Historical Legacies: A Model Linking Africa's Past to its Current Underdevelopment

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Abstract

Recent studies have found evidence linking Africa's current underdevelopment to colonial rule and the slave trade. Given that these events ended long ago, why do they continue to matter today? I develop a model, exhibiting path dependence, that explains how these past events could have lasting impacts. The model has multiple equilibria: one equilibrium with secure property rights and a high level of production and others with insecure property rights and low levels of production. I show that external extraction, when severe enough, causes a society initially in the high production equilibrium to move to a low production equilibrium. Because of the stability of low production equilibria, the society remains trapped in this suboptimal equilibrium even after the period of external extraction ends. The model provides one explanation why Africa's past events continue to matter today.

JEL classification: B52; C72; D72; D74; J24

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1 Introduction

Africa's economic performance since independence has been poor. Between 1974 and 2002, the average individual in sub-Saharan Africa saw their real income decline by 11% (Artadi and Sala-i-Martin, 2003, p. 2). A common explanation for Africa's poor economic performance is its unique history, characterized by two events: the slave trade and colonial rule. Economic historian Paul Bairoch argues 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" (Bairoch, 1993, p. 88). African historian Patrick Manning writes that "slavery was corruption: it involved theft, bribery, and exercise of brute force as well as ruses. Slavery thus may be seen as one source of precolonial origins for modern corruption" (Manning, 1990, p. 124).

Findings from a number of recent empirical studies provide mounting evidence that Africa's poor economic performance in the second half of the 20th century can be partially explained by either colonialism or the slave trade. Grier (1999) finds that the identity of the colonizer is an important determinant of human capital levels at independence, as well as subsequent growth. Englebert (2000a, 2000b) finds that the inadequacies of arbitrarily imposed post-colonial institutions explains a significant proportion of the underdevelopment of the countries of sub-Saharan Africa. Acemoglu et al. (2001, 2002) show that in former colonies, where the colonizer's focus was on extraction, weak institutions of private property were established and these poor institutions persist today. Bertocchi and Canova (2002) find that within Africa, colonial heritage and the extent of economic penetration during colonialism exert a direct influence on post-colonial growth rates, as well as the accumulation of human and physical capital after independence. Price (2003) argues that colonial heritage is able to explain the difference in growth between countries in sub-Saharan Africa and other developing countries. Lange (2004) shows that among former British colonies, colonies that were governed by indirect rule are now less politically stable, have a worse rule of law and have a lower quality of institutions. Nunn (2004) finds that among African countries, the larger the number of slaves taken from a country during the slave trade, the worse is the country's economic performance in the second half of the 20th century, measured using either the rate of growth or the level of real per capita GDP.

Given the mounting evidence of a relationship between Africa's past and its current economic performance, a natural question arises. Why do these events, which ended years ago, continue to matter today? In this paper, I develop a formal model that provides an answer to this question. It explains why Africa's contact with Europe during the slave trade and colonial rule continues to affect economic performance today, years after the events have ended.

This paper is not the first to model the impact that European contact had on Africa. Darity (1982) develops a general equilibrium model of the 18th century system of trade between Europe, Africa and the colonies in the Americas. The model allows for the possibility that the slave trade had an adverse effect on Africa's production possibilities and that Africans were under-compensated for the slaves taken from Africa. Darity then uses the model's predicted rates of income growth in Africa, Europe and the colonies to test the proposition that the Atlantic slave trade was responsible for Europe's development and Africa's underdevelopment. Findlay (1990) also develops a general equilibrium model of three corner trade. Findlay uses the model to analyze what effects different historical events, such as the industrial revolution or the British abolition of the slave trade, had on the price and quantities of goods produced and traded.

Darity (1982) and Findlay (1990) model the direct impacts that European contact had on Africa while trade was occurring (in the 18th century). The model developed here complements their work by considering additional persistent long-run consequences of early European contact with Africa. The model highlights how European contact may have consequences that continue to persist long-after the end of the slave trade and colonial rule.

The model has two stages. In the first stage, a colonizer chooses a policy that has two instruments: the rate of extraction and the amount of resources to devote towards the enforcement of domestic property rights.[1] The model's second stage focuses on an important determinant of Africa's poor performance: the widespread presence of robbery, theft, fraud, corruption, and civil conflict (World Bank, 2005; Rowley, 2000). These are all activities that do not result in value being created. Individuals engaged these activities gain by taking from others. To model this, I use a distinction first make by Bhagwati (1982) and Baumol (1990). I assume that individuals engage in activities that are either 'productive' or 'unproductive'. Individuals en-

[1] The period for which the model applies includes the period of the Atlantic slave trade prior to official colonial rule. At this time one colonizer (even for a specific area) did not exist. Foreign extraction was carried out by competing slave traders from different European nations. When modelling the 'colonizer' and its strategy I am not literally modelling one colonizer and its colonial policy, but the general impact that foreign extraction had on Africa. Therefore, in the game when referring to the 'colonizer' I am referring to this theoretical abstraction, and the term should be interpreted in this manner.

gaged in productive activities receive a payoff by producing output. Those engaged in unproductive activities receive a payoff by appropriating the output of producers. Because unproductive activities simply redistribute value, those engaged in this activity gain at the expense of the producers that are taken from. Therefore, unproductive activities exert a negative externality on those engaged in productive activities, while productive activities do not exert a negative externality. This is the core difference between the two types of activities. A number of other studies make this same distinction (see Hirshleifer, 1991; Skaperdas, 1992; Murphy et al., 1991, 1993; Acemoglu, 1995; Francois and Baland, 2000; Grossman and Kim, 2002; Lloyd-Ellis and Marceau, 2003). In the analysis, I use the terminology of Baumol (1990) and call individuals engaged in productive activities 'productive entrepreneurs' and those engage in unproductive activities 'unproductive entrepreneurs'.

I show that when the colonizer is absent, the second stage subgame always has an equilibrium without unproductive activities. I call this the high production equilibrium. The intuition behind this equilibrium is as follows. Because everyone is engaged in productive activities, the return to production is high, causing individuals to remain engaged in productive activities. The game may also have equilibria where many entrepreneurs are engaged in unproductive behavior. I call these low production equilibria. The intuition behind these equilibria is as follows. Because many entrepreneurs are engaged in unproductive activities that exert a negative externality on those that produce, the return to production is low and many individuals choose to engage in unproductive activities rather than productive activities.

I show that when a colonizer is present and chooses a high enough level of extraction in the first stage, the high production equilibrium disappears in the second stage, leaving a unique low production equilibrium. This arises because of an asymmetry between those engaged in the two types of activities. Individuals engaged in unproductive activities are able to avoid extraction, while individuals engaged in productive activities are not. In the end, the introduction of foreign extraction can move a society initially in the high production equilibrium to a low production equilibrium. Following the period of extraction, the high production equilibrium returns, but because of the stability of the low production equilibrium, the society remains trapped in this equilibrium.

