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Reassessing the interaction between investment and tenure uncertainty

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ABSTRACT. A diverse body of empirical literature recognizes that investment can influence tenure security, yet this phenomenon has rarely been examined analytically. This paper develops a theoretical model that demonstrates explicitly conditions under which the probability of eviction is endogenous to investment undertaken on illegally encroached land. By accommodating explicitly the government's objective function and its ability to commit credibly to an eviction policy, the model reveals why both those farmers who under-invest, and those who raise their investment levels to improve tenure security, may be behaving rationally. Indeed, both types of behaviour are accommodated within a single model.

1. Introduction

This paper revisits an old question, but within a new context: whether uncertainty over land tenure should be expected to result in less or more investment than would occur with secure property rights. Uncertainty over property rights has long been put forward as an explanation for why individuals are unwilling to make long-term, sunk-cost investments (more recent examples of the literature include Feder and Onchan, 1987; Gavian and Fafchamps, 1996). The conventional literature typically models uncertainty as a tax that augments the discount rate, hence reducing the chosen level of investment (Johnson, 1950; Reed, 1984; Basu, 1989; Mendelsohn, 1994).

Uncertainty has also been demonstrated to delay investment until that uncertainty has been resolved, a conclusion highlighted in the literature on real options. If decision making is sequential, if investment is costly to reverse, and if the investor has the option to delay investing until uncertainty is resolved, investments may be postponed to avoid the associated downside risk (Arrow and Fisher, 1974; Dixit and Pindyck, 1994; Trigeorgis, 1996). In both these literatures, uncertainty is exogenous.

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Individuals respond to the uncertainty by reducing the risk associated with investment, either by reducing the level of investment or postponing the investment.

In contrast, the separate literature on squatting suggests that the opposite may be true, that individuals may take action to reduce the probability that they are evicted. By strategically increasing their level of investment, the probability of eviction is reduced (Fass, 1990; Baviskar, 1993; Razzaz 1993). Razzaz (1993: 351) found that settlers in Jordan would often use permanent materials to build houses even though there was a risk of demolition. The settlers 'know that a makeshift shelter stands little chance and that the more they invest in permanent material the more their claim to the land is legitimised'. In a study of illegal settlements in Latin America, Fass (1990) observed that investment often occurs before permanent rights are granted and is undertaken, in part, to improve tenure security. Farmers invest in their land up to the point at which eviction is not economically feasible for the government.

The squatting literature typically focuses on urban areas. However, the phenomenon of investing to improve tenure has also been recognized in rural settings. In China, greater uncertainty over future government policy on land holdings has resulted in relatively lower levels of investment in animals and equipment and higher levels in fixed assets (Feder *et al.*, 1992). Feder *et al.* (1992: 8) observed that 'by building a house, a Chinese farm household in effect established permanent use rights on the land on which the house stands'. In Africa, tree planting, a long-term sunk cost investment, is a way of improving tenure security (for example, Bruce and Fortmann, 1991/2; and Brasselle *et al.*, 2002). Besley (1995) has considered empirical evidence that suggests that farmers make investments on their land to enhance their land rights (although the evidence is far from conclusive).[1] Alston *et al.* (2000) demonstrate that in Brazil, insecure property rights to land, due in part to inconsistent civil and constitutional laws, have encouraged both landowners and squatters to clear forest to improve their claims to the land.

Sjaastad and Bromley (1997) have put forward a model in which an individual faces one of two discrete probabilities of eviction, depending on whether he has made an investment in the land. The authors assume that, based on empirical evidence, higher investment corresponds to a lower probability of eviction. However, these probabilities are exogenous and discrete, and so no attempt is made to explain why, or under what conditions, the probability of eviction is a function of investment. Brasselle *et al.* (2002) undertake an empirical study that accommodates explicitly the possible reverse causality between investment and land tenure security. Their paper highlights the difficulty of undertaking econometric analysis when such an endogeneity bias exists.

The author observed that farmers who encroach government common land in Karnataka, southern India, exhibit many different types of investment behaviour (Robinson, 1997). Some farmers reported that they avoided

[1] Similarly, Biglaiser *et al.* (1995: 43) find 'anecdotal evidence that firms do recognize that their investments can affect subsequent regulation'.

