Department of Agricultural & Resource Economics, UCB
CUDARE Working Papers
(University of California, Berkeley)

Year 2003 *Paper* 942

Property rights, mobile capital, and comparative advantage

Larry Karp
University of California, Berkeley and Giannini Foundation

Property Rights, Mobile Capital, and Comparative Advantage

Larry Karp*

April 28, 2003

Abstract

Recent papers use sector-specific factor models with mobile labor to show that imperfect property rights can be a source of comparative advantage. In these model, weaker property rights to the specific factor in a sector attract the mobile factor and increase 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. The presence of a second mobile factor also makes the relation between the equilibrium wage-rental ratio and the degree of property rights ambiguous.

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

JEL Classification numbers: F02, F16, F18, D23

*Department of Agricultural and Resource Economics, 207 Giannin hall, University of California, Berkeley CA 94720. karp@are.berkeley.edu

1 Introduction

Classical 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. We show that when capital (in addition to labor) is mobile, these previously established results can be reversed if imperfect property rights make it difficult to capture all of the returns to capital, or if the degree of property rights is endogenous.

These circumstances also make the relation between the degree of property rights and the real return to factors ambiguous. National income accrues to owners of capital, labor, and the natural resource. Legal owners of the natural resource have imperfect property rights; they always benefit from strengthening these rights. In sector-specific factor models, an improvement in property rights benefits capitalists and harms workers. When capital is mobile, and property rights are initially weak, an improvement in these rights may benefit workers and harm capitalists. Thus, 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 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. Karp, Sacheti, and Zhao (2001) imbed Chichilnisky's model in a dynamic setting, in which the resource stock changes endogenously. They compare the short and long run effects of trade liberalization. Karp, Zhao, and Sacheti (forthcoming) use the same model to study environmental reform and the harmonization of policies. Copeland and Taylor (1999) study trade and property rights in a dynamic Ricardian model. In Hotte, van Long, and Tian (2000) and Margolis and Shogren (2000) agents use factors of production to protect their property rights. The equilibrium degree of property rights is endogenous. It depends on prices, the "protection technology", and on the resource stock. As the resource stock changes, the degree

of property rights also changes.

These papers use variants of a two-country, two-commodity model with one mobile factor, labor –i.e., they use a sector-specific factors model. 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.

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, or if property rights are endogenous. 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 relative supplies of factors remaining for the production of other goods (including the resource-based good). At a constant relative factor price, this change in relative factor supply changes the ratio of outputs, as in the Rybczynski theorem.[1] Furthermore, a change in the relative factor supply typically changes the relative factor price, holding fixed commodity prices. This change occurs because the resource-based sector is unlikely to have constant returns to scale in mobile inputs, due to the presence of the fixed input (the natural resource stock).

Suppose, for example, that the non-resource-based sector and the activity that maintains and protects property rights both use capital intensively, relative to the resource-based sector. In this case, at constant factor prices, the use of resources to produce stronger property rights increases

[1] In a similar context, Chau (2003) notes that tighter environmental policy can increase a country's comparative advantage for a polluting good. This type of relation is reminiscent of results in Bhagwati (1982).

the output of the resource-based sector, relative to output in other sectors, via a Rybczynski-type effect. A change in factor prices reinforces this effect, because it makes production of the resource-based good relatively cheaper. In this situation, stronger property rights can be associated with greater comparative advantage for the resource-based good. This particular reason for a positive relation between property rights and comparative advantage in the resource-based sector requires the existence of a mobile factor other than labor – a feature found in none of the previous models.

The distributional effects of stronger property rights are also worth noting. In (a simple version of) the sector-specific factors model, weaker property rights unambiguously increase the equilibrium wage and decrease the return to the sector-specific factor. This relation is ambiguous in a model with two mobile inputs.

The empirical significance of the theoretical results in previous papers has not been confirmed, although Deacon and Bohn (2000) provide evidence that property rights may be an important determinant of production. Nevertheless, the models are potentially influential because they are consistent with a widely held view: Market failures in developing countries lead to excessive exploitation of resource-based industries; trade liberalization increases this exploitation, damaging the environment, and possibly lowering national income (welfare). There are many ways in which trade and the environment might be related. However, the unambiguous relations between property rights and comparative advantage, and between property rights and real factor returns found in previous models may be too much of a simplification.

