Access Econ
Scholarly communication without the middle men

Submission Number: PET11-11-00297

"Public provision of security in an insecure property rights environment."

Ranojoy Basu
Iowa State University

Shubhro Bhattacharya
Iowa State University

Abstract

Why do some economies remain technologically backward even when technologies on the frontier are available for adoption, virtually freely? If institutions are fragile and property rights insecure, potential adopters of frontier technologies may be dissuaded if adoption leads to increased expost conflict over rightful shares to the higher returns. In such a setting, publicly-funded protection of private property rights may successfully support the adoption of best-available technologies as a Nash equilibrium. The movement to more-secure property rights may or may not be welfare-enhancing.

Submitted: March 15, 2011.

Public Provision of Security in an Insecure Property Rights Environment

Ranojoy Basu
Iowa State University

Shubhro Bhattacharya
Iowa State University

November 23, 2010*

Abstract

Why do some economies remain technologically backward even when technologies on the frontier are available for adoption, virtually freely? If institutions are fragile and property rights insecure, potential adopters of frontier technologies may be dissuaded if adoption leads to increased expost conflict over rightful shares to the higher returns. In such a setting, publicly-funded protection of private property rights may successfully support the adoption of best-available technologies as a Nash equilibrium. The movement to more-secure property rights may or may not be welfare-enhancing.

*The authors are graduate students with the Department of Economics at Iowa State University. Please address any comments to Shubhro Bhattacharya or Ranojoy Basu, Department of Economics, Iowa State University, 260 Heady Hall, Ames IA 50014, USA. E-mail: `shubhro.econ@gmail.com`; `rbasu@iastate.edu`

1 Introduction

The term property rights refers to an owner's legal right to use a good/asset for consumption or income generation and also, the right to transfer the good to another party. Property rights have received pride of place in all analyses of the development and dominance of capitalism and the market system in modern societies. Over two centuries ago, Adam Smith and other thinkers expounded on the idea that property rights encourage their holders to develop the property, generate wealth, and efficiently allocate resources via the market mechanism.[1] They noted that the anticipation of profit from "improving one's stock of capital" rests on clear delineation and enforcement of private property rights, which, in turn leads to more wealth and improved standards of living for all.[2]

While the above prescription for material progress and prosperity has been around for over two hundred years, not every country has succeeded in using it to achieve sustained growth and development. Indeed, in most less-developed and transition economies, institutions aimed at defining and preserving property rights are woefully fragile, and as such, property rights are terribly insecure. This insecurity comes at a hefty price – heightened conflict over property and the accompanying dissipation of scarce resources in the creation of effective property rights.[3]

[1] A practical application of this principle can be found in the introduction of the Permanent Settlement System (around 1800) in colonial India. Under this system, the colonizers – the British under Lord Cornwallis, one of the leading British generals in the American War of Independence – granted proprietarial rights to former landholders (would-be zamindars) to the land they occupied. This method of incentivisation of zamindars was intended to encourage improvements of the land, such as drainage, irrigation and the construction of roads and bridges. The land tax was also fixed in perpetuity. Cornwallis successfully argued that "when the demand of government is fixed, an opportunity is afforded to the landholder of increasing his profits, by the improvement of his lands".

[2] Besley (1995) investigates the interconnection between investment and land rights using data from Ghana, when the country was in a state of transition between traditional and modern land rights. His findings for Wassa, a cocoa growing region where most of the land is owned, was supportive of the idea that "better land rights facilitate investment".

[3] In recent times, economists have popularized this line of thinking. De Soto (2000) has brought the argument into a broader public domain. Economic historians such as North (1981), Jones (1986), and Mokyr (2002) have cited evidence to support this view. There is a growing literature that focuses on the links between the security of property and economic behavior at the institutional level in a variety of specific institutional settings. For example Besley (1995), Goldstein and Udry (2008) study

Our paper studies the consequences of insecure property rights on the mechanics of technological innovation. The work is motivated by a certain "social resistance" to technological change that characterizes many poor economies. For example, Platteau (2000, p.200) documents how fishermen in Congo refused to use a new net technology which was offered to them at no cost. More generally, it has been documented that economic agents in impoverished societies often reject superior technologies – technologies that are on the frontier – even when the cost of adoption appear negligible. In explaining this apparent paradox, Parente and Prescott (1999) make the convincing case that technological innovation is not a Pareto-superior outcome. There are economic winners and losers, and the latter have an incentive to block technology adoption by others because it necessarily influences the expost distribution of wealth. This view finds prominence in Olson (1982), Mokyr (1990), Krusell et al. (1996), among others.

In a recent paper, Gonzalez (2005) argues that the aforementioned paradoxical choice of inferior technologies can be understood as "a strategic response to the anticipation of conflict" over the expost distribution of newly-created wealth especially when property rights over it are insecure. Gonzalez (2005) has in mind a setting in which two agents contemplate adoption of a superior technology in an insecure property-rights environment. While each recognize that such adoption would lead to an increase in future output, each is nevertheless afraid that this newly-created wealth generates an incentive for the rival to engage in a costly game of predation. The expected predatory response discourages adoption of the superior technology in the first place, and thus "... poverty becomes the price of peace." (Bates 2001).[4]

the impact of insecure land rights on investment and productivity in rural Ghana. In a related study Field (2007) finds that issuing of "property titles" in urban Peru has led to a significant increase in labor supply. Johnson et al. (2002) studies the impact of insecure property rights on the investment decisions taken by manufacturing firms in post-communist countries when bank loans were available. A common thread running through these studies is secure property rights facilitates the creation of wealth.

[4]Hall and Jones (1999) provide evidence that poor enforcement of property rights can be a serious impediment to technological progress.

The upshot of the Gonzalez (2005) analysis is that adoption of the best-available technology is never sustainable as a Nash equilibrium.

If people are hesitant to adopt superior technologies because of a fear of subsequent conflict, would some sort of external intervention be beneficial? Would it help, if a third party intervenes in this conflict by providing some manner of public protection of rights on private property? To implement this, we introduce a "government" in the framework of Gonzalez (2005). We think of the government as imposing a non-distortionary tax on the initial endowments of each agent at the start of their life. The tax proceeds are utilized to finance the hiring of a "guard". The guard is simply a public security service whose sole aim is to reduce the effectiveness of each agents' predatory activities, without directly interfering in the expost conflict. The posting of a guard is shown to influence agents' decisions on allocation of resources to productive and predatory activities. In sharp contrast to the main result in Gonzalez (2005), we prove that adoption of the frontier technology by each agent can now be supported as a Nash equilibrium.

We go on to extend the analysis by allowing the government to directly influence the nature of the expost conflict. In other words, we allow the government to use its tax-financed resources to alter the existing regime of property rights. Presumably, a government can achieve increased security of property rights by funding the police, the judiciary, and the corrections systems better. We find that adoption of the best-available technology by each agent continues to emerge as a Nash equilibrium. Within this equilibrium, we find that improved property rights, though growth enhancing, is not always socially optimal from an aggregate-welfare point of view. [5]

The paper is organized in the following manner. Section 2 describes the benchmark model due to Gonzalez (2005). In section 3, we introduce the public security of

[5] In a somewhat-related study, Gonzalez (2007) analyzes the growth-welfare trade-off in an exogenously-specified property rights environment. He showed a symmetric equilibrium allocation associated with more-secure property rights and faster growth can be Pareto dominated by one associated with poorer property rights and slower growth.

private property and analyze the equilibrium outcomes. In section 4, we endogenize the property rights regime. Section 4 concludes the paper.