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investing on the encroached land, fearing that they might be evicted in the future. Rather than prepare the land properly, removing stones and levelling, they simply scattered seeds and harvested whatever grew. Yet other farmers showed significant sunk-cost investments they had made, such as clearing trees, planting perennial crops, sinking wells, or even building a dwelling. These farmers reported that they believed the government was unlikely to evict them since it would be wasteful of resources. Hence farmers were exhibiting both under-investment and over-investment relative to the types of investment that would be expected on land to which farmers have secure tenure.

In contrast to papers that assume either over-investment or under-investment due to tenure uncertainty, this paper demonstrates that a single model can accommodate the different investment strategies documented in the literature discussed above. That is, the distinct literatures concerning investment and uncertainty that have been developed independently can, in fact, be considered special cases of a more general model. Hence, the various strands of the existing literatures fall within a single framework.

The paper uses as an example, encroachment of government-owned land and the subsequent conversion of this land for private cultivation. To understand how tenure uncertainty affects investment, and, the converse, how investment affects tenure uncertainty, this paper demonstrates that it is critical to model explicitly the nature of the uncertainty. Because detection of encroachment and restoration of the common land once investment has occurred are both costly, typically not all those who encroach will be punished. At the margin it is less costly for the government to permit the illegal activity than to prevent it. Hence, not all encroaching farmers will be affected by the government's enforcement policy in the same way.[2] Some farmers are caught and evicted, others are not and so get *de facto* permanent rights to the encroached land. Hence, tenure is uncertain because it is sub-optimal for the government to enforce property rights fully (see Polinsky and Shavell, 1998, for a survey article of optimal enforcement).

A game-theoretic model is developed that accommodates explicitly the interaction between the farmers who invest on the encroached land and the government that has legal jurisdiction over the land. Uncertainty over eviction is the outcome of a strategic interaction between the government that chooses whether, and how much, to spend trying to evict the farmer, and the farmer who chooses how much to invest. Rather than assuming that policies and budgets for eviction once set do not change, this paper recognizes that in practice the government *ex ante* sets the land laws, and *ex post*, after the encroachment has occurred, chooses the extent to which these laws will be enforced. The government may update the amount it chooses to spend enforcing the law in response to a farmer's investment, and the farmer, recognizing that the government chooses the extent to which a law is enforced, may engage in strategic investment behaviour. Whether

[2] In practice the enforcing agency could be the state government body – in the case of Karnataka both the forest department and revenue department have responsibility for government lands – or it could be a community-based management group responsible for an area of village common land.

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farmers accept the probability of eviction as an exogenous parameter, or make strategic investments to influence the probability that they are evicted, turns out to be a function of the parameterization and calibration of the model.

The model, therefore, is able to demonstrate both over- and under-investment, by taking account of the interaction of investment, enforcement, and tenure uncertainty, and by modelling explicitly the government's objective function, the timing of investment and eviction decisions, the ability of the government and farmer to commit credibly to their actions, and the cost of restoring the occupied land to its original state. A key finding of the model is that over-investment by farmers undertaken to lower the probability of eviction may occur, as observed in the squatting literature, but will be an equilibrium only under very specific circumstances that cannot be determined without calibration of the model.

2. A model of endogenous tenure uncertainty

The model is presented as a two-period game comprising two sets of players. A large number of identical forward-looking, risk-neutral farmers, acting independently of one another, each occupy an equal area of common land at the start of the game.[3] The government, also forward-looking and risk-neutral, has jurisdiction over the land and hence the right to evict the farmers since encroachment is illegal. A representative farmer chooses an investment strategy that maximizes her expected net returns to the encroached land. She chooses how much to invest in period one and how much in period two, the latter contingent on her not having been evicted at the end of period one. If the farmer is not caught and evicted, she gains *de facto* permanent rights to the land and any income that is derived from the land for all future periods. That is, property rights are such that, if she is not evicted at the end of period one, the probability of eviction in the future is zero.

The government, for its part, chooses an enforcement strategy comprising the amount to spend on detecting and punishing farmers at the end of period one (in this way, the model permits investment before and after uncertainty over tenure is resolved), and hence the extent to which it will enforce the land laws that prohibit encroachment. The only punishment is eviction, and evicted farmers are not required to restore the land to its original state.[4] In keeping with the standard assumptions of the law

[3] How the farmers came to occupy that land is not an issue here, although it might have been the result of a game with more periods. For example, in Robinson (1997), encroachment is modelled as a rational decision made by farmers who have private land adjacent to an area of common land. Farmers choose the area of common land to encroach (illegally) each period, the greater the area encroached the greater the probability that encroachment is detected. In this model, farmers are assumed to act independently. However, although not addressed in this paper, a model could be envisaged in which farmers formed a coalition in an attempt to influence the government.