Section 2 provides an informal discussion of the model. Section 3 provides a formal model and illustrates the relations described above using examples. A conclusion summarizes and mentions a related issue.

2 The intuition

There are two sectors, Cloth (C) and Forestry (F) and two mobile factors of production, capital and labor (K and L). Production of cloth uses only K and L, with constant returns to scale; there are perfect property rights in this sector. Production in the forestry sector 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.

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 this sector means that we can replace N by one without loss of generality; that is, we use a representative firm model. The presence of the sector-specific factor f means that there are decreasing returns to (K, L) in Forestry. Consequently, there are potential rents in this sector. The forestry firm can hire both capital and labor to exploit the resource. Imperfect property rights make it difficult for this firm to keep poachers from entering the sector.

The representative Forestry firm takes output and factor prices as given. However, the firm recognizes that its employment and investment decisions 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.

We begin by treating the index of the property rights as exogenous. The index is negatively related to the wedge between the marginal value of product of labor in Forestry and the wage. The next section gives it an exact meaning, when we specify the model. At the end of this section we consider the case where the index is endogenous.

As property rights become weaker, the labor market distortion increases. If production in the forestry sector uses only f and L, we have the type of model described in the Introduction. In this case, weaker property rights lead to greater forestry production (for fixed f); the relation between property rights and comparative advantage is as described above. The presence of another mobile input, K, complicates this relation.

The effect of mobile capital depends on the type of investment opportunities. There are two important cases: investment can be in a "local public good", such as a road or a bridge, or in a project that creates private (i.e., excludable) benefits. The distinction between these two types of investment in our model occurs only because of imperfect property rights. If there were perfect property rights, we assume that the firm would be able to internalize all of the benefits of the road or bridge, so it would be like any other private investment.

For an investment that provides excludable benefits, there are two possibilities. The investment opportunity may be equally available to the Forestry firm and poachers, or available only to the firm. For example, labor productivity increases when workers have chain saws. In the absence of credit constraints or similar distortions, poachers and the Forestry firm have the same ability to buy chain saws. However, only the legal owner can invest in a sawmill, or some

other piece of capital that can be easily identified and confiscated.

In the case where property rights are exogenous, the presence of investment opportunities that create *private* benefits has no qualitative effect on the simpler model with a single mobile input: weaker property rights increase a country's comparative advantage in the resource-intensive sector. Both poachers and the Forestry firm have an incentive to buy chain saws in order to increase their own productivity. The firm has an additional (strategic) incentive to make this kind of investment, in order to discourage poachers. Chain saws increase a worker's ability to exploit the scarce resource, decreasing the rents available to other workers, including poachers. The decrease in rent discourages poachers from entering. The firm takes this externality into account in deciding how many chain saws to buy. Weaker property rights increase agents' incentives to buy chain saws, thereby increasing Forestry output, and the country's comparative advantage in this sector. If only the firm has the investment opportunity, as with a sawmill, it has the standard incentive to invest in order to increase labor productivity. It also has the strategic incentive to invest, as with a chain saw. In neither case (i.e., for the investment that resembles a chain saw or a sawmill) does the presence of a second mobile factor alter the conclusion that weaker property rights increase the comparative advantage in the resource-intensive sector.

We therefore emphasize the case in which investment creates a local public good, such as a road or a bridge. All workers in the forestry sector (poachers as well as those hired by the forestry firm) benefit from these investments. 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.

Investment in infrastructure that facilitates access to a resource is an important component of investment in resource-based sectors. This type of investment is also complementary to other investments whose benefits can be privately appropriated. A road increases the value of a sawmill, and it also increases the appeal of poaching (with or without a chain saw). In cases where the firm invests in the local public good, our model is directly applicable. In some cases, this investment is funded by the government. To the extent that the decision-making agency in the government is interested in maximizing rents from the resource-based sector – that is, to the extent that the agency identifies with the legal owners of the resource – the model is again applicable. Only the name of the agent that chooses investment changes.