2 The model

2.1 Physical environment

We consider a two-period model of imperfect security of private property and its impact on technology choice. The model economy is inhabited by two agents, named R and P ("rich" and "poor") – these agents can be thought of either as individuals or collectives (such as tribes, nation states, and so on). There is a single good and the aggregate endowment of this good in period 1 is a fixed amount Y. Agent R is endowed with a share $p \in (1/2, 1]$ of Y; correspondingly, Agent P is endowed with the remaining share, $1-p$. Rights to this property in period 1 are perfectly secure for each agent. However, property rights in period 2 are not secure, and all the action in this model derives from this insecurity.

Each agent uses a portion of his property in period 1 and undertakes some productive investment; the latter, via a production technology, produces consumables in period 2. At the start of period 1, each agent costlessly chooses a technology from a set of available technologies, $[A^L,\ A^H]$. A technology is to be interpreted as a blueprint that transforms investment into output in the following period. We assume that each agent has access to the same AK production technology and that productive investments of the agents are decided independently of each other. To be specific, productive investment K_i by agent i $[i \in \{R, P\}]$ at period 1 produces output $A_i K_i$ at period 2 where $A_i \in [A^L, A^H]$ is the technology choice of agent i.

In a world with secure property rights, the resources available to agent R in period 2 would be $A_R K_R$, and that to agent P would be $A_P K_P$. Not so here. Here, the total amount of consumables ("common property") available at the start of period 2 is $Y' \equiv (A_R K_R + A_P K_P)$ and property rights over Y' is insecure, that is, it is subject to pillage and appropriation. This insecurity prompts agents to invest in appropriative investments that help convert their claims on production into effective property rights on the common output. Let X_i denote agent i's investment in appropriation, and let p' denote agent R's share of Y'; henceforth p' is labeled the "appropriation function". Then,

$$p' \equiv \frac{(X_R)^m}{(X_R)^m + (X_P)^m} \in [0,1]\,; \quad m > 0, \tag{1}$$

where (1) is a share function – taken as a primitive – capturing the technology of conflict over claims on future output. Note p' is increasing in an agent's own appropriative investment and decreasing in that of his rival's. This is the workhorse functional form for the technology of conflict. For future reference, note that p' is symmetric and homogeneous of degree zero in X_R and X_P. This last property is analytically convenient and largely accounts for the widespread use of this functional form in the conflict literature. As an aside, note that resources allocated to productive investment in period one are not subject to appropriation, only the final output in period two is. Finally, note that if property rights were perfectly secure, agent R's share of Y' would be given by $A_R K_R / Y'$; therefore, as long as p' in (1) deviates from this ratio, property rights are insecure. For future use, note that p' in (1) can never approach $A_R K_R / Y'$. This last observation will make a major appearance in the penultimate section of this paper.

It is instructive to outline a time-line of events. At the start of period 1, each agent chooses a technology from the aforementioned set of available technologies. Once that is done, and cognizant of his own technology choice but not that of his rival's, an agent makes consumption, appropriation, and productive investment decisions, financing everything from his endowment. Production activity is then initiated. Agents consume and undertake the planned appropriation investments. When period 2 arrives, the common production, Y', is realized and agents receive their share which they consume; agent R gets a share p' and agent P, a share $1 - p'$. Note that p' is determined by *past* appropriation investments of both parties, as is described by (1).

The resource constraints in period 1 can be written as

$$pY = C_{1R} + X_R + K_R, \text{ for } i = R \tag{2}$$

$$(1-p)Y = C_{1P} + X_P + K_P, \text{ for } i = P \tag{3}$$

where C_{1i}, $i \in \{P, R\}$ is consumption by agent i in period 1. The second period constraints are

$$C_{2R} = p'(A_R K_R + A_P K_P), \text{ for } i = R \tag{4}$$

$$C_{2P} = (1-p')(A_R K_R + A_P K_P), \text{ for } i = P. \tag{5}$$

where C_{2i}, $i \in \{P, R\}$ is consumption by agent i in period 2.

The description of the physical environment is complete once preferences are specified. We assume that agent i has preferences described by the separable utility function $U_i \equiv \ln C_{1i} + \beta \ln C_{2i}$, $\beta > 0$.

2.2 Equilibrium

The aforediscussed time-line of events suggests the following characterization of the game. Period one is characterized by two stages, where in each stage, agents act non-cooperatively to maximize their payoffs without any information on their rivals' strategies. Therefore, we are faced with a two-stage game, where at each stage, agents play a simultaneous move game, and the outcome of the first stage is not revealed before the actions of the second stage are taken. To find a reasonable solution, we look for the set of subgame-perfect equilibria. In other words, for any choice of technology at stage one, first we find the optimal consumption and investment strategies for each agent which are mutual best responses to each other. These optimal responses are solely a function of the technology choices made in stage one. Then, we incorporate these optimal decisions in the agents' utility maximization problem and find the set of technologies in stage one that produce non-cooperative optima for each agent.

Consider the problem faced by agent R at stage two of period 1. At this point in the game, agent R knows A_R; he takes A_P, X_P and K_P as given, and solves the following problem:

$$\max\ U_R \equiv \ln C_{1R} + \beta \ln C_{2R}$$

subject to

$$pY = C_{1R} + K_R + X_R,$$

$$p'Y' = C_{2R},$$

$$p' = \frac{(X_R)^m}{(X_R)^m + (X_P)^m},$$

$$\text{and } Y' = A_R K_R + A_P K_P.$$

The interior optimality conditions for agent R are given by the following equations:

$$\frac{1}{C_{1R}} = \beta \frac{(X_R)^m}{(X_R)^m + (X_P)^m} A_R \frac{1}{C_{2R}}, \tag{6}$$

$$\frac{A_R}{A_R K_R + A_P K_P} = \frac{(X_P)^m}{(X_R)^m + (X_P)^m} \frac{m}{X_R}. \tag{7}$$

Equation (6) is a standard intertemporal Euler equation equating the marginal rate of substitution (MRS) of consumption between the two time periods with the marginal rate of transformation (MRT). In a standard model with perfect property rights, the MRT for agent R would simply be A_R; here, because of insecure property rights, it is $p'A_R$. The second condition, (7) reflects the equality of marginal returns across different the two types of investment activities. An unit of resource can be invested either in productive or in appropriative activities. In equilibrium, these avenues should generate the same return.

Analogously, the reaction functions for agent P are given by

$$\frac{1}{C_{1P}} = \beta \frac{(X_P)^m}{(X_R)^m + (X_P)^m} A_P \frac{1}{C_{2P}}, \tag{8}$$

$$\frac{A_P}{A_R K_R + A_P K_P} = \frac{(X_R)^m}{(X_R)^m + (X_P)^m} \frac{m}{X_P}. \tag{9}$$

We can use the symmetry of the reaction functions for the two agents to write $(A_R/A_P) = (X_P/X_R)^{m+1}$ which we use in (1) to get

$$p' = \frac{1}{1 + \left(\frac{A_R}{A_P}\right)^{\frac{m}{m+1}}}. \tag{10}$$

Notice how the appropriation function in (1) is transformed to depend solely on the ratio of the technology choices of both agents.