[4] Since in this model capital does not depreciate and all uncertainty is resolved at the end of period one, the farmer would never benefit from investing after period

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enforcement literature, detection of encroachment is assumed costly but eviction itself is costless (Becker, 1968).[5]

Unlike most of the enforcement literature, which does not address the problem of reversing the damage of the illegal activity, in this paper once the government has evicted a farmer, it must choose whether to restore fully the now unoccupied land back to its original state or to leave the land as it is and give or sell it to another individual. Hence, although the process of eviction may be costless, restoring the land may not be.

Assuming a discount rate r, that capital does not depreciate, and that the area occupied by the farmer is the numeraire, the forward-looking farmer maximizes $E\{W^F\}$, the expected net returns to investing

$$\max E\{W^F\} = \max_{I_1, I_2} \left\{ 0, R_1^F(K_1) - wI_1 + (1-\phi)\left[\frac{R_2^F(K_2)}{r} - \frac{wI_2}{1+r} \right] + \phi \cdot 0 \right\} \tag{1}$$

where I_1 is the investment in period t, $K_1 = I_1$, $K_2 = I_1 + I_2$, $R_t^F(K_t)$ is the per-period income per unit area ($R'(K) > 0$, $R^n(K) < 0$, $R(0) = 0$), and w is the cost per unit of investment.[6]

Unless the probability of eviction is either zero or one, each individual farmer faces uncertainty as to whether she will be evicted or will remain on the land. In contrast, the government's optimization is deterministic because there are many farmers. The government's objective function depends on whether it recognizes returns to all land, both cultivated and common, or returns only to common land. To accommodate these different possibilities, a parameter θ is included in the government's objective function. This parameter can be varied between zero and one to weight the value of the illegally cultivated land (see Milliman, 1986; Clarke *et al.*, 1993;

two. Hence, although revenues from land are in perpetuity, only two periods need be considered: period one before, and period two immediately after, uncertainty is resolved. The assumption that a farmer only faces eviction once is a simplification of the actual situation in Karnataka in which the government sporadically acts over encroachment and typically either evicts a farmer or grants him rights to the encroached land.

[5] In practice, enforcement costs would comprise costs of detection, prosecution, and eviction. In this model the typical assumption of much of the law enforcement literature is made, that detection is costly, and punishment is costless (see Polinsky and Shavell (1998) for a comprehensive survey of this literature). The key point of the model specification is that the more that is spent on enforcement, the greater the probability that an individual is evicted. If punishment were costly then enforcement costs would be a function of the total number of squatters caught.

[6] Such a specification permits the farmer to postpone some or all of her investment and hence avoid the downside risk associated with investing in period one. That is, the specification accommodates any option value associated with postponing investment. Although income is received at the end of each period, R_t^F is the equivalent income that would be received at the start of the period.

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Robinson, 1997).[7] The government might try to maximize total social returns to all the land, $\theta = 1$, or might have a mandate to maximize the net legal returns to land and, therefore, not recognize farmers' (illegal) income, $\theta = 0$. The government's optimization per unit area of land can be written

$$\max_E\{W^G\} = \max_E \left\{0, -C(E) - \delta\phi G(I_1) + \frac{\phi V}{r} + \theta W^F\right\} \tag{2}$$

where $C(E)$ is the cost of enforcement effort E $(C'(E) > 0, C''(E) \geq 0, C(0) = 0)$, $G(I_1)$ is the cost per unit area of reconverting encroached land, $\delta = 1$ if the government reconverts land after eviction else $\delta = 0$, and $\phi(E)$ is the proportion of farmers evicted or equivalently the probability that the individual representative farmer is evicted $(\phi'(E) > 0,\ \phi''(E) < 0$, and $\phi(0) = 0)$.[8] The social returns to common land V equal V^S if either $\delta = 1$ or $I_1 = 0$, else $V = R^F$. V^S is a constant, and could take into account externalities such as groundwater recharge, or equity considerations such as access of the poor to grazing land and fuelwood. $R^F(K) < V^s$ for all K, else a social welfare maximizing government would privatize all the land upfront whether by permitting encroachment or via some other mechanism.