This outcome describes one of two possible equilibria of the full game. I call equilibria of this type 'underdevelopment equilibria'. There also exist 'development equilibria', in which the optimal colonial policy is one of low rates of extraction and high levels of protection of private property. In these equilibria, a society initially in the high production equilibrium remains in this equilibrium during and after colonial rule. I contend that underdevelopment equilibria describe the history of many African countries. In summary, the model provides the following explanation linking Africa's past to its current underdevelopment:

- Prior to European contact, many African societies are located in high production equilibria.
- During contact, external extraction lowers the return to productive activities relative to unproductive activities. This causes the high production equilibrium to disappear, leaving a unique low production equilibrium.
- Individuals switch from productive activities to unproductive activities, as the society moves to the new equilibrium.
- Following the period of extraction, the society is free from the colonial policy and a high production equilibrium again exists. However, the society is now trapped in a low production equilibrium. The stability of this suboptimal equilibrium makes moving to the more efficient high production equilibrium difficult.

In the following section, I describe the game in detail, characterizing the players' optimal strategies and the game's set of equilibria. In Section 3, I show that the predictions of the model are consistent with Africa's history. In Section 4, I show how the model provides insights into the findings of recent empirical studies. In Section 5, I describe the model's relationship with the existing theoretical literature. Section 6 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 that consists of two instruments. The first is the rate of extraction τ. This is the fraction of each productive entrepreneur's production that is expropriated. The second instrument is the amount of resources devoted towards enforcing the security of private property in the society. These resources determine the proportion $q \in (0, 1)$ of a productive entrepreneur's output that an unproductive entrepreneur 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 engage in productive activities or unproductive activities; these decisions are made simultaneously. Each individual engaged in productive activities produces the output A. Each individual engaged in unproductive activities, when successful, obtains the proportion q of the output of a producer.[2] Search is costless and unproductive entrepreneurs can perfectly identify productive entrepreneurs. Given these assumptions, the probability of an unproductive entrepreneur's success depends on the division of the population between productive and unproductive entrepreneurs. Denote the fraction of unproductive entrepreneurs by x. If there are fewer unproductive entrepreneurs in the society than productive entrepreneurs ($x < 1 - x$), then each unproductive entrepreneur finds a productive entrepreneur to rob with certainty; otherwise, the probability of an unproductive entrepreneur's finding a productive entrepreneur to rob is $\frac{1-x}{x}$. Thus, the probability of an unproductive entrepreneur's finding a productive entrepreneur to rob is

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

or alternatively

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

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

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

Expected payoffs depend on the proportion of unproductive entrepreneurs in the society, x, and on the policy chosen by the colonizer in the first stage, (τ, q). A producer'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,

$$\begin{aligned} \pi_{\mathrm{P}}(x, \tau, q) \quad = \quad & \min\left\{\frac{x}{1-x}, 1\right\}(1-\tau)(1-q)A \\ & + \left(1 - \min\left\{\frac{x}{1-x}, 1\right\}\right)(1-\tau)A \qquad (1) \end{aligned}$$

[2]One could also assume that with probability q individuals engaged in unproductive activities are able to steal all of the output from a producer. Because individuals are risk neutral, the model is consistent with either interpretation.

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

$$\pi_{\mathrm{U}}(x, \tau, q) = \min\left\{\frac{1-x}{x}, 1\right\} qA \tag{2}$$

Because the colonizer is unable to extract from individuals that do not produce, τ does not directly enter an unproductive entrepreneur's expected payoff.

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

$$\begin{aligned}\pi_{\mathrm{C}}(x, \tau, q) &= \tau \left[\min\left\{\frac{x}{1-x}, 1\right\}(1-q)\,A \right.\\ &\quad \left. + \left(1 - \min\left\{\frac{x}{1-x}, 1\right\}\right) A\right](1-x) - c(q)\end{aligned} \tag{3}$$

A crucial assumption of the model is the specific form of colonial extraction. I make this assumption because I want τ to reflect an important feature of foreign extraction in Africa; that those engaged in unproductive activities (i.e. bandits, slave raiders, warlords, mercenaries, etc.) were better able to avoid European extraction than those engaged in productive activities (i.e. the peasantry).

Europeans had difficulty extracting from unproductive entrepreneurs because they were able to either fight back, flee, or even steal back from the Europeans. In addition, Europeans often required their help to extract resources from the rest of the population. During the slave trade, domestic slave raiders, slave traders and middlemen were needed to capture slaves and to bring them to coastal ports, where they were then shipped across the Atlantic. This was also true during colonial rule when Africans were required to work in the colonial army, bureaucracy, treasury or police force. Those lucky enough to work with the colonial government were able to escape the taxation, forced labor and general coercion that was inflicted upon the peasant population. In short, because those engaged in unproductive activities were specialists in violence and predation, they were either used by Europeans to help extract resources from others, or they were able to successfully avoid foreign extraction. I consider these issues in more detail and provide further evidence in Section 3 of the paper.[3]

[3]Others have modelled this same interaction between productive entrepreneurs, un-

If one finds the assumed form of European extraction too restrictive, a more general specification is possible. This would allow for two rates of extraction: τ_{P} for productive entrepreneurs and τ_{U} for unproductive entrepreneurs. All results of the paper would hold, dependent on $\Delta\tau \equiv \tau_{\mathrm{P}} - \tau_{\mathrm{U}}$, rather than τ. What is key for the results is the difference between the two rates of extraction. Throughout the paper, I have chosen to sacrifice generality for expositional simplicity and set $\tau_{\mathrm{U}} = 0$ and $\tau_{\mathrm{P}} = \tau$.

2.1 Second Stage - Pre-Contact Africa

The second stage of the game, without 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 x only: $\pi_{\mathrm{P}}(x)$ and $\pi_{\mathrm{U}}(x)$. 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:

$$\begin{aligned} \text{either } x = 0 \text{ and } \pi_{\mathrm{U}}(x) &\leq \pi_{\mathrm{P}}(x) \\ \text{or } 0 < x < 1 \text{ and } \pi_{\mathrm{U}}(x) &= \pi_{\mathrm{P}}(x) \\ \text{or } x = 1 \text{ and } \pi_{\mathrm{U}}(x) &\geq \pi_{\mathrm{P}}(x) \end{aligned} \tag{4}$$

The set of possible Nash equilibria is most easily seen by graphing $\pi_{\mathrm{P}}(x)$ and $\pi_{\mathrm{U}}(x)$ against x for differing efficiencies of theft, q, as in Figure 1. As the figure shows, the slopes of the two value functions switch their relative sizes before and after $x = .5$. That is,

$$\begin{aligned} \frac{\partial \pi_{\mathrm{U}}(x)}{\partial x} > \frac{\partial \pi_{\mathrm{P}}(x)}{\partial x} \quad &\text{if} \quad 0 \leq x \leq .5 \\ \frac{\partial \pi_{\mathrm{U}}(x)}{\partial x} < \frac{\pi_{\mathrm{P}}(x)}{\partial x} \quad &\text{if} \quad .5 \leq x \leq 1 \end{aligned}$$

This feature of the payoff functions is the reason for the game's multiple equilibria. It is a result of the differing effects that an increase in x has on the returns to both strategies. When the number of unproductive entrepreneurs is less than the number of productive entrepreneurs ($x < 1 - x$), an increase in x has no effect on the payoffs to individuals engaged in unproductive activities, since each unproductive entrepreneur can still find a productive

productive entrepreneurs and a government. In Grossman (2002) it is assumed that the society's 'king' is unable to tax the 'predators' of the economy and is only able to tax the 'producers'.