The type of investment that we have in mind is not literally mobile. Roads used to extract

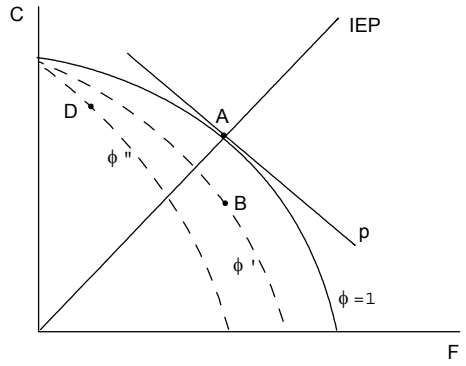

Figure 1: Production points for different levels of property rights

logs cannot be converted to factories that produce cloth, just as machines that produce cloth cannot be converted to roads. When capital is locked into this kind of input, its degree of mobility is determined by the rate of depreciation of the input. (Gross investment at a rate less than the depreciation rate of the input represents a transfer of capital to another sector.) A more complete model would distinguish between factors on the basis of their speed of adjustment, as in Karp and Paul (2001). The importance of this sort of dynamic extension depends on the relation between the speed of change of a trade regime and the speed of reallocation of capital. If the trade regime changes quickly relative to the speed of adjustment of capital, then the previous models with a single mobile factor are appropriate, at least for short-run analysis. However, if trade liberalization occurs over the same time span needed to transfer capital across sectors, the model that we sketch here is appropriate.

Figure 1 illustrates the effect of different degrees of property rights, indexed by ϕ.[2] The value $\phi = 1$ represents complete property rights in Forestry, and a value $\phi < 1$ represents weaker property rights in that sector. The solid curve labelled $\phi = 1$ is the production possibility frontier under perfect property rights, and the curves labelled ϕ' and ϕ'' are the production possibility frontiers under successively weaker property rights, $\phi'' < \phi' < 1$. As property rights become weaker the distortion becomes more severe, causing the production possibility frontier to shift in. This shift occurs because weak property rights encourage too much labor

[2]Our discussion of Figures 1 and 2 is intended to explain the forces at work in a "reasonable" general equilibrium model with mobile capital, exogenous property rights, and non-excludable investment in the resource-based sector. We do not claim that *every* reasonable model has these features – although the example in Section 3.2 does.

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 produces only cloth, the market failure is irrelevant, so all the production possibility frontiers have the same vertical intercept.

Suppose that the autarkic price of Forestry goods in a country with perfect property rights is p and all agents (in all countries) have identical and 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 price p, for two countries with property rights indexed by ϕ' and ϕ''. Since production is not efficient in these countries, the slope of the production possibility frontier differs from p at both points B and D.

For the country with property rights ϕ', there is excess supply for Forestry products at p. In this case, 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 ϕ'', 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.[3]

The non-monotonicity arises because imperfect property rights (together with non-excludable capital) affect the choice of both inputs. There are three types of 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, attracting labor into the Forestry sector and increasing output there. The poaching incentive occurs in the earlier (sector-specific factor) models, but the next two forces arise only when there is an additional mobile factor. The second force is the Forestry firm's *investment incentive*. 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. Third, there

[3]National income 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.

is the indirect, or "general equilibrium effect", that arises due to the change in factor prices. (If the firm can internalize all the benefits of investment, the poaching incentive and the investment incentive work in the same direction, leaving only the general equilibrium effect as a source of ambiguity between property rights and comparative advantage.)

If we begin with perfect property rights ($\phi = 1$), and weaken these rights, the poaching incentive causes labor to flow into Forestry. The resulting decrease in the amount of labor in Cloth increases the value of its marginal product in that sector. This change causes the equilibrium wage to rise. The 0 profit condition in Cloth requires that the equilibrium rental rate falls – thus the wage-rental ratio rises. Beginning with perfect property rights, the level of investment in Forestry is optimal, so the investment incentive has only a second order effect on the change in Forestry capital. However, the fall in the rental rate causes a first order effect, leading to *increased* Forestry capital. Figure 2 shows this relation over the interval $(\phi^*, 1)$, where $\frac{L_f}{L}$ and $\frac{K_f}{K}$ are the fractions of labor and capital in Forestry. (The heights and the point of intersection of the two curves are arbitrary; only their turning points matter for this discussion.).