3. Equilibrium behaviour

The equilibrium interaction for the open-loop solution, in which the government commits credibly and irreversibly to its enforcement budget at the start of period one, is trivial. However, solving the open-loop equilibrium permits comparison with the more interesting closed-loop equilibrium. The farmer takes the enforcement effort as predetermined and fixed and chooses her optimal level of investment.[9] For an interior solution, the first-order conditions for the farmer are

$$\frac{\partial W^F}{\partial I_1} = \frac{\partial R_1^F(I_1)}{\partial I_1} - w + (1-\phi)\frac{1}{r}\frac{\partial R_1^F(I_1+I_2)}{\partial I_1} = 0$$

$$\frac{\partial W^F}{\partial I_2} = (1-\phi)\left(\frac{1}{r}\frac{\partial R_2^F(I_1+I_2)}{\partial I_2} - \frac{w}{1+r}\right) = 0 \text{ where } \phi = \phi(E) \tag{3}$$

Assuming the following functional form, $R_t^F(K_t) = bK_t^\gamma\ (0 \leq \gamma \leq 1)$, the equilibrium levels of investment in periods one and two are

$$I_1^* = \left[\frac{\gamma b(1+r)}{w(r+\phi)}\right]^{\frac{1}{1-\gamma}} \quad \text{and} \quad I_2^* = \bar{I} - I_1, \text{ where } \bar{I} = \left[\frac{\gamma b(1+r)}{wr}\right]^{\frac{1}{1-\gamma}} \tag{4}$$

[7] The assumption that the authority responsible for enforcement aims to maximize overall social welfare, equivalent to $\theta = 1$, is common in the law enforcement literature. However, Stigler (1970), and Lewin and Trumbull (1990), among others have questioned this assumption.

[8] If the farmer makes no investment in period one, the government maximizes $V^S - C(E) + \phi V^S/r + \lambda W^F$.

[9] The open-loop model, whilst unrealistic, is the implicit model used in most of the optimal enforcement literature.

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where $\bar{I}$ is the level of investment that the farmer would make if the probability of eviction were zero.[10] As expected, the higher the probability of eviction, the lower the level of period-one investment. If the farmer is not evicted at the end of period one, her period-two investment is such that the total investment is privately efficient.

The government's equilibrium choice of eviction effort, E^*, is simply a function of the model parameters, including the cost of restoring the land, $G(I_1)$, and the weight θ that the government puts on the returns to occupied land. The government compares its objective function for the three possible strategies and chooses the strategy that yields the highest returns: evict a proportion of farmers and restore the common land to its original pre-encroached state; evict a proportion of farmers but do not restore the common land; or do nothing in which case the enforcement effort is zero. If it is not cost-effective for the government to restore the common land after a farmer has been evicted, the socially optimal action is to permit an individual or group to make an efficient private investment on the land in period two.

The above analysis simply confirms that in the open-loop analysis, investment is a function of tenure uncertainty, rather than the opposite. That is, the open-loop model cannot accommodate strategic investment by an individual farmer to improve the probability that she remains on the land. Yet whereas any investment made by a farmer is sunk and hence credible, the policy choice made by the government over how much to spend on eviction may not be credible if it is announced before, but enacted after, the farmers have invested. Unless some mechanism exists for the government to pre-commit to its chosen level of eviction effort, the question of the government's credibility must be addressed explicitly (as occurs in the time-inconsistency literature). A closed-loop model accommodates the possibility that the government updates its choice of enforcement effort after any investments by the encroaching farmers have been made (such is the implicit assumption in the squatting literature, though it has not been modelled in this literature).

In the closed-loop equilibrium, the farmer is the *de facto* credible Stackelberg leader because investment is sunk but enforcement budgets can be reassessed. When the farmer invests in period one, she now can do so strategically, knowing that the government's *ex ante* equilibrium choice of eviction effort can change in response to the investment. From the government's perspective, the level of period-one investment

[10] If the farmer could invest in only one period, she would make one of the following investments; either:

$$I_1 = \left[\frac{\gamma b(1+r-\phi)}{wr}\right]^{\frac{1}{1-\gamma}} \quad \text{or} \quad I_2 = \left[\frac{\gamma b(1+r)}{wr}\right]^{\frac{1}{1-\gamma}}$$

The farmer's actual choice of investing in period one or two depends on the option-value of waiting until period two to avoid the downside risk of eviction in period one, which is a function of ϕ and the relative costs and benefits from investing.

