Resources, Conflict and Development Choices – Public Good Provision in Resource Rich Economies*

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Abstract

Natural resource wealth can be a blessing or a curse for a country. The differing experiences come in several forms, one of them being the (under)provision of public goods. We argue that the threat of conflict - inherent when a country possesses resources - impacts upon the policy choice of a leader. In particular, we model the policy choice of a ruler in a resource rich country who can, either invest in military repression or in productive public goods, such as physical and social infrastructure. While both policies aim at keeping the population from fighting over the resource, which of the two is chosen depends on the relative effectiveness of the ruler and the population in contesting the resources. Depending on these parameters, different policy choices are taken, and thus differing experiences of resource rich countries are explained. We present empirical evidence consistent with the hypotheses put forth by the model.

Keywords: Resource curse, Public good provision in dictatorships

JEL: O13; O50

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1 Introduction

Recent studies in political economy have found that the quality of leaders, particularly in authoritarian regimes, is a key determinant of economic outcome (Jones and Olken, 2005). If true, the fate of resource-rich countries, often ruled by non-democratic or authoritarian regimes (Ross, 2001) is shaped by the policy choices made by these regimes.[1] Robinson (2001) has analysed some of the key policy choices made in dictatorships. In particular, he investigates what drives non-democratic countries to choose predatory policies while pro-development policies—in the form of public good investment—are more efficient. He shows that the threat of political replacement consecutive to developmental policies may deter public investment. In this context, he argues that the presence of natural resources—easily appropriable by incumbent elites—creates an even greater disincentive to invest in necessary public goods.

Under this backdrop, the propensity of resources to generate civil conflicts (Collier and Hoeffler, 1998 and 2004), or political replacement, may explain that some autocrats see under-development and repression as optimal policies as they prevent potential contenders from threatening their hold on the country's riches. For instance, Zaire under Mobutu's reign saw its road network literally "disintegrate"; out of the 90,000 miles of road at independence in 1960, only 6,000 miles were left by 1980. Robinson (2001) Under-investment in essential infrastructure was so common that some observers view it as a deliberate strategy of underdevelopment to maintain his position and thwart potential opposition. (Callaghy, 1984; Robinson, 2001; and Acemoglu et al., 2004) Similarly, in the nineties under authoritarian regimes, child immunisation against DPT (diphtheria, pertussis and tetanus) and measles fell in Nigeria from 54% to 26% and from 54% to 35% respectively.

However, the major shortcoming of these papers is their failure to explain the substantial disparity in the provision of productive public goods among resource-rich countries. Malaysia for instance has consistently invested in physical and social infrastructure. Over the 1990s, measles immunisation progressed by 18 percentage points (from 70% to 88%), while secondary school enrollment increased from 56% to 69%. Power generation also almost doubled between 1990 and 1995 from 282 to 520 kWh per capita. Given the importance of social and physical infrastructure as a determinant of growth and development (Calderon and Serven, 2004), these large variations in public good provision may contribute to explain the large variations in economic performance among resource-rich countries.

Such heterogeneity calls for a *conditional theory.* (Dunning 2005) Why do resource-rich countries vary considerably in providing essential and productive public goods to their populations? For instance, why did Botswana consistently invest the revenues from diamonds in productive infrastructure, education and health (Acemoglu et al., 2003) while Nigeria (Barro and Subramanian, 2003) and many others did not? This paper tries to provide some answers to this question.

In this paper, we investigate what determines the decision of a self-interested ruling elite (represented by an autocrat), in a resource-rich country, to invest in productivity enhancing public goods[2] given the looming threat of conflict. In particular, we examine the conditions under which an autocrat finds it optimal to buy the peace by creating incentives for the people to allocate their effort to productive activities (which both can

[1] Our work focuses on dictatorships and does not explain why countries like Norway, the US, Canada or Australia have escaped the so-called curse. Nor does it say much about the evidence of the resource curse among regions of the same country—see Michaels (2006) for evidence in American states.

[2] The idea that it makes rational sense for an autocratic ruler to invest in public goods as they increase production which in turn accrues (at least in part) to the ruler is discussed for example in McGuire and Olson (1996).

benefit from) rather than to fight over the control of the resources. We develop a Stackelberg game to analyse the strategic interaction between a ruler and its population, where potential conflict over natural resources drives the optimal policy choice made by the ruler. In particular, we are concerned with the extent to which the ruler's decision to provide a public good is affected by the potential conflict over natural resources.

In this model, the ruler has two instruments to keep the population from contesting the resources. One is to try to lure the people into production by increasing productivity (by means of public good provision), the other is to simply militarily oppress them. The people, by contrast, choose the allocation of their time between working in the non-resource sector and fighting to appropriate resources. We show that the ruler's policy choice depends critically on 1) the investment worthiness of the non-resource sector; 2) the extent of the resource wealth; and 3) the ruler's and the people's relative effectiveness in fighting over the resource. The dictator is likely to invest in public goods when the non-resource sector is productive enough. He is less likely to do so if he is relatively effective in appropriating the resources—compared to the people. If, on the other hand, the ruler is relatively ineffective in controlling the resources, he is more likely to invest in development of the economy.

We provide empirical evidence that gives support to the predictions of our theoretical framework using data on physical infrastructure (power generating capacity, and road network) and social infrastructure (education and health) as proxies for public goods provision. We use a panel with and without country fixed effects to estimate both the effect of resources and the effect of the ruler's effectiveness in controlling resources on public good provision. We find that the combination of resource wealth and the ruler's effectiveness in controlling resources is negatively associated with public good levels. This finding corroborates our theory and points to a channel through which leaders' choices in resource-rich countries may impede or encourage investment in public goods.

The paper follows the tradition of conflict models in economics. Like Grossman (1994) and Azam (1995), we assume the *people* might rebel and fight against the *ruling elite*. The dilemma between repressing the people or buying the peace is also analysed within this literature by Azam (1995) and Wick (2008). Our paper also relates to the empirical literature on resources and conflict. Seminal contributions by Collier and Hoeffler (1998, 2004) present empirical evidence that resource wealth triggers conflicts and civil war. Their work provides support for two assumptions we make: 1) that agents in resource-rich countries have a strong incentive to engage in appropriation rather than productive activities; 2) that the outbreak of a conflict is more likely when earnings foregone from rebellion are low.

This paper makes two contributions to the current literature. First, it offers a conditional theory that accounts for the diverging policy choices among resource-rich countries and therefore contributes to a better understanding of the resource curse. Second, our predictions are tested empirically. To the best of our knowledge only Mehlum et al. (2006) make such contributions to the resource curse literature.

The paper is organised as follows: In section 2, we lay out the fundamentals of the model and explain our assumptions in detail. We then turn to a concrete specification of the model. In section 3, we discuss the ruler's decision to invest and find the determinants of his policy choice. Based on this we derive in some testable predictions of the theoretical model. Section 4 provides an empirical analysis. Finally, section 5 concludes.

2 The model

Consider a resource-rich country populated by two groups, the ruling elite represented by a self-interested and authoritarian ruler and the population.[3] The economy consists of two sectors, a resource sector which generates a resource rent Z and a non-resource sector (agriculture or manufacturing). Both sectors are potential sources of income for both groups. Following Caselli (2006), the non-resource sector output is divided between the two groups according to some exogenous parameter τ. On the other hand, the ruling elite considers the resource stock and the associated earnings Z as its own property. The division of the resource rent may create a conflict between the ruling elite and the population and depends on their respective efforts to appropriate it.

The ruler and the population have two possible actions at their disposal. The population allocates its time endowment (T) between working in the non-resource sector (W) and fighting (E) the ruler in an attempt to capture part of the resource earnings. By contrast, the ruler can initiate a development policy by investing in a productivity enhancing public good ϕ. He can also use force and repress (R) the population to deter it from contesting the resource rent.

2.1 Fundamentals of the model

The non-resource sector produces according to the production function $(1 + A)f(\phi, W)$, where A is productivity, $\phi = \{0, 1\}$ is the binary investment decision (1 represents investment, and 0 means no investment).[4]

Assumptions PF[5]: $\dfrac{\partial f}{\partial \phi} > 0$, $\dfrac{\partial f}{\partial W} > 0$, $\dfrac{\partial^2 f}{\partial W^2} \leq 0$ and $\dfrac{\partial^2 f}{\partial \phi \partial E} < 0$

We assume that production increases with investment and work effort, and exhibits non-increasing returns to labour. Moreover, a marginal rise in the fighting effort causes production to decrease at an increasing rate when investment is undertaken. In other words, the marginal cost in terms of lost production increases with ϕ.

The population allocates its time T between working W and fighting E so that $T \geq W + E$. Its effort in contesting the ruler's control over the resource rent has an adverse effect on the level of output produced in the non-resource sector.[6] However, it gives the population the opportunity to appropriate or grab a share of the resource rent according to a so-called grabbing function $G(E, R)$. Consequently, a share of the resource $(1 - G(\cdot))$ accrues to the government.

Assumptions GF: $\dfrac{\partial G}{\partial E} > 0$, $\dfrac{\partial G}{\partial R} < 0$, $\dfrac{\partial^2 G}{\partial E^2} < 0$, $\dfrac{\partial^2 G}{\partial R^2} > 0$, and $\dfrac{\partial^2 G}{\partial R \partial E} < 0$

[3] Following Robinson (2001), our model only applies to authoritarian regimes, where a ruling group takes decisions purely motivated by self-interest. This captures the situation in many (developing) resource-rich countries.