The above formulation of p' highlights the possibility of wealth-ranking reversal in this setup. To see this, suppose the technologies adopted satisfy $A_R > A_P$ (i.e., suppose the initially-wealthier agent adopts the superior technology). Then, (10) makes clear that $p' < 1/2$ is possible even when $p > 1/2$ was true. In other words, a wealth-ranking reversal is possible. The fact that there is a scope for redistribution of wealth, from the wealthier and more productive agent to the poorer one, should not come as a surprise. After all, the agent choosing the superior technology has a higher opportunity cost of investing in appropriative activities, which in turn give him a comparative advantage (relative to the other agent) in production. The optimal allocation of saving between different investment activities (or, the equalization of marginal return across productive and appropriative activities) implies that the agent invests more in production and cut back on appropriative investments, and thus end up with less share of future output.

Using (6)-(10), it is possible to derive the optimal allocation of resources to consumption and appropriation in terms of the stage-one technology choices of both parties:

The optimal choices for agent R are given by

$$C_{1R} = \frac{A_P}{A_R} C_{1P} = \frac{\left[(p + (1-p)\frac{A_P}{A_R})Y\right]}{\beta(1+m)+2}, \tag{11}$$

$$X_R = \left(\frac{1}{\left(\frac{A_P}{A_R}\right)^{\frac{m}{m+1}} + 1} \right) \frac{m\beta\left[(p + (1-p)\frac{A_P}{A_R})Y\right]}{2+\beta(1+m)}, \tag{12}$$

and

$$C_{2R} = \frac{\beta}{1+\left(\frac{A_R}{A_P}\right)^{\frac{m}{m+1}}} . \frac{[(pA_R + (1-p)A_P)Y]}{2+\beta(1+m)}. \tag{13}$$

Analogous expressions for agent P are given by

$$C_{1P} = \frac{A_R}{A_P} C_{1R} = \frac{A_R}{A_P} \frac{\left[(p + (1-p)\frac{A_P}{A_R})Y\right]}{\beta(1+m)+2}, \tag{14}$$

$$X_P = X_R \left(\frac{A_R}{A_P}\right)^{\frac{1}{1+m}} = \left(\frac{A_R}{A_P}\right)^{\frac{1}{1+m}} \left(\frac{1}{\left(\frac{A_P}{A_R}\right)^{\frac{m}{m+1}} + 1}\right) \frac{m\beta \left[(p + (1-p)\frac{A_P}{A_R})Y\right]}{2+\beta(1+m)}, \tag{15}$$

and

$$C_{2P} = \left(\frac{A_R}{A_P}\right)^{\frac{m}{1+m}} C_{2R} \tag{16}$$

If the income distribution is highly unequal, we may end up at a corner solution where the poorer agent does not contribute anything to productive investment and invests only in appropriation. Similarly, the richer agent may have absolute advantage in appropriation. Implicitly then, we assume that the initial distribution of income is not very skewed i.e., p is not very close to 1.

From the expressions of (11), (13), (14), (16), it is evident that if the initially-wealthier agent adopts a superior technology, he enjoys less consumption in both periods than the poorer agent. Also note that the equilibrium share of output is less for the relatively more-productive agent. These results are invariant to whether the more-productive agent is initially richer or not. This is because equilibrium allocation of resources are determined by comparative advantage. For example, when $A_R > A_P$, agent R has a comparative advantage in production and poor in appropriation. From standard trade theory, it follows that agent P should invest relatively more in appropriation and thus enjoy higher second period consumption i.e. $C_{2P} > C_{2R}$. On the other hand, agent P is reluctant to sacrifice current consumption to increase the size of the pie as he is relatively less productive and therefore he consumes more in the first period i.e., $C_{1P} > C_{1R}$. Similar arguments hold when $A_R < A_P$.

It remains to incorporate these optimal decisions, (11)-(16), in the agents' utility maximization problem and compute the technology choices (A_R, A_p) in stage one that produce non-cooperative optima for each agent. In other words, we compute U_R as a function of A_R (given A_p) and U_p as a function of A_p (given A_R). These represent the mutual best-responses. A pure strategy Nash equilibrium is a fixed point of these best-response functions that is consistent with positive levels of productive and appropriative investments, and consumption in each period, by both agents.

Proposition 1 *(Gonzalez, 2005) If p is sufficiently close to half and $\frac{A^H}{A^L} \to 1$, then a pure-strategy Nash equilibrium exists. $\left(A_R = A^H,\ A_P = A^H\right)$ is not a pure-strategy Nash equilibrium, i.e., the equilibrium technology profile cannot involve each agent adopting the best available technology.*

Why might agents not wish to adopt the best available technology even when it is costlessly available? In this environment of insecure property rights, the answer lies in the anticipation of future conflict. While adoption of a better technology by an agent raises tomorrow's common output, the very increase in tomorrow's pie elicits a harmful response from his rival (in the form of an increase in appropriative investment), and this dissuades the agent from adopting superior technologies in the first place. More specifically, the optimality conditions imply that agents allocate resources by equating marginal returns from the two types of investment activities. It follows that adoption of a superior technology raises the opportunity cost of appropriative investments for the adopter, inducing him to shift resources from appropriative to productive activities. Ceteris paribus, this raises future common output. On the flip side, the adoption of a superior technology lures his opponents to specialize in appropriation – appropriative investments act as strategic substitutes – thereby increasing the "expost tax" on the returns to adoption. The upshot is that choosing to adopt a superior technology confers a strategic disadvantage in the subsequent distribution of wealth.

The starting point of our analysis is this striking result in Gonzalez (2005): people are hesitant to adopt superior technologies because of the fear of subsequent heightened conflict. This presents a prima facie case for some sort of external involvement. Would it help, if a third party, say, a government, intervenes in this conflict by providing some manner of public protection of rights on private property? In the next section, we take up a slice of this issue.

3 Guard posting: introducing public security

3.1 Modified environment

To implement the idea discussed above, we introduce a third party, called "government" in the framework of the benchmark model. We think of the government as imposing a non-distortionary tax on the initial endowments of each agent at the start of their life. The tax proceeds are utilized to finance the hiring of a "guard". In terms of the model economy, the guard is simply a public security service whose sole aim is to reduce the effectiveness of each agents' appropriative investments by a constant amount. Since agents' share of future output depends on their effective appropriative investments, the presence of a guard, in effect, creates a threshold below which all appropriative investments are rendered ineffective. This influences agents' decisions on allocation of resources to various activities, which in turn, affects their marginal returns. The question at hand is: can the presence of a guard induce a reallocation of resources in such a way that adoption of the best-available technology by each agent evolves as a Nash equilibrium? [6]

As discussed above, assume each agent is required by law to pay as a tax, a

[6]By posting a guard, the government can act as a more-effective deterrent against one party capturing more of the final output than is due to that party. A question that legitimately arises at this juncture is, why does the government, via the posting of a guard, get involved in this conflict in the first place? Presumably, the government cares about improving property rights. A fuller discussion of this issue is presented in Section 4 below.

fixed proportion (τ) of his inherited wealth. Since inherited wealth is exogenously-specified – pY for agent R and $(1-p)\,Y$ for agent P – the tax is non-distortionary. We denote the total tax revenue by G, where $G = \tau Y$. The government uses the tax proceeds to post a guard whose only job is to equally reduce the effective amounts of the appropriative investments of *each* agent. Specifically, if X_i^e is the effective appropriation investment for agent i, then $X_i^e \equiv X_i - G$ where X_i is the corresponding investment made by agent i in the benchmark model. The technology of conflict, the analog of (1), is redefined in the following manner:

$$p'_G = \frac{(X_R^e)^m}{(X_R^e)^m + (X_P^e)^m}. \tag{17}$$

The new formulation, which looks a lot like (1), maintains the properties of symmetry and homogeneity of degree zero in *effective* appropriative investments; this keeps the model analytically tractable. This formulation requires that each agent invests at least an amount G – the threshold – to get a positive return from appropriative activities. Since τ can be quite small, the threshold – the restriction that $X_i^e > 0$ has to hold – may not be too onerous for the agents. What is important to note is that diminishing returns in appropriative investments imply that the marginal effect of an extra unit invested in appropriation (over and above the threshold) is much lower than in the benchmark model; additionally, the marginal return on appropriative investments is lower than the marginal utility from consumption or the return to productive activities.