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now becomes the pre-determined variable. The equations governing the equilibrium interaction between farmer as *de facto* Stackelberg leader and the government, assuming I_1 to be greater than zero, are

$$\frac{\partial W^G}{\partial E} = \frac{\partial \phi}{\partial E}\left(\frac{V}{r} - G(I_1)\right) - \frac{\partial}{\partial E}C(E) + \theta \frac{\partial}{\partial E} W^F(I_1, E)$$

$$\frac{\partial W^F}{\partial I_1} = \frac{\partial R_1^F}{\partial I_1} - w + (1-\phi)\frac{1}{r}\frac{\partial R_2^F}{\partial I_1} - \frac{\partial \phi}{\partial I_1}\left(\frac{1}{r}R_2^F - \frac{w I_2}{1+r}\right) \tag{5}$$

$$I_2 = \min(0, \bar{I} - I_1)$$

In general, the equilibrium conditions differ from those of the open-loop equilibrium. The first-order condition governing the farmer's equilibrium behaviour is more complex. An additional term accounts for the probability of eviction being a function of investment in period one, so long as $\partial\phi/\partial I_1$ is non-zero. Hence, rather than investment being a function of eviction effort, eviction effort may be a function of the level of period-one investment. Further, it is feasible that the equilibrium period-one investment is greater than $\bar{I}$, the privately efficient investment.

Only when $G(I_1)$ and θ are both equal to zero do the equilibrium conditions for the open-loop and closed-loop equilibria coincide, and the familiar result is obtained in which the government's choice of eviction effort is not influenced by the farmer's period-one investment, whichever party moves first. However, if the government either takes into account in its objective function the returns to the occupied land ($\theta > 0$), or if it is costly to restore the land ($G(I_1) > 0$), the farmer can, through her investment, influence the probability of being evicted.

4. A numerical example

Unless θ and $G(I_1)$ are both equal to zero, it is not possible, simply by looking at the first-order conditions, to determine whether the equilibrium investment is less than, equal to, or greater than the efficient private investment. The actual equilibrium depends on the particular calibration of the model and so is demonstrated with a numerical example and comparative statics. For the farmer: $b = 6$; $w = 4$; $\gamma = 0.45$; $r = 0.1$. For the government: $C(E) = cE^{\mu}$ where $c = 3$ and $\mu = 1.3$; $G(I_1) = gI_1$; $\phi = 1 - e^{-aF}$ where $\alpha = 0.1$; and $V^S = 38$. These functional forms and calibration are chosen so that the social optimum corresponds to a situation in which all the land is in its original unencroached common state. The impact of costly reversal of the effects of the farmers' investments is demonstrated by parametric variation of g from 0 through 20. The impact of the government recognizing returns to the occupied land in its objective function is demonstrated by parametric variation of θ from 0 through 1.

The results of the numerical optimization and comparative statics are summarized in table 1, which gives the equilibrium choices of I_1, I_2, and E, for $\theta = 0$ and 1, and for $g = 0$ and 20. Under open-loop conditions, when $\theta = 0$ and $g = 0$, the farmer postpones most of her investment to period two after the uncertainty has been resolved. It is always optimal for the government

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Table 1. *Summary of simulation results*

	Farmer investment		*Expected returns*		*Area of common land recovered*
	I_1	I_2	*To farmer*	*To all land*	
Base-line data					
Efficient private investment	38.3	0	187.2	187.2	0%
Efficient social use of land	0	0	0	418.0	100%
Government as credible leader (open loop)					
$\theta = 0, g = 0$	0.8	37.5	42.0	235.9	77%
$\theta = 0, g = 20$	0.7	37.6	41.2	223.5	78%
$\theta = 1, g = 0$	1.0	37.3	67.2	246.3	62%
$\theta = 1, g = 20$	1.0	37.3	64.5	233.3	64%
Farmer as *de facto* leader (closed loop)					
$\theta = 0, g = 0$	0.8	37.5	42.0	235.9	77%
$\theta = 0, g = 20$	38.3	0	187.2	187.2	0%
$\theta = 1, g = 0$	55.8	0	180	180	0%
$\theta = 1, g = 20$	38.3	0	187.2	187.2	0%

to restore any recovered land upon which investments have been made. Even though restoration is costly, the period one level of investment is low so the cost of reversion is low.