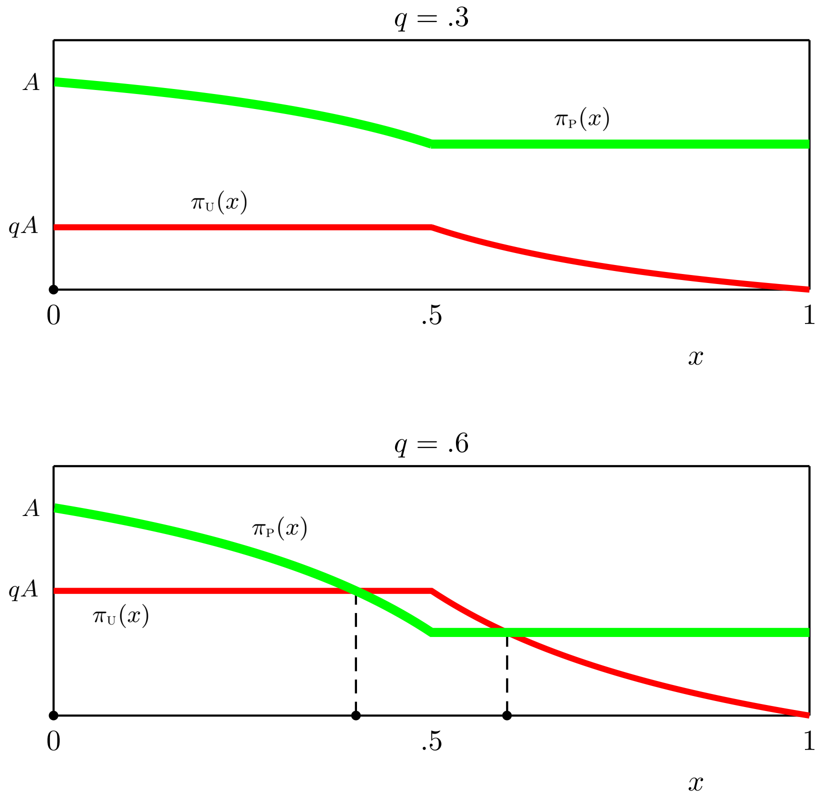

Figure 1: $\pi_P(x)$ and $\pi_U(x)$ graphed against x, assuming different values of q. $\bullet$ indicates a Nash equilibrium.

entrepreneur to rob with certainty. However, an increase in x increases each productive entrepreneur's probability of being robbed, and thus decreases the expected payoff to those engaged in productive activities. If $x > 1 - x$, then all producers are stolen from with certainty and an increase in x no longer decreases a productive entrepreneur's expected payoff. However, now the expected payoff to an unproductive entrepreneur is strictly decreasing in x. This is because there is crowding out among individuals engaged in unproductive activities and an increase in x decreases each unproductive entrepreneur's probability of finding a productive entrepreneur to steal from.

Figure 1 also shows that there always exists an equilibrium in which $x = 0$. For low values of q this equilibrium is unique. However, as q increases eventually other equilibria arise. In these equilibria, both productive activities and unproductive 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 produce, $x^\star = 0$. If $q < .5$, this equilibrium is unique. If $q = .5$, the subgame has one additional equilibrium with $x^\star = .5$. If $.5 < q < 1$, the subgame has two additional equilibria; one with $x^\star = 1 - q < .5$ and the other with $x^\star = q > .5$.*

As summarized by Proposition 1, absent external contact, a high production equilibrium always exists and if q low enough, then this equilibrium is unique. In the next section, I show how this result changes once foreign extraction by a colonizer is introduced.

2.2 Second Stage - Post-Contact Africa

To analyze the changes that occur following European expansion, I consider the model in a dynamic environment. To model dynamics, I have chosen to use the two-player version of the standard replicator dynamic[4]

$$\frac{x_{t+1} - x_t}{x_t} = \gamma \left[\pi_{\text{U}}(x_t, \tau, q) - \overline{\pi}(x_t, \tau, q)\right] \tag{5}$$

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

$$\overline{\pi}(x_t, \tau, q) = x_t \pi_{\text{U}}(x_t, \tau, q) + (1 - x_t)\pi_{\text{P}}(x_t, \tau, q) \tag{6}$$

Although the original interpretation of the dynamic is biological, the dynamic is also consistent with models of local information or social evolution (Gintis, 2000; Weibull, 1995). I assume that the population is imperfectly informed about the value of x_t. In every period each player, with probability $\gamma > 0$, compares her payoff in the previous period to that of another randomly selected player. If the other player's payoff is higher, then she switches. If not, the player maintains her original strategy. Given these assumptions the replicator dynamic (5) can be derived (Gintis, 1997, p. 28).

[4]None of the results of the paper depend on the specific dynamic that I have chosen to use. One could use any dynamic that establishes the stability of the game's equilibria. For example, one could assume an overlapping generations setting, where each period the proportion γ of the population die and are replaced with new players. These new players are perfectly informed, but must make a once-and-for-all choice to engage in productive or unproductive activities. See Acemoglu (1995) for a dynamic of this type.

I make the additional assumption that a very small proportion of the population $\varepsilon > 0$ is fully informed about the game[5] and therefore these individuals choose in each period the strategy that yields the highest payoff.[6] Therefore, when $x_t = 0$, if $\pi_{\text{U}}(0, \tau, q) - \pi_{\text{P}}(0, \tau, q) \leq 0$, then $x_{t+1} = 0$, but if $\pi_{\text{U}}(0, \tau, q) - \pi_{\text{P}}(0, \tau, q) > 0$, then

$$x_{t+1} = \varepsilon \tag{7}$$

Combining (5), (6) and (7), we have

$$x_{t+1} - x_t = \begin{cases} \varepsilon & \text{if } x_t = 0 \text{ and } \pi_{\text{U}}(0, \tau, q) > \pi_{\text{P}}(0, \tau, q) \\ F(x_t) & \text{otherwise} \end{cases} \tag{8}$$

where

$$F(x_t) \equiv x_t(1 - x_t)\gamma \left[\pi_{\text{U}}(x_t, \tau, q) - \pi_{\text{P}}(x_t, \tau, q)\right] \tag{9}$$

A Nash equilibrium, $x^\star$, is stable if and only if

$$F'(x^\star) < 0 \tag{10}$$

Condition (10) ensures that a small perturbation of x above $x^\star$ results in a subsequent decrease in x back to $x^\star$, and that a small perturbation of x below $x^\star$ results in an increase in x back to $x^\star$. It is useful to define the *basin of attraction* of a stable equilibrium $x^\star$. The basin of attraction of $x^\star$ is the set of points x_0 such that a trajectory through x_0 converges over time to $x^\star$. That is, it is the set of initial population proportions that converge to $x^\star$.

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

[5]It is assumed that ε is sufficiently small that the actions of this fraction of the population can be ignored in expression (5).

[6]Without this modification, members from a population with only productive entrepreneurs ($x = 0$) would never switch to unproductive activities. This is true even when $\pi_{\text{U}}(0, \tau, q) > \pi_{\text{P}}(0, \tau, q)$. Intuitively, because only productive entrepreneurs exist in the population, an unproductive entrepreneur's payoff is never sampled and therefore members of the population never switch to unproductive activities. This is a general feature and short-coming of the standard replicator dynamic. See Gintis (2000), pp. 191–192 for a discussion of this issue.