It is evident that compared to the benchmark model, the only qualitative changes in this section are the imposition of a tax in the first period and the modification of the share function/technology of conflict. The sequence of activities and the information available to each agent at each point of time are exactly the same as that in the baseline model. Therefore, we proceed exactly as before to obtain the set of subgame perfect Nash equilibria (SPNE).

3.2 Equilibrium

Analogous to (6)-(7), the interior optimality conditions for agent R are given by:

$$\frac{1}{C_{1R}} = \frac{\beta p'_G A_R}{C_{2R}} \tag{18}$$

and

$$\frac{m(X_P - G)^m}{(X_R - G)\{(X_R - G)^m + (X_P - G)^m\}} = \frac{A_R}{Y'}. \tag{19}$$

The first condition, (18), is the familiar intertemporal Euler equation that equates the marginal utility of an unit of consumption across periods. For agent R, an unit of consumption forgone today and invested in the productive technology produces A_R units of future output. Since property rights are insecure, agent R gets to consume only his effective share, $p'_G A_R$. The second optimality condition requires that the marginal returns from both types of investment activities – productive and appropriative – be equated in equilibrium.

It is easy to check that (10) continues to hold in this reformulated environment, i.e.,

$$p'_G = \frac{1}{1 + \left(\frac{A_R}{A_P}\right)^{\frac{m}{m+1}}} \tag{20}$$

holds. Analogous to (11)-(16), we now have

$$C_{1R} = \frac{Y\left[\left(p + (1-p)\frac{A_P}{A_R}\right)(1-\tau) - \left(1 + \frac{A_P}{A_R}\right)\tau\right]}{\beta(1+m)+2}, \tag{21}$$

$$C_{2R} = \frac{\beta}{1 + \left(\frac{A_R}{A_P}\right)^{\frac{m}{m+1}}} \cdot \frac{Y\left[(A_R p + (1-p)A_P)(1-\tau) - (A_R + A_P)\tau\right]}{2 + \beta(1+m)}, \tag{22}$$

$$C_{1P} = \frac{Y\left[\left(\frac{A_R}{A_P}p + (1-p)\right)(1-\tau) - \left(1 + \frac{A_R}{A_P}\right)\tau\right]}{\beta(1+m)+2}, \tag{23}$$

and

$$C_{2P} = \frac{\beta\left(\frac{A_R}{A_P}\right)^{\frac{m}{m+1}}}{1 + \left(\frac{A_R}{A_P}\right)^{\frac{m}{m+1}}} \cdot \frac{Y\left[(A_R p + (1-p)A_P)(1-\tau) - (A_R + A_P)\tau\right]}{2 + \beta(1+m)}. \tag{24}$$

Additionally,

$$X_R = \left(\frac{1}{\left(\frac{A_P}{A_R}\right)^{\frac{m}{m+1}} + 1} \right) \frac{m\beta}{2 + \beta(1+m)} \Delta + \tau Y, \tag{25}$$

and

$$X_P = \left(\frac{1}{\left(\frac{A_P}{A_R}\right)^{\frac{m}{m+1}} + 1} \right) \frac{m\beta}{2 + \beta(1+m)} \Delta \left(\frac{A_R}{A_P} \right)^{\frac{1}{m+1}} + \tau Y \tag{26}$$

hold where $\Delta \equiv \left[\left(p + (1-p)\frac{A_P}{A_R} \right)(1-\tau)Y - \left(1 + \frac{A_P}{A_R}\right)\tau Y \right]$. It is clear from (25)-(26) that X_R^e and X_P^e are positive.

What are the main margins on which all the action in this model rests? First, at the margin, a higher tax rate reduces disposable income generating a first order negative effect on utility. However, there may arise a countervailing positive effect since the proceeds from the tax are used to employ a guard, whose actions may help secure property rights, and thereby encourage better technology adoption. How might this happen? Recall that the presence of a guard creates a threshold below which all appropriative investments are rendered ineffective. As a result, the marginal effect of an extra unit invested in appropriation (over and above the threshold) is considerably lowered, raising the corresponding return from productive activities. Both agents now have an incentive to respond to these favorable returns by adopting better technologies. The whole thing turns on the following tension: does the presence of a guard reduce the anticipation of future conflict by so much that the benefit to agents from adopting superior technologies outweighs their contribution to the financing of the guard in the first place? The next proposition argues that for a range of tax rates, the answer may be in the affirmative.

Proposition 2 *(Guard-posting) If* $p \to 1/2$ *and* $\frac{A^H}{A^L} \to 1$*, a pure strategy equilibrium with positive investment in productive activities exists for* $\tau \leq \tau_{inv}$*. Moreover for* $\tau \in [\tau_H, \tau_{inv}]$*,* $[A^H, A^H]$ *can be achieved as an equilibrium technology profile.*

The definitions of τ_{inv} and τ_H – all in terms of underlying parameters – can be found in the appendix. Proposition 2 is the central result of our paper. It argues that under the same sorts of parametric restrictions imposed in Proposition 1, a publicly-financed guard can significantly improve the equilibrium technology choice. In particular, $[A^H, A^H]$ can now be supported as a Nash equilibrium, something that was not possible in Proposition 1 or in Gonzalez (2005). [7]

3.2.1 Welfare Analysis

As discussed earlier, there is a tension between utility losses from lower disposable income when young and possible welfare gains from superior technology adoption in the presence of a guard. On net, can we say anything about overall welfare levels with and without public provision of security? To that end, we posit a Benthamite social welfare function:

$$SWF = U_R + U_P. \tag{27}$$

Since there are multiple equilibria possible both in the benchmark and in the guard-posting models, indeed the set of equilibria are different, the choice of which equilibria to compare becomes critical. Here we choose to compare social welfare across two symmetric equilibria, $\left(A^L, A^L\right)$ in the benchmark model and $\left(A^H, A^H\right)$ in the guard-posting model.

Corollary 3 *If (A^H, A^H) and (A^L, A^L) are equilibrium technology profiles in the guard-posting model and the benchmark model respectively, then aggregate social welfare is higher in the former equilibrium if the following parameter condition holds:*

$$\frac{A^H}{A^L} \geq \left(\frac{1}{(1-3\tau)^{2(\beta+1)}}\right)^{\frac{1}{2\beta}}.$$

[7] A few words about Proposition 2 are in order. When the tax rate lies within the interval $[\tau_H, \tau_{inv}]$, each agent's best response is to choose either the best or the worst available technology. That is, any equilibrium technology profile must be situated in the boundaries of the set of available technologies. If the tax rate lies outside the interval $[\tau_H, \tau_{inv}]$ then emergence of an interior equilibrium in technology choice is possible. In the baseline model, this was never a possibility.

Before we close this section, it would be useful to summarize our findings thus far. Gonzalez (2005) argued that a primary reason for technological backwardness is insecurity of property rights. If agents anticipate increased conflict from adoption of a superior technology, they may choose not to. The best-available, and yet free, technologies may never be adopted, with serious consequences for growth and welfare. We introduced the notion of public security of private property rights. In our setup, a guard is posted by the government with the sole aim of reducing the effectiveness of the appropriative investments of each agent. We find that the best-available technology can now be supported as a Nash equilibrium. This new equilibrium may also exhibit superior welfare.