[4] See for example Dunning (2005) who also models public good investment as a binary choice variable.

[5] Since ϕ is a discrete variable strictly speaking the partial derivative with respect to ϕ is not defined as such. For expositional purposes, and notational ease, we however use it throughout this paper.

[6] Because the endowment constraint of the people is binding in the equilibrium, an increase in fighting effort results necessarily in a decrease in working effort ($\frac{\partial W}{\partial E} \geq -1$), leading to a lower level of output in the non-resource sector.

We assume that the share of resources grabbed by the population increases with their fighting effort E and decreases with the ruler's repression R. The grabbing function is also assumed to have decreasing returns in E and is convex in R. In other words, both the marginal benefit to the people from fighting $\frac{\partial G}{\partial E}$, and the marginal benefit to the ruler from repressing $\left|\frac{\partial G}{\partial R}\right|$ decrease respectively in E and R. In addition, a marginal increase in E causes grabbing to increase at a decreasing rate as R increases, that is the marginal benefit to the population from grabbing decreases with R.

The ruler chooses two actions. First, he can invest in a productivity enhancing public good. This investment (e.g. road network, a hospital or a school) comes at investment cost I. The payoff from investing in a public good increases with the level of productivity A. We investigate when—i.e. at which levels of productivity A—a self-interested ruling elite chooses to invest in a public good. Second, the ruler chooses the repression effort R to prevent the people from grabbing resources and incurs some costs $c(R, \phi)$.

Assumptions CF: $\frac{\partial c}{\partial \phi} > 0$, $\frac{\partial c}{\partial R} > 0$, $\frac{\partial^2 c}{\partial R^2} = 0$, and $\frac{\partial^2 c(R, \phi)}{\partial R \partial \phi} > 0$

The total cost of repression is assumed to increase with the amount of repression R and with public good provision. In addition, the marginal cost of repression increases with ϕ. Because investment in public goods results in better educated and healthier people, running a repressive dictatorship then becomes more costly to the ruler. This follows Robinson's (2001) argument that many authoritarian rulers are unwilling to construct or maintain socially productive infrastructure because providing such public goods may "reduce the cost of contesting elite control". As an example we may reasonably assume that it is harder to repress well educated people because they have more interest in public affairs and demand more accountability from the government.[7] A similar assumption is also found in Bourguignon and Verdier (2000) and Dunning (2005).

To sum up, the interaction between the two agents takes place according to the following timing:

1. For a given A, the ruler decides whether to invest: $\phi = \{0, 1\}$

   Then the **subgame** Γ starts:

2. **Stage 1** of the subgame Γ: Population reacts choosing a fighting effort E (where the working effort W is determined simultaneously)
3. **Stage 2** of the subgame Γ: Ruler chooses a repression level R in response to E
4. Conflict is settled with each contender grabbing a share of the available natural resources according to his equilibrium strategy. Output in the non-resource sector is produced and divided between the two groups according to the parameter τ.

[7]Formally correct would be the following specification. We assume that the flow variable ϕ increases the stock of human capital in the economy, that is $H = h(\phi)$, with $\frac{\partial h}{\partial \phi} > 0$. As just discussed, we further assume that people with higher human capital are harder to repress, that is repression costs are higher. Formally this means repression costs $c = c(H)$ with $\frac{\partial c}{\partial H} > 0$. One can now readily verify that $\frac{\partial c}{\partial \phi} > 0$. As a shortcut we include ϕ directly into the repression cost function.

First, the ruler chooses whether or not to invest in the public good. Conditional on the investment decision observed by the population, a contest over the resources takes place in subgame Γ where the players decide sequentially their appropriative efforts. This subgame features a Stackelberg contest where the population has the first move. The ruler reacts by an appropriate repression level. With this timing, we take the view that the lack of the ruler's provision of necessary public goods will fuel discontent among the population and lead to rebellion. We have nonetheless tried a different time sequence where the ruler is the first mover in the subgame. We found that the results are qualitatively similar: the order has no impact on the comparative statics although it affects the equilibrium levels of fighting and repression. We chose the timing laid out above because it provides simpler expressions for the equilibrium levels and the comparative statics that are fairly easy to interpret. By backwards induction, we first solve for the equilibrium outcome in the subgame Γ and later analyze the investment decision of the ruler.

2.2 Specification of the model

In this section we derive the results of the model using a specific functional form. We specify the total production of the economy, given inputs (A, ϕ, W) as:

$$(1+A)f(\phi, W) = (1+A)(1+\phi)(1+W) \tag{1}$$

It is easily verified that for $\phi = 0$ the production function exhibits decreasing returns to scale. If $\phi = 1$ on the other hand we find that the production function exhibits decreasing returns if and only if $W < \frac{1}{\lambda}$, where λ is the scaling factor of inputs.[8]

The repression costs are specified as:

$$c(\phi, R) = c(1+\phi)R \tag{2}$$

Resource earnings are split between the two parties according to the so-called "grabbing function". This is given by:

$$G(E, R) = \min\left(\frac{E^{\alpha}}{R^{\gamma}}, 1\right), \tag{3}$$

where G denotes the share of the resource grabbed by the rebels and $0 < \alpha < 1$ and $0 < \gamma < 1$. These conditions ensure that G is well behaved. The two parameters α and γ capture the elasticity of the grabbing function with respect to the respective fighting inputs, E and R. If $\alpha < \gamma$, a one percent increase in the fighting input by the government has more effect on the grabbing outcome than a similar increase in the rebels' fighting. Thus the difference $\alpha - \gamma$ reflects the relative effectiveness of the opponents in the contest. If $\alpha < \gamma$, the ruler is more effective in keeping control of the resources whereas if $\alpha > \gamma$, the population is more effective in grabbing resources. Said differently, if $\alpha < \gamma$ the same effort level of both groups is translated in more effective fighting power of the government as compared to the people's. The two parameters α and γ play a crucial role in determining the outcome of the model.

We are now ready to solve the subgame Γ by backward induction. Note that we will focus on interior solutions.[9] In the second stage of the subgame, the ruler's problem is:

[8] Traditionally returns to scale are increasing iff $f(\lambda\phi, \lambda W) > \lambda f(\phi, W)$.

[9] Formally this means we assume $(1+A)(1+\phi)^{\frac{\alpha-\gamma}{\alpha}} > \frac{\alpha}{(\gamma+1)(1-\tau)}\left(\frac{c}{\gamma}\right)^{\frac{\gamma}{\alpha}} Z^{\frac{\alpha-\gamma}{\alpha}}$.

$$\max_{R} \ \tau(1+A)(1+\phi)(1+W) + \left(1 - \frac{E^{\alpha}}{R^{\gamma}}\right) Z - c(1+\phi)R - I \tag{4}$$

The ruler's reaction function is:

$$R(E) = \left(\frac{\gamma Z}{c(1+\phi)}\right)^{1/(\gamma+1)} E^{\alpha/(\gamma+1)} \tag{5}$$

In the first stage of the subgame Γ, the people maximize their own payoff taking into account the ruler's reaction:

$$\max_{E} \ (1-\tau)(1+A)(1+\phi)(1+W) + \left(\frac{\gamma Z}{c(1+\phi)}\right)^{-\gamma/(\gamma+1)} E^{\alpha/(\gamma+1)} Z \tag{6}$$

$$s.t. \ E + W \leq T \tag{7}$$

Note that the endowment constraint is always binding. If that was not the case then at the optimum, we could slightly increase E and R, satisfy the constraint while increasing the population's payoff. This is a contradiction of the optimum.

The subgame perfect equilibrium of Γ is given by (E^*, R^*):

$$E^* = K_1 \left(\frac{Z}{1+\phi}\right)^{\frac{1}{\gamma+1-\alpha}} (1+A)^{-\frac{\gamma+1}{\gamma+1-\alpha}} \qquad \text{where} \quad K_1 = \left(\frac{\alpha}{(\gamma+1)(1-\tau)}\right)^{\frac{\gamma+1}{\gamma+1-\alpha}} \left(\frac{c}{\gamma}\right)^{\frac{\gamma}{\gamma+1-\alpha}} \tag{8}$$

$$R^* = K_2 \left(\frac{Z}{1+\phi}\right)^{\frac{1}{\gamma+1-\alpha}} (1+A)^{-\frac{\alpha}{\gamma+1-\alpha}} \qquad \text{where} \quad K_2 = \left(\frac{\alpha}{(\gamma+1)(1-\tau)}\right)^{\frac{\alpha}{\gamma+1-\alpha}} \left(\frac{\gamma}{c}\right)^{\frac{1-\alpha}{\gamma+1-\alpha}} \tag{9}$$

$$G = K_3 \left(\frac{Z}{1+\phi}\right)^{\frac{\alpha-\gamma}{\gamma+1-\alpha}} (1+A)^{-\frac{\alpha}{\gamma+1-\alpha}} \qquad \text{where} \quad K_3 = \left(\frac{\alpha}{(\gamma+1)(1-\tau)}\right)^{\frac{\alpha}{\gamma+1-\alpha}} \left(\frac{c}{\gamma}\right)^{\frac{\gamma}{\gamma+1-\alpha}} \tag{10}$$

Proposition 1

1) *The population's fighting effort decreases with investment and higher productivity, but increases with resource wealth.*

2) *The ruler's repression level decreases with investment and higher productivity, but increases with resource wealth.*

3) *Grabbing decreases with higher productivity. It is ambiguous with respect to investment and resource wealth, and depends on the opponents effectiveness in the contest.*

Proof: derive the partial derivatives.■

This proposition suggests three important results. First, investment in the public good reduces both the population's fighting effort E and the ruler's repression R. Indeed, the people fight less as a result of an investment in ϕ since the increase in marginal cost of fighting in terms of lost production is greater than the increase in marginal benefit of fighting. In other words, by investing in ϕ, the ruler raises the population's opportunity cost of fighting so that fighting becomes less profitable than engaging in the productive activity. Moreover, because investment increases the marginal costs of R by Assumption CF, the provision of a public good leads to a lower level of R for each level of E.

