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# Property Rights, Mobile Capital, and Comparative Advantage

## **Abstract**

Recent papers show that imperfect property rights to a natural resource—a sector-specific factor—can be a source of comparative advantage. In these models, weaker property rights attract labor—the only mobile factor—to the resource sector, increasing the country’s comparative advantage for that sector. If capital in addition to labor is mobile, and if the benefits of capital are non-excludable or if the degree of property rights is endogenous, a deterioration of property rights has ambiguous effects on comparative advantage and on the equilibrium wage-rental ratio.

# Property Rights, Mobile Capital, and Comparative Advantage\*

Larry Karp<sup>†</sup>

June 7, 2004

## Abstract

Recent papers show that imperfect property rights to a natural resource – a sector-specific factor – can be a source of comparative advantage. In these models, weaker property rights attract labor – the only mobile factor – to the resource sector, increasing the country's comparative advantage for that sector. If capital in addition to labor is mobile, and if the benefits of capital are non-excludable or if the degree of property rights is endogenous, a deterioration of property rights has ambiguous effects on comparative advantage and on the equilibrium wage-rental ratio.

Key words: imperfect property rights, comparative advantage, general equilibrium.

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# 1 Introduction

Trade theory shows that differences in technology or factor endowments can be a source of comparative advantage. Institutional failure – in particular, imperfect property rights – is another source of comparative advantage. The relation between comparative advantage and institutional failure is particularly important for North-South trade. Property rights tend to be defined and protected to a greater extent in the North, relative to the South. In addition, many of South’s exports are resource-based. Poorly defined property rights to this resource may increase, or even be the source of South’s comparative advantage in the resource-based sector. In this situation, trade exacerbates a market failure and it can lower South’s national income. This paper shows that weaker property rights in the resource-intensive sector can *weaken* comparative advantage in that sector under two circumstances: (i) Imperfect property rights to the natural resource make it difficult to capture all of the returns to an intermediate investment used in that sector. (ii) The degree of property rights is endogenous. We illustrate both possibilities using a model with mobile capital and labor.

In previous models, an improvement in property rights benefits the owners of sector-specific capital and harms workers. In the circumstances that we describe, nominal owners of the natural resource always benefit from strengthening their property rights; however, the effect of stronger property rights on the real return to workers and the owners of capital is ambiguous. The identity of the resource owner’s natural ally in the effort to improve property rights can vary with the level of property rights. National income (at constant output prices) can also be non-monotonic in property rights.

Chichilnisky (1994) uses a North-South model with mobile labor to show that property rights can be the source of comparative advantage, and that trade between two regions that differ only with respect to their property rights can lower the welfare of the country with weaker property rights. Brander and Taylor (1997, 1998), and Copeland and Taylor (1999) study trade and property rights in a dynamic Ricardian model. Copeland and Taylor (2003) review and extend static models of trade and the environment. Karp, Sacheti, and Zhao (2001) and Karp, Zhao, and Sacheti (2003) imbed Chichilnisky’s model in a dynamic setting in order to compare the short and long run effects of trade liberalization, environmental reform and the harmonization of policies. In Hotte, van Long, and Tian (2000) and Margolis and Shogren (2000) agents use the single mobile factor of production to protect their property rights. The endogenous equilibrium level of property rights depends on prices, the “protection technology”,

and on the resource stock.

Most of these papers use variants of a two-country, two-commodity model with one mobile factor, labor. Property rights in the resource-based sector are imperfect, causing an excessive (relative to the social optimum) amount of labor to enter that sector. The weaker are property rights, the more labor enters the sector, other things equal. A central conclusion of these models is that weaker property rights are unambiguously associated with an increased comparative advantage in the resource-based sector. If the two countries are identical, apart from their differing property rights, the country with the weaker property rights exports the resource-based good.<sup>1</sup>

This conclusion can be reversed if there are investment opportunities in the resource-based sector, and if imperfect property rights in this sector make it difficult to capture all of the returns from this investment. For example, investment in roads and other infrastructure makes it easier to extract forest products. Weaker property rights make it more difficult to capture the benefits of these kinds of investments, making them less attractive. For a given level of investment, weaker property rights attract mobile factors, leading to increased production, as the earlier papers note. However, when we recognize that weaker property rights discourage certain investments, the net effect of property rights on resource allocation is ambiguous, and may be non-monotonic.

If factors are mobile and the degree of property rights is endogenous, there is an additional reason why the relation between property rights and comparative advantage is ambiguous. The use of factors to secure property rights can change the prices and the relative supplies of factors remaining for the production of other goods (including the resource-based good).

The combination of weak property rights and trade might be important in many sectors. Abaza and Jha (2002) summarize six case studies of forestry, agriculture and fisheries that investigate the effect of trade liberalization in the presence of market imperfections.<sup>2</sup> Coxhead

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<sup>1</sup>If the two countries differ in, for example, their factor endowments (as in Copeland and Taylor (2003)), tastes or technology, those differences might either reinforce or offset the effect of differing property rights. In that case, the relation between property rights and comparative advantage is ambiguous. In a dynamic model where the resource stock changes endogenously, the country with weaker property rights might degrade its resource, leading to the eventual loss in comparative advantage in the resource-intensive sector, as in Brander and Taylor (1997). En route to a steady state, comparative advantage might switch back and forth between countries with differing levels of property rights, as in Karp, Sacheti, and Zhao (2001).

<sup>2</sup>These imperfections are not restricted to imperfect property rights. For example, the developed countries' subsidies to fleets used in developing country fisheries is an important distortion. In some cases the distortions

and Jayasuriya (2003) analyze the effect of property rights in open Asian economies.

The following review concentrates on forestry and agriculture. Trade liberalization can put pressure on forest resources by increasing the exports of forest products and by encouraging the conversion of forests into agricultural land. Deacon (1995, 1999) finds that land tenure insecurity increases deforestation. Bohn and Deacon (2000) show that property rights can be an important determinant of production levels, and that the direction of the effect depends on the type of investment problem; for example, it differs for forestry and oil. Lopez (1997) shows that the degree of property rights affects deforestation in Ghana. Barbier and Burgess (2001) review the empirical literature on deforestation. They also estimate the strength of factors contributing to the expansion of agricultural land, thus providing indirect evidence concerning deforestation. They find that the property rights variable is insignificant in all regressions, and that it has the “wrong sign” (stronger property rights decreases agricultural land expansion) in most cases. For Asian countries, higher corruption (a proxy for weak property rights) is associated with statistically significant *lower* levels of agricultural expansion; this variable is not significant for other regions. Ferreira (forthcoming) regresses deforestation rates against measures of openness and institutional indices and interacts these variables. Coefficients on the institutional indices are not significant; some interaction terms are significant, but their signs vary.