In the environment studied thus far, the extent of involvement of the government in the post-production conflict was limited to posting a guard. All the guard did was thwart the appropriative activities of each agent, much like a policeman would. As an intuition-building exercise, this thought experiment was useful. What happens if the government takes on a more direct, proactive role in the post-production conflict, and is not restricted to merely impeding the appropriative activities of agents?

4 Improving property rights

In this section, we allow the government to utilize the tax proceeds to directly influence the technology of conflict with a view to improving the security of private property rights. This is achieved via the following reformulation of the conflict technology:

$$p'_e = \frac{x_R^{m\theta}(A_R K_R)^{1-\theta}}{x_P^{m\theta}(A_P K_P)^{1-\theta} + x_R^{m\theta}(A_R K_R)^{1-\theta}},\ \theta \in [0,1]. \tag{28}$$

In this formulation, p'_e denotes the share of second period output that accrues to agent R. As is clear from (28), p'_e reduces to p' (see (1) in the benchmark model) when $\theta = 1$ and to $A_R K_R / Y'$ when $\theta = 0$. In other words, the technology of conflict in

(28) straddles two extremes, the insecure property-rights regime from the benchmark model and an environment of perfect property rights (where agent R receives his legitimate share, $A_R K_R / Y'$).

We posit that θ is a choice variable for the government, i.e., it can influence θ directly as follows: $\theta \equiv \Phi(G)$, where, recall, $G = \tau Y$. Furthermore, $\Phi(0) = 1$, $\Phi(G^*) = 0$, and $\Omega'(G) < 0$. If the government wishes to improve property rights, it raises τ (and hence, G) and uses the revenue to reduce θ.[8] In the limit, as G approaches a critical level, G^*, a perfect property rights regime is established. In a laissez-faire regime, the government takes no part in post-production conflict and sets $G = 0$. This establishes the polar opposite regime of insecure property rights. Henceforth, θ measures the exact level of insecurity of agents' claims to private property.

The rest of the environment is exactly as it is in the benchmark model. Analogous to (6)-(7), the interior optimality conditions for agents R and P are given by

$$\frac{1}{(1-\tau)pY - X_R - K_R} = \frac{\beta A_R}{A_R K_R + A_P K_P} + \frac{(1-\theta) X_P^{m\theta} (A_P K_P)^{1-\theta}}{[X_P^{m\theta}(A_P K_P)^{1-\theta} + X_R^{m\theta}(A_R K_R)^{1-\theta}] K_R}$$
$$\frac{1}{(1-\tau)pY - X_R - K_R} = \frac{m\theta X_P^{m\theta}(A_P K_P)^{1-\theta}}{[X_P^{m\theta}(A_P K_P)^{1-\theta} + X_R^{m\theta}(A_R K_R)^{1-\theta}] X_R}$$

and

$$\frac{1}{(1-p)(1-\tau)Y - X_p - K_p} = \frac{\beta A_P}{A_R K_R + A_P K_P} + \frac{(1-\theta) X_R^{m\theta} (A_R K_R)^{1-\theta}}{[X_P^{m\theta}(A_P K_P)^{1-\theta} + X_R^{m\theta}(A_R K_R)^{1-\theta}] K_P}$$
$$\frac{1}{(1-p)(1-\tau)Y - X_p - K_p} = \frac{m\theta X_R^{m\theta}(A_R K_R)^{1-\theta}}{[X_P^{m\theta}(A_P K_P)^{1-\theta} + X_R^{m\theta}(A_R K_R)^{1-\theta}] X_P}$$

respectively. The equilibrium technology profile involves solving the above system of equations for K_R, K_P, X_R and X_P, where $p \in (1/2, 1]$, $\beta \in [0,1]$, $\tau \in [0,1]$, $m \in [0,1]$, $\theta \equiv \Phi(G) \in [0,1]$, and $Y > 0$.

As is clear, the first-order interior optimality conditions are highly non-linear. These equations do not allow us to get closed form expressions of the optimal resource allocations as a function of initial technology choice. We resort to solving the problem

[8] This action could be interpreted as improving funding for the police and the judiciary at large.

using numerical methods. We assume the following parametric specification: $Y = 100$, $\beta = 0.6$, $p = 0.6$, $[A^L = 9.1,\ A^H = 10.4]$ and $m = 0.5$. We also assume $\Phi(G) = 1 - G$. We investigate the effects of a change in the property rights regime and its associated welfare implications. Our focus is restricted to studying these effects within the confines of a particular equilibrium. To that end, we confine our analysis to an interval for τ that supports $\left(A^H, A^H\right)$ as an equilibrium technology profile. The appropriate interval is $\tau \in [0.0005, 0.0079]$. Within such an interval, given that his rival has adopted A^H, the best response for an agent is to choose the same or a better technology.Within that interval, the movements of the relevant variables with respect to property right parameter θ are captured in the following graphical representations.