With larger distortions, the poaching incentive and general equilibrium effects continue to operate, but the investment incentive becomes more important, i.e. it has a first order effect. Thus, larger distortions eventually lead to a decrease in the amount of Forestry capital, as shown in the interval (ϕ^{**}, ϕ^*) of Figure 2. Over this interval, the capital-labor ratio in Cloth rises, so the wage-rental ratio must also rise, as ϕ falls.

Eventually the investment incentive becomes very strong, leading to a large decrease in investment (as property rights are weakened) and a large fall in the average product of labor in Forestry (for a given allocation of labor). The decline in Forestry capital makes it less attractive to work in that sector – either as a legal worker or a poacher – causing a decline in Forestry labor. This relation occurs for $\phi < \phi^{**}$ in Figure 2. Over this interval, the change in the capital-labor ratio in Cloth is ambiguous, as is the change in the wage-rental ratio. In contrast, with a (simple) sector-specific factor model, a deterioration in property rights always increases the wage-rental ratio.

The discussion above assumes that property rights are exogenous, and relies on the assumption that investment in Forestry provides (to a significant extent) a local public good. With *endogenous* property rights and two or more mobile factors, the relation between comparative advantage and property rights is ambiguous even when investment in Forestry provides excludable benefits – the case we now consider. With endogenous property rights maintained by

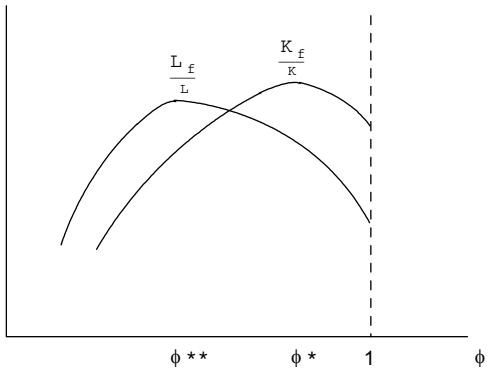

Figure 2: Capital and labor used in Forestry as functions of property rights

factors of production, the amounts of factors available for production of Cloth and Forestry are also endogenous.

Consider two economies that differ in the efficiency of their judicial systems, but which are otherwise identical. The judicial system is analogous to a production function for property rights. In order to create or maintain property rights, the judicial system uses factors of production, e.g. lawyers and guards. The country with a more efficient judicial system is able to create/maintain property rights using fewer resources. Holding fixed the commodity prices, the equilibrium allocation of factors to create/maintain property rights differs between the countries, as does the resulting equilibrium level of property rights.

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 in the sector. Stronger property rights causes the production possibility frontier to shift out, but the withdrawal of factors of production tends to offset this effect. For example, the U.S. has highly developed property rights, but arguably has too many lawyers (or economists) and prison guards.

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 are likely to be different in the two countries. 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 is likely to be ambiguous.[4]

[4]As mentioned in a previous footnote, this relation between property rights and comparative advantage has a great deal in common with the type of relation discovered by the literature on directly unproductive activities.

3 The formal results

We adapt Hotte, van Long, and Tian (2000)'s model by including a second mobile factor of production, capital. We consider two reasons why the relation between imperfect property rights and comparative advantage can be ambiguous.

The first arises because investment in the resource-intensive sector creates a local public good. For this situation we emphasize the case where property rights are exogenous. We use the possible endogeneity of property rights only in order to show that perfect property rights corresponds to a particular value of our index of property rights. This value is the upper bound for our index. After presenting the model we provide an example that illustrates the ambiguity between property rights and comparative advantage, and between property rights and the real returns to capital and labor.

We then consider the case in which the benefits of investment in the resource-based sector can be privately appropriated. That is, investment looks like a chain saw or a sawmill rather than a bridge or road. In this case, the mobility of capital does not alter the conclusion of the models with one mobile factor. However, if property rights are endogenous, and the creation or maintenance of these rights uses capital, we again find an ambiguous relation between the equilibrium level of property rights and comparative advantage.

3.1 The model with investment as a local public good

Each worker has one unit of time. A poacher in Forestry has to spend the fraction γ 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.

There are two important differences. First, here the outside activity is productive, because it shifts out the production possibility frontier. Second, the activity typically changes the factor prices.