Second, more fighting leads to more repression because an increase in E raises the marginal benefit of repressing (i.e. R has more effect on the grabbing outcome if E is high by Assumption GF) without affecting the marginal costs of repressing. A consequence of these two results is that E and R change in the same direction, which implies that the effect of ϕ and Z on the grabbing function is a priori ambiguous. In particular, the effect depends on the sign of $\alpha - \gamma$. Grabbing increases in ϕ when $\alpha < \gamma$ and decreases in ϕ when $\alpha > \gamma$. Indeed, the provision of a public good causes E and R to decrease proportionately so that the ratio $\frac{E^*}{R^*}$ is independent of ϕ.[10] When $\alpha > \gamma$ the decrease in the fighting effort E has a larger impact on grabbing than the decrease in repression R so that the ruler can control more resources and $G(.)$ decreases. This is because the loss of an effective unit of E is more detrimental to the population when $\alpha > \gamma$ than the loss of a (less effective) unit of R is to the ruler. When $\alpha < \gamma$, the opposite is true.

Third, an increase in resource wealth raises the stakes of controlling the resources and therefore intensifies conflicts (more fighting and more repression). Both opponents increase their effort in contesting the resource. Thus, the effect on grabbing is ambiguous and depends on the effectiveness in fighting: the most effective party will have the advantage.
In contrast, by increasing the people's opportunity cost of fighting, a more productive non resource sector (i.e. a higher value of A) is conducive to a less conflict-prone environment. The population reduces its fighting effort E. This in turn leads to a lower level of repression R. It also results in a decrease in grabbing $G(.)$, because a higher A decreases E more than R.

3 Ruler's investment decision

3.1 Characterisation of the decision

In order to understand when a self-interested ruler in a resource-rich country finds it optimal to invest, we now consider his investment decision given the subgame perfect equilibrium discussed above. In the previous section we laid out the players' responses to a public good investment. Under certain conditions, the provision of a public good might bring about an undesirable outcome from the point of view of the ruler (through the effect of public good provision on the conflict outcome), since—as we just saw—the sign of the change in grabbing as a result of public good provision is ambiguous. If those conditions occur, they discourage public good investment. Given the equilibrium strategy in subgame Γ, the ruler's investment decision depends solely on the productivity level A. The objective of the present section is to find the productivity levels A for which the ruler finds it in his best interest to invest.

[10] $\frac{E^*}{R^*} = \frac{c}{\gamma} \frac{\alpha}{(1+\gamma)(1-\tau)} \frac{1}{(1+A)}$ is independent of ϕ. Independence depends on the assumption that both the production function and the cost of repression are linear in $1+\phi$.

The ruler solves the following problem:

$$\max_{\phi} \left(\Pi_G(A, \phi = 1) - I, \Pi_G(A, \phi = 0)\right) \tag{11}$$

He chooses the strategy (investment or no investment) that gives him the highest payoff. Investment is optimal if and only if the relative benefit of investing exceeds the cost (I) :

$$\Delta\Pi_G \equiv \Pi_G(A, \phi = 1) - \Pi_G(A, \phi = 0) \geq I \tag{12}$$

Before solving this problem, we first carry out a discussion of the relative value of investing $\Delta\Pi_G$. A formal analysis of the properties of $\Delta\Pi_G$ is undertaken in Appendix A.1.

$$\begin{aligned} \Delta\Pi_G &= \tau(1+A)(1+T) + \overbrace{\tau(1+A)[E^*(\phi=0) - 2E^*(\phi=1)]}^{(i)} \\ &- \underbrace{[G(\phi=1) - G(\phi=0)]}_{(ii)} Z - \underbrace{c[2R^*(\phi=1) - R^*(\phi=0)]}_{(iii)} \end{aligned} \tag{13}$$

The relative value of investing $\Delta\Pi_G$ is equal to the increase in output resulting from investment plus *additional effects* captured by three additional components: *(i)* represents the impact of the people's fighting effort on the non-resource output when a public good is provided; *(ii)* is the difference in grabbing due to investment; and *(iii)* reflects the difference in repression costs triggered by investment. This can be written as:

$$\Delta\Pi_G = \tau(1+A)(1+T) + \underbrace{[\tau P_1 - cP_2 - P_3] Z^{\frac{1}{\gamma+1-\alpha}} (1+A)^{-\frac{\alpha}{\gamma+1-\alpha}}}_{\text{additional effects}} \tag{14}$$

where $P_1 = \left[1 - \left(\frac{1}{2}\right)^{\frac{\alpha-\gamma}{\gamma+1-\alpha}}\right] K_1$, $P_2 = \left[\left(\frac{1}{2}\right)^{\frac{\alpha-\gamma}{\gamma+1-\alpha}} - 1\right] K_2$, $P_3 = \left[\left(\frac{1}{2}\right)^{\frac{\alpha-\gamma}{\gamma+1-\alpha}} - 1\right] K_3$.

These effects reflect the impact of public good provision on the contest in resource-rich countries. Their direction and magnitude depend on the sign of $\alpha - \gamma$. When $\alpha < \gamma$, slightly less effort is devoted to resource appropriation (E^* and R^* decrease slightly) as a consequence of public good investment. This has the positive effect of raising the output. However this positive effect is outweighed by two negative effects. First, the population grabs more of the resources because the decrease in E^* and R^* has a detrimental effect on the resource appropriation of the more effective contender (the ruler in this case). This finding was discussed in section 2. Second, public good provision results in higher total costs of repression because the increased unit cost of repression offsets the decrease in R^*. Thus the sum of the additional effects of public good investment is negative if $\alpha < \gamma$.

On the other hand, public good investment causes both the people and the ruler to decrease substantially their appropriation effort when $\alpha > \gamma$. This has three positive effects on the ruler's payoff: First, the output from the non-resource sector increases as the people provide significantly more working effort. Second, the people grab less of the resource, and therefore more of the resource is left for the ruler.[11] Third, total repression costs decline since the increase in unit costs of repression is offset by the dramatic fall in the ruler's repression level.

We can now shed light on our main question as to when an authoritarian ruler finds it optimal to invest in public goods rather than carry out predatory policies.

Lemma:

1) For any α and γ, if $\Delta\Pi_G(A=0) < I$, then there exists a unique A^* such that investment is optimal for any $A \geq A^*$. A^* is defined as $\Delta\Pi_G(A^*) = I$

2) For any α and γ, if $\min_A [\Delta\Pi_G(A)] > I$, then investment is optimal for any A.

Proof: See Appendix A.2.■

Intuitively, only sufficiently high productivity levels in the non-resource sector give the ruler the incentive to invest in the economy. In other words, there is a productivity threshold A^* above which investment becomes optimal. The level of the threshold is informative of the likelihood of the ruler to undertake an investment in public goods. The higher the productivity threshold, the less likely investment will be; inversely, a lower threshold makes investment more likely.

The productivity threshold A^* solves $\Delta\Pi_G(A^*) = I$ so that:

$$\tau(1+A^*)(1+T) + (\tau P_1 - P_2 - P_3) Z^{\frac{1}{\gamma+1-\alpha}} (1+A^*)^{\frac{-\alpha}{\gamma+1-\alpha}} - I = 0 \tag{15}$$

Resource wealth affects the threshold A^* and the direction of their relationship is determined by the sign of $\alpha - \gamma$.

Proposition 2:

In a resource-rich country the ruler's investment decision is characterized by:

1) If $\alpha > \gamma$ then $\dfrac{\partial A^*}{\partial Z} < 0$

2) If $\alpha < \gamma$ then $\dfrac{\partial A^*}{\partial Z} > 0$.

Proof: See Appendix A.3.■

This proposition says that increased resource wealth provides a disincentive to invest in productive public goods if the ruler is relatively more effective in contesting the resource. In addition, increased resource wealth

[11] As explained in the discussion following proposition 1, a proportionate decrease in E^* and R^* has a detrimental effect on the resource appropriation of the more effective contender (in this case the people).

provides an incentive to invest in productive public goods if the people are relatively more effective in grabbing the resource. A corollary of this proposition is stated as follows.

Corollary:

$A^*_{\alpha>\gamma} < A^*_{\alpha<\gamma}$, *that is in a resource-rich country the provision of public goods requires a lower productivity when* $\alpha > \gamma$ *than when* $\alpha < \gamma$.

Proof: See Appendix A.4.■

The model accounts for the differing investment behaviour of rulers in resource-rich countries according to the respective effectiveness of the population and the ruler in contesting the resource rent. A ruler who can secure the control over resources easily will tend to invest less in public goods than a ruler whose population is effective in contesting the resource rent. By investing in a productive public good, the ruler provides an incentive to work in the non-resource sector rather than fight over the resource riches. Providing such incentive is obviously more pressing when the ruler faces a population effective in fighting and appropriating the resources.