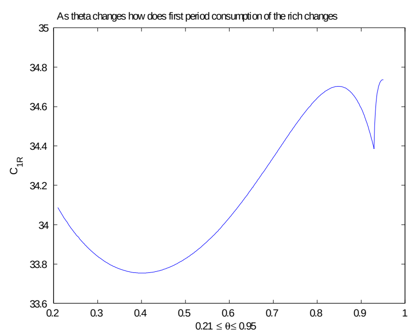

Fig 1: Change in C_{1R} w.r.t θ

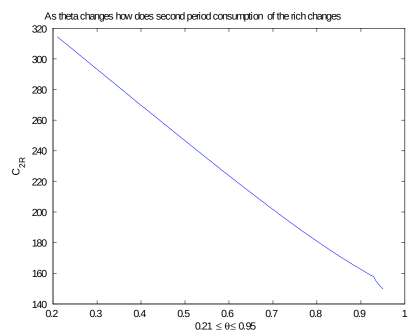

Fig 2: Change in C_{2R} w.r.t θ

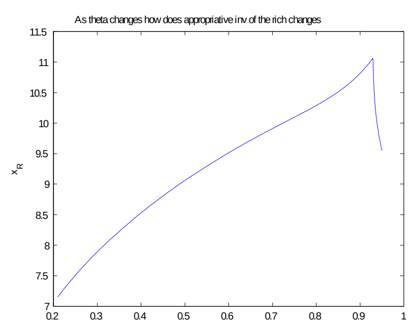

Fig 3: Change in X_R w.r.t θ

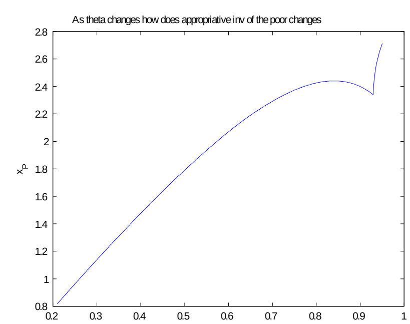

Fig 4: Change in X_P w.r.t θ

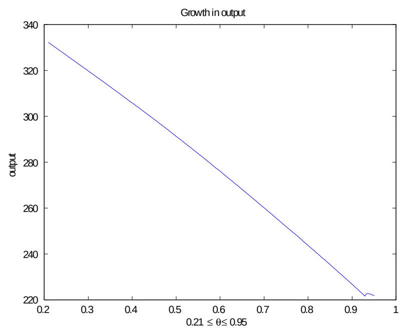

Fig 5: Change in Y' w.r.t θ

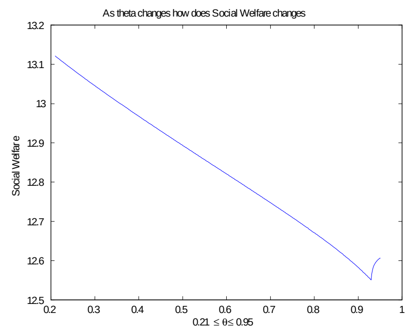

Fig 6: Change in SW w.r.t θ

Here, we study how an improvement in property rights shapes optimal resource allocations when the best-available technology has already been adopted. Intuition suggests that within this interval, enhanced security of property rights should induce larger productive investments and thereby foster economic growth.This is substantiated in the findings of fig (3) through (5). From fig (3) and (4) it is quite clear that the appropriative investment of both the agents falls. This is quite intuitive since more secure property reduces the returns from appropriation. Fig (5) illustrates that there is a one to one correspondence between tomorrow's output and more secure property rights. An explanation put forward to substantiate the above findings runs along the following lines. More secure property increases the returns to productive activities, which in turn reduces the diversion of resources and thus promotes growth. A natural question that comes up is whether enhanced security in private property accompanied by higher growth comes at the cost of lower aggregate welfare? Are more secure property rights always desirable? If the government could ensure perfectly secure property rights, would it? We show that there exists an interval of taxation such that an increase in property security leads to a decrease in welfare. This is basically demonstrated in fig (6). Note first period consumption of the rich falls while second period consumption increases as property rights are more secured. As to why this happens we can say as an agent's rights over tomorrow's output get more secured he wants to invest more in productive investment and this comes at the cost of current consumption as a result of which current consumption falls. Second period consumption increases due to the cumulative effect of increased future output as well as more secure property rights. There exists a critical zone of taxation over which the fall in current consumption dominates the rise in future consumption resulting in a dip in the social welfare function. Beyond the critical level the rise in second period consumption more than offsets the fall in current consumption as a result social welfare rises with an increase in security of private property. From a policy perspective this result calls for a caution in recommending improved property rights enforcement, particularly when such improvements are to be made in middle income countries.

5 Conclusion

We have considered the role institutions of property rights and conflict management can play in both achieving prosperity and mitigating conflict in developing countries. In the first half of our paper, we consider a scenario where public-funded protection of private property rights may successfully support the adoption of best-available technologies as Nash equilibrium. Such a scheme may even be welfare enhancing. Here the government's role in post production conflict is limited to " posting a guard" who thwarts the appropriative activities each agent much like a policeman Next we try to answer a more pertinent question: what happens if government takes on a more direct, proactive role in post-production conflict? Basically we endogenize the property rights by introducing a new formulation of the conflict technology, where government can explicitly intervene in the existing level of property rights by choosing the tax rate. We allow the government to utilize the tax proceeds to directly influence the technology of conflict with a view to improve the security of private property. With in this set up we study how an improvement in property rights shapes optimal resource allocations when the best-available technology has already been adopted. This addresess a fundamental question. When govt has the option to choose a tax rate that ensure perfect property rights, is that always desirable? Would such a choice of tax rate be always welfare enhancing? We show that there exists an interval of taxation such that an increase in property security leads to a decrease in welfare. From a policy perspective this surprising result calls for a caution in recommending improved property rights enforcement, particularly when such improvements are to be made incrementally in middle income countries.

6 Appendix

Optimal resource allocation of agents R and P: The optimization problem of agent R in the second stage of first period is:

$$Max \;\; \ln C_{1R} + \beta \ln C_{2R} \tag{29}$$

$$st \; pY(1-\tau) = C_{1R} + K_R + X_R \tag{30}$$

$$\acute{p}Y' = C_{2R} \tag{31}$$

$$\acute{p} = \frac{(X_R - G)^m}{(X_R - G)^m + (X_P - G)^m} \tag{32}$$

$$Y' = A_R K_R + A_P K_P \tag{33}$$

The interior optimality conditions are:

$$\frac{1}{C_{1R}} = \frac{\beta A_R}{Y'} \tag{34}$$

$$\frac{m(X_P - G)^m}{(X_R - G)\{(X_R - G)^m + (X_P - G)^m\}} = \frac{A_R}{Y'} \tag{35}$$

Analogus expressions for agent P are given by:

$$\frac{1}{C_{1P}} = \frac{\beta A_P}{Y'} \tag{36}$$

$$\frac{m(X_R - G)^m}{(X_P - G)\{(X_R - G)^m + (X_P - G)^m\}} = \frac{A_P}{Y'} \tag{37}$$

Denote, $\alpha = (X_R - G)^m + (X_P - G)^m$. Dividing (35) by (37), we get

$$\frac{m(X_P - G)^m}{(X_R - G)\alpha} \cdot \frac{(X_P - G)\alpha}{m(X_R - G)^m} = \frac{A_R}{A_P} \tag{38}$$

$$or, \left(\frac{X_P - G}{X_R - G}\right)^{m+1} = \frac{A_R}{A_P} \tag{39}$$

$$or, \frac{(X_P - G)}{(X_R - G)} = \left(\frac{A_R}{A_P}\right)^{\frac{1}{m+1}}. \tag{40}$$

Dividing (32) by $(X_R - G)^m$ we get

$$\acute{p} = \frac{1}{1 + \left(\frac{X_P - G}{X_R - G}\right)^m} \tag{41}$$

Substituiting the expression in (40) in (41) we get

$$\acute{p} = \frac{1}{1 + \left(\frac{A_R}{A_P}\right)^{\frac{m}{m+1}}} \tag{42}$$

Using the resource constraints and above formulation of $\acute{p}$, we can reduce the FOC's of agents R and P as a system of linear equations in C_i and $X_i, i \in \{R, P\}$. The unique solution to the linear system is given by:

$$\begin{aligned}
C_{1R} &= \frac{1}{\beta(1+m)+2}\left[(p + (1-p)\frac{A_P}{A_R})(1-\tau)Y - (1 + \frac{A_P}{A_R})\tau Y\right] \qquad (43)\\
C_{1P} &= \frac{1}{\beta(1+m)+2}\left[(\frac{A_R}{A_P}p + (1-p))(1-\tau)Y - (1 + \frac{A_R}{A_P})\tau Y\right]\\
X_R &= \left(\frac{1}{\left(\frac{A_P}{A_R}\right)^{\frac{m}{m+1}} + 1}\right)\frac{m\beta}{2+\beta(1+m)}\Delta + \tau Y\\
X_P &= \left(\frac{1}{\left(\frac{A_P}{A_R}\right)^{\frac{m}{m+1}} + 1}\right)\frac{m\beta}{2+\beta(1+m)}\Delta\left(\frac{A_R}{A_P}\right)^{\frac{1}{m+1}} + \tau Y
\end{aligned}$$

where, $\Delta = [(p + (1-p)\frac{A_P}{A_R})(1-\tau)Y - (1 + \frac{A_P}{A_R})\tau Y]$. This concludes the derivation of the optimal consumption and resource allocation.

Proof of Proposition 2. We state a lemma which we would invoke while proving proposition 2.

Lemma 1. If $\tau \leq \tau_{inv}$, positive investment equilibrium exists..