This review suggests that there is mixed empirical evidence for the hypotheses that property rights are an important determinant of deforestation/land conversion, or that the price changes resulting from trade liberalization damage the environment because of weak property rights. This lack of unequivocal evidence might simply be due to statistical problems.<sup>3</sup> Even if trade does harm the environment of developing countries, it might be hard to establish this econometrically. A second interpretation of the mixed empirical evidence is that the relation between trade liberalization and the environment in the presence of weak property rights is actually

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had substantial environmental effects. In Tanzania, trade-induced growth led to a building boom that increased deforestation rates; however, the direct effect of trade operating through increased timber exports or conversion to agricultural land was small. That is, the environmental effect occurred because of higher income, not directly because of price changes.

<sup>3</sup>Within the economics profession the acceptance of the hypothesis “trade increases aggregate growth” is probably much stronger than is the acceptance of the hypothesis “trade harms the environment of developing countries”. The first hypothesis has received much more attention, over a longer period of time and using better data, than has the second. Nevertheless, the empirical support for the first hypothesis is still mixed (Harrison 1996), (Rodriguez and Rodrik 2001), (Milanovic 2003).

ambiguous.

The price changes, increased competition, and technology flows associated with globalization have many opposing effects on the environment. There are consequently many reasons why the relation between openness and resource degradation might be ambiguous even where imperfect property rights are important. We do not need a new model to show that the trade-environment nexus is complicated. However, previous North-South trade-environment models have been persuasive because their principal results seem so intuitive. It is therefore worth pointing out that reasonable changes in the models can reverse the conclusions.

The next section shows that the relation between exogenous property rights and both comparative advantage and real factor returns can be ambiguous when production in the resource-intensive sector uses a non-excludable investment. The subsequent section shows that endogeneity of property rights can reverse the standard results. The final section contains concluding comments.

## 2 Non-excludable investments

This section explains the possibly non-monotonic relations between property rights and both comparative advantage and returns to factors when there is a non-excludable investment. We first describe the model and explain the importance of non-excludable investments in this setting. The next subsection specifies the model. In order to emphasize the role of investments, we digress to review the conclusions from simpler models without these investments. The next two subsections illustrate our results and discuss their generality.

There are two sectors in the economy, Cloth ( $C$ ) and Forestry ( $F$ ). Production of Forestry but not of Cloth requires a natural resource, for which property rights are imperfect. There are two mobile factors of production, capital and labor ( $K$  and  $L$ ). Cloth production uses only  $K$  and  $L$ , with constant returns to scale; there are perfect property rights in Cloth.

Forestry production uses  $K$  and  $L$  and a stock of natural resources, denoted  $f$ ; this sector has constant returns to scale in  $(f, K, L)$ . In a dynamic setting,  $f$  changes endogenously. However, in order to make our point as simply as possible, we treat  $f$  as a constant.<sup>4</sup>

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<sup>4</sup>A static model does not show how a change in the demand for forestry services changes the forestry stock. Therefore, this model does not formally describe the environmental consequences of changes in property rights. Nevertheless, higher demand for forestry services are often associated with environmental damages, so we can use this model to informally discuss the connection between the environment and property rights.



There are a large number of price-taking firms in the forestry sector,  $N$ . Firm  $i$  has legal title to  $f_i$  units of the resource ( $\sum_i f_i = f$ ), but imperfect property rights limit the firm's ability to enforce this title. The assumption of constant returns to scale in  $(f, K, L)$  for Forestry means that we can replace  $N$  by one without loss of generality; that is, we use a representative firm model. The forestry firm can hire both capital and labor to exploit the resource. Poachers can use the resource illegally but they incur a cost of avoiding detection.

The representative Forestry firm takes commodity and factor prices as given. However, the firm recognizes that its employment and investment decisions – its choice of  $K$  and  $L$  – affect the number of poachers on its land. Thus, the firm behaves strategically with respect to poachers. Poachers are non-strategic: they take as given prices and the decisions of all agents.

If Forestry production uses only  $f$  and  $L$  (without an intermediate investment good) we have the type of model described in previous papers. In this case, weaker property rights attract labor into Forestry, increasing forestry production; that is, weaker property rights increase a country's comparative advantage in the resource-intensive sector. The presence of an investment opportunity in Forestry complicates this relation. Investment opportunities might result in either excludable and non-excludable benefits. For both of these cases, imperfect property rights to the natural resource create an investment distortion, but the direction of the distortion depends on the nature of the investment.

Investments that provide excludable benefits might be available only to the firm (e.g., a sawmill) or to both the firm and poachers (e.g., chainsaws). The Forestry firm has a strategic incentive to increase either of these kinds of excludable investment, as a means of capturing more of the product of the natural resource, thereby discouraging poaching. This strategic incentive increases as property rights worsen. Therefore, the presence of excludable investment opportunities reinforces the standard result that weaker property rights encourage Forest production. (Appendix A.2 demonstrates this fact.)

The firm might be able to invest in a local public good, such as a road or a bridge. We assume that the public good nature of this investment is due to the fact that property rights to the natural resource are imperfect. For example, the road or bridge might be entirely on the land of a single owner, so that with perfect property rights it provides no public benefits. Alternatively, the investment might provide benefits that are external to the firm, but the investment decision is made by an owners' association or a government agency that maximizes owners' rents. The existence of this association or agency solves the standard problem associated with

the provision of the public good, so that in the absence of imperfect property rights the optimal amount of the investment good would be provided. However, the imperfect property rights to the natural resource tends to discourage these non-excludable investments, thus reducing Forestry production. Roads, bridges, and similar investments increase the marginal product of all Forestry workers (poachers as well as those hired by the Forestry firm). The firm's strategic incentive in this case is the opposite as in the case of privately appropriable investment. By constructing fewer roads and bridges, the Forestry firm discourages the entry of poachers.

Since only the non-excludable type of investment changes previous results, we emphasize that case. Pfaff (1999) confirms the importance of these kinds of investments in Brazil's forestry sector. Bohn and Deacon (2000) emphasize that imperfect property rights to the investment – i.e., expropriation risk – can decrease investment and thereby decrease resource extraction; this effect might be important for oil extraction in some countries. (Insecurity of land tenure, a different kind of expropriation risk, increases resource extraction.) Expropriation risk is fundamentally different than the imperfect property rights to the resource that drives our model. We assume that there is no expropriation risk; obviously, including that kind of risk discourages investment. Imperfect property rights give the legal owner a strategic incentive to increase or decrease investment, depending on the nature of the investment. This strategic incentive is the source of the investment distortion, and it disappears when the legal owner has perfect property rights to the resource.

In this model, the investment decision is synonymous with the choice of  $K$ . At the end of Section 2.4 we briefly discuss an alternative model in which labor is the only mobile factor. In that model, labor can be employed to produce an intermediate investment good (e.g., roads) used in Forestry, and also used to produce the final good. Our results depend on the presence of a second input choice for the firm, and the assumption that imperfect property rights to the resource prevent the firm from capturing all of the benefit of this input. It does not matter whether the second input is  $K$  or an intermediate good produced using  $L$ .

