institutions, rather than extracting resources from the colony. The model suggests one reason why settlement may have affected the colonial strategy chosen. During this period of time, European control of other lands was tenuous. Settlement of an area was a primary determinant of which country controlled a region, and how secure this control was. If a country was able to settle an area, they could be relatively more confident that they would have long-term

control of the land. In the model this long-term control is given by δ, the probability of the game continuing for the colonizer. High rates of settler mortality, by making settlement more difficult, increased the probability of the colonizer losing control of an area (a low δ). Thus, from Proposition 4, the model predicts that, all else equal, an LR strategy was more likely to be chosen in areas with a hospitable environment, with high rates of settlement, while an SR strategy was more likely to be chosen in areas with a high level of disease, where settlement did not occur.

9 The Model's Relationship with the Existing Literature

The model's second stage subgame is related to the theoretical literature that attempts to explain the existence of multiple equilibria in corruption and rent-seeking behavior. These studies include Acemoglu (1995), Advig and Moene (1990), Ehrlich and Lui (1999), Mehlum et al. (2003) and Tirole (1996). The model developed in Acemoglu (1995) is the most similar to the second stage of the model developed here. He assumes, as I do, that labor can be allocated to production or rent-seeking. In every period, each individual chooses which activity to undertake. Unlike my model, his model assumes that producers also choose their level of investment, and that each period agents are randomly matched. He shows that, depending on the parameters of the model and the cost function for investment, there is the possibility of multiple equilibria, with one equilibrium with no rent-seeking and another with a positive level of rent-seeking.

With the exception of one working paper, no other studies have attempted to formally model how the period of colonial extraction in former colonies could have had lasting impacts. The exception is Bertocchi (1994), who attempts to formally model the long-run impacts of colonialism. Using a dynamic OLG model, he considers the impact of restricted direct foreign investment and directly exploitative activities on the colony's economy. One shortcoming of his model is that the lasting distortions from colonial rule are *assumed* rather than derived endogenously within the model. These distortions enter as a permanent distortion to physical and human capital accumulation, leading to a reduction in income levels. The advantage of the model developed here is that the long-run detriment to the colony is derived

endogenously within the model, rather than assumed at the outset.

Other studies have formally modelled other aspects of colonialism, but none address the question considered here. Darity (1982) and Findlay (1990) develop general equilibrium models of the Atlantic three-cornered slave trade of the 18th century. The models describe the process whereby the movement of slaves to the European colonies in the Americas increased the production of raw materials in the colonies, which were then used in Europe as inputs in producing manufactured goods. The models illustrate the divergent growth paths of Europe and Africa during the Atlantic slave trade. However, rent-seeking behavior or institutions are not incorporated into their model and their model is not able to explain the persistent poor African performance after the end of the Atlantic slave trade. Grossman and Iyigun (1995, 1997) and Lucas (1990), looking at colonialism, model the profitability and choice of foreign investment by the colonizing country, while Garoupa and Gata (2002) model the European decolonization process.

10 Conclusions

I have developed a model that attempts to shed light on the lasting impact that European contact has had in African. It provides an explanation for Africa's continued economic stagnation, the persistence of corruption and rent-seeking, and the lack of secure property rights. It provides a theoretical basis for recent empirical work, which suggests that colonialism has had, and continues to have, a persistent impact on the economic development of former colonies, the most notable being those of Africa.

The model suggests that prior to European contact, societies within Africa were located in a stable equilibrium without rent-seeking behavior. Following European contact, these societies would have remained in this equilibrium, had it not been for the large amount of colonial extraction, which caused the zero rent-seeking equilibrium to disappear and a subsequent movement to a stable high rent-seeking equilibrium. Even after the period of extraction has ended, the past effects of extraction are still felt, because the society has been permanently moved to a new equilibrium characterized by high levels of corruption, rent-seeking, and insecure property rights. This is the legacy of colonialism.

A Proofs

Proof of Proposition 1. Consider each statement of the proposition in turn.

For all values of q and A, the second-stage subgame has a Nash equilibrium in which every person chooses to be a producer, $P^\star = 0$.

From (7), if $\pi_E(0) \geq \pi_R(0)$, then a Nash equilibrium with $P = 0$ exists. Using (4) and (5), this condition simplifies to $1 \geq q$, which is satisfied for all values of A and q.

If $q < .5$, this equilibrium is unique.

If $q < .5$, then $\pi_E(P) > \pi_R(P)$ for all values of P, and no additional equilibria exist.