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

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

If $\gamma=0$ there is open access; larger values of γ are equivalent to stronger property rights.

We will use the fact that γ is bounded below one. In order to establish this bound we consider the situation in which γ is endogenous. Here the forestry firm chooses the amount of monitoring. The "production function" for γ is $g(K_m,L_m)$, where (K_m,L_m) are factors employed in monitoring. The cost of achieving a given level of γ is

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

The timing of decisions is unimportant, but for clarity of exposition we treat the Forestry firm as solving a three-stage problem, first choosing γ, 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).

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 γw. 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

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

Differentiating equation (1) implies

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

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

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

In the case where γ is endogenous, it is the solution to

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

(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 $c(\gamma)$ is strictly convex, $\phi < 1$. For $c(\gamma) \equiv 0$, $\phi = 1$.*

To confirm this Remark, we can show that the necessary condition for profit maximization ($\frac{\partial \pi}{\partial \gamma} = 0$) in the case where $c(\gamma) \equiv 0$ requires that $pF_L = w$. When γ 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 γ (thus raising ϕ), the optimal value satisfies $\phi < 1$.

For the special case where $F(K_f, L_f) = f(K_f)L_f^{\delta}$, with $\delta < 1$, we have $F_L = \frac{\delta F}{L}$ and $\phi = \frac{\delta}{1-\gamma}$. In this case, Remark 2 implies that $\gamma \leq 1 - \delta$. With this functional form, the equilibrium conditions (equations (1) and (5)) simplify to

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

These two equations show that imperfect property rights (together with investment in non-excludable capital) induce the Forestry firm to use too much labor (as a means of deterring entry by poachers) and too little capital (also as a means of deterring entry). For a more general production function, the relation between ϕ and γ depends on factor prices.

3.2 An example

For the purpose of illustrating the claims in Section 2, we now take $\phi \leq 1$ as exogenous, and consider the comparative statics with respect to this parameter. 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 $\beta + \delta < 1$. We first examine the partial equilibrium model, in which the factor prices w and r are fixed. In this case, only the poaching incentive and the investment incentive affect the allocation of factors. We then consider the general equilibrium model in which factor prices are endogenous. We hold the commodity price p fixed, since our objective is to study the relation between property rights and comparative advantage.

In a partial equilibrium setting, substituting the function $F(K_f, L_f) = K_f^{\beta} L_f^{\delta}$ into the equilibrium conditions enables us to determine the comparative statics of inputs and Forestry output with respect to γ. (We can confirm that for all $\gamma > 0$ the Forestry sector operates. Thus, the following comparative static results are not vacuous.) We omit the tedious computations, and merely present the results:

$$\frac{d \ln K_f}{d\gamma} = \frac{1-\delta-\gamma}{(1-\gamma)\,\gamma\,(1-\beta-\delta)} > 0 \tag{7}$$

$$\frac{d \ln L_f}{d\gamma} = \frac{\beta-\gamma}{(1-\gamma)\,\gamma\,(1-\beta-\delta)} \tag{8}$$

$$\frac{d \ln F}{d\gamma} = \frac{\beta\,(1-\gamma)-\delta\gamma}{(1-\gamma)\,\gamma\,(1-\beta-\delta)}. \tag{9}$$

Stronger property rights (an increase in γ) unambiguously increases Forestry capital, because of the absence of general equilibrium effects. With strong property rights ($\gamma \approx 1-\delta$) an improvement in property rights decreases the amount of labor in Forestry, just as in the models with a single mobile factor. However, when property rights are quite weak ($\gamma < \beta$), an improvement in property rights leads to an increase in the amount of labor in Forestry. If property rights satisfy $\gamma > \frac{\beta}{\beta+\delta} \equiv \hat{\gamma}$, an increase in property rights leads to a reduction in Forestry output, as occurs in the models with a single mobile input. However, this relation is reversed for $\gamma < \hat{\gamma}$.

These results illustrate the possibly non-monotonic relation between property rights and output in the resource-based sector. They also show that 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.