## 2.1 A model with non-excludable investment

We adapt Hotte, van Long, and Tian (2000)'s model by including a second mobile factor of production, capital.<sup>5</sup> Each worker has one unit of time. A poacher in Forestry has to spend the

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<sup>5</sup>Our results do not depend on the specific reason for imperfect property rights. We would obtain the same kinds of results using the common property model in Chichilnisky (1994). The important feature is that the

fraction  $\gamma$  of her time in order to avoid detection. The amount of labor in the forestry sector is  $L_f = L_f^e + (1 - \gamma) L_f^p$ , where  $L_f^e$  is the number of workers employed by the legal owner, and  $L_f^p$  is the number of poachers. Workers decide whether to work in the Cloth sector or in Forestry, either as legal employees or poachers. For each unit of time spent working (as distinct from avoiding detection) a poacher receives the value of average product of labor in Forestry,  $\frac{pF(K_f, L_f)}{L_f}$ , where  $K_f$  is the amount of capital in Forestry,  $p$  is the price of Forestry products (relative to the numeraire, Cloth), and  $F(\cdot)$  is the production function for Forestry. Without loss of generality in this static model, we set  $f$ , the stock of the natural resource used in Forestry, equal to one, and suppress it as an argument to the production function.

In equilibrium, a worker is indifferent between poaching and working as a legal employee (in either Forestry or Cloth), where she receives the wage  $w$ . This equilibrium condition is

$$(1 - \gamma) \frac{pF(K_f, L_f)}{L_f} = w. \quad (1)$$

In this model, the parameter  $\gamma$  determines the extent of property rights. If  $\gamma = 0$  there is open access; larger values of  $\gamma$  are equivalent to stronger property rights.

If  $\gamma$  is greater than a critical level, poaching is so unattractive that the Forestry firm ignores poachers. We assume that  $\gamma$  is less than or equal to this critical level, so that equation (1) holds in equilibrium. To determine this critical level, we consider the situation in which  $\gamma$  is endogenous. Here the forestry firm chooses the amount of monitoring, thereby implicitly choosing the value of  $\gamma$ . The “production function” for  $\gamma$  is  $g(K_m, L_m)$  where  $(K_m, L_m)$  are factors employed in monitoring. The cost of achieving a given level of  $\gamma$  is

$$c(\gamma; w, r) = \min rK_m + wL_m \text{ subject to } g(K_m, L_m) \geq \gamma. \quad (2)$$

The timing of decisions is unimportant, but for clarity of exposition we treat the Forestry firm as solving a three-stage problem, first choosing  $\gamma$ , then choosing  $K_f$ , then choosing  $L_f^e$ , subject to equation (1).

For the third stage, involving the choice of labor, we have

**Remark 1** (*Hotte, van Long, and Tian 2000*) Suppose that it is optimal for the Forestry firm to operate, i.e.  $L_f^e > 0$ . In equilibrium  $L_f^p = 0$  and  $L_f^e = L_f$ , which satisfies equation (1).

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imperfection of property rights tends to attract a mobile factor (in our case, labor) to the resource sector.

The basis for this result is that if poachers were present, the Forestry owner could induce one poacher to leave by hiring  $1 - \gamma$  additional workers, increasing his profits by  $\gamma w$ . The Forestry owner has exhausted this means of increasing profits only when  $L_f^p = 0$ .

Denote the solution to equation (1) as  $L^*(K_f, \gamma)$ . Using this notation and Remark 1, the firm's profit function is

$$\pi(\gamma; w, r) = \max_{K_f} pF(K_f, L_f) - wL_f - rK_f = \max_{K_f} \frac{\gamma}{1 - \gamma} wL^*(K_f, \gamma) - rK_f. \quad (3)$$

Differentiating equation (1) implies

$$\frac{\partial L^*}{\partial K_f} = \frac{pF_K}{\frac{w}{1 - \gamma} - pF_L}, \quad (4)$$

where subscripts denote partial derivatives. Using equation (4) to simplify the first order condition to the problem in equation (3), we have

$$r = \phi pF_k, \quad \phi \equiv \frac{\gamma w}{w - (1 - \gamma) pF_L}. \quad (5)$$

In the case where  $\gamma$  is endogenous, it is the solution to

$$\max_{\gamma} \pi(\gamma; w, r) - c(\gamma; w, r). \quad (6)$$

De Meza and Gould (1994) note that private decisions are in general not socially optimal in this context. Provided that the maximand in equation (6) is concave, we have

**Remark 2** *If  $c(\gamma; w, r)$  is strictly convex,  $\phi < 1$ . For  $c(\gamma; w, r) \equiv 0$ ,  $\phi = 1$ .*

To confirm this Remark, we can show that the necessary condition for profit maximization ( $\frac{\partial \pi}{\partial \gamma} = 0$ ) in the case where  $c(\gamma; w, r) \equiv 0$  requires that  $pF_L = w$ . When  $\gamma$  can be adjusted costlessly, its optimal level requires equality between the value of marginal product of labor and the wage, implying that  $\phi = 1$ . If it is expensive to increase  $\gamma$  (thus raising  $\phi$ ), the optimal value satisfies  $\phi < 1$ .

The function  $\phi$  is an index of property rights;  $\phi = 1$  implies perfect property rights and lower values of  $\phi$  imply weaker rights. For some comparative statics experiments and for the discussion in Section 2.4 it is convenient to use this index rather than the parameter  $\gamma$ . In general, the relation between  $\phi$  and  $\gamma$  depends on factor prices. For the special case where  $F(K_f, L_f) = m(K_f)L_f^\delta$ , with  $\delta < 1$ , we have  $F_L = \frac{\delta F}{L}$  and  $\phi = \frac{\gamma}{1 - \delta}$ . In this case, Remark 2

implies that  $\gamma \leq 1 - \delta$ . (This inequality gives the critical upper bound on  $\gamma$ , above which the possibility of poaching does not alter the first best equilibrium.) With this functional form, the equilibrium conditions (1) and (5) simplify to

$$pF_L(K_f, L_f) = \phi w \quad pF_K(K_f, L_f) = \frac{r}{\phi}. \quad (7)$$

These two equations show how imperfect property rights (together with investment in non-excludable capital) distort the allocation of inputs in the Forestry sector. For given factor prices, the Forestry firm wants to use more labor and less capital – relative to the first best levels – as a means of deterring poaching. (Of course, the equilibrium factor prices are endogenous.)

The non-monotonic relation between property rights and comparative advantage arises because weak property rights can discourage (non-excludable) investments. Some non-excludable investments are made by governments rather than Forestry owners. If the government wants to maximize rents in the Forestry sector, the identity of the investor is unimportant. The appendix shows that imperfect property rights can discourage investment even if the government wants to maximize national income, rather than rents in the resource sector. Therefore, the non-monotonic relation between property rights and comparative advantage can also arise in this case.