Proof. We need to find a bound on τ such that $X_P - G \geq 0$, $X_R - G \geq 0, K_P \geq 0$, $K_R \geq 0$. From the expressions of appropriative investments from (43) we see that $X_R - G \geq 0$ if $\Delta \geq 0$. Now $\Delta \geq 0$ implies

$$\frac{1-\tau}{\tau} \geq \frac{1+\frac{A_P}{A_R}}{p+(1-p)\frac{A_p}{A_R}} \ \forall \ \frac{A_P}{A_R} \in [\frac{A^L}{A^H}, \frac{A^H}{A^L}] \tag{44}$$

Taking limit on both sides as $\frac{A^H}{A^L} \rightarrow 1$ we have $\frac{1-\tau}{\tau} \geq 2$ this implies $1-\tau \geq 2\tau$, or $3\tau \leq 1$, i.e. $\tau \leq \frac{1}{3}$. similar reasoning holds good for $X_P - G \geq 0$. Thus for $\tau \in [0, \overline{\tau}]$, where $\overline{\tau} = \frac{1}{3}$, equibrium effective appropriative investments are positive. We check the conditions under which K_R,$K_P \geq 0$. Substituting the values of X_R, C_{1R} in the expression of K_R we see that K_R reduces to

$$K_R = pY(1-\tau) - [\frac{m\beta}{2+\beta(1+m)} \frac{\Delta}{\left(\frac{A_P}{A_R}\right)^{\frac{m}{m+1}}+1} + \tau Y] - \frac{\Delta}{2+(1+m)\beta} \tag{45}$$

Upon tedious manipulation we see that $K_R \geq 0$ implies

$$p(1-\tau) - a + b - \tau - \frac{(1-\tau)\Delta}{2+\beta(1+m)} + \frac{(1+z)\tau}{2+\beta(1+m)} \geq 0 \tag{46}$$

Where $a = \frac{m\beta(1-\tau)\Delta}{(2+\beta(1+m))(z)^{\frac{m}{m+1}}+1}$, $b = \frac{m\beta(1+z)\tau}{(2+\beta(1+m))(z)^{\frac{m}{m+1}}+1}$, $z = \frac{A_P}{A_R}$. Taking limit on both sides of the above equation as $\frac{A^H}{A^L} \rightarrow 1$ we have

$$\tau[-(1-p) + \frac{6+3m\beta}{2(2+\beta(1+m))}] \geq \frac{m\beta+2}{2(2+\beta(1+m))} - p \tag{47}$$

If we assume, $[-(1-p) + \frac{6+3m\beta}{2(2+\beta(1+m))}] > 0$, we arrive at a condition that states $p < \frac{1}{2}$, which contradicts our basic assumption. Thus $-(1-p) + \frac{6+3m\beta}{2(2+\beta(1+m))} < 0$. By similar reasoning $\frac{m\beta+2}{2(2+\beta(1+m))} - p < 0$. Rearranging terms we see that $K_R \geq 0$ iff $\tau \leq \frac{\frac{m\beta+2}{2(2+\beta(1+m))}-p}{-(1-p)+\frac{6+3m\beta}{2(2+\beta(1+m))}}$. Let us call $\tau_1 = \frac{\frac{m\beta+2}{2(2+\beta(1+m))}-p}{-(1-p)+\frac{6+3m\beta}{2(2+\beta(1+m))}}$. Again, for $K_P \geq 0$, we substitute the values of X_P and C_P in the expression of K_P, which gives,$K_P = (1-p)(1-\tau)Y - c - \tau Y - d$ where $c = \frac{m\beta\Delta[(1-\tau)}{2+\beta(1+m)} \frac{1}{(1+\left(\frac{A_P}{A_R}\right)^{\frac{m}{m+1}})} \left(\frac{A_R}{A_P}\right)^{\frac{1}{m+1}}$, $d = \frac{\Delta}{2+\beta(1+m)}$. Taking limit on both sides of the expression of K_P as $\frac{A^H}{A^L}$ goes to 1 we get $K_P \geq 0$ iff

$$(1-p)(1-\tau) - \frac{m\beta Y}{2+\beta(1+m)}[\frac{(1-3\tau)}{2} + (1-3\tau)] - \tau \geq 0$$

$$iff,\ \tau \leq \frac{2+m\beta+2(p-1)(2+\beta(1+m))}{-2(1-p)(2+\beta(1+m))+2+m\beta-2\beta}$$

Let $\tau_2 = \frac{2+m\beta+2(p-1)(2+\beta(1+m))}{-2(1-p)(2+\beta(1+m))+2+m\beta-2\beta}$. Thus $K_P \geq 0$ iff $\tau \leq \tau_2$. Thus for $\tau \leq \min\{\overline{\tau}, \tau_1, \tau_2\}$ all the three inequalities are satisfied. We denote $\tau_{inv} = \min\{\overline{\tau}, \tau_1, \tau_2\}$.Thus there exists positive levels of investment for $\tau < \tau_{inv}$ as, $\frac{A^H}{A^L} \longrightarrow 1$ .Q.E.D.

Proof of Proposition 2. We first prove the second part of the proposition. We show that an agent's best response to any choice of technology by the other agent involves in either choosing the best technology or the worst one i.e $A_i \in \{A^L, A^H\}$ for a given interval. Substituting the values of C_{1R} and C_{2R} into the utility function, we get $U_R = U_R(A_R, A_P)$. Differentiating U_R w.r.t A_R we get,

$$\frac{\partial U_R}{\partial A_R} \geq 0 \text{ iff } \frac{\tau}{1-\tau} \geq \Gamma(x) \tag{48}$$

provided $(1-\tau)(p+(1-p)x)-(1+x)\tau \geq 0$ and $\phi k(x)(1+x)+x-\beta \geq 0$. Here $\Gamma(x) = \frac{f(x)}{g(x)}$, $x = \frac{A_P}{A_R}$, $f(x) = (p+(1-p)x)[1+\phi k(x)]-(1+\beta)p$, $g(x) = \phi k(x)(1+x)+x-\beta$. Also, $\phi = \frac{m\beta}{m+1} < \beta$,and $k(x) = \frac{1}{1+x^{\frac{m}{m+1}}}$. Now,

$$\Gamma'(x) \geq 0$$

$$iff,\ [\beta(2p-1)+\phi(1-\beta)(1-2p)k(x)+\phi^2(1-2p)k(x)^2+\phi(1+\beta)(2p-1)k'(x)x \geq 0$$

$$iff,\ \beta x^{\frac{2m}{m+1}} + [(\beta-\phi)(1+\phi)+\beta(1-(\frac{m}{m+1})^2)]x^{\frac{m}{m+1}} + (\beta-\phi)(1+\phi) \geq 0. \tag{49}$$

The above is an equation of a parabola where both the roots, say x_1 and x_2, are negative. Therefore, for all $x \geq \max\{x_1, x_2\}$, the $\Gamma(x)$ is positively sloped. For the values of x that satisfy equations $(43)-(49)$, we get the best response of agent R is to choose either A^L or A^H. This interval of x implicitly put a restriction on τ. We denote that critical value of $\tau \geq \tau_R = \frac{1-p}{2-p}$. Again, substituting C_{1P} and C_{2P} into the utility function, we get

$$U_P = U_P(A_R, A_P)$$

Following the same steps for the poor agent, we get if ,$(1-\tau)(py+1-p)-\tau(1+y) \leq 0$, and $(1+\beta)(1-p)-(py+1-p)(1+\phi k(y) \leq 0$ then,

$$\frac{\partial U_P}{\partial A_P} \geq 0 \ iff \ \frac{1-\tau}{\tau} \geq G(y) \ where, \tag{50}$$

$$G(y) = \frac{\beta - y - \phi k(y)(1+y)}{(1+\beta)(1-p)-(py+1-p)(1+\phi k(y)}, y = \frac{A_R}{A_p}$$