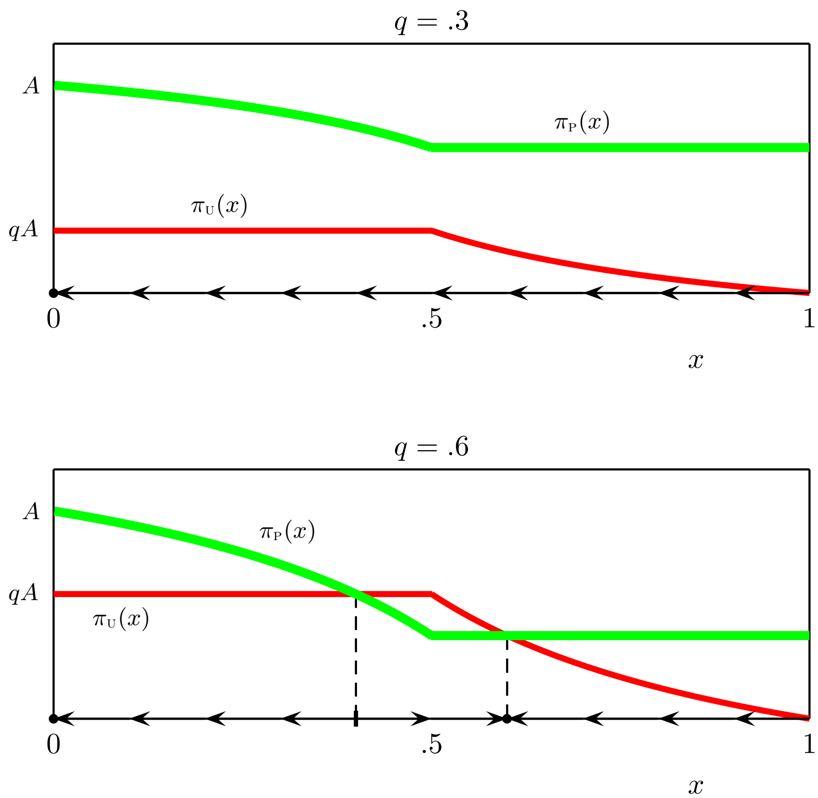

Figure 2: $\pi_{\mathrm{P}}(x)$ and $\pi_{\mathrm{U}}(x)$ graphed against x, assuming different values of q. • indicates a stable equilibrium, and ❙ indicates an unstable equilibrium.

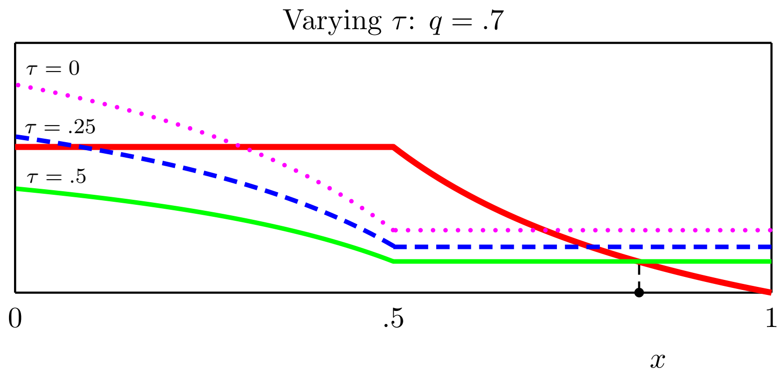

Figure 3: Illustration of Proposition 3. If τ is high enough then a unique stable Nash equilibrium exists.

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

I now consider the impact that European extraction has on the African society. From Proposition 2, we know that without extraction ($\tau = 0$) there always exists a high production equilibrium. However, as Proposition 3 states, if extraction is severe enough, then the high production equilibrium disappears, leaving a unique, stable low production equilibrium.

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

The rationale behind Proposition 3 is illustrated in Figure 3. As shown, increases in τ have an asymmetric effect on the payoff to each activity. Increases in τ decrease the payoff to productive activities, while leaving the payoff to unproductive activities unchanged. Therefore, as τ is increased, eventually at $x = 0$ the payoff to unproductive activities becomes larger than the payoff to productive activities, and this leaves a unique low production equilibrium.

2.3 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 be given. This is done graphically in Figure 4. The top graph of the figure illustrates an African society initially located in the high production equilibrium $x_0^\star$ prior to European contact. After contact, because of the introduction of new technologies, A may increase. But, the increase in A shifts the payoffs to both types of activities proportionately and therefore does not affect the equilibria. In reality, q may also have increased because of the introduction of firearms and other weapons to the continent, but I assume here that q remains constant. Allowing q to change does not affect any of my arguments.

Next, consider what occurs if the colonizer chooses a level of extraction so high that $\tau > 1 - q$. This is illustrated in the middle graph of Figure 4. European extraction distorts the relative returns to the two types of activities enough to cause the high production equilibrium $x_0^\star$ to disappear. This leaves a unique stable low production equilibrium $x_2^\star$. Each period, individuals who were previously engaged in productive activities switch to unproductive activities, causing x to increase over time. This continues until $x_2^\star$ is reached. In reality, individuals, families and tribes that had been cultivators or 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 3.

The situation following independence is illustrated in the bottom graph of Figure 4. After independence, τ returns to zero. If the period of European extraction was long enough, then x will have increased sufficiently such that by independence x will be within the basin of attraction of the new low production equilibrium $x_3^\star$. More precisely, if at independence $x > x_B$, then after independence x will converge to $x_3^\star$.

In the end, European extraction has permanently moved a society initially in the high production equilibrium $x_0^\star$ to a low production equilibrium $x_3^\star$, characterized by insecure property rights and low levels of production.

2.4 First Stage - The Colonizer's Strategy

The model's explanation for the historical origins of Africa's 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 $\tau > 1 - q$ (see 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