In contrast, except when $\theta = 0$ and $g = 0$, the comparable equilibria for the closed-loop analysis vary considerably. When $g = 20$, whether $\theta = 0$ or 1, the farmer makes the privately efficient investment in period one and the government chooses not to undertake any eviction. In contrast, when $g = 0$ and $\theta = 1$, the farmer 'over-invests' in period one, investing well above the privately efficient investment, and again the government chooses not to undertake any eviction. Hence under closed-loop assumptions, under-investment (when $g = 0$ and $\theta = 0$), efficient private investment ($g = 20$ and $\theta = 0$ or 1), and over-investment ($g = 0$ and $\theta = 1$), have all been demonstrated simply by varying the values of g and θ. Table 2 summarizes the general relationship between g and θ, period-one investment, and whether the probability of eviction is endogenous or exogenous to the farmer's investment.

The full relationship between investment in period one and returns to the farmer when $g = 0$ and $\theta = 1$ is illustrated in figure 1. In this figure there are two local maxima. A small change in parameter values can change the equilibrium level of period one investment dramatically. For example, if γ is reduced from 0.45 to 0.4, the benefits from over-investing are eliminated. Although again two local maxima exist, rather than over-invest to reduce uncertainty, the farmer prefers to postpone most of her investment to avoid the downside risk.

More interesting is the sensitivity of the results to the specific values of θ and g under closed-loop assumptions. Parametric variation of θ, g, and I_1 is undertaken to illustrate this sensitivity. Parametric variation

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Table 2. *Summary of impact of investment on probability of eviction*

	Period 1 investment (relative to privately efficient investment of 38.3)	*Probability of eviction*
Government as credible leader (open loop)		
$\theta = 0, g = 0$	Always <	Exogenous
$\theta = 0, g > 0$	Always <	Exogenous
$\theta > 0, g = 0$	Always <	Exogenous
$\theta > 0, g > 0$	Always <	Exogenous
Farmer as *de facto* leader (closed loop)		
$\theta = 0, g = 0$	Always <	Exogenous
$\theta = 0, g > 0$	Ambiguous	Endogenous
$\theta > 0, g = 0$	Ambiguous	Endogenous
$\theta > 0, g > 0$	Ambiguous	Endogenous

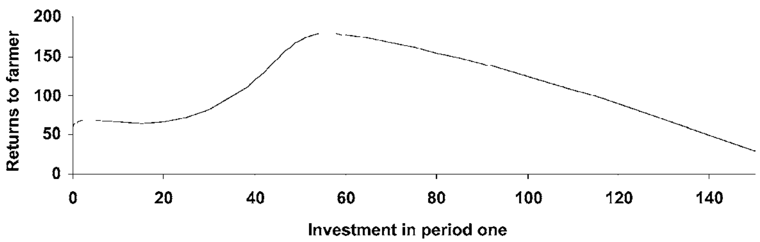

Figure 1. *Relationship between investment in period one and returns to the farmer*

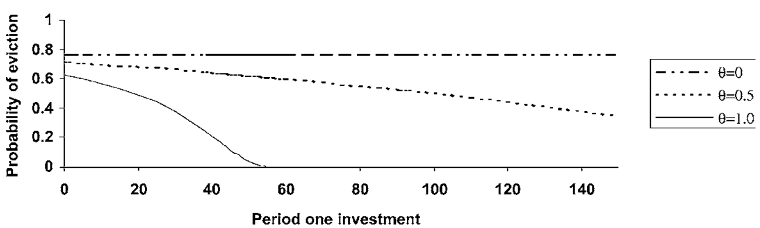

Figure 2. *The relationship between investment and the probability of eviction when* $g = 0$ *for different values of* θ

of the farmer's period one investment when $g = 0$, plotted in figure 2, demonstrates explicitly the relationship between investment and ϕ, the probability of eviction. Unless $\theta = 0$, the probability that a farmer is evicted is indeed a monotonically decreasing function of her period one investment. And with sufficient investment a farmer can drive down the probability of eviction to zero and so remove all uncertainty. However, the relationship between investment and probability of eviction does not confirm whether it is rational for the farmer to over-invest.