## 2.2 Immobile capital: a review

For purpose of comparison, we review the results in the special case where there are no investment opportunities in Forestry and labor is the only mobile factor;  $K$  and  $f$  are specific to the Cloth and Forestry sectors, respectively. The production function for Cloth is  $C(K, L_c)$ . For this model, the equilibrium conditions are

$$\begin{aligned} w &= C_L(K, L_c) = (1 - \gamma) p \frac{F(f, L - L_c)}{L - L_c}. \\ r &= C_k(K, L_c) \quad \eta = \frac{pF(f, L - L_c) - w(L - L_c)}{f}. \end{aligned}$$

The first line determines the equilibrium wage and the equilibrium allocation of labor, and the second line determines the return to the sector specific factors,  $K$  and  $f$  ( $r$  and  $\eta$ ).

A familiar comparative statics exercise establishes that in this model an increase in property rights ( $\gamma$ ) decreases Forestry output, increases  $r$  and  $\eta$ , and decreases  $w$ . Owners of the two specific factors always prefer stronger property rights, since these reduce the wage; weaker property rights increase the country's comparative advantage in Forestry.

## 2.3 An example with mobile capital

Here we consider the comparative statics with respect to  $\gamma$ , which we treat as exogenous. The analysis using general functional forms is too complex to be insightful, so we consider the special case where  $F(K_f, L_f) = K_f^\beta L_f^\delta$ , with  $\beta + \delta < 1$ ; this inequality is due to the assumption that there are constant returns to scale in  $(K_f, L_f, f)$ . Recall that for this production function,  $\phi = \frac{\gamma}{1-\delta}$ ;  $\phi \leq 1$  implies that  $\gamma \leq 1 - \delta$ . We hold the commodity price  $p$  fixed, since our objective is to study the relation between property rights and comparative advantage.

To obtain insight into the general equilibrium setting, we first examine the partial equilibrium model, in which the factor prices  $w$  and  $r$  are fixed. Using  $F(K_f, L_f) = K_f^\beta L_f^\delta$  and the equilibrium conditions (7), the partial equilibrium comparative statics for inputs and Forestry output are:

$$\frac{d \ln K_f}{d\gamma} = \frac{1 - \delta - \gamma}{(1 - \gamma) \gamma (1 - \beta - \delta)} > 0 \quad (8)$$

$$\frac{d \ln L_f}{d\gamma} = \frac{\beta - \gamma}{(1 - \gamma) \gamma (1 - \beta - \delta)} \quad (9)$$

$$\frac{d \ln F}{d\gamma} = \frac{\beta (1 - \gamma) - \delta \gamma}{(1 - \gamma) \gamma (1 - \beta - \delta)}. \quad (10)$$

For all  $\gamma > 0$  the Forestry sector operates, so these comparative static results are not vacuous.

Weaker property rights (a decrease in  $\gamma$ ) decrease Forestry capital. (Equation (8)) However, the relations between property rights and both the amount of Forestry labor and Forestry output depend on the level of property rights. When property rights are initially strong ( $\gamma \approx 1 - \delta$ ) weakening these rights increases the amount of labor in Forestry, just as in the earlier models. However, when property rights are initially weak ( $\gamma < \beta$ ), weakening these rights decreases the amount of labor in Forestry. (Equation (9)) Weakening of already weak property rights causes such a large reduction in Forestry capital that it becomes less attractive to poach. If property rights are strong (i.e. if  $\gamma > \frac{\beta}{\beta + \delta}$ ), an increase in property rights reduces Forestry output, as occurs in the earlier models. However, this relation is reversed for  $\gamma < \frac{\beta}{\beta + \delta}$ . (Equation (10))

These comparative statics results illustrate two forces that cause factor allocation to change with property rights. First, there is the *poaching incentive*. Weaker property rights enable poachers to capture a larger share of Forestry output, thus encouraging poaching at a given level of investment. In this model poaching does not occur in equilibrium, but the Forestry firm hires more workers to discourage poachers' entry when  $\gamma$  falls. The poaching incentive also exists in models with a single mobile factor. The second force, the Forestry firm's *investment*

*incentive* arises only because of the investment opportunity. Weaker property rights cause the firm to capture less of the marginal product of capital, and they also create a strategic incentive for firms to reduce investment in order to make poaching less attractive. The investment and the poaching incentives work in the opposite direction, leading to the possibility of a non-monotonic relation between property rights and comparative advantage.<sup>6</sup>

In this example, non-monotonicity requires that the market failure is large relative to the share of capital in the resource-based sector. If capital is unimportant ( $\beta \approx 0$ ), the model is essentially the same as the models with a single mobile factor.

In the general equilibrium setting, factor prices are endogenous. In this case, in addition to the poaching and the investment incentives, there is a third force at work: an indirect, or *general equilibrium effect*, that arises due to the change in factor prices. Again we set  $F = f(K_f)L^\delta$ ; the supply of factors is  $L = K = 1$ . The equilibrium conditions are

$$\begin{aligned} 0 &= \frac{\partial C}{\partial K_c} - \frac{p(\phi - \delta)}{(1 - \delta)\phi} \frac{\partial F}{\partial K_f} \\ 0 &= \frac{\partial C}{\partial L_c} - \frac{p}{\phi} \frac{\partial F}{\partial L_f} \\ L &= K = 1. \end{aligned}$$

Even when both production functions are Cobb Douglas ( $F = K_f^\beta L_f^\delta$ ,  $C = K_c^\alpha L_c^{1-\alpha}$ ) this system does not lead to closed form comparative statics. Since our objective is merely to show that the non-monotonicity survives in a general equilibrium setting, we present numerical results for the case where  $p = K = L = 1$ ,  $\delta = \beta = 0.3$ , and  $\alpha = 0.5$ .

Table 1 shows the comparative statics with respect to  $\phi \equiv \frac{\gamma}{1-\delta}$ . When property rights are strong ( $\phi \approx 1$ ), weakening these rights (decreasing  $\phi$ ) leads to an increase in both factors in Forestry. We noted that for fixed input prices,  $K_f$  is strictly increasing in property rights (equation (8)). The fact that  $K_f$  rises as  $\phi$  falls is due to a general equilibrium effect – a change in factor prices.

Beginning with strong property rights, weakening these rights causes labor to leave the Cloth sector due to the poaching incentive. This change raises the capital-labor ratio in Cloth. Given constant returns to scale, the wage-rental rate must rise. Since the output price is fixed, the value of  $r$  falls and the value of  $w$  rises. In the neighborhood of  $\phi = 1$ , the strategic incentive to reduce Forestry investment (following a weakening of property rights) is negligible.

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<sup>6</sup>If the firm can internalize all the benefits of investment, the poaching incentive and the investment incentive work in the same direction.

$\phi$	$L_F$	$K_F$	$\frac{C}{F}$	$\frac{w}{r}$	income loss (%)
1	0.279	0.279	1.55	1	0
.9	0.32	0.284	1.44	1.04	0.07
.7	0.41	0.281	1.25	1.21	0.93
.6	0.455	0.264	1.19	1.35	1.95
.5	0.5	0.22	1.22	1.55	3.75
.4	0.49	0.12	1.57	1.72	7.42
.33	0.34	0.02	3.47	1.49	12.98
.31	0.19	0.003	8.06	1.24	15.03
.3	0	0	$\infty$	1	15.68

Table 1: Comparative statics with respect to property rights

The fall in  $r$  creates a non-negligible incentive to increase Forestry investment, so the net effect of the decrease in property rights is to increase both factors in Forestry.