3.2 Testable predictions

The key prediction of the model is that the effect of the resource rent on the investment decision depends on the effectiveness of the two parties in contesting resources. We test this prediction by estimating the following econometric specification:

$$PG_{it} = \beta_0 + \beta_1 Resources_{it} + \beta_2 Strong_{it} + \beta_3 Resources_{it} * Strong_{it} + \beta_4 X_{1it} + \varepsilon_{it} \tag{16}$$

where PG_{it} denotes country i's level of the public good at time t; $Resources_{it}$ is the amount of resource rent; $Strong_{it} = 1$ indicates that the ruler is more effective than the people in appropriating resources (that is in terms of the theoretical model the case where $\alpha < \gamma$); X_{1it} denotes all the other control variables. We are interested in coefficients β_1 and β_3: β_1 represents the marginal effect of resources on the public good provision when $Strong_{it} = 0$; while β_3 indicates how the effect of resource rent differs between an effective ruler ($Strong_{it} = 1$) and an ineffective one ($Strong_{it} = 0$). Finally, the sum $\beta_1 + \beta_3$ reflects the effect of resource rent when $Strong_{it} = 1$. The model predicts that $\beta_1 > 0$ and $(\beta_1 + \beta_3) < 0$, implying that while an ineffective ruler has an incentive to provide more public goods as resource rent increases, public good supply decreases with the resource rent in the presence of an effective ruler. This happens if the negative interaction effect outweighs the positive direct effect, i.e. if $\beta_1 > 0$, $\beta_3 < 0$ and $|\beta_3| > \beta_1$.

Second, we test the prediction that, ceteris paribus, public good investment is (i) less likely when the ruler is effective in controlling the resources; and (ii) more likely when he is not effective in doing so. This prediction is tested using specification (16). We predict that $\beta_2 + \beta_3 Resources_{it} < 0$ as the resource level increases.

4 Empirical Analysis

4.1 Data

Our data set runs from 1970 to 2000 and contains 67 countries that have been led by an authoritarian regime at some point since 1970. We use the variable polity2 from Polity IV dataset to indicate whether a regime is authoritarian. For any given year, a country with a polity2 score less than or equal to 0 is considered authoritarian.

Dependent variables Following the literature on the determinants of provision of public goods, we define public goods as "goods or services enjoyed by all or a large share of a jurisdiction".[12] As the dependent variable, we use physical infrastructure—power generating capacity and road network—and social infrastructure—education and health indicators. These variables are used as a proxy for public good provision. We believe that the provision of these public goods by the state is indicative of the state's commitment to development policies. Although the model treats the decision of providing a public good as discrete, the empirical analysis will be concerned with public goods as continuous variables. Empirically, it is more meaningful to think of the supply of public goods in terms of levels and not as a binary decision. For instance, whether a country extends its road network by 1 km or 100 km is the same binary decision while it is certainly different if we consider the potential contribution of 1km and 100 km to development.

The data on the stock of physical infrastructure includes 1) electricity generating capacity measured as the number of kWh available per capita in log (from Canning, 1998) and spans the period 1970–1995; 2) the road network in km per square km expressed in log (from Canning and the World Development Indicators, 2006) and covers the period 1970–2000.

The data on illiteracy rate comes from the World Development Indicators and covers the years 1970–1999. For clarity, this variable has been transformed into literacy rate (where literacy rate is 100 minus illiteracy rate).

The public health data measures the percentage of children aged 12-23 months who have been immunised against DPT and Measles. The immunisation series come from the World Development Indicators (1980–2000).

Key Independent Variables In the theoretical model, we have established that the ruler's relative effectiveness in appropriating the resource crucially determines public good provision. We hypothesise that such effectiveness is derived from the form of the political power. In particular, we assume that the elite is effective in appropriating and keeping the resources for its own benefit whenever the state is controlled by the most autocratic regimes. Here, we capture such regimes as those ruled by leaders who have no finite term constraint.[13] When they face popular discontent, these strong regimes are able to successfully contain

[12] See for example Lake and Baum (2001), Deacon (2003), and Deacon and Saha (2006) for a review of the literature.

[13] Note that the average polity score for such countries is -6.19 so that these regimes qualify to Fearon and Laitin's definition of full autocracy. As an illustration, Malaysia has been ruled by autocrats with a finite term constraint, while was Nigeria led by dictators with no constraints on their terms.

civil strife through repression (Fearon and Laitin, 2003; Hegre et al., 2001; and Muller and Weede, 1990), and are therefore considered to be relatively effective in controlling resource rents. We construct a dummy variable $Strong_{it}$ (with value 1 when the ruler has no finite term) from the Database of Political Institutions compiled by Beck et al. (2004 update). This series covers the period 1975–2000.

We use resource rents as the measure of *contestable* resource endowment. The data is provided by K. Hamilton and G. Ruta from the World Bank and covers the period 1970–2000. Resource rent is measured as the product of the quantity of resources extracted by the difference between the resource price and the average extraction cost. It is expressed as a percentage of the GDP.[14]

Descriptive Evidence Table 4.1 below displays the mean and standard deviation of our main variables broken down into two sub-samples: rulers *with* finite term constraint and rulers *without* finite term. Casual observation suggests that the countries governed by rulers with no constraint on their term provide less public goods on average. These countries are also substantially more dictatorial (with a average polity score of -6.18 vs. -0.88 for their constrained counterparts) and more resource abundant (18% of GDP as opposed to 7.6%).

Table 1: Descriptive Evidence of Key Variables

Sample (1975 - 2000)			
Variables	Obs	Mean	Std. Dev.
Power Generation (kWh per capita in log)	1363	4.60	1.53
Phone Lines (per 1000 people in log)	1326	2.46	1.56
Literacy Rate in %	1542	59.79	23.00
Immunization DPT in %	1284	62.72	26.37
Immunization MSL in %	1257	63.38	25.10
Polity Score	1704	-2.75	6.16
Resource Rent in % GDP	1565	11.04	16.11

Sub-Sample: Rulers *with* Finite Term			
Variables	Obs	Mean	Std. Dev.
Power Generation (kWh per capita in log)	843	4.65	1.35
Phone Lines (per 1000 people in log)	829	2.59	1.49
Literacy Rate in %	985	64.57	22.25
Immunization DPT in %	885	65.68	23.42
Immunization MSL in %	869	66.53	22.55
Polity Score	1105	-0.88	6.31
Resource Rent in % GDP	1041	7.56	10.53

Sub-Sample: Rulers *without* Finite Term			
Variables	Obs	Mean	Std. Dev.
Power Generation (kWh per capita in log)	520	4.51	1.78
Phone Lines (per 1000 people in log)	497	2.26	1.65
Literacy Rate in %	557	51.34	21.85
Immunization DPT in %	399	56.15	30.98
Immunization MSL in %	388	56.32	28.82
Polity Score	599	-6.19	4.02
Resource Rent in % GDP	524	17.96	21.99

[14] This measure includes coal, oil, natural gas, and ten different minerals—bauxite, copper, gold, iron, lead, nickel, phosphate, silver, tin, zinc.

4.2 Estimation Results

The five public good equations will be estimated individually in this panel. We suspect that these equations may not be independent as the values of the variables are collected from the same set of observations (same countries). The simultaneous estimation of these equations using a seemingly unrelated regressions (SUR) method may be warranted to control for this correlation to avoid inefficient estimates. However, this is not an issue here. Because all public good equations have the same regressors, there is no efficiency gain using a SUR estimation. (Greene 2000, p. 616-617)

Following the work by Lake and Baum (2001), and Canning (1995) on public good provision, we control for geographic variables such as population and urbanization. In addition, we control for productivity, proxied by the real GDP per capita. As the real GDP per capita might be endogenous—reverse causality—we instrument it by its three-year lag to avoid serial correlation. We also include time dummies to control for aggregate effects that impact on all countries in a given year and country fixed effects.

Table 3 presents the estimation results for prediction 1. We investigate whether the effect of the level of resources on public good provision depends on the relative effectiveness to control resources.

We first analyse the finding for the physical infrastructure. The effect of resource rents on public good provision when the regime is not effective in controlling the resources is positive and but not statistically significant for power generation. One standard deviation increase in resource rent (16.1) raises power generation by 3.2% (16*0.002). For road network, resources have an unexpected negative effect significant at the 10% level (one standard deviation increase of resources results in 4.8% decrease in the road network). However, the ruler's choice differs significantly when he is effective in controlling the resources. The negative and statistically significant effect of the interaction term indicates that, all else equal, an effective ruler will provides less of both public goods. Furthermore, the magnitude of the differing behaviour is so large that the negative interaction effect outweighs the positive main effect for power generation (-16%) and reinforces the negative main effect for road network (-9.7%). Thus, the total effect—i.e. the effect of resources when an effective ruler is in power—is negative and significant as predicted. One standard deviation increase in resources causes power generation to decrease by almost 13% and road network by 14.5%.

Concerning literacy rate and immunisation against DPT and measles, the results are qualitatively very much in line with power generation. The main effect of resources is positive but not significant, while the total effect is negative and statistically significant. Our result suggests that an increase in resources by one standard deviation reduces immunisation against DPT and measles by 5.8 and 7.2 percentage points, and literacy rate by 0.7 percentage point.