If $q = .5$, the subgame has one additional equilibrium with $P^\star = .5$.

If $q = .5$, then $\pi_E(.5) = \pi_R(.5)$. Condition (7) is satisfied and one additional Nash equilibrium exists, with $P^\star = .5$ when $q = .5$.

If $.5 < q < 1$, the game has two additional equilibria; one with $P^\star = 1-q < .5$ and the other with $P^\star = q > .5$.

First consider possible equilibria with $P > .5$. From (4) and (5) it follows that if $P > .5$, then $\pi_E(P) = \pi_R(P)$ when $P = q$. Therefore, (7) is satisfied and an additional Nash equilibrium exists with $P^\star = q > .5$.

If $P < .5$, then $\pi_E(P) = \pi_R(P)$ when $P = 1-q$. Therefore, an additional Nash equilibrium exists with $P^\star = 1 - q < .5$. Q.E.D.

Proof of Proposition 2. Using (4), (5), and (14), $F'(P^\star)$ can be written

$$F'(P^\star) = \begin{cases} \gamma A(2P^\star - 1 + q) & \text{if} \quad P^\star \leq .5 \\ \gamma A(2P^\star - 1 - q) & \text{if} \quad P^\star \geq .5 \end{cases} \tag{22}$$

Consider each statement of the proposition in turn.

For all values of q and A, the second-stage subgame has a stable Nash equilibrium with $P^\star = 0$.

From Proposition 1, there exists a Nash equilibrium with $P = 0$, for all values of q and A. From (22), $F'(0) = -\gamma A(1 - q) < 0$. Therefore, this equilibrium is stable for all values of q and A.

If $q = .5$, the subgame has one additional unstable equilibrium with $P^\star = .5$.

Because $F'(P) > 0$ for $P \leq .5$, a small decrease in P from $P^\star = .5$, does not result in an increase in P, but causes P to fall further. Therefore, the equilibrium $P^\star = .5$, that exists when $q = .5$, is unstable.

If $.5 < q < 1$, the subgame has one additional stable equilibrium, with $P^\star = q > .5$, and one unstable equilibrium, with $P^\star = 1 - q < .5$.

Consider each of the two Nash equilibria from Proposition 1. First, consider the equilibrium with $P^\star = q > .5$. From (22), $F'(q) = -\gamma A(1-q) < 0$; therefore, this equilibrium is stable. Next, consider the equilibrium with $P^\star = 1 - q < .5$. Because $F'(1-q) = \gamma A(1-q) > 0$, this equilibrium is unstable.

The unstable equilibrium defines the border of the basins of attraction of the two stable equilibria.

Consider the middle graph of Figure 2. Any initial population proportion to the left of the unstable equilibrium will converge to $P^\star = 0$. Any initial population proportion to the right of the unstable equilibrium will converge to $P^\star = q > .5$. Therefore, the unstable equilibrium defines the border of the basins of attraction of the two stable equilibria. Q.E.D.

Proof of Proposition 3. From the pattern of the slopes of the payoff functions, stated in (8) and (9), it follows that a necessary and sufficient condition for the existence of a unique Nash equilibrium with $P^\star > .5$ is that $\pi_R(0, \tau, q) > \pi_E(0, \tau, q)$. Using (4) and (5), this condition is equivalent to

$$\tau > 1 - q \tag{23}$$

Given (7), from (4) and (5) it follows that if $\tau > 1 - q$, then the unique Nash equilibrium is

$$P^\star = \frac{q}{q + (1-\tau)(1-q)} \tag{24}$$

which is greater than .5 for all (τ,q) that satisfies $\tau > 1 - q$. Using (22) and (24),

$$F'(P^\star) = -\gamma A\,(1-\tau)\,(1-q) < 0 \tag{25}$$

Therefore, the equilibrium is stable. Q.E.D.