Thus, when property rights are strong, weakening these rights benefits workers and harms capitalists. Weakening property rights always decreases the rents to the Forestry firms. For strong property rights, capitalists and resource owners are natural allies, since they both benefit from stronger property rights; workers prefer weaker property rights. This result is the same as in models with a single mobile input.

Further weakening of property rights continues to attract labor to Forestry (due to the poaching incentive), but eventually the amount of capital attracted to the sector decreases (due to the investment incentive). When  $\phi$  falls below approximately 0.6, a further weakening of property rights causes the country's comparative advantage in Forestry to decrease. For  $\phi$  less than 0.4, the country has a comparative advantage in Cloth (relative to the country with perfect property rights). Forestry shuts down at  $\phi = 0.3$ . Investment in the sector is unprofitable, and without capital, labor produces nothing.

For  $\phi > 0.3$  but small, a reduction in  $\phi$  causes a greater percentage outflow of labor than of capital from Forestry, thereby decreasing the capital-labor ratio in Cloth and reducing the wage-rental ratio. Thus, for low levels of property rights, workers and the natural resource owner are the natural allies in the desire to improve property rights, and they are opposed by capitalists.

Given that  $p = 1$ , national income is  $F+C$ . With perfect property rights, the Forestry sector



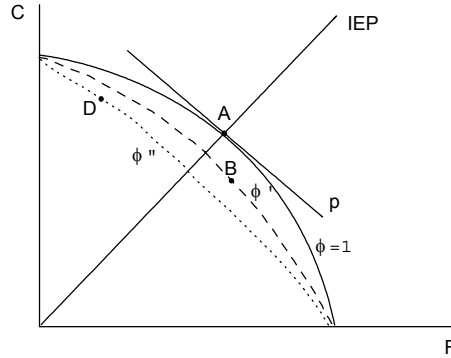


Figure 1: Production points and equilibrium production *loci* for different values of  $\phi$

accounts for nearly 40% of national income. The last column of Table 1 shows the percentage loss in national income due to incomplete property rights. For this example, weaker property rights always reduce national income.

A change from  $\phi = 1$  to  $\phi = .7$  causes a 20% increase in  $\frac{w}{r}$  and a 12% increase in Forestry output, but a loss in national income of less than 1%. This kind of result is familiar from general equilibrium modelling (e.g., evaluations of the gains from trade liberalization): distributional effects swamp efficiency effects. A change from  $\phi = 1$  to  $\phi = .3$ , causing the Forestry sector to shut down, creates an efficiency loss of nearly 16%, all of which comes at the expense of Forestry owners; real returns to capitalists and workers are at the same level under  $\phi = 1$  and  $\phi = .3$ . When property rights are weak, a further weakening of these rights can benefit the environment, by reducing the demand for services of the fixed Forestry factor.

## 2.4 Discussion of results

In order to emphasize the simplicity and the plausibility of the possibilities illustrated in the example above, we turn to a more general setting. Figure 1 illustrates the effect of different degrees of property rights, indexed by  $\phi$ , under the assumption that investment in Forestry is non-excludable. The solid curve labelled  $\phi = 1$  is the production possibility frontier under perfect property rights, and the curves labelled  $\phi'$  and  $\phi''$  are the equilibrium production *loci* under successively weaker property rights,  $\phi'' < \phi' < 1$ .<sup>7</sup> As property rights become weaker

<sup>7</sup>When property rights are imperfect, factors' value of marginal product differ across sectors, so the economy is not on the production possibility frontier, the curve labelled  $\phi = 1$ , unless the economy is specialized. If we hold  $\phi < 1$  fixed and change the relative commodity price we obtain a particular *locus* of equilibrium output levels.

the distortion becomes more severe, causing the equilibrium production *locus* to shift in. Weak property rights encourage too much labor to enter Forestry (given the level of capital), and the inability to capture all of the rents from investment results in too little capital in Forestry (given the level of labor). If the country is specialized in either commodity, the output does not depend on the market failure, so all the curves have the same intercepts.

Suppose that the autarkic price of Forestry in a country with perfect property rights is  $p$  and all agents (in all countries) have identical homothetic preferences. (Cloth is the numeraire.) The Income Expansion Path at price  $p$  (labelled IEP in Figure 1) is a ray from the origin through  $A$ ; this point is the autarkic production and consumption level for the country with perfect property rights. At point  $A$ , the slope of the production possibility frontier is  $-p$ . Points  $B$  and  $D$  represent equilibrium production points, corresponding to the same price  $p$ , for two countries with property rights indexed by  $\phi'$  and  $\phi''$ . Since production is not efficient in these countries, the slope of the production locus differs from  $-p$  at both points  $B$  and  $D$ .

The country with property rights  $\phi'$  has an excess supply of Forestry products at  $p$ . If the countries with  $\phi = 1$  and  $\phi' < 1$  trade, the country with weaker property rights exports Forestry products, as in the previous models with a single mobile input. For the country with property rights  $\phi''$ , there is excess demand for Forestry products at  $p$ . If the countries with  $\phi = 1$  and  $\phi'' < 1$  trade, the country with weaker property rights imports Forestry products, contrary to the previous models with a single mobile input. The relation between property rights and comparative advantage in this example is non-monotonic.<sup>8</sup>

The non-monotonicity arises because imperfect property rights (together with non-excludable investments) affect the choice of both inputs. The previous subsection identified the three forces that cause factor allocation to change with property rights: the poaching and investment incentives, and the general equilibrium effect. The poaching incentive arises in the simpler models without the intermediate investment. The investment and the poaching incentives work in the opposite direction, leading to the possibility of a non-monotonic relation between property rights and comparative advantage.

The general equilibrium effect is due to the change in factor prices. The direction of the

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These *loci* need not be concave to the origin.

<sup>8</sup>For a small country facing fixed world prices, national income (excluding any expenditures on the enforcement property rights) might be higher at a point such as  $D$ , compared to income at a point such as  $B$ . In that case, weaker property rights are associated with higher welfare. This outcome is an example of the Theory of the Second Best: imperfect property rights distorts the allocation of both factors of production.

general equilibrium effect is ambiguous: relative factor prices are non-monotonic in property rights. In the neighborhood of  $\phi = 1$ , weakening property rights causes labor to leave the Cloth sector, reducing the value of marginal product of capital, thus reducing the price of capital. This reduction causes capital to flow into the Forest sector, because at  $\phi \approx 1$  the investment incentive is negligible. In contrast, for small values of  $\phi$  the investment incentive is strong and there is little investment in the Forest sector. Weakening property rights causes a further reduction in investment, which leads to a large fall in the value of marginal product of Forest labor. This fall in marginal product swamps the poaching incentive, causing both labor and capital to leave Forestry and enter the Cloth sector. For sufficiently small  $\phi$ , when most of the capital is already in the Cloth sector, a further reduction in  $\phi$  makes the inflow of labor into Cloth large relative to the inflow of capital, leading to a fall in the capital-labor ratio in Cloth. This fall causes a rise in the price of capital and a fall in the price of labor. Since commodity prices are constant the sign of the changes in real factor returns and factor prices are the same.