The overall conclusion is that there is little relationship between public good levels and resources when the ruler is ineffective in controlling the resources—although it is positive as predicted—but this relationship becomes negative and statistically significant with a "strong" ruler. Moreover the magnitude of the effect is sizable except for literacy.

From Table 3, we also test the prediction that, a ruler relatively effective in fighting over resources provides comparatively lower levels of public goods. The interest lies in the sign of $\beta_2 + \beta_3 Resources_{it}$. The coefficient β_2 of the variable "No finite term" tests whether the two types of rulers significantly differ in their public good provision when the resource rent is equal to 0. Most importantly, the interaction effect $\beta_3 Resources_{it}$ indicates that the difference in public good provision between the two types of rulers depends on the level of the rent, for all types of infrastructure. At higher resource levels, the gap widens, making the strong or effective dictator less likely to invest.

For illustration purposes, Table 4 shows the effect of an effective or strong ruler on public good provision, when the resource rent is equal to 0, 11% (sample mean) and 30% (case of a resource-rich country like Nigeria). As the resource level increases, the effect of a strong dictator becomes more negative and significant. For a country with a sizable resource base (e.g. 30%), a strong ruler is an obstacle to the provision of public goods. The effect is generally large and significant except for literacy: -19% for power generation, -19.4% for road network, -15.4 and -16 percentage points for immunisation against DPT and measles. Finally, Figures 1 to 3 illustrate how the differential effect deepens with the level of resource rent for the various types of public good.

Overall, the empirical evidence is consistent with the main results of the model, namely that 1) the effect of resources on the provision of public goods hinges generally on the ruler's relative effectiveness in fighting; and 2) a ruler who is relatively more effective in controlling the resource endowment—i.e. when $\alpha < \gamma$ according to our model—tends to provide less public good. Finally, although we find that an ineffective ruler has a positive effect on public good provision, this effect is not significant.

As a robustness check, we also perform an estimation without country fixed effects but controlling for regional dummies. To mitigate the problem of omitted variables bias, we control for institutional features (proxied by the percentage of the population speaking a European language as in Hall and Jones, 1999), ethnic diversity (measure of ethnic fractionalization), former colonial power (French and British), and the size of the country. The results, presented in Table 5, do not differ from those reported above using country fixed effects, except for road network. In that equation, the coefficient of resource rent is negative and the interaction effect is positive, which is the exact opposite to what we expect and to our result with the fixed effect estimation. This may suggest the presence of omitted variables in the road network equation.

Our results are robust to the range of public goods considered, whether they are physical or social. They are also robust to the use of an alternative proxy for the effectiveness in controlling resources. We create a dummy variable denoted "Strong Executive" which indicates whether the executive is controlled by a monarch or a military regime (see Table 6 and 7). Monarchies tend to benefit from long lasting and established systems that enable effective appropriation of the resource rent, while military regime have the power to control and defend the rent. We find similar results to the one presented above. Besides, our findings using this alternative proxy are consistent with the evidence of the poor record of military dictatorships in providing public goods. (Lake and Baum, 2001)

5 Conclusion

In this paper we follow an idea that has gained much support in recent years, namely the role of policy choices in producing resource curse outcomes. As the term "policy *choice*" suggests such outcomes are by no means deterministic, and thus our model is one of the few that attempts to provide a *conditional* theory of the resource curse.

In particular, we follow the idea that easily appropriable resource rents may lead (among other things) to distortions in public policy (Bulte et al., 2005). Recognising the inherent threat of conflict in resource-rich countries, we present a model in which the ruler's policy choice, is entirely driven by economic motives. Our model points to reasons why some resource abundant countries have performed poorly whereas others have proved highly successful. We suggest that the stark difference in policy decisions regarding public good provision among resource-rich countries is a plausible reason. This difference results from various factors—the degree of resource wealth, the investment worthiness of the economy and most importantly the ruler's relative effectiveness in controlling the resource—which determine whether developmental or repressive policies are carried out. Testing our model empirically, we find evidence that 1) the effect of resource wealth crucially depends on the ruler's relative strength; and 2) a relatively strong leader who can control effectively resources tends to invest less in public good.

Along with Mehlum et al. (2006) who point to the differing effect of institutions on economic outcome in resource-rich countries, this paper demonstrates that a better understanding of the resource curse puzzle requires conditional rather than uni-dimensional theories.

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Table 2: List of Countries in the Sample

List of Countries	
Algeria	Madagascar
Angola	Malaysia
Argentina	Mauritania
Bahrain	Mexico
Bangladesh	Morocco
Benin	Mozambique
Bolivia	Nepal
Brazil	Nicaragua
Burkina Faso	Niger
Burundi	Nigeria
Cameroon	Oman
Central African Republic	Pakistan
Chile	Peru
China	Philippines
Congo Brazzaville	Qatar
Cote d'Ivoire	Rwanda
Ecuador	Saudi Arabia
Egypt	Senegal
El Salvador	Sierra Leone
Gabon	Singapore
Ghana	South Africa
Guatemala	Sri Lanka
Guyana	Sudan
Haiti	Suriname
Honduras	Syria
Indonesia	Thailand
Iran	Togo
Iraq	Tunisia
Jordan	Turkey
Kenya	UAE
Korea South	Uganda
Kuwait	Zaire
Liberia	Zambia
	Zimbabwe

Table 3: Effect of Resource Rent on Public Good Provision with Fixed Effects

Dependent Variable: Provision of Public Good

	(1) Power Generation Capacity per Cap	(2) Density Road Network	(3) Literacy	(4) Immunization DPT	(5) Immunization Measles
Resources	0.002	-0.003*	0.02	0.056	0.02
	[0.002]	[0.001]	[0.019]	[0.108]	[0.124]
No Finite Term	0.125***	-0.02	1.154***	-2.556	-1.476
	[0.025]	[0.031]	[0.270]	[1.586]	[1.748]
Resources*No Finite Term	-0.010***	-0.006***	-0.063**	-0.414***	-0.468***
	[0.003]	[0.002]	[0.025]	[0.136]	[0.156]
Real GDP in log	0.840***	0.458***	1.904***	1.837	14.992***
	[0.064]	[0.048]	[0.613]	[3.201]	[4.142]
Population in log	1.377***	1.185***	34.191***	7.696	15.189
	[0.310]	[0.193]	[1.941]	[11.738]	[12.353]
Urban Population in %	0.021***	-0.002	0.173***	0.155	0.162
	[0.003]	[0.002]	[0.031]	[0.173]	[0.208]
Constant	-30.569***	-30.023***	-657.128***	-127.08	-379.183
	[6.520]	[4.135]	[42.982]	[257.978]	[268.620]
Resources + Resources*No Finite Term	-0.008***	-0.008***	-0.043*	-0.358***	-0.449***
	[0.003]	[0.002]	[0.022]	[0.118]	[0.144]
Country fixed effect	Yes	Yes	Yes	Yes	Yes
Observations	1104	1102	1250	1036	1011
R-square	0.97	0.96	0.99	0.83	0.79
Number of Countries	57	45	54	56	56
Time Period	1975 - 1995	1975 - 2000	1975 - 1999	1980 - 2000	1980 - 2000

Robust standard errors. Control for Population, Urban population, Country fixed effect and Year dummies.
*** indicates 1% significance; ** 5%; and * 10%.

Table 4: Difference in Public Good Provision with a "strong" ruler

Variables	Differential Provision Rent = 0	Differential Provision Rent = 11% (mean)	Differential Provision Rent = 30%
Power Generation in log	0.125***	0.013	-0.189***
Road Network in log	-0.02	-0.082***	-0.194***
Literacy Rate in %	1.154***	0.459	-0.739
Immunization DPT in %	-2.556	-7.104***	-15.375***
Immunization MSL in %	-1.476	-6.629***	-15.998***

This table is obtained from Table 4.3 by setting Rent to 0, 11% (mean) and 30% (Nigeria) using country fixed effects

Table 5: Effect of Resource Rent on Public Good Provision without Fixed Effects

Dependent Variable: Provision of Public Good

	(1)	(2)	(3)	(4)	(5)
	Power Generation Capacity per Cap	Density Road Network	Literacy	Immunization DPT	Immunization Measles
Resources	0.012***	-0.016***	0.371***	0.037	0.091
	[0.003]	[0.003]	[0.060]	[0.084]	[0.089]
No Finite Term	-0.101*	-0.253***	-0.302	-7.591***	-7.005***
	[0.057]	[0.049]	[1.162]	[1.725]	[1.716]
Resources*No Finite Term	-0.019***	0.010***	-0.729***	-0.332***	-0.335***
	[0.004]	[0.003]	[0.071]	[0.099]	[0.105]
Real GDP in log	0.600***	0.308***	7.241***	6.491***	5.781***
	[0.050]	[0.033]	[0.861]	[1.213]	[1.228]
Population in log	0.004	0.515***	-0.809*	-2.008***	-1.450**
	[0.024]	[0.023]	[0.427]	[0.684]	[0.689]
Urban Population in %	0.030***	0.003***	0.323***	0.007	0.066
	[0.002]	[0.001]	[0.034]	[0.044]	[0.044]
Constant	-3.088***	-5.243***	16.754*	39.920***	20.854
	[0.585]	[0.401]	[8.888]	[14.474]	[14.445]
Resources + Resources*No Finite Term	-0.007***	-0.007***	-0.358***	-0.295***	-0.244***
	[0.002]	[0.002]	[0.037]	[0.054]	[0.061]
Controls					
Regional Dummies	Yes	Yes	Yes	Yes	Yes
Time Dummies	Yes	Yes	Yes	Yes	Yes
Ethnic Diversity	Yes	Yes	Yes	Yes	Yes
Coloniser (British and French)	Yes	Yes	Yes	Yes	Yes
Institutional Feature	Yes	Yes	Yes	Yes	Yes
Country Area	Yes	Yes	Yes	Yes	Yes
Observations	1084	1102	1250	1015	990
R-square	0.79	0.82	0.70	0.69	0.68
Number of Countries	56	45	54	55	55
Time Period	1975 - 1995	1975 - 2000	1975 - 1999	1980 - 2000	1980 - 2000

Robust standard errors. Control for Institution, Ethnic Diversity, Colonizer, Country area, Population, Urban population, Region and Year dummies. *** indicates 1% significance; ** 5%; and * 10%.