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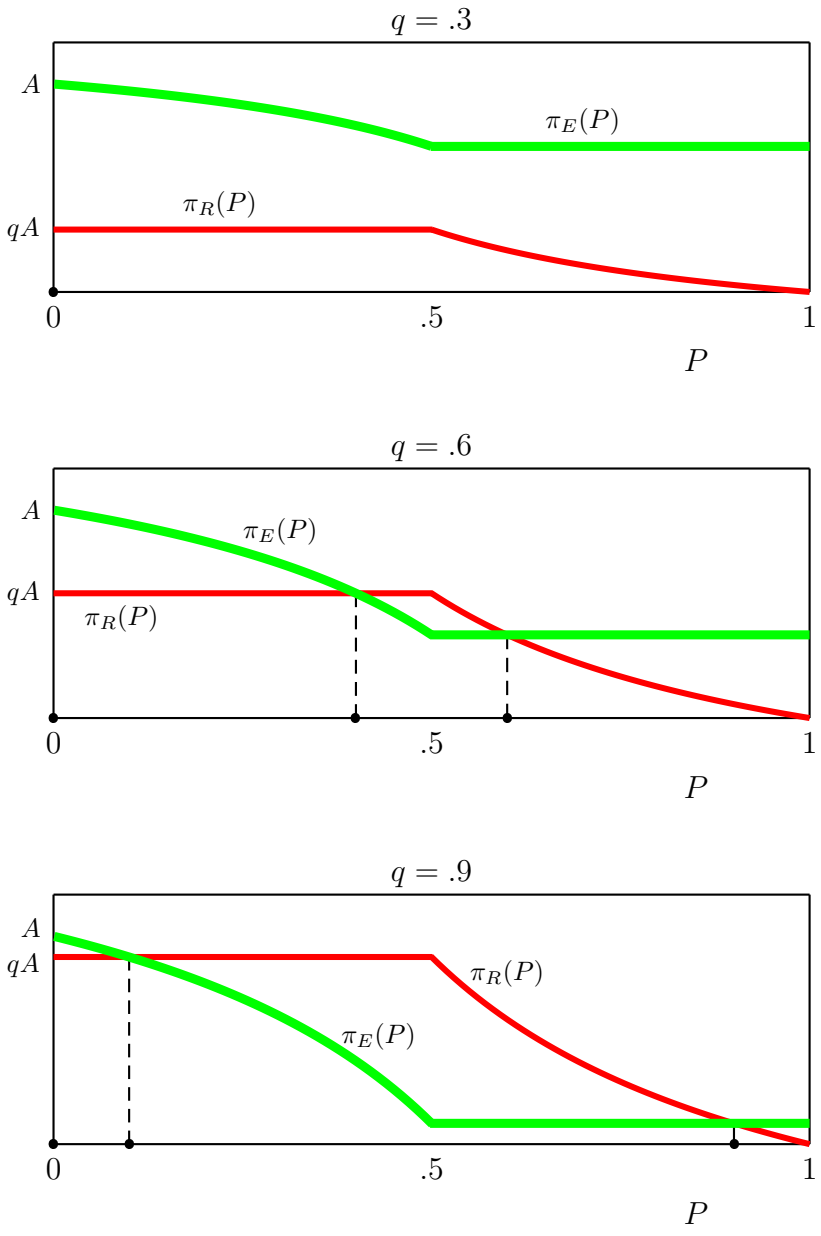

Figure 1: $\pi_E(P)$ and $\pi_R(P)$ graphed against P, assuming different values of q. • indicates a Nash equilibrium.