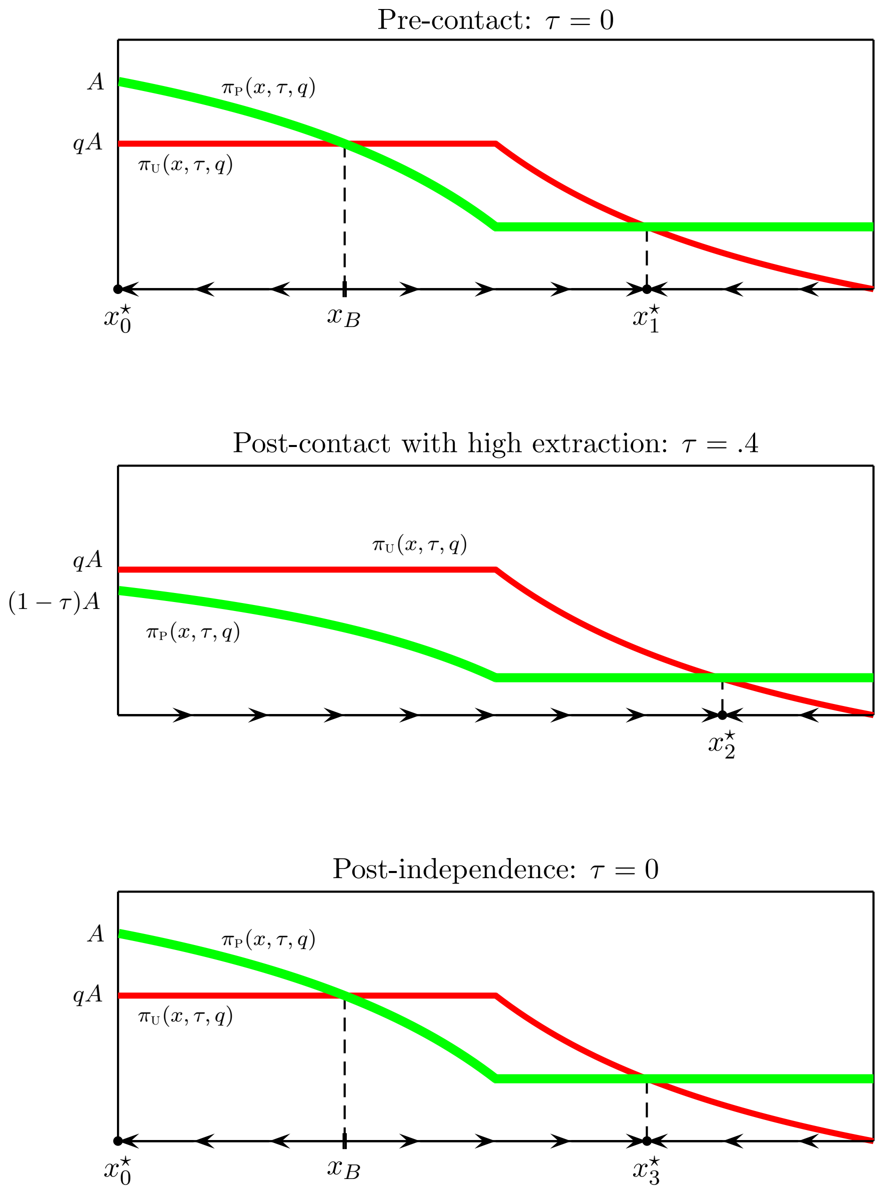

Figure 4: An explanation for the historical origins of Africa's persistent underdevelopment. In each figure $q = .7$.

one of the two strategies $\tau > 1 - q$.

In choosing the rate of extraction τ and the protection of private property, which determines q, the colonizer is 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, with positive probability, the colonizer loses control of the colony. 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

$$\Pi_{\text{C}}(\tau, q) = (1 - \delta) \sum_{t=0}^{\infty} \delta^t \pi_{\text{C}}(x_t, \tau, q) \tag{11}$$

As will be shown, δ is key in determining the colonizer's optimal strategy. During this time, a primary determinant of δ would have been the number of settlers from the colonizer's country. If a country was able to settle an area, they could be relatively more confident that they had long-term control over the area. I consider this aspect of the model in more detail in Section 4.3, where I discuss the relationship between the model and the empirical work of Acemoglu et al. (2001).

Consider a society that is initially located in the high production equilibrium with $x_0 = 0$. 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 $\tau < 1 - q$, then $x_t = 0$ for all t, and from (3), the colonizer's payoff is

$$\Pi_{\text{C}}(\tau, q) = \pi_{\text{C}}(0, \tau, q) = \tau A - c(q) \tag{12}$$

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 x_t to converge to $x^\star = \frac{q}{q+(1-\tau)(1-q)} > .5$.

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

I argue that both LR and SR strategies can be optimal, and that which is optimal depends on 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,

$$\pi_{\mathrm{C}}(0, \tau, q) = \tau A - c(q) \tag{13}$$

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 x_t increases from $x_0 = 0$ to $x^\star = \frac{\hat{q}}{\hat{q}+(1-\hat{\tau})(1-\hat{q})} > .5$. Consider a period t large enough that under $(\hat{\tau}, \hat{q})$, $x_t \geq .5$. From (3), the colonizer's payoff in this period is

$$\pi_{\mathrm{C}}(x_t, \hat{\tau}, \hat{q}) = \hat{\tau}(1-\hat{q})A(1-x_t) - c(\hat{q}) \tag{14}$$

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

$$\pi_{\mathrm{C}}(0, \tau, q) = (1-q)A - c(q) \tag{15}$$

Denote the value of (τ, q) that maximizes (15) by $(\tau^\star, q^\star)$. This is the best LR strategy. Then, using (14) and (15), we have the following result

$$\begin{aligned}
\pi_{\mathrm{C}}(0, \tau^\star, q^\star) &= (1-q^\star)A - c(q^\star) \\
&\geq (1-\hat{q})A - c(\hat{q}) \\
&> \hat{\tau}(1-\hat{q})A(1-x_t) - c(\hat{q}) \\
&= \pi_{\mathrm{C}}(x_t, \hat{\tau}, \hat{q})
\end{aligned}$$

That is, for t large enough that $x_t \geq .5$ 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

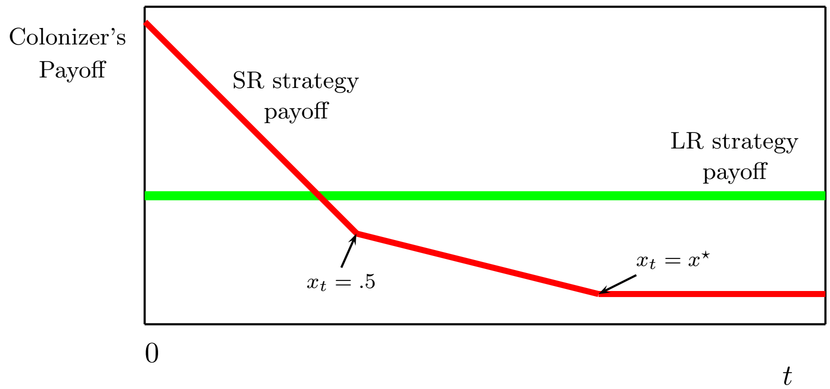

Figure 5: The streams of payoffs under an LR strategy and an SR strategy.

larger payoffs in later periods. This is shown clearly in Figure 5, 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 $\pi_{\mathrm{C}}(x_t, \tau, q)$ is decreasing in x_t. Therefore, over time, as x_t monotonically increases under any SR strategy, $\pi_{\mathrm{C}}(x_t, \tau, q)$ monotonically decreases. The figure also shows that under any LR strategy $x_t = 0$ for all t and thus $\pi_{\mathrm{C}}(0, \tau, q)$ remains constant.

From Lemmas 1 and 2, and Figure 5, 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 high), 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.

2.5 Equilibria

Combining both stages, the game's two types of equilibria can be described.

1. **Development Equilibria**. The colonizer chooses an LR strategy, with $\tau = 1 - q$. In the second stage, every period each individual chooses to engage in productive activities and the economy remains in the high production equilibrium, with $x^{\star} = 0$. After the colonizer exits the country and τ returns to zero, the society remains in the high production equilibrium.

2. **Underdevelopment Equilibria**. The colonizer chooses an SR strategy, with $\tau > 1 - q$. Over time, individuals switch from productive activities to unproductive activities as the society converges to a low production equilibrium. If enough time has passed, then the society will be located within the basin of attraction of a post-colonial low production equilibrium. After independence the society remains trapped in this stable low production equilibrium.

3 Historical Evidence

I have argued that the model's underdevelopment equilibria provide one explanation for the historical origins of Africa's persistent underdevelopment. If this is true, then looking at Africa's past the following parts of the model's explanation should be observed: (1) prior to European contact, many African societies were located in high production equilibria (2) external extraction, during the slave trade and colonial rule, lowered the return to productive activities relative to unproductive activities (3) after European contact, the proportion of individuals engaged in unproductive activities increased over time. In what follows, I show that Africa's history provides support for each part of the model's explanation.