Figure 1: Effect of "Strong" Ruler on Power Generation and Road Network

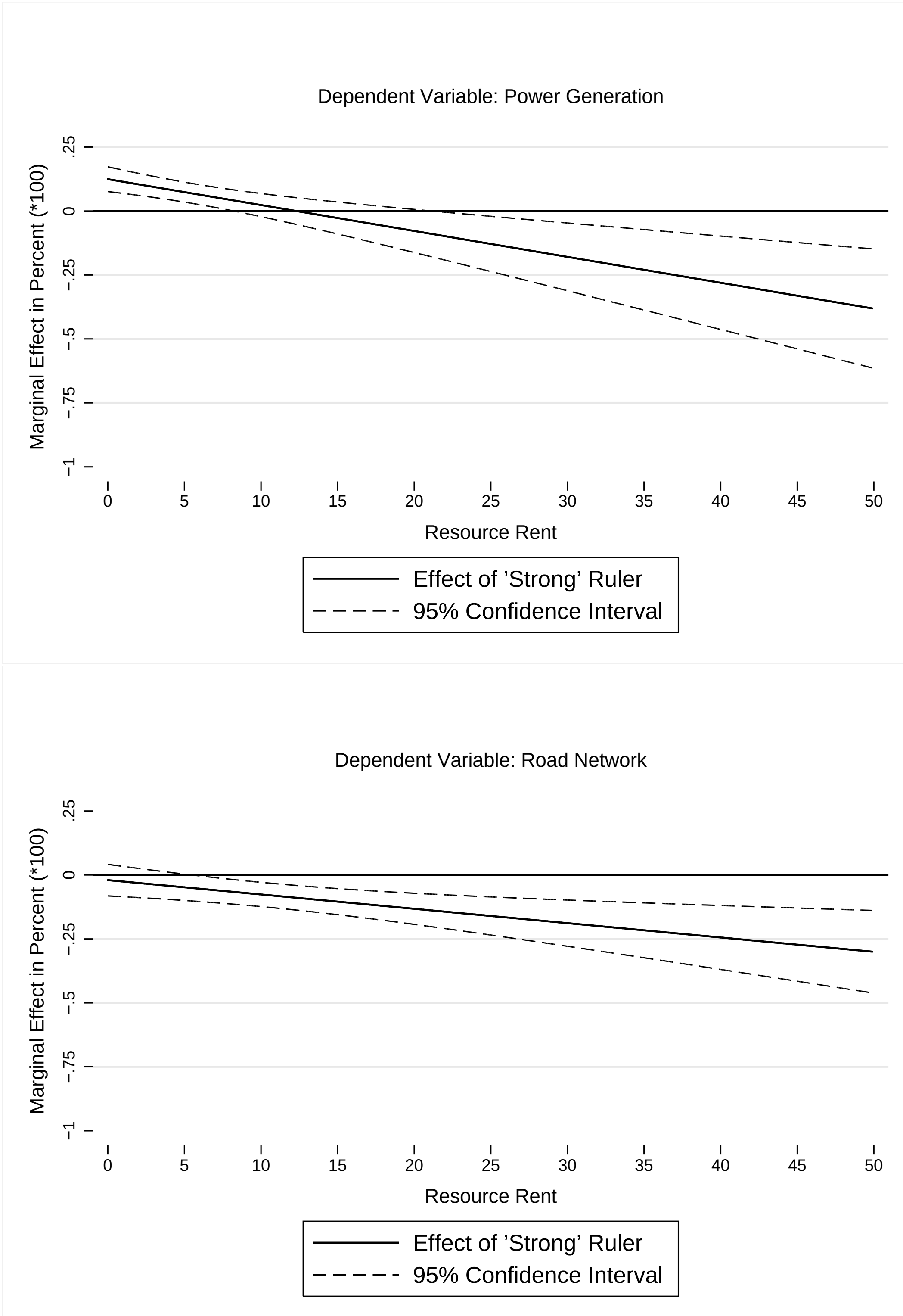


Figure 2: Effect of “Strong” Ruler on Literacy

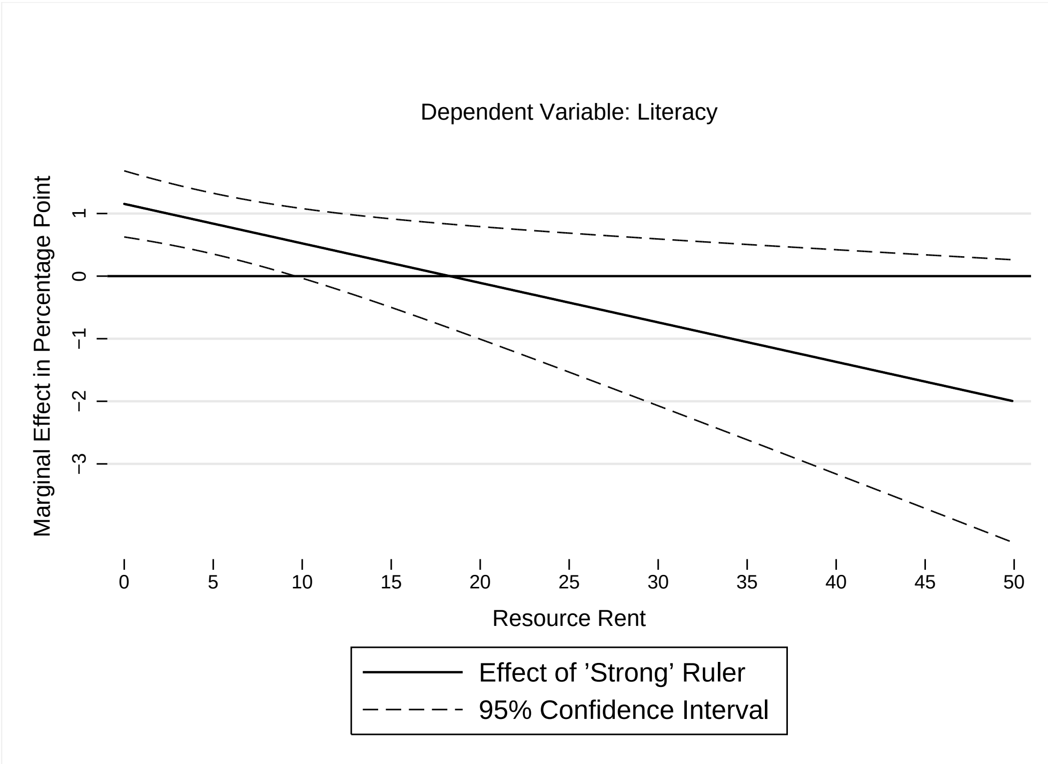
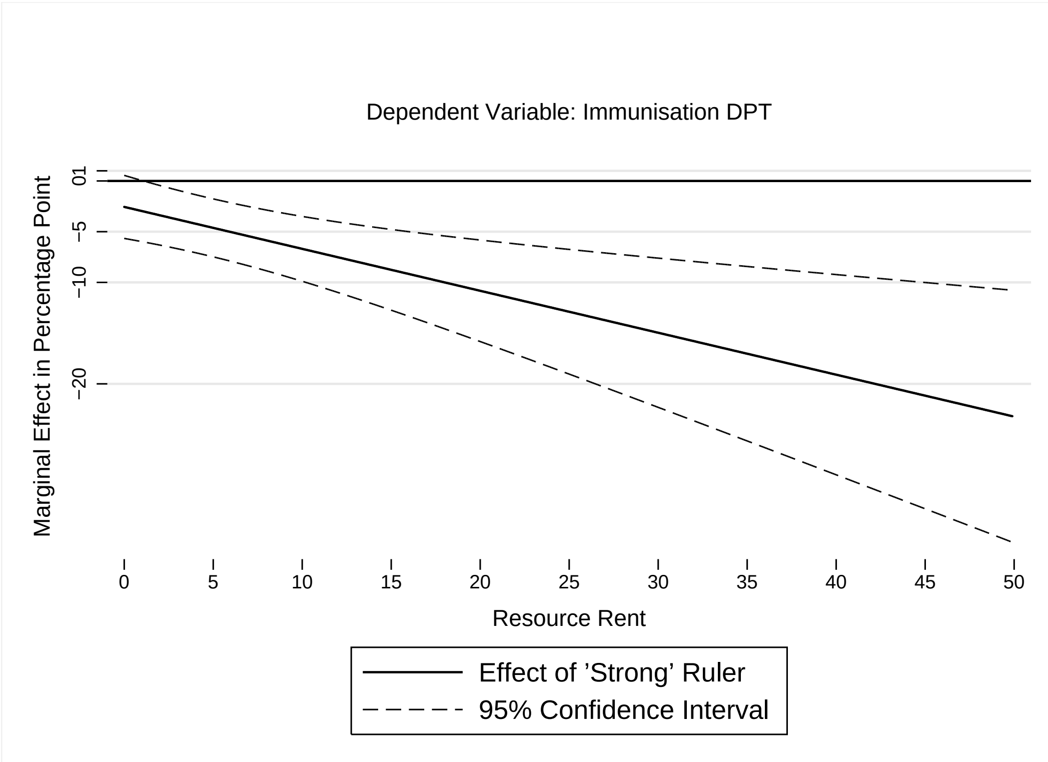