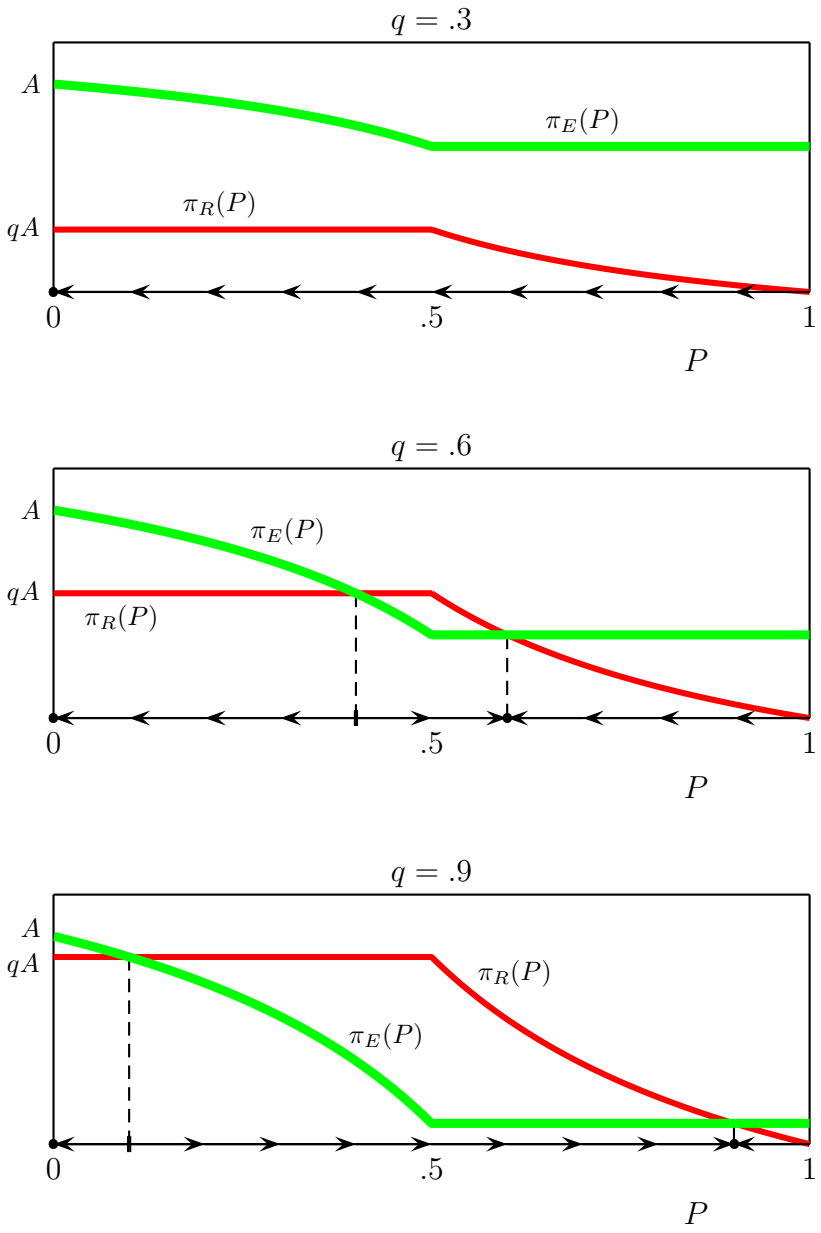

Figure 2: $\pi_E(P)$ and $\pi_R(P)$ graphed against P, assuming different values of q. • indicates a stable equilibrium, and ı indicates an unstable equilibrium.

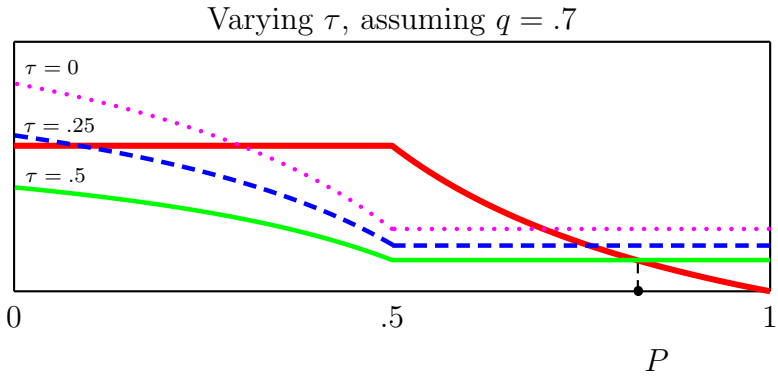

Figure 3: Illustration of Proposition 3. If τ is high enough then a unique stable Nash equilibrium exists.