Part 1. *Prior to European contact, many African societies were located in high production equilibria.*

Although it is not possible to directly observe the proportion of pre-contact African societies that were in high production equilibria prior to European contact, the available evidence suggests that African societies had levels of economic and social development that were similar to other societies around the world. Amin (1972) writes that "Black Africa was not on the whole more backward than the rest of the world. The continent was characterized by complex social formations, sometimes accompanied by the development of the state, and almost invariably based on visible social variations which revealed the disintegration of the primitive village community" (p. 506). African societies had developed customs, laws, conventions, ethics or rituals to resolve conflict and enforce order. Many societies maintained order through kinship ties or a lineage system, where disputes were either resolved by consensus or through a council of elders. The more centralized societies had developed formal political systems and advanced legal institutions that resemble modern day courts (Bohannan and Curtin, 1998, pp. 147–167; Adejumobi, 2000).

One of the only first-hand written account of pre-contact Africa comes from the Moroccan traveller Ibn Battúta, who travelled to the empire of Mali in 1352. He describes the road from Walāta, located in modern Mauritania, to the capital of Mali as being safe and the empire as well functioning with peaceful inhabitants (Ibn Battúta, 1929, p. 322). "The negroes possess some admirable qualities. They are seldom unjust, and have a greater abhorrence of injustice than any other people. . . There is complete security in their country. Neither traveller nor inhabitant in it has anything to fear from robbers or men of violence." (Ibn Battúta, 1929, p. 329).

Although, systematic quantitative evidence of the degree to which individuals engaged in unproductive activities is unavailable, information is known about certain specific activities. Recent studies have shown that one unproductive activity, chattel slavery, was not commonly practiced before European contact in those parts of Africa that were untouched by the trans-Saharan slave trade (Inikori, 2000; Rodney, 1966). The most extensively studied part of Africa is west central Africa. Studies by linguists show that the people of this area did not have words for 'slave' or 'slavery' before the rise of the trans-Atlantic slave trade. Other words, which originally meant 'servant', 'prisoner' or 'captive', took on new meaning and were applied to describe slaves and slavery (Hilton, 1985; Vansina, 1989, 1990). The writings of African explorer David Livingstone provide added support for this finding. Livingstone documents that prior to contact with the Portuguese, the Makololo of west central Africa were completely alien to the concept of people being bought and sold (Beachey, 1979, p. 206).

As Bairoch (1988) argues and as Acemoglu et al. (2002) document, an area's urban population is a good indicator of its prosperity, progress and overall level of economic development. The available data on city size and urbanization rates provide additional evidence that the regions of sub-Saharan Africa were as prosperous and developed as other regions of the world. Many of the cities in Central Sudan had large populations. By the end of the 15th century, Gao's population reached 60,000, Gobir's population was 28,000, Kano's was 50,000, Timbuktu's was 25,000, and Jenne's was 20,000. The cities of modern Nigeria were also large. Katunga, the capital of Oyo, had a population of 50,000 during the 15th century (Chandler, 1987, pp. 282–296).

The city of Benin had a population between 60,000 and 70,000 and was a "well-ordered urban center with a system of water conduits and a sizable artisanry working at an advanced level" (Bairoch, 1988, p. 58). Further south, Mbanza Kongo, the capital of the Kongo Kingdom, had a population of 40,000 during 15th century (Chandler, 1987, p. 300). Eastern Africa had also enjoyed nearly 300 years of "remarkable prosperity" prior to the arrival of the Portuguese at the end of the 15th century (Oliver and Fage, 1962, p. 98). Before the Portuguese conquest of Kilwa, its population had reached 30,000. The population of the ancient city of Zimbabwe had reached 40,000 by the end of the 15th century (Chandler, 1987, pp. 286, 301).

Combining data from McEvedy and Jones (1978) and Chandler (1987), I have constructed urbanization estimates for sub-Saharan countries in 1500. I follow the exact methodology used in Acemoglu et al. (2002). Zimbabwe's urbanization rate is 15%, Mali's is 12.7%, Mauritania's is 6.7%, Nigeria's is 4.8%, Angola's is 3.1%, Niger's is 2.3%, Ethiopia's is 2.7% and Tanzania's is 1.7%. Outside of Europe, these urbanization rates are among the highest in the world. As a comparison, for this same period of time, the urbanization rates of Peru and Mexico, the locations of the Inca and Aztec empires, are 2.5% and 6.5%. The urbanization rate of India is 1.8% and Portugal is 5.8% (Acemoglu et al., 2002).

Part 2. *External extraction, during the slave trade and colonial rule, lowered the return to productive activities relative to unproductive activities.*

From the beginning of the 16th century to the end of the 19th century, European contact with Africa primarily took the form of the trans-Atlantic slave trade. During this time approximately 12 million slaves were shipped to the Americas (Lovejoy, 2000). The external demand for slaves provided increased opportunities for individuals to engage in activities that did not produce output. Slave raiders, slave traders and other middlemen were needed to capture slaves and to bring them to coastal ports, where they were shipped across the Atlantic by the Europeans. Slave raiding and slave trading are unproductive activities because they do not create value. The source of the surplus gained by those engaged in these activities ultimately comes from the labor stolen from the slave. Although he does not use the model's terminology, Darity (1992) describes the change in relative payoffs of the two types of activities when he 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." (p. 165).

Beginning in the early 19th century, the trans-Atlantic slave trade was slowly brought to an end. As the slave trade declined, European colonization of the continent was beginning, with the Berlin Conference of 1884–1885 marking the beginning of official colonial rule. Although the period of colonial rule was very different from the slave trade, it continued to alter the return to productive activities relative to unproductive activities.

Colonial policies of land expropriation, taxation, and forced labor targeted those that produced: the peasantry. Land expropriation was common in colonial Africa. In South Africa, by 1925 over 90% of the land had been expropriated by European settlers (Buell, 1928a, p. 513). Poll, head and hut taxes were the main tools used to raise revenues for the colonies. Taxes also served as an indirect tool of extraction by forcing the African peasantry into extractive employment relations. Annual taxes, usually equivalent to about 30 days of work, could only be paid in the official colonial currency, not in-kind (Buell, 1928a, 1928b; Nzula et al., 1979). 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. Once signed, these contracts could not be broken by the native without severe punishment (Buell, 1928a, pp. 498–500, 629). Forced labor was also common. Peasants were required to engage in employment that was either provided without compensation or for wages well below the market rates. In the Belgian Congo, natives were required to spend 40 hours each month gathering rubber for the colony, while in Uganda natives were obliged to provide 30 days of free labor a year on the roads (Buell, 1928b, pp. 429–431; Buell, 1928a, p. 567). 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 (Berman and Lonsdale, 1980, p. 68).

Those that were engaged in unproductive activities were better able avoid European extraction. Some chose to either work for the Europeans, fight against the Europeans, or join roaming bandit groups. Those that worked with the Europeans in the colonial administration, either as part of the colonial army, bureaucracy, treasury or police force, were exempt from the taxation, forced labor and general coercion that was inflicted upon the rest of the population. These individuals survived not by producing, but by obtaining a portion of the resources that were extracted from the peasantry. Those who were able to escape colonial extraction by joining rebel armies or bandit groups also did not produce. Bandits lived by raiding local communities and caravan routes. Rebel armies lived off the transfer of food and goods from rural peasants. At times the transfers were made voluntarily, but most often rebels plundered local peasant populations or extorted payment through threats of violence and other forms of coercion (Kriger, 1988; McCann, 1985).