When factor prices are endogenous, $F = f(K_f)L^{\delta}$, and with total supply of factors given by $L = K = 1$, 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, with constant returns to scale in Cloth ($F = K_f^{\beta} L_f^{\delta}$, $C = K_c^{\alpha} L_c^{1-\alpha}$) 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 $\alpha = 0.5$. For these values, the critical value at which Forestry output reaches its maximum (with respect to γ) in the partial equilibrium setting is $\hat{\gamma} = 0.5$; the corresponding value of ϕ is $\hat{\phi} = 0.6$.

Table 1 shows the comparative statics with respect to $\phi \equiv \frac{\delta}{1-\gamma}$, illustrating the relations described in Section 2. In terms of the notation in Figure 2, the critical values of ϕ for this example are approximately $\phi^* \approx 0.8$ and $\phi^{**} \approx 0.45$. When property rights are strong ($\phi \approx 1$), weakening property rights (smaller ϕ) leads to an increase in both factors in Forestry. This increase implies that Forestry output increases absolutely, as does the ratio $\frac{F}{C}$. We noted that for fixed input prices, K_f is strictly increasing in property rights. The possibility that K_f rises as ϕ falls is a general equilibrium effect.

Beginning with strong property rights, weakening these rights raises the capital-labor ratio in Cloth, raising the wage-rental rate. Since the output price is fixed, the value of r falls and the value of w rises. 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 that property rights are weaker in Forestry.

Further weakening of property rights continues to attract labor to Forestry (the poaching incentive), but eventually the amount of capital attracted to the sector decreases (the investment incentive). When ϕ falls below approximately 0.6, a further weakening of property rights causes the country's comparative advantage in Forestry to decrease. For ϕ less than 0.4, the country has a comparative advantage in Cloth (relative to the country with perfect property rights). As property rights become sufficiently weak, the absolute amount of labor in Forestry is less than in 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 ϕ causes labor to exit Forestry more rapidly than capital, 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 $F + C$. The last column of Table 1 shows the

ϕ	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	∞	1	15.68

Table 1: Comparative statics with respect to property rights

percentage loss in national income due to incomplete property rights. For this example, weaker property rights always reduce national income. With perfect property rights, the Forestry sector accounts for nearly 40% of national income. Provided that $\phi \geq 0.7$, incomplete property rights lead to a loss of less than 1% of income; the loss rises to nearly 16% if weak property rights cause the forestry sector to shut down.

It is worth comparing the results described above with the results in the standard sector-specific factor model, with factors K and f specific to the Cloth and Forestry sectors. For this model, we have

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

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 η). A familiar comparative statics exercise establishes that in this model an increase in property rights (γ) increases Forestry output, increases r and η, and decreases w. In this model, owners of the specific factors always prefer stronger property rights since it reduces the wage; weaker property rights increase the country's comparative advantage in Forestry.

3.3 The model where benefits of investment are excludable

Here we assume that investment in Forestry increases labor productivity 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 $h\left(K_f, L_f^e\right)$. For brevity, we consider in the text only the case where only the firm can hire capital. That is, capital resembles sawmills rather than chain saws.[5]

The effective units of labor in Forestry are $h\left(K_f, L_f^e\right) + (1-\gamma) L_f^p$. In the absence of investment, employees and poachers are equally productive ($h\left(0, L_f^e\right) = L_f^e$) and investment does not decrease productivity ($h_K\left(K_f, L_f^e\right) \geq 0$). We take the special case where capital increases Forestry output only by increasing the effective units of labor. In this case, the production function is $F = F\left(h\left(K_f, L_f^e\right) + (1-\gamma) L_f^p\right)$. We assume that F is increasing and concave in effective labor.[6] For exposition, we again view the firm as solving a three stage optimization problem.

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

$$(1-\gamma)\frac{pF\left(h\left(K_f, L_f^e\right) + (1-\gamma) L_f^p\right)}{h\left(K_f, L_f^e\right) + (1-\gamma) L_f^p} = w. \tag{10}$$

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 (10) imply that the

[5] If a poacher is also able to hire capital, we need additional notation. Suppose that each poacher hires k_p units of capital. Her effective units of labor are $m(k_p, 1-\gamma)$ and the total effective units of labor in Forestry is $h\left(K_f, L_f^e\right) + L_f^p m(k_p, 1-\gamma)$. If poachers and the firm have the same investment opportunities, then the use of this model requires that $h(k,1) = m(k,1)$, where k is the capital labor ratio, so the functions must have constant returns to scale in labor and capital. More generally, poachers and firms may have different investment opportunities, in which case this restriction on functions need not hold. Poachers have an incentive to buy too much capital, in an attempt to increase their rents. Investment by both types of agents exacerbates the distortion in property rights.