Figure 3: Effect of "Strong" Ruler on Immunisation



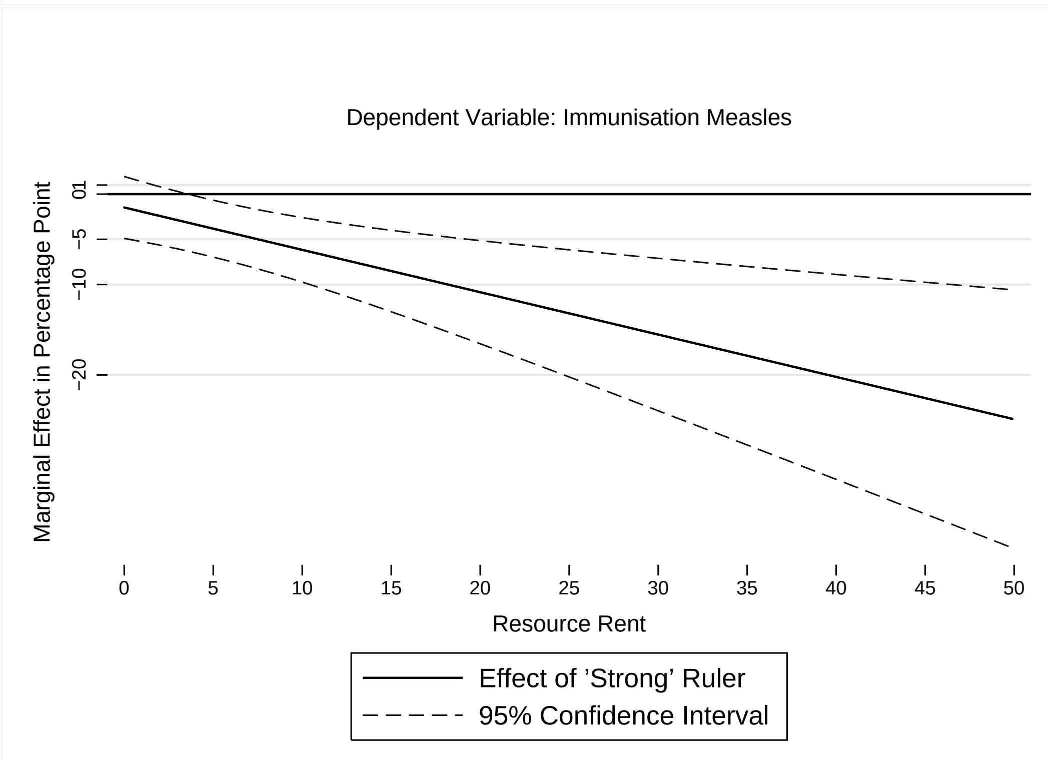


Table 6: Effect of Resource Rent on Public Good Provision: Alternative Measure

Dependent Variable: Provision of Public Good

	(1)	(2)	(3)	(4)	(5)
	Power Generation Capacity per Cap	Density Road Network	Literacy	Immunization DPT	Immunization Measles
Resources	0.014***	-0.013***	0.339***	0.042	0.145
	[0.003]	[0.002]	[0.056]	[0.086]	[0.089]
Strong Executive	0.055	-0.058	3.637***	3.239**	-0.248
	[0.051]	[0.040]	[1.084]	[1.550]	[1.554]
Resources*Strong Executive	-0.026***	0.002	-0.818***	-0.448***	-0.527***
	[0.004]	[0.003]	[0.064]	[0.097]	[0.102]
Real GDP in log	0.641***	0.352***	8.049***	7.878***	7.465***
	[0.047]	[0.033]	[0.829]	[1.218]	[1.253]
Population in log	0.02	0.535***	-0.536	-1.095	-0.861
	[0.025]	[0.023]	[0.443]	[0.706]	[0.696]
Urban Population in %	0.030***	0.003**	0.318***	-0.014	0.044
	[0.001]	[0.001]	[0.032]	[0.046]	[0.046]
Constant	-3.517***	-6.016***	5.52	20.993	-7.677
	[0.566]	[0.402]	[8.681]	[13.914]	[14.157]
Resources + Resources*Strong Executive	-0.012***	-0.011***	-0.479***	-0.406***	-0.382***
	[0.003]	[0.002]	[0.037]	[0.056]	[0.059]
Observations	1193	1192	1359	1029	1004
R-square	0.79	0.82	0.70	0.67	0.67
Number of Countries	56	45	54	55	55
Time Period	1970 - 1995	1970 - 2000	1970 - 1999	1980 - 2000	1980 - 2000

Robust standard errors. Control for Institution, Ethnic Diversity, Colonizer, Country area, Population, Urban population, Region and Year dummies. *** indicates 1% significance; ** 5%; and * 10%.

Table 7: Difference in Public Good Provision with a "strong" ruler: Alternative Measure

Dependent Variables	Differential Provision Rent = 0	Differential Provision Rent = 11% (mean)	Differential Provision Rent = 30%
Power Generation in log	0.055	-0.234***	-0.733***
Road Network in log	-0.058	-0.037	-0.0002
Literacy Rate in %	3.637***	-5.359***	-20.899***
Immunization DPT in %	3.239**	-1.693	-10.212***
Immunization MSL in %	-0.248	-6.045***	-16.058***

This table is obtained from Table 4.6 by setting Rent to 0, 11% (mean) and 30% (Nigeria)

6 Appendix A.1: Properties of function $\Delta\Pi_G(A)$

Properties

1) If $\alpha < \gamma$ then $\Delta\Pi_G$ is strictly increasing and strictly concave in A

2) If $\alpha > \gamma$ then $\Delta\Pi_G$ is strictly decreasing in $[0, \underline{A}]$ and strictly increasing in $(\underline{A}, +\infty)$ where $\underline{A} = \left(\frac{\alpha}{\gamma+1-\alpha}\frac{\tau P_1 - cP_2 - P_3}{\tau(1+T)}\right)$ $\Delta\Pi_G$ is also strictly convex everywhere.

Let $\Delta\Pi_G(A) = J(A) + [\tau P_1 - cP_2 - P_3] Z^{\frac{1}{\gamma+1-\alpha}} (1+A)^{-\frac{\alpha}{\gamma+1-\alpha}}$ where $J(A) = \tau(1+A)(1+T)$. It is straight forward to establish that:

$$\frac{\partial \Delta\Pi_G}{\partial A} = \tau(1+T) - \frac{\alpha}{\gamma+1-\alpha}[\tau P_1 - cP_2 - P_3] Z^{\frac{1}{\gamma+1-\alpha}} (1+A)^{-\frac{\gamma+1}{\gamma+1-\alpha}}$$

$$\frac{\partial^2 \Delta\Pi_G}{\partial A^2} = \frac{\alpha(\gamma+1)}{(\gamma+1-\alpha)^2}[\tau P_1 - cP_2 - P_3] Z^{\frac{1}{\gamma+1-\alpha}} (1+A)^{-\frac{2\gamma+2-\alpha}{\gamma+1-\alpha}}$$

$$\lim_{A\to\infty} \Delta\Pi_G(A) - J(A) = 0$$

Case 1: $\alpha < \gamma$

In this case, we established that $P_1 < 0$, $P_2 > 0$ and $P_3 > 0$. As a consequence, $\frac{\partial \Delta\Pi_G}{\partial A} > 0$ and $\frac{\partial^2 \Delta\Pi_G}{\partial A^2} < 0$ for any A, i.e. $\Delta\Pi_G$ is strictly increasing and strictly concave in A. In addition, $\Delta\Pi_G(A)$ is below $J(A)$ for any A, and converges asymptotically to $J(A)$.

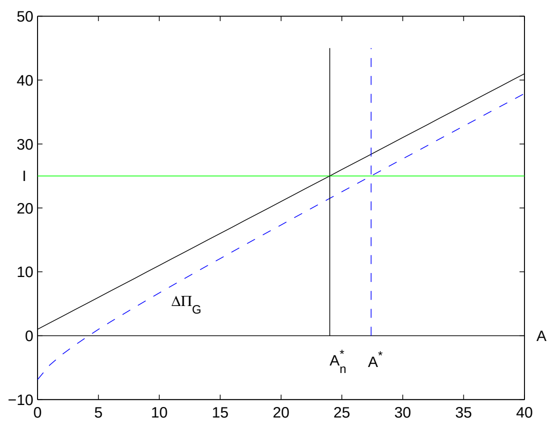


Figure 4: $\Delta\Pi_G$ as a function of A when $\alpha < \gamma$

When $\alpha < \gamma$, an increase in A has two reinforcing positive effects on $\Delta\Pi_G$: first, a direct positive effect of increasing output (through $J(A)$), and second an additional (positive) effect that is shrinking with A. Both effects contribute to increase $\Delta\Pi_G$.