We used a model with two mobile inputs to illustrate the possibility of a non-monotonic relation between property rights and both comparative advantage and real factor returns. This non-monotonicity arises because Forestry uses an investment that confers non-excludable benefits. In our model, this investment uses capital. As a referee pointed out, we would obtain the same results in a model in which labor, the only mobile input, can be used both to produce the intermediate investment good and to operate the investment. For example, instead of the function  $F = m(K_f)L_f^\delta$  used in Section 2.2 we could have set  $F = m(L_I)L_f^\delta$ , where  $L_I$  is the amount of labor that the Forestry firm hires to produce the intermediate investment good. With this formulation, the equilibrium conditions (7) are replaced by

$$pF_{L_f}(L_I, L_f) = \phi w \qquad pF_{L_I}(L_I, L_f) = \frac{w}{\phi}.$$

The results discussed above also arise in this model.

### 3 Endogenous property rights

With endogenous property rights, the relation between comparative advantage and property rights is ambiguous even when investment in Forestry provides excludable benefits. The amounts of factors available for production of Cloth and Forestry are endogenous when endogenous property rights are produced/maintained by factors of production.

As shorthand, we speak of property rights being produced/maintained by an exogenous “judicial system”. We view this judicial system as a production function that converts factors of production into property rights. Consider two economies that differ in the efficiency of their exogenous judicial systems, but which are otherwise identical and face the same commodity prices. The country with a more efficient judicial system is able to create/maintain property rights using fewer factors of production. The equilibrium allocation of factors to create/maintain property rights – and the equilibrium level of property rights – differ between the countries. The country with the more efficient judicial system will have stronger property rights, but it might also use more factors to maintain these rights. A country with a very inefficient judicial system may end up with weak property rights, and also use few factors to protect those rights. Stronger property rights cause the production possibility frontier to shift out, but the withdrawal of factors of production tends to offset this effect.

The fact that there are decreasing returns to scale in Forestry (due to the existence of the resource stock,  $f$ ) means that the factor prices depend on factor supplies and therefore depend on the endogenous degree of property rights. Taking into account these two effects – different stocks of factors available for Cloth and Forestry, and differing factor prices – it is clear that the relation between property rights and comparative advantage can be non-monotonic.

The relation between endogenous property rights and comparative advantage noted here is similar to the relation between environmental protection and comparative advantage discussed in Chau (2003). That paper shows that stricter environmental policy can increase a country’s comparative advantage for a polluting good. This relation can arise if the increased demand for abatement (following the stricter environmental policy) uses primarily the factor that is used relatively intensively in the non-polluting sector. This type of possibility is reminiscent of results in the literature on directly unproductive rent/revenue seeking, e.g. Bhagwati (1982).

By analogy, in our setting it is clear that stronger property rights might be associated with a comparative advantage in Forestry when the creation of property rights uses primarily the mobile input that is used intensively in Cloth (relative to Forestry). The appendix illustrates the ambiguity between endogenous property rights and comparative advantage by considering an extreme case in which Forestry production uses only labor and the natural resource, and the production of Cloth and property rights use only capital. In this model, the Forestry firm’s investment in property rights merely shifts rents from workers to the firm, without affecting Forestry output. Greater investment in maintaining property rights is “directly unproductive”,

in the standard sense.

We conduct comparative statics with respect to a parameter that determines the efficiency of production of property rights. If the judicial system is inefficient, it is very costly for Forest owners to protect their property rights. The equilibrium level of property rights is low but so is the amount of capital devoted to the production of these rights. This country has weak property rights but produces a relatively large amount of cloth, since there is little competing demand for capital. The country therefore tends to have a comparative advantage in Cloth. An increase in the efficiency of the judicial system makes it more attractive to invest in the protection of property rights. This change results in an increase in the amount of capital in the judicial sector, leading to stronger property rights and lower production of Cloth – and a corresponding fall in  $\frac{C}{F}$ . In this case, stronger property rights are associated with a greater comparative advantage in Forestry, contrary to the results in previous models.

In contrast, a country that begins with an efficient system has a high endogenous level of property rights and a relatively small amount of capital devoted to the production of these rights. An increase in efficiency leads to less capital in the judicial system (and more production of Cloth) but a higher level of property rights. Here, stronger property rights are associated with a greater comparative advantage in Cloth, just as in previous models with a single mobile input.

For both the model in the previous section (non-excludable investment and exogenous property rights) and the model in this section (endogenous property rights with a second mobile factor), the relation between property rights and comparative advantage is ambiguous. In both cases, stronger property rights are associated with greater comparative advantage in the resource-intensive sector when property rights are strong – just as in the earlier models. However, the relation between property rights and comparative advantage is reversed when property rights are weak.

## 4 Conclusion

Previous models show that imperfect property rights can contribute to a country's comparative advantage in the resource-intensive sector, whether property rights are fixed or endogenous. This result is important because it is intuitive and it appears to describe some elements of North-South trade. Many developing country exports are resource-based, and property rights appear weaker in some of these countries (relative to developed countries). Previous models

also imply that workers always benefit from weaker property rights to the natural resource, and owners of capital benefit from stronger rights. These results can be overturned if there is the opportunity to invest in an intermediate input in the resource intensive sector, and imperfect property rights make this investment non-excludable. The familiar result can also be reversed if property rights are endogenous and there are at least two mobile inputs.

Unlike previous papers that discuss investment, there is no expropriation risk in our model. The investment distortion here is due to a strategic incentive that arises from imperfect property rights to the natural resource. By assumption, the investment distortion vanishes if property rights to the resource are perfect. If the investment is excludable, the strategic incentive encourages excessive investment and strengthens the (negative) relation between property rights and a comparative advantage in the resource sector. If the Forestry investment is non-excludable the relation between property rights and comparative advantage in the resource sector is ambiguous. This ambiguity also occurs when a social planner rather than the Forestry firm chooses the level of the non-excludable investment.

The relation between real returns to factors and property rights can be non-monotonic. The resource owner always wants to strengthen property rights. The identity of the owner's natural ally in the desire to improve property rights – capitalists or workers – might vary with the extent of the market failure. For our numerical example capitalists are the resource owner's natural ally when property rights are quite strong; this alliance always holds in previous models. Workers are the resource owner's natural ally when property rights are quite weak. The demand for environmental services associated with the fixed factor in Forestry are non-monotonic in property rights.