Now, $G'(y) \geq 0$

$$iff \ \ [\beta(2p-1)+\phi(1-\beta)(1-2p)k(y)+\phi^2(1-2p)k(y)^2+\phi(1+\beta)(2p-1)k'(y)y \geq 0$$

$$iff \ \ (\beta-\phi)(1+\phi)x^{\frac{2m}{m+1}}+[(\beta-\phi)(1+\phi)+\beta(1-(\frac{m}{m+1})^2)]x^{\frac{m}{m+1}}+\beta \geq 0 \tag{51}$$

Which is again an equation of a parabola, where both the roots (say x_3, x_4) are negative, though different in values. Then, $x \geq \max\{x_3, x_4\}, G(y)$ is positively sloped. Thus, for $x \geq 0$,both $\Gamma(x)$ and $G(y)$ are postively sloped. Therefore, for the values of x that satisfy equations (46)−(51), we get the best response for agent P is to choose either A^L or A^H.This interval of x implicitly put a restriction on τ. We denote that critical value of $\tau \leq \tau_P = \frac{p}{1-p}$.

Let $\frac{A^H}{A^L} \rightarrow 1$. If $\tau \in [\frac{1-p}{2-p}, \frac{p}{1+p}]$, then both the agents best response is to adopt either A^H or A^L. We denote $\tau_H = \frac{1-p}{2-p}$. From the Lemma 1, we know that positive investment equilibrium exists for $\tau \leq \tau_{inv}$. Thus for $\tau \in [\tau_H, \tau_{inv}]$, $[A^H, A^H]$ can be sustained as a positive investment equilibrium. This completes the proof.

Proof of Corollary 3. Given (A^L, A^L) is an equilibrium in the bench-mark model the optimal choices of C_{1i} and C_{2i}, $i \in \{R, P\}$ are given as $C_{1i} = \frac{Y}{2+\beta(1+m)}$,$C_{2i} = \frac{\beta Y A^L}{2(2+\beta(1+m))}$. The SWF in this case is given by

$$SWF(A^L, A^L) = (\ln C_{1P} + \beta \ln C_{2P}) + (\ln C_{1R} + \beta \ln C_{2R})$$

plugging in the values of C_{1i} and C_{2i} into the above equation we have

$$SWF(A^L, A^L) = \ln \frac{Y^2}{(2+\beta(1+m))^2} \left(\frac{\beta A^L Y}{2\,(2+\beta(1+m))} \right)^{2\beta}$$

Similarly when (A^H, A^H) is an equilibrium in the guard posting framework the optimal choices of C_{1i} and C_{2i}, $i \in \{R, P\}$ are $C_{1i} = \frac{Y(1-3\tau)}{2+\beta(1+m)}$ and $C_{2i} = \frac{\beta A^H(1-3\tau)Y}{2(2+\beta(1+m))}$ respectively. Plugging in the expressions of C_{1i} and C_{2i} in the social welfare function $SWF = U_R + U_P$ and rearranging the terms we get

$$SWF(A^H, A^H) = \ln[\left(\frac{(1-3\tau)Y}{(2+\beta(1+m))}\right)^2 \left(\frac{\beta A^H Y(1-3\tau)}{2\,(2+\beta(1+m))}\right)^{2\beta}]$$

From this it follows that

$$SWF(A^H, A^H) \geq SWF(A^L, A^L)$$

$$if \quad \left(\frac{(1-3\tau)Y}{(2+\beta(1+m))}\right)^2 \left(\frac{\beta A^H Y(1-3\tau)}{2\,(2+\beta(1+m))}\right)^{2\beta} \geq \frac{Y^2}{(2+\beta(1+m))^2} \left(\frac{\beta A^L Y}{2\,(2+\beta(1+m))}\right)^{2\beta}$$

$$if \quad (1-3\tau)^2 \left(A^H\right)^{2\beta} (1-3\tau)^{2\beta} \geq \left(A^L\right)^{2\beta}$$

$$or \quad \frac{A^H}{A^L} \geq \left(\frac{1}{(1-3\tau)^{2(\beta+1)}}\right)^{\frac{1}{2\beta}}$$

This completes the proof of Corollary 3.

References

[1] Alesina, A. and Perotti R. (1996). Income distribution, political instability, and investment. European Economic Review 40: 1203-1028.

[2] Bates, R. H. (2001). Prosperity and Violence, New York: Norton & Company.

[3] Besley.T. (1995), Property Rights and Investment Incentives, Theory and Evidence from Ghana. Journal of Political Economy, 103, (5), pp. 903-937.

[4] Benhabib, J., and A. Rustichini. (1996), Social Conflict and Growth. Journal of Economic Growth, Vol. 1, No. 3, March. pp. 125-142.

[5] De Meza, D. and Gould, J. R. (1992), The social efficiency of private decisions to enforce property rights. Journal of Political Economy, vol. 100 (June), pp. 561–80.

[6] Field, E. (2007), Entitled to work: urban property rights and labor supply in Peru, Quarterly Journal of Economics 122, 1561-1602.

[7] Garfinkel, Michelle R. and Stergios Skaperdas. (2007), Economics of Conflict: An Overview, in T. Sandler and K. Hartley (eds.), Handbook of Defense Economics, Vol. II, pp. 649-709.

[8] Gonzalez,.F.M. (2010), "The use of coercion in society: insecure property rights, conflict and economic backwardness", forthcoming in Michelle Garfinkel and Stergios Skaperdas (editors), Oxford Handbook of the Economics of Peace and Conflict.

[9] Gonzalez, F.M. (2007), Effective Property Rights, Conflict and Growth. Journal of Economic Theory, November 2007,pp. 127-139.

[10] Gonzalez, F.M. (2005), Insecure Property and Technological Backwardness. Economic Journal, July, pp. 703-721.

[11] Goldstein, M. and C. Udry (2008), The profits of power: land rights and agricultural investment in Ghana, Journal of Political Economy 116, 981-1022.

[12] Grossman H. I. (1995), Robin Hood and the redistribution of property income. European Journal of Political Economy, vol. 11, pp. 399-410.

[13] Grossman, H., and M. Kim. (1996), Predation and Accumulation. Journal of Economic Growth, Vol. 1, No. 3, September, pp. 333-351.

[14] Hall, R. E. and Jones, C. I. (1999), Why do some countries produce so much more output per worker than others?. Quarterly Journal of Economics, vol. 114 (February), pp. 83-116.

[15] Hirshleifer, J. (1995a), Anarchy and its breakdown. Journal of Political Economy 103 pp. 26-52.

[16] Krusell, P. and J.V. Rios-Rull (1996), Vested interests in a theory of growth and stagnation," Review of Economic Studies 63, 301-329.

[17] Loyd-Ellis, H., and N. Marceu. (2003), Endogenous Insecurity and Economic Development. Journal of Development Economics, Vol. 72. pp.1-29.

[18] Mokyr, J. (1990), The lever of riches, New York: Oxford University Press.

[19] Olson, M. (1982). The Rise and Decline of Nations, New Haven: Yale University.

[20] Parente, S.L. and E.C. Prescott (1999), Monopoly rights: a barrier to riches, American Economic Review 89, 1216-1233.

[21] Skaperdas, S. (1992), Cooperation, conflict, and power in the absence of property rights. American Economic Review, vol. 82 (September), pp. 720-39.