Overall, during the slave trade and colonial rule, those engaged in unproductive activities were either used by Europeans to help extract resources from the peasantry or they were better able to successfully avoid foreign extraction.

Part 3. *After European contact, the proportion of individuals engaged in unproductive activities increased over time.*

The increases in unproductive activities such as banditry, kidnapping, and warfare during the period of the slave trade have been well documented by African historians. Patrick Manning (1990) writes that "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." (p. 147). Law (1991) 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." (p. 346). Among those that did not engage directly in the slave trade, some formed bandit groups that raided local agricultural communities for slaves and goods. Others became highway robbers and stole from caravans along trade routes (Miller, 1988, pp. 134, 147). In Borguland, West Africa, armed banditry and the raiding of caravans had intensified to such an extent during the 18th and 19th centuries, that by the 20th century all forms of commercial activities had all but disappeared completely (Akinwumi, 2001).

Trade data from the port of Quelimane, Mozambique, provide added evidence of the extent of the switch from productive to unproductive activities during the slave trade. Between 1806 and 1821, slave exports increased by 240%. At the same time, rice exports fell by 88% and wheat exports fell by 95% (Austen, 1987, pp. 68–71). In 1705, the Dutch Director-General wrote about similar drops in production that were occurring on the Gold Coast: "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." (Richards, 1980, p. 46).

During colonial rule, unproductive activities continued. Many of the Africans that had been involved in the slave trade made the switch to working for the colonial government. For example, the former Yao slave raiding chiefs Matipwiri, Chikumbo and Tambala of the Nyasa area, all became assistants for the colonial government (Beachey, 1976, p. 219). For others, the only way to escape the oppression of colonial rule was to flee and join bandit groups. These groups raided local African communities, looting goods, and stealing African women and children to sell into domestic slavery. Although data on the number of individuals who lived through theft and banditry are unavailable, historic accounts suggest that the practices were widespread. Studies have documented the pervasiveness of various forms of raiding, theft and banditry in Tanzania (Shorter, 1968); South Africa and Namibia (Lau, 1986); Angola (Clarence-Smith and Moorson, 1975; Clarence-Smith, 1985); Nigeria and Benin (Falola, 1996); Ethiopia (Caulk, 1978; McCann, 1985; Simpson, 1996); Sudan (Sikainga, 1989); Mauritania (Taylor, 1995); and Mali (Hall, 2003).

Others were able to work with the colonial authorities in the colonial army, police force or native treasury as tax collectors. These individuals did not produce, but lived by receiving a portion of the value that was taken from the peasantry. In addition, colonial employment conferred power to these individuals that could be used to extract even greater resources from the general population (Buell, 1928b, pp. 431–432; Falola, 1996, pp. 86–95). The colonial armies formed at this time continued to persist after independence. The adverse effects of this persistent have been studied by Boahen (1985) who writes that the "armies have become the heaviest millstones round the necks of African governments and peoples" (p. 789).

A final unproductive activity that arose during this period was rebellion against the colonialists. As Collier (2000) point outs, "rebellion is large-scale predation of productive economic activities" (p. 3). Guerilla fighters did not produce, but lived through transfers from peasant populations obtained primarily through coercion, threats of violence or direct force (Kriger, 1988; McCann, 1985).

4 Additional Predications of the Model and Related Empirical Evidence

4.1 Explaining Africa's Economic Deterioration since Independence

As documented by Artadi and Sala-i-Martin (2003), sub-Saharan Africa has been in economic decline over the past 30 years. Among the 40 countries of sub-Saharan Africa for which income data back to independence are available, 18 or 45% were poorer in 2000 than they were at independence.[7] A similar deterioration is also found in a recent survey on corruption reported in Hoddess (2001). Individuals from seven former British colonies were asked whether they felt that corruption is lower under the current government relative to the previous government. In only two of the seven countries did the majority of the respondents feel that there was less corruption under the current regime than the previous one (p. 309).

The model provides an explanation for this deterioration since independence. Consider the model's explanation for Africa's underdevelopment, shown in Figure 4. As argued, if the colonizer chooses an SR strategy, then x will increase over time. If at independence x is between x_B and $x_3^\star$, then after independence x will continue to increase and total production in the economy, given by $(1-x)A$, will continue to decrease. Therefore, the model is able to explain the fall in output and increase in corruption that has occurred since independence in many African countries.

4.2 Length of Colonial Rule and Severity of Extraction

The model provides an explanation for the seemingly contradictory findings of Bertocchi and Canova (2002), Nunn (2004) and Grier (1999). Bertocchi and Canova (2002) and Nunn (2004) show that European extraction, measured using either repatriated profits from the colony or the number of slaves exported during the slave trade, is negatively correlated with subsequent economic performance. This finding suggests that for African countries European contact was detrimental for growth. However, Grier (1999) finds that the longer a country was colonized the better it tended to perform after independence. This suggests that greater European contact was beneficial for growth. The model is able to provide a consistent explanation for the two seemingly contradictory results.

The measures of penetration used by Bertocchi and Canova (2002) and Nunn (2004) are captured by τ in the model. From the model we know that colonies with a lower τ are more likely to remain in the high production equilibrium after independence. Therefore, countries with lower rates of extraction during colonialism should perform better after independence. To see how the model is able to explain Grier's (1999) finding that colonies with longer periods of rule perform better, consider Figure 6 which reproduces

[7] These figures are based on the author's calculations using real per capita GDP data from the Penn World Tables Mark 6.1. The variable used is 'rgdpch'. For some countries data are unavailable for 2000. For these countries I use the most recent year for which data are available.

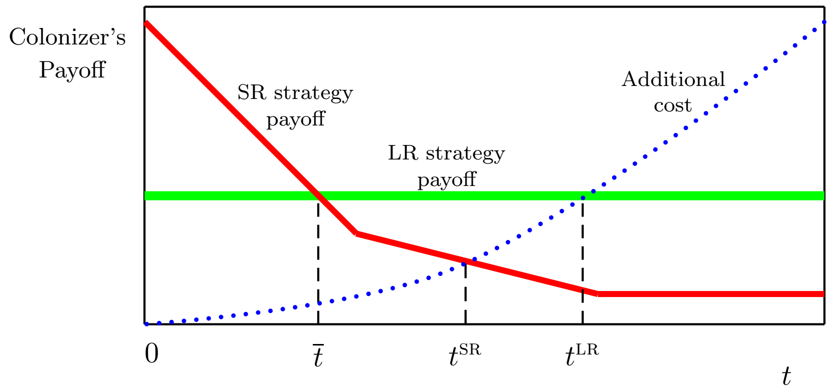

Figure 6: The decolonization process of a colonizer pursuing an LR strategy and a colonizer pursuing an SR strategy.

the stream of per period payoffs overtime under both colonial strategies from Figure 5. The two payoffs can be interpreted as representing two different colonies, with colonizers pursuing different strategies. Assume that there also exists an additional, initially unanticipated cost to colonialism that is increasing over time. This may be a political cost due to changing public opinion in the home country. The cost is given by the dotted line in the figure. If the cost increases sufficiently, then eventually the net benefit of the colony becomes negative. It it is no longer profitable to keep the colony and independence is granted. If independence occurs after period $\bar{t}$, then the colonizer pursuing the SR strategy will grant the colony independence sooner than the colonizer pursuing the LR strategy. This is shown in the figure where colonial rule lasts longer under the LR strategy: $t^{\text{SR}} < t^{\text{LR}}$. Intuitively, this is because in the long-run, colonies under LR strategies are more profitable than colonies under SR strategies, and therefore LR strategy colonies are kept longer than SR strategy colonies.