There is a rather subtle general equilibrium effect involving property rights. In the neighborhood of perfect property rights, the strategic incentive to invest is a second order consideration. In this neighborhood, weakening property rights to the resource reduces the equilibrium cost of capital. This reduction encourages investment in Forestry, regardless of whether this investment is excludable or non-excludable.

When property rights are endogenous and there is a second mobile factor, the relation between property rights and comparative advantage is ambiguous regardless of whether investment confers excludable or non-excludable benefits. If the creation of stronger property rights uses intensively the factor that is used intensively in Cloth (relative to Forestry), stronger property rights can be associated with a comparative advantage in Forestry.

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## Appendix

### A.1 The government chooses non-excludable investment

Suppose that the government of a small open economy wants to maximize national income,  $Y(K_f) \equiv pF(L^*, K_f) + C(L - L^*, K - K_f)$ , where  $C(\cdot)$  is cloth output. Suppose in addition that the government cannot change the level of property rights, so it is constrained by the equilibrium level of labor,  $L^*$ , implicitly defined by equation (1). The government recognizes the endogeneity of factor prices; with trade, it takes the commodity price  $p$  as given. Denote the level of  $K_f$  that maximizes  $Y$ , subject to equation (1), as the second best level. Denote the level of  $K_f$  chosen by the Forestry firm as the competitive level.

Under the assumption that  $Y$  is concave in  $K_f$  with an interior maximum, and for the particular case  $F(K_f, L_f) = m(K_f)L_f^\delta$ , a straightforward calculation establishes<sup>9</sup>

**Remark 3** *The level of investment in Forestry in the competitive equilibrium is less than the second best level if and only if*

$$\frac{r}{w} > \phi \frac{dL^*}{dK_f}, \quad (11)$$

*evaluated at the competitive equilibrium.*

Inequality (11) might hold or fail, so the second best level of Forestry investment might be greater or less than the competitive level.<sup>10</sup> Given that the labor equilibrium condition (1) must be satisfied, both the social planner and the Forestry firm have a strategic incentive to reduce

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<sup>9</sup>The assumed concavity of  $Y$  implies that the second best level of investment exceeds the competitive level if and only if  $\frac{dY}{dK_f} > 0$  evaluated at the competitive equilibrium. We evaluate this derivative using the equilibrium conditions in equation (7) and the conditions in the cloth sector,  $C_K = r$  and  $C_L = w$ . The resulting inequality involves the total derivative  $\frac{dL^*}{dK_f}$  (rather than a partial derivative) because  $w$  is endogenous. Rearranging  $\frac{dY}{dK_f} > 0$  gives inequality (11).

<sup>10</sup>Suppose that Cloth production is Leontieff, i.e.  $C = \min(L_c, \alpha K_c)$ , so that in equilibrium  $L - L_f = \alpha(K - K_f)$ ; the parameter  $\alpha > 0$  is the labor/capital ratio in Cloth. In this case,  $\frac{dL^*}{dK_f} = \alpha$ , and zero profits in Cloth requires  $1 = w + \frac{r}{\alpha}$ , or  $\frac{r}{w} = \frac{\alpha r}{\alpha - r}$ . Using these relations we can rewrite inequality (11) as  $r > \frac{\alpha \phi}{1 - \phi}$ . The fact that there are decreasing returns to scale in Forestry precludes a closed form expression for the endogenous value of  $r$ . However, we are free to choose the function  $m(K_f)$  in the Forestry production function  $F(K_f, L_f) = m(K_f)L_f^\delta$ . This “degree of freedom” and the choice of  $\alpha$ ,  $\phi$ , and  $\delta$  enable us to construct cases where  $r > \frac{\alpha \phi}{1 - \phi}$  or  $r < \frac{\alpha \phi}{1 - \phi}$ .

Forestry investment. However, their incentives are not the same since they have different objectives; in addition, the social planner recognizes the endogeneity of factor prices. In general we cannot say which regime leads to higher Forestry investment. Consequently, the relation between property rights and comparative advantage is ambiguous even if the government decides on the level of non-excludable investment and wants to maximize national income.

## A.2 Investment is excludable and property rights are endogenous

Here we assume that investment in Forestry increases labor productivity only for the agent who makes the investment. Capital increases the effective units of labor. If the firm hires  $K_f$  units of capital and  $L_f^e$  units of labor, its effective units of labor are  $h(K_f, L_f^e)$ . For brevity, we emphasize the case where only the firm can hire capital. That is, capital resembles sawmills rather than chain saws.

The effective units of labor in Forestry are  $h(K_f, L_f^e) + (1 - \gamma)L_f^p$ . In the absence of investment, employees and poachers are equally productive ( $h(0, L_f^e) = L_f^e$ ) and investment does not decrease productivity ( $h_K(K_f, L_f^e) \geq 0$ ). In the special case where the only effect of capital is to increase the effective units of labor, the production function is  $F = F(h(K_f, L_f^e) + (1 - \gamma)L_f^p)$ ; this function is increasing and concave in effective labor. For exposition, we again view the firm as solving a three stage optimization problem, first choosing property rights, then choosing investment, and then choosing labor.

As above, workers are indifferent between working as employees in Cloth or Forestry or as poachers, where they obtain the fraction of output equal to their share of total effective labor time. The equilibrium condition is

$$(1 - \gamma) \frac{pF(h(K_f, L_f^e) + (1 - \gamma)L_f^p)}{h(K_f, L_f^e) + (1 - \gamma)L_f^p} = w. \quad (12)$$

Remark 1 also holds for this model: whatever the level of the firm's investment, if  $L_f^p > 0$ , the firm can increase its profits by increasing the amount of labor it hires in order to drive out poachers. Therefore  $L_f^p = 0$  in equilibrium. This relation and equation (12) imply that the value of  $h$  is fixed by  $w$  and  $\gamma$ . We can rewrite equation (12) as<sup>11</sup>

$$\frac{pF(h(K_f, L_f^e))}{h(K_f, L_f^e)} = \frac{w}{1 - \gamma}.$$

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<sup>11</sup>In this model, investment is chosen to minimize the cost of providing  $h$  effective units of labor. This result follows from the fact that  $h$  is fixed by the equilibrium condition, equation (12).

This relation and the concavity of  $F$  implies that  $h$  is a decreasing function of  $\gamma$ . We restate this as

**Remark 4** *When the Forestry firm is able to appropriate all of the returns from investment, and property rights are exogenous, a regime of stronger property rights (larger  $\gamma$ ) decreases the equilibrium supply of Forestry.*

Given exogenous properties rights, opportunities to invest in projects whose benefits can be entirely appropriated do not affect the qualitative relation between property rights and comparative advantage identified by models with a single mobile input. Nevertheless, the relation between equilibrium property rights and comparative advantage might still be ambiguous when property rights are endogenous. This reason for ambiguity occurs regardless of whether there are investment opportunities in the resource-based sector, but it requires the existence of a second mobile factor.