Case 2: $\alpha > \gamma$

$$\frac{\partial \Delta\Pi_G}{\partial A}\begin{cases} < 0 & \text{if } A < \underline{A} \\ = 0 & \text{if } A = \underline{A} \\ > 0 & \text{if } A > \underline{A} \end{cases}, \text{ where } \underline{A} = \left(\frac{\alpha}{\gamma+1-\alpha}\frac{\tau P_1 - cP_2 - P_3}{\tau(1+T)}\right)^{\frac{\gamma+1-\alpha}{\gamma+1}} Z^{\frac{1}{\gamma+1}} - 1.$$

In addition, $\frac{\partial^2 \Delta\Pi_G}{\partial A^2} > 0$ for any A. So $\Delta\Pi_G(A)$ is strictly convex and decreases in the interval $[0, \underline{A}]$, reaches the minimum at $\underline{A}$ and increases in the interval $[\underline{A}, +\infty)$. Note that as $\Delta\Pi_G(A)$ is decreasing in the interval $[0, \underline{A}]$, $\min[\Delta\Pi_G(A)] = \Delta\Pi_G(A = \underline{A}) < \Delta\Pi_G(A = 0)$.

$\Delta\Pi_G(A)$ is also above $J(A)$ for any A, and converges asymptotically to $J(A)$.

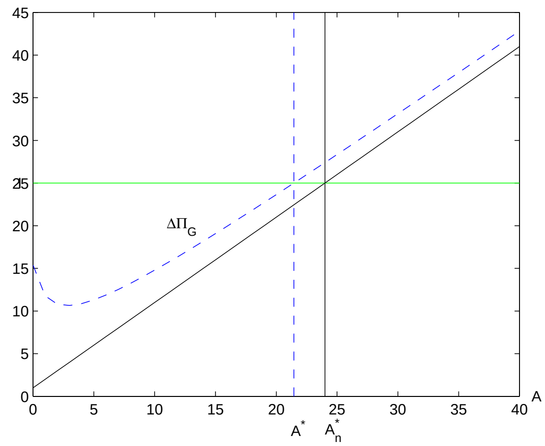


Figure 5: $\Delta\Pi_G$ as a function of A when $\alpha > \gamma$

When $\alpha > \gamma$, an increase in A is associated with two opposite effects: an increase in the output level through $J(A)$, and a decrease in the positive additional effects. The latter effect dominates for low levels of productivity, so that $\Delta\Pi_G$ decreases in A. The former effect dominates for high levels of productivity resulting in the increase of $\Delta\Pi_G$.■

7 Appendix A.2: Proof of the Lemma

According to (12), investment is optimal if and only if $\Delta\Pi_G(A) \geq I$.

Case 1: $\alpha < \gamma$

Since $\lim_{A\to\infty} \Delta\Pi_G(A) = +\infty$, and I is finite, the continuity of $\Delta\Pi_G(A)$ guarantees that $\Delta\Pi_G(A)$ must cross I at least once if $\min[\Delta\Pi_G(A)] = \Delta\Pi_G(A = 0) < I$ (Existence).

If $\Delta\Pi_G(A=0) < I$, then uniqueness is guaranteed since $\Delta\Pi_G(A)$ is strictly increasing in A whereas I is constant in A. Hence there exists a unique productivity level A^* such that investment is optimal whenever $A > A^*$.

On the other hand if $\min[\Delta\Pi_G(A)] = \Delta\Pi_G(A=0) > I$, then $\Delta\Pi_G(A) > I$ for any A, that is whatever the value of A, the ruler will always find it optimal to invest.

Case 2: $\alpha > \gamma$

Since $\lim_{A\to\infty} \Delta\Pi_G(A) = +\infty$, and I is finite, the continuity of $\Delta\Pi_G(A)$ guarantees that $\Delta\Pi_G(A)$ must cross I at least once if $\min[\Delta\Pi_G(A)] = \Delta\Pi_G(A=\underline{A}) < I$ (Existence).

- If $\min[\Delta\Pi_G(A)] < \Delta\Pi_G(A=0) < I$, then uniqueness is guaranteed since $\Delta\Pi_G(A)$ is strictly increasing in the interval $(\underline{A}, +\infty)$ and I is constant in A. Hence there exists a unique productivity level A^* such that investment is optimal whenever $A > A^*$.
- If $\min[\Delta\Pi_G(A)] < I < \Delta\Pi_G(A=0)$, then $\Delta\Pi_G(A)$ crosses I twice in A^*_{low} and in A^*_{high}. Hence investment is optimal for any $A < A^*_{low}$ and for any $A > A^*_{high}$.

  Note that it is obvious that $A^*_{low} < \underline{A}$ and $A^*_{high} > \underline{A}$.

  This case is presented for completeness of the proof. However, we will assume that I is large enough so that there exists at most only one threshold.

On the other hand if $\Delta\Pi_G(A=0) > \min[\Delta\Pi_G(A)] > I$, then $\Delta\Pi_G(A) > I$ for any A, that is whatever the value of A, the ruler will always find it optimal to invest. ■

8 Appendix A.3: Characterization of A^*

Applying the implicit function theorem using equation (15) yields:

$$\frac{\partial A^*}{\partial Z} = -\frac{\frac{1}{\gamma+1-\alpha}\left[Z^{\frac{\alpha-\gamma}{\gamma+1-\alpha}}(1+A^*)^{\frac{-\alpha}{\gamma+1-\alpha}}[\tau P_1 - P_2 - P_3]\right]}{\tau(1+T) - \frac{\alpha}{\gamma+1-\alpha}Z^{\frac{1}{\gamma+1-\alpha}}(1+A^*)^{\frac{-\gamma-1}{\gamma+1-\alpha}}[\tau P_1 - P_2 - P_3]}$$

The denominator is equal to $\dfrac{\partial\Delta\Pi_G(A^*)}{\partial A}$ and the sign of the numerator depends on the sign of $\alpha-\gamma$.

Case 1: $\gamma > \alpha$

We established in Appendix A.1 that in this case, $\dfrac{\partial\Delta\Pi_G}{\partial A} > 0$ for any A so that by continuity the denominator is positive at $A = A^*$. Moreover, since the numerator is negative we have $\dfrac{\partial A^*}{\partial Z} > 0$. An increase in resource abundance increases the threshold, reducing the incentive to invest.

Case 2: $\alpha > \gamma$

The numerator is positive while the denominator is negative if $A < \underline{A}$ and positive if $A > \underline{A}$ (see Appendix A.1). As a result,

- If $\min[\Delta\Pi_G(A)] < \Delta\Pi_G(A=0) < I$, then $\frac{\partial A^*}{\partial Z} < 0$ since $A^* > \underline{A}$
- If $\min[\Delta\Pi_G(A)] < I < \Delta\Pi_G(A=0)$ (there are two thresholds A^*_{low} and A^*_{high}), then $\frac{\partial A^*_{low}}{\partial Z} > 0$ since $A^*_{low} < \underline{A}$ and $\frac{\partial A^*_{high}}{\partial Z} < 0$ since $A^*_{high} > \underline{A}$.
  This case is presented for completeness of the proof. However, we will assume that I is large enough so that there exists at most only one threshold. ■

9 Appendix A.4: Proof Corollary

1) Case 1: $\alpha < \gamma$

We have established that in this case $P_1 < 0$, $P_2 > 0$ and $P_3 > 0$, i.e. $\Delta\Pi_G(A) < J(A)$ for all A.

Therefore for any A, $\Delta\Pi_G(A) - I < J(A) - I$. Define $A = A^*_n$ the productivity level such that $J(A^*_n) - I = 0$. By continuity, for $A = A^*_n$, $\Delta\Pi_G(A^*_n) - I < J(A^*_n) - I$, i.e. $\Delta\Pi_G(A^*_n) - I < 0$. At $A = A^*_n$, it is not optimal for the ruler to undertake an investment. As a result $A^*_n < A^*$. This case is depicted in Figure 6.

2) Case 2: $\alpha > \gamma$

We have established that in this case $P_1 > 0$, $P_2 < 0$ and $P_3 < 0$. i.e. $\Delta\Pi_G(A) > J(A)$ for all A.

It follows that for any A, $\Delta\Pi_G(A) - I > J(A) - I$. By continuity, for $A = A^*_n$, $\Delta\Pi_G(A^*_n) - I > 0$. That is investment is optimal for a lower productivity level $A^* < A^*_n$. This case is depicted by Figure 6

We have now established that :

- $A^* > A^*_n$ if $\alpha < \gamma$, in other words $A^*(\text{strong ruler}) > A^*_n$
- $A^* < A^*_n$ if $\alpha > \gamma$, in other words $A^*(\text{strong people}) < A^*_n$

Moreover, A^*_n is independent of Z by assumption. In proposition 3 we showed that $A^*(\text{strong ruler})$ increases in Z and $A^*(\text{strong people})$ decreases in Z. It follows that for any Z, we have: $A^*(\text{strong people}) < A^*_n < A^*(\text{strong ruler})$.■