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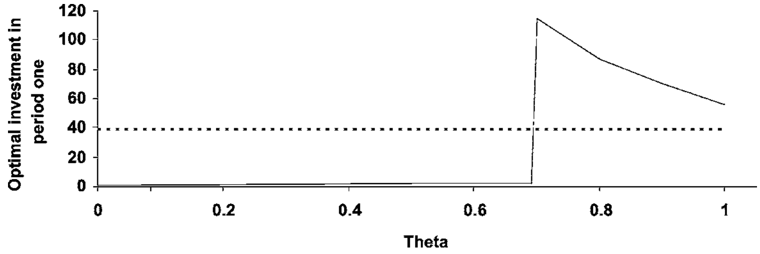

Figure 3. *Optimal choice of period one investment as a function of θ when $g = 0$*

Figure 3 demonstrates the optimal choice of period one investment as a function of θ. The relationship is shown to be non-monotonic and non-linear. For all $\theta > 0.69$, it is optimal for the farmer to over-invest. Moreover, farmers would be better off, social welfare would be higher, and the impact on the remaining area of common land would be the same (none would remain) if the government could pre-commit credibly not to evict any of the farmers at the end of period one. To achieve this, the government could transfer the land rights to those occupying the common land at the start of period one. These new legal owners could not be evicted and so would make privately efficient investments in period one. But if the farmer made the efficient investment in period one when the government's hands were not tied, the government would then find it worthwhile *ex post* to evict a proportion of the farmers. Such an example simply highlights the problems of dynamically inconsistent policy leading to sub-optimal results.

Costly restoration of the common land enables the government to commit not to evict encroaching farmers who invest efficiently. For example, when $\theta = 0$, for all $g > 5.05$ the cost of reversing the damage caused by the investment plus the cost of enforcement is greater than the returns to the recovered common land, and so it is never worthwhile for the government to evict any farmers. Knowing this, the farmer makes the privately efficient investment in period one. Hence, even though the government's hands are not tied, a commitment by the government not to evict any farmers is dynamically consistent when restoration is sufficiently costly and both the government and the farmer are better off than when restoration is costless. Costly restoration is therefore an alternative to a commitment mechanism such as up front privatization of the land.

5. Discussion of results and conclusions

The calibrated model developed in this paper demonstrates that by taking explicit account of the underlying causes of tenure uncertainty, one model is able to accommodate conclusions that have been reached independently in the investment under uncertainty literature, the squatting literature, and the time-inconsistency literature, merely by varying the conditions within the model. Closed-loop analysis demonstrates that, in the context of property rights, the common assumption that uncertainty is exogenous to investment decisions is limited to a small number of specific situations, and that it is not possible to generalize as to whether individuals will under-invest or over-invest.

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Two strategies are available to the farmer to avoid the downside risk of investing under uncertainty. She can postpone investment, thereby taking advantage of the option value of waiting to invest until the government has acted. Or she can invest to the point at which it is not worthwhile for the government to evict her, typically eliminating all uncertainty. Further, observation of efficient investments may just as likely be evidence of individuals investing to improve their chances of remaining on the land as it is of individuals investing because they are, a priori, confident of not being evicted.

Whether an individual under-invests, postpones her investment, makes a privately efficient investment, or over-invests, has been shown to be highly sensitive to the specific circumstances. Hence, cross-sectional analyses (such as Place and Hazell, 1993; Gavian and Fafchamps, 1996) should not necessarily expect a strong relationship between investment and tenure security because investment can be both a response to, and a cause of, the level of tenure insecurity an individual household faces. Moreover, observations of different investment strategies on encroached land in close proximity, and different responses to the encroachment by the government, as observed by the author in Karnataka, may not reflect irrational behaviour by farmers nor inconsistent policy. Rather, these differences may be due, for example, to small variations among farmers in terms of the returns to their investments, or variations in the effectiveness of the different government agents.