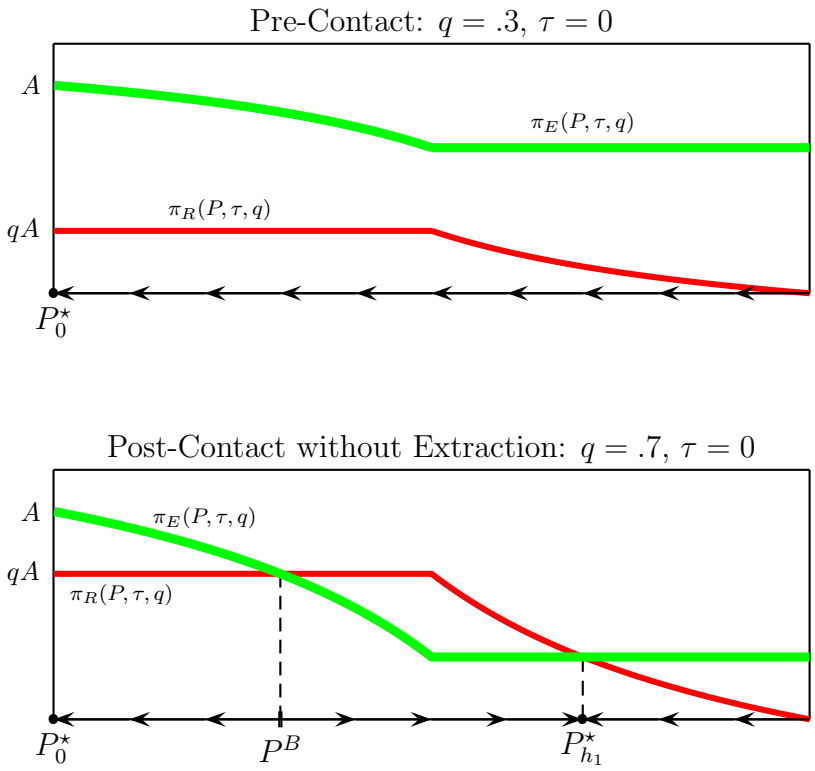

Figure 4: Africa's Underdevelopment: Pre-Contact and Post-Contact without Extraction.

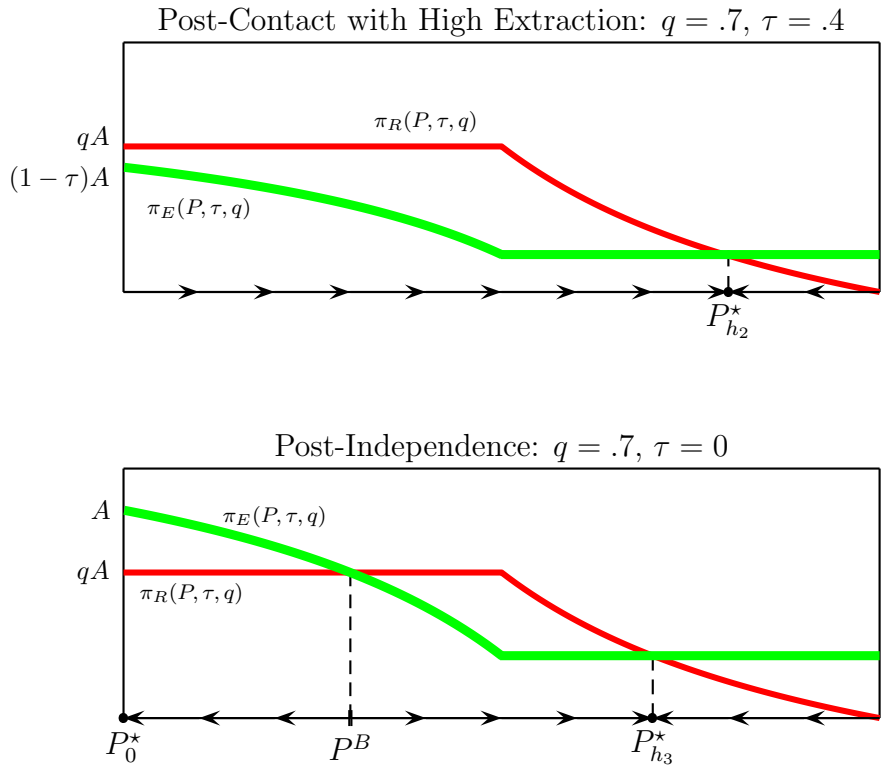

Figure 5: Africa's Underdevelopment: Post-Contact with High Extraction and Post-Independence.

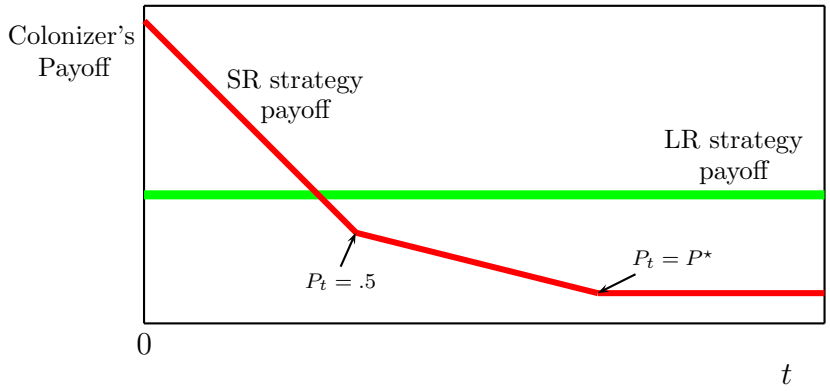

Figure 6: The streams of payoffs under an LR strategy and an SR strategy.