In view of this fact, it is simpler to use a model without investment in Forestry to examine the relation between endogenous property rights and comparative advantage. In this model Forestry uses only labor, so Cloth is capital intensive relative to Forestry. In the interests of simplicity, we consider the extreme case where the judicial system uses only capital.

Remark 1 holds when labor is the only input in Forestry, so the equilibrium level of Forestry labor is implicitly given by

$$(1 - \gamma) \frac{pF(L_f)}{L_f} = w. \quad (13)$$

Equation (2) defines the cost function for property rights,  $c(\gamma; r)$ , but now the judicial production function is specialized to  $g(K_m)$ . We use the parameter  $\varepsilon$  to represent differences in judicial systems. If a country's judicial production function is  $\frac{g(K_m)}{\varepsilon}$ , its cost function is  $c(\varepsilon\gamma; r)$ . A larger value of  $\varepsilon$  represents a less efficient judicial system. We conduct comparative statics on  $\varepsilon$ .

The firm's optimal level of property rights is  $\gamma^*$ , defined as

$$\gamma^* \equiv \arg \max_{\gamma \geq 0} \left( \frac{\gamma w L}{1 - \gamma} - c(\varepsilon\gamma; r) \right). \quad (14)$$

Remark 2 still holds. If  $\varepsilon = 0$  there are perfect property rights; that is,  $pF' = w$  in equilibrium. For *fixed* factor prices,  $\gamma^*$  is decreasing in  $\varepsilon$  at an interior solution.

In general, the equilibrium factor prices depend on the exogenous parameter  $\varepsilon$ . One extreme case, however, provides a clear result. Suppose that Cloth uses only capital, and that one unit of

cloth production requires one unit of capital. In this situation, the full employment constraint for labor fixes output in Forestry at  $F(L)$  and the (assumed) positive production of Cloth fixes the rental rate at  $r = 1$ . We take  $F = L_f^\delta$  and set the total supply of labor to  $L = 1$ . Equation (13) implies  $\frac{\partial L}{\partial \gamma} = \frac{L}{(1-\gamma)(\delta-1)}$ . The full employment condition (labor is used only in Forestry) and the labor demand implied by equation (13) fixes the wage at  $w = (1 - \gamma)p$ .<sup>12</sup>

Performing the maximization in equation (14), using the expression for  $\frac{\partial L}{\partial \gamma}$  and for the equilibrium wage gives the first order condition

$$p \frac{1 - \delta - \gamma}{(1 - \gamma)(1 - \delta)} = \frac{\partial c}{\partial \gamma} = \varepsilon c'. \quad (15)$$

Denote the amount of capital used to produce/maintain property rights as  $k$  and suppose that the production function for this sector is  $\gamma = \frac{k^\rho}{\varepsilon}$ ,  $0 < \rho < 1$ . Using  $r = 1$  gives the cost function  $c = (\varepsilon \gamma)^{\frac{1}{\rho}}$ . Using this relation in equation (15) and simplifying implies that  $k$  satisfies

$$Q(\varepsilon; k) \equiv \frac{k^{1-\rho}}{\rho} (\delta - 1) \varepsilon^2 + (1 - \delta) \left( \frac{k^{1-\rho}}{\rho} k^\rho + p \right) \varepsilon - p k^\rho = 0.$$

The function  $Q$  is a quadratic in  $\varepsilon$ ; for any  $k > 0$ , sufficiently small, there are two positive roots. As  $k$  increases, the distance between these roots declines. At a critical level of  $k$  there is a single root, and beyond this critical level there are no (real) roots. This critical level is the maximum amount of  $k$  that could be used (for any  $\varepsilon$ ) in the production/maintenance of property rights, for given  $p, \rho, \delta$ .

Using the production function to write  $\varepsilon = \frac{k^\rho}{\gamma}$  and substituting this expression into  $Q$  gives the relation between the equilibrium level of  $\gamma$  and  $k$ :

$$R(\gamma; k) \equiv p k^\rho \rho \gamma^2 + (\delta - 1) (k^{1+\rho} + p k^\rho \rho) \gamma + (1 - \delta) k^{1+\rho} = 0.$$

The function  $R$  has the same shape as  $Q$ , so the amount of capital used to produce/maintain property rights is a non-monotonic function of the equilibrium level of property rights.

Figure 2 shows the graph of  $\varepsilon$  and of  $\gamma$  (the roots of  $Q = 0$  and  $R = 0$ ) as function of  $k$ , with  $p = 1, \rho = 0.9, \delta = 0.3$ . This figure can be used to determine the equilibrium value of  $\gamma$  and of

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<sup>12</sup>We can also obtain a non-monotonic relation between the equilibrium level of property rights and comparative advantage using a model in which the judicial system uses only labor, Cloth uses only capital, and Forestry uses only labor and the natural resource. In that model, the equilibrium factor prices are more difficult to determine, and the model is more difficult to analyze. Since it does not offer significantly different insight, we do not consider it further.

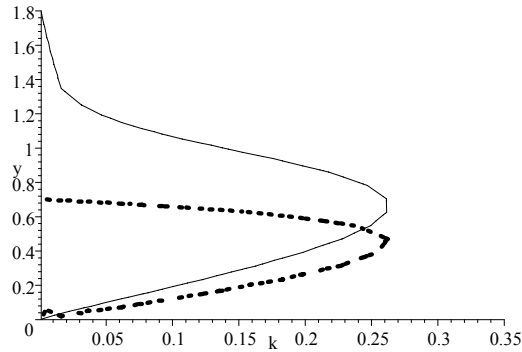


Figure 2: The relation between  $k$  and  $\varepsilon$  (solid) and  $\gamma$  (dotted)

Cloth production as functions of the exogenous value of  $\varepsilon$ , the technology parameter. For any value of  $\varepsilon$  (a point on the vertical axis labelled  $y$ ), the solid graph determine the equilibrium level of  $k$ . Corresponding to this value of  $k$ , the dashed graph has two values of  $\gamma$ , say  $\gamma_1$  and  $\gamma_2$ ,  $\gamma_1 < \gamma_2$ . By inspection of the functions  $Q$  and  $R$ , we see that if the value of  $\varepsilon$  is above (respectively, below) the turning point of the solid graph, the equilibrium value of  $\gamma$  is  $\gamma_1$  (respectively,  $\gamma_2$ ). For example, if a particular value of  $k$  is associated with a value of  $\varepsilon$  above the turning point of the  $Q = 0$  graph, the economy has an inefficient system for producing property rights, so the equilibrium value of  $\gamma$  is small.

The use of more capital to produce/maintain property rights means that less capital is available to produce Cloth. In this example, cloth production is  $K - k$ , where  $K$  is the endowment of capital. (If  $K > 0.27$  our assumption that Cloth production is positive is satisfied for all  $\varepsilon$  for the numerical example shown in Figure 2.) Since Forestry output is fixed, the non-monotonicity of  $k$  implies that the relation between property rights in the resource-based sector and comparative advantage in that sector is non-monotonic. The relation between property rights and national income is also non-monotonic.