In the end, the two seemingly contradictory findings can be explained by the model. Colonies under an LR strategy are extracted from less and remain in the high production equilibrium, performing better after independence. Because in the long-run these colonies are more profitable, they are granted independence later than the less profitable SR strategy colonies.

4.3 Institutions, Settler Mortality and Equilibrium Selection

The model developed here complements the recent empirical work of Acemoglu et al. (2001). The study finds that among former colonies, different colonization strategies implemented by Europeans led to very different paths of development. Colonies where the European focus was on extraction did not develop and stagnated economically. In other colonies the focus was not on extraction and the colonizer implemented institutions to enforce the rule of law and protect private property. Today these colonies are among the richest 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 settlement was difficult and extractive institutions were implemented, while in areas with a low disease environment settle was possible and institutions of private property were implemented.

By providing a theoretical framework for their analysis, the model helps clarify two points from Acemoglu et al. (2001). First, it is not clear why initially implemented institutions should persist and why they should continue to matter decades after the end of colonialism. The model provides one explanation. In colonies with a high disease environment, 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 the colonizer pursued an SR strategy, with $\tau > 1 - q$. This led to a permanent movement to a low production equilibrium. These colonies remain trapped in this equilibrium today. On the other hand, colonies with a low disease environment could be settled and institutions to protect private property were implemented. In these areas the colonizer pursued an LR strategy with $\tau = 1 - q$ and the colony remained in the high production equilibrium.

Acemoglu et al. (2001) assume that in areas with low disease environments, settlement occurred and colonizers did not focus on extraction, but instead chose to implement good institutions. The model provides support for this assumption by showing that it is an equilibrium outcome of the game. This can be seen as follows. At this time, because of competition between European nations, control over foreign territory was tenuous. The best way to secure control of a region was through settlement. If a country was able to settle an area, they could be 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. Low rates of settler mortality increased settlement, which decreased the probability of the colonizer losing control of an area, raising δ. From Proposition 4 we know that the higher is δ, the more likely it is that an LR strategy is chosen. Overall, in areas where settlement was feasible, δ was high, and the colonizer was more likely to choose an LR strategy with a lower rate of extraction and more secure property rights.

5 Related Theoretical Literature

Other studies have formally modelled other aspects of colonialism. Grossman and Iyigun (1995, 1997) and Lucas (1990) model the profitability and choice of foreign investment by the colonizing country and Garoupa and Gata (2002) model the European decolonization process.

The model's second stage subgame is related to the theoretical literature on conflict and appropriation, beginning with Hirshleifer (1991) and Skaperdas (1992), and more recently Grossman and Kim (2002) and Mehlum et al. (2003). The model's second stage is also related to papers that model the existence of multiple equilibria in corruption or other unproductive activities. These studies include Murphy et al. (1993), Acemoglu (1995), Advig and Moene (1990), Ehrlich and Lui (1999), and Tirole (1996). The model developed in Acemoglu (1995) is the most similar to the model's second stage. He assumes that labor can be allocated to productive activities called 'entrepreneurship' or unproductive activities called '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: one equilibrium with no rent-seeking and another with a positive level of rent-seeking.

6 Conclusions

Findings from a number of recent empirical studies provide mounting evidence that Africa's poor performance in the second half of the 20th century can be partially explained by its unique history, which is characterized by two key events: the slave trade and colonial rule. Given this evidence, a natural question arises. Why do these events, which ended years ago, continue to matter today? I have developed a model, exhibiting path dependence, that provides one answer to this question. The model features multiple equilibria. There is one equilibrium with secure property rights and a high level of production and other equilibria with insecure property rights and low levels of production. I have shown that external extraction, when severe enough, causes a society initially in the high production equilibrium to move to a low production equilibrium. Because of the stability of low production equilibria, the society remains trapped in this suboptimal equilibrium even after the period of external extraction ends. This is how Africa's past continues to affect economic performance today.

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 produce, $x^\star = 0$.

From (4), if $\pi_{\mathrm{P}}(0) \geq \pi_{\mathrm{U}}(0)$, then a Nash equilibrium with $x = 0$ exists. Using (1) and (2), 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 $\pi_{\mathrm{P}}(x) > \pi_{\mathrm{U}}(x)$ for all values of x, and no additional equilibria exist.

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

If $q = .5$, then $\pi_{\mathrm{P}}(.5) = \pi_{\mathrm{U}}(.5)$. Condition (4) is satisfied and one additional Nash equilibrium exists, with $x^\star = .5$ when $q = .5$.

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

First consider possible equilibria with $x > .5$. From (1) and (2) it follows that if $x > .5$, then $\pi_{\mathrm{P}}(x) = \pi_{\mathrm{U}}(x)$ when $x = q$. Therefore, (4) is satisfied and an additional Nash equilibrium exists with $x^\star = q > .5$.

If $x < .5$, then $\pi_{\mathrm{P}}(x) = \pi_{\mathrm{U}}(x)$ when $x = 1 - q$. Therefore, an additional Nash equilibrium exists with $x^\star = 1 - q < .5$. Q.E.D.

Proof of Proposition 2. Using (1), (2), and (9), $F'(x^\star)$ can be written

$$F'(x^\star) = \begin{cases} \gamma A(2x^\star - 1 + q) & \text{if} \quad x^\star \leq .5 \\ \gamma A(2x^\star - 1 - q) & \text{if} \quad x^\star \geq .5 \end{cases} \tag{16}$$

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 $x^\star = 0$.

From Proposition 1, there exists a Nash equilibrium with $x = 0$, for all values of q and A. From (16), $F'(0) = -\gamma A(1-q) < 0$. Therefore, this equilibrium is stable for all values of q and A.

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

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

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

Consider each of the two Nash equilibria from Proposition 1. First, consider the equilibrium with $x^\star = q > .5$. From (16), $F'(q) = -\gamma A(1-q) < 0$; therefore, this equilibrium is stable. Next, consider the equilibrium with $x^\star = 1 - q < .5$. 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 $x^\star = 0$. Any initial population proportion to the right of the unstable equilibrium will converge to $x^\star = q > .5$. 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 (5) and (5), it follows that a necessary and sufficient condition for the existence of a unique Nash equilibrium with $x^\star > .5$ is that $\pi_{\text{U}}(0,\tau,q) > \pi_{\text{P}}(0,\tau,q)$. Using (1) and (2), this condition is equivalent to

$$\tau > 1 - q \tag{17}$$

Given (4), from (1) and (2) it follows that if $\tau > 1-q$, then the unique Nash equilibrium is

$$x^\star = \frac{q}{q + (1-\tau)(1-q)} \tag{18}$$

which is greater than .5 for all (τ,q) that satisfies $\tau > 1 - q$. Using (16) and (18),

$$F'(x^\star) = -\gamma A\,(1-\tau)\,(1-q) < 0 \tag{19}$$

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

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