In Karnataka, successive governments have struggled to stick to their policies over land encroachment, and have been influenced by the investments made on encroached land (Robinson, 1997). Indeed, the willingness of Indian officials to regularize encroached land, despite the existing land laws, suggests that committing to an enforcement policy over land is politically very difficult. A state government official himself confirmed unofficially that once a farmer had invested heavily on encroached land, it might be better to give or sell the farmer the land, that is, to regularize the encroachment, rather than go through the cost and uncertainty of trying – not always successfully – to evict the farmer (Karnataka State Official from Forestry Department, personal communication, 1995). That way at least the government could collect taxes from the farmer. The worst outcome for the government is if the land is encroached but formal title is not granted, in which case the common land and all its benefits are lost and the government receives no income from the land in the form of taxes. Further, the government knows that farmers who are not evicted, and also society, would be better off if these farmers made privately efficient investments.

Hence, the government often faces a dilemma, common in the time-inconsistency literature: it would prefer the conversion of the land not to occur, but would also prefer farmers to invest efficiently if the encroachment cannot be prevented (see the seminal article by Kydland and Prescott, 1977; Kleit, 1990 and 1992). Unfortunately, each time a government decides to regularize some or all of the encroached land, its ability to deter encroachment in the future diminishes, as its credibility is eroded through its lack of commitment to evict previous illegal encroachment. In Karnataka, despite the government's efforts to prevent the loss of the commons, the

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trend has been gradual but relentless encroachment (Rajan, 1986; Aziz and Krishna, 1997; Robinson, 1996).

In the model presented in this paper, it is assumed that enforcement costs are non-linear, specifically that they are a convex function of effort. Further, it is assumed that the probability of eviction exhibits diminishing returns to effort. These assumptions are typical in the optimal law enforcement literature, and in part explain why rarely it is optimal to prevent all non-compliance with laws and regulations. Either of the non-linearities can also explain why the probability of eviction from land is not simply zero or one, and hence why not all farmers will be affected in the same way by a change in enforcement policy. This result is in contrast to the traditional time-inconsistency literature in which all players are affected in the same way by a policy. If, in this paper, the cost of enforcement were constant and the probability of eviction a linear function of effort, the general points would still be demonstrated. Yet uncertainty would be eliminated under all scenarios; all farmers would know with certainty whether or not they would be evicted. To demonstrate that investment can change the probability of eviction rather than eliminate a negative outcome, some enforcement non-linearity is required.

This paper has focused on tenure insecurity over encroached land. Yet the 'takings' controversies in the United States demonstrate that the problem of inappropriate investment, undertaken in part to influence policy outcome, is also pertinent to more-developed countries. The private sector may invest more than is socially optimal, thereby discouraging a government that has to pay compensation from taking the land (Blume *et al.*, 1984). And because secure rights to land do not always bestow rights to develop the land at will, an individual may destroy a socially valuable resource on her land to reduce the probability that it is discovered and hence reduce the probability that privately efficient development on the land is prevented (see, for example, Innes, 1997; and Innes *et al.*, 1998).

Several extensions to the model would make the paper particularly relevant to a less-developed country context. In less-developed countries, credit constraints, risk aversion, and exogenous shocks are facts of life for many rural squatters and tenants. If each of these three factors is taken into account, the specification of the model presented in this paper will change and different equilibrium behaviour will be predicted. Farmers who are credit constrained might not be able to make the significant investments necessary to prevent eviction, while richer individuals could. A strategy in which those who are unable to invest in the land are more likely to be evicted might be more efficient, both in terms of enforcement costs and in terms of the land use from a social perspective. However, such a strategy would raise equity issues and over the long-term could encourage the destruction of areas of common land by richer villagers.

The uncertainty faced by the encroaching farmers in this paper is entirely endogenous to their actions. This extreme is plausible in the case of property rights, which by their nature represent the policy of some authority. Ample evidence exists to suggest that policy is influenced by the actions of those who will be affected by the policy. And since policy is often announced before it is enacted, the possibility of dynamic inconsistency cannot be

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ruled out. In contrast, the investments made by individual farmers tend to be irreversible, or reversible at a cost, and hence may be more credible than policy announcements pertaining to the whole category of property rights. Of course, some uncertainty may be more nearly exogenous to local land disputes, including changes in the legal system more widespread than land law. But such shocks would interact with the investment alternatives either the farmer or the government enjoys, and hence would reinforce this paper's main conclusion: Because specific circumstances influence each party's decision, there is no general theoretical result regarding whether uncertainty over tenure rights increases or reduces investment.

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