[6] The assumptions on F and h are not consistent with constant returns to scale in K_f and L_f^e, so for this model the distribution of ownership of the forestry resource is not innocuous. We assume that each firm has equal share of forestry resources and that the number of forestry firms, N, is fixed. We therefore suppress this parameter.

value of h is fixed by w and γ. We can rewrite equation (10) as

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

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

Remark 3 *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 γ) 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.[7] 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, Cloth uses labor and capital, and the creation/maintenance of property rights uses one or both inputs. In this setting, Cloth is always capital intensive relative to Forestry. From the discussion in Section 2 it is clear that we are more likely to find a positive relation between stronger property rights and a comparative advantage in Forestry when the judicial system relies mostly on capital in order to produce/maintain property rights. In the interests of simplicity, we therefore 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 condition with imperfect property rights is

$$(1-\gamma)\frac{pF(L_f)}{L_f} = w. \tag{11}$$

The equilibrium level of employment in Forestry is $L_f^*(\gamma)$, with

$$\frac{\partial L_f^*(\gamma)}{\partial \gamma} = \frac{pF}{(1-\gamma)\,pF' - w}.$$

[7] To complete the analysis of this model, it is straightforward to show that investment is chosen to minimize the cost of providing h effective units of labor. This result is obvious, since the value of h is fixed by the equilibrium condition, equation (10).

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

The firm's optimal level of property rights is γ^*, defined as

$$\gamma^* \equiv \arg\max_{\gamma \geq 0} \left(\frac{\gamma w L}{1-\gamma} - c(\varepsilon\gamma) \right). \tag{12}$$

Remark 2 still holds. If $\varepsilon = 0$ there are perfect property rights; that is, $pF' = w$ in equilibrium. For fixed w, γ^* is decreasing in ε for $\gamma^* > 0$ (i.e. at an interior solution).

In general, the equilibrium w is a function of the exogenous parameter ε. One extreme case, however, provides a clear result. Suppose that Cloth uses only 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 $L = 1$. The full employment condition (labor is used only in Forestry) and the labor demand implied by equation (11) fixes the wage at $w = (1-\gamma)p$. In this model, the Forestry firm's investment in maintaining stronger property rights merely shifts rents from workers to the firm, without affecting the return to capital. Greater investment in this activity is "directly unproductive", in the standard sense.

Performing the maximization in equation (3) and using the expression for wages implies that

$$p\frac{1-\delta-\gamma}{(1-\gamma)(1-\delta)} = \frac{\partial c}{\partial \gamma} = \varepsilon c'. \tag{13}$$

Denote the amount of capital used to produce/maintain property rights as k and suppose that the production function for this sector is $\gamma = \frac{k^\rho}{\varepsilon}$. Using $r = 1$ gives the cost function $c = (\varepsilon\gamma)^{\frac{1}{\rho}}$. Using this relation in equation (13) and simplifying implies that k satisfies

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

The function Q is a quadratic in ε; 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 ε) in the production/maintenance of property rights, for given p, ρ, δ.

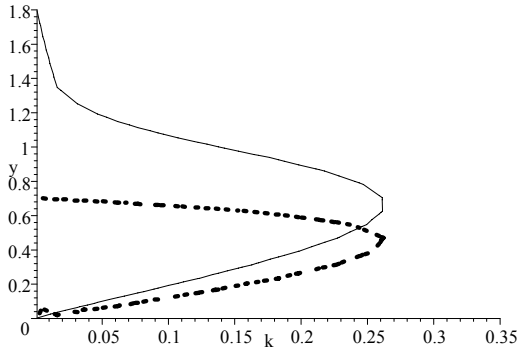

Figure 3: The relation between k and ε (solid) and γ (dotted)

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 γ and k:

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

The function R has the same properties as Q, so the the amount of capital used to produce/maintain property rights is a non-monotonic function of the equilibrium level of property rights. Figure 3 shows the graph of ε and of γ as function of k, with $p = 1, \rho = 0.9, \delta = 0.3$.[8]

The use of a larger amount of 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 ε for the numerical example shown in Figure 3.) 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.

In this example, an endogenous increase in property rights beginning at a low level (i.e., γ increases from a low level because it becomes cheaper to protect property rights) increases the country's comparative advantage in Forestry ($\frac{F}{C}$ rises). An increase in property rights in a country that already has relatively strong property rights (γ close to $1 - \delta$) decreases the

[8]For any value of ε (a point on the vertical axis labelled y), we use the solid graph to determine the equilibrium level of k. Corresponding to this value of k, the dashed graph has two values of γ, say γ_1 and γ_2, $\gamma_1 < \gamma_2$. If the value of ε is above (respectively, below) the turning point of the solid graph, the equilibrium value of γ is γ_1 (respectively, γ_2).

country's comparative advantage in Forestry.

4 Conclusion

Previous sector-specific factor 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. The empirical significance of this type of result has not been confirmed, but the result is nevertheless important because 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).

The presence of a second mobile factor, such as capital, can make the relation between property rights and comparative advantage non-monotonic. This complication can occur if there are opportunities to invest capital in the resource-based sector, and the imperfect property rights in this sector make it impossible to capture all of the benefits of this investment. It can also occur if capital is used to create or maintain property rights, regardless of whether the entire return to investments in the resource-based sector can be captured by the firm. We also explained why the relation between real returns to factors and property rights might be non-monotonic. The resource owner always wants to increase property rights. The identity of the owner's natural ally – capitalists or workers – might vary with the extent of the market failure.

We used simple examples to illustrate these possibilities. These examples have no empirical basis, so we cannot assess whether they represent likely outcomes or mere theoretical curiosities. We intend to adapt a realistic CGE model to assess this issue.

North-South trade motivates the questions studied here, but they also arise in other contexts. There is (plausibly) a common property problem in certain types of research, e.g. in biotechnology. The patent system may encourage excessive investment in research, leading to a dissipation of rents. Here the "common property" consists of the set of potential discoveries. This common property problem may discourage basic research, i.e. research that generates knowledge that cannot easily be patented. The potential gains from strengthening property rights may also result in too many lawyers and too few engineers and scientists.

References

BHAGWATI, J. N. (1982): "Directly unproductive rent-seeking activities," *Journal of Political Economy*, 90, 988 – 1002.

CHAU, S. (2003): "Does tighter environmental policy lead to a comparative advantage in less polluting goods?," *Oxford Economic Papers*, 55, 25–35.

CHICHILNISKY, G. (1994): "North-South Trade and the global environment," *American Economic Review*, 84, 581–71.

COPELAND, B., AND M. TAYLOR (1999): "Trade, spatial separation, and the environment," *Journal of International Economics*, 47(1), 137–168.

DE MEZA, D., AND J. GOULD (1994): "The social efficiency of private decisions to enforce property rights," *Journal of Political Economy*, 100, 561–580.

DEACON, R., AND H. BOHN (2000): "Ownership risk, investment, and the use of natural resources," *American Economic Review*, 90, 526–49.

HOTTE, L., N. VAN LONG, AND H. TIAN (2000): "International trade with endogenous enforcemnt of property rights," *Journal of Development Economics*, 62, 25–54.

KARP, L., AND T. PAUL (2001): "Intersectoral Adjustment and Policy Intervention: the Importance of General Equilibrium Effects," Giannini Foundation of Agricultural Economics, Working Paper No. 893, University of California, Berkeley; http://are.Berkeley.EDU/ karp/.

KARP, L., S. SACHETI, AND J. ZHAO (2001): "Common Ground Between Free-traders and Environmentalists," *International Economic Review*, 42(3), 617–47.

KARP, L., J. ZHAO, AND S. SACHETI (forthcoming): "The Long-Run Effects of Environmental Reform in Open Economies," *Journal of Environmental Economics and Management*.

MARGOLIS, M., AND J. SHOGREN (2000): "Unprotected resources and voracious markets," Department of Economics and Finance, University of Wyoming.