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Market Integration, Development, and Smallholder Forest Clearance[ψ]

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A significant proportion of deforestation in Latin America is caused by smallholders living at the frontier of modern rural markets. This paper develops a household model that examines the roles of market integration, subsistence, time preference, and non-timber forest uses in the household's decision to clear forest for future agriculture. The model explores the possible impacts of development programs that encourage market integration. The model shows that rates of forest clearance should be exacerbated in areas in which market integration is most rapid. An empirical estimation, using household data from the Tsimane people of Bolivia, tests hypotheses from the model.

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1 Introduction

Development policies for the rural areas of tropical Latin America often follow a simple plan to both improve smallholder welfare and reduce tropical forest clearance: encourage market integration, make credit more easily available in the rural sector, and improve agricultural productivity. The ideas behind this approach have been threefold: 1) farmers are poor because they face burdensome transaction costs for market goods and for their crops, 2) scarce credit makes farmers myopic in their decision making, and 3) most tropical soils are too nutrient poor to support sustainable agriculture; without improved agricultural technologies, farmers have little choice but to constantly clear neighboring forested areas. Unfortunately, forest clearance continues unabated in many rural areas, even when development programs have succeeded in their main objectives.

In this paper we develop a two period, household model to investigate the role that key development parameters play in the smallholder's decision to clear forest for agriculture. Specifically, we examine the ways in which market integration may affect the rate at which indigenous farmers clear both secondary and old growth forests. Of special interest in the model is the way market integration may result in changes in the prices of agricultural goods sold, the cost of consumption goods, and the take-home wage for employment outside the village. The model also examines explicitly the ways in which the smallholder's discount rate influences deforestation decisions and how this may reinforce the effects of market integration. Finally, the model incorporates technological factors including changes in agricultural productivity and the ease of clearing forested areas.

The model is a partial equilibrium model; it is not a comprehensive model of forest clearance. Because we focus on policy parameters, we do not attempt to explicitly model every factor in the household production function. We also make certain simplifying assumptions in order to make the comparative statics more clear. Specifically, we assume a) that the smallholder is risk-neutral, b) that the smallholder is rational and has full information about prices and wages in the present and following year, and c) that there exists some contribution from standing forest that acts as a complement to subsistence agriculture. The result is a highly flexible model that can be adapted and expanded easily to explore smallholder forest clearance in a variety of settings.

In section 2) we begin with a brief background of development strategy in Latin American. In section 3) we provide an overview of the problem of smallholder forest clearance in Latin America. In section 4) we develop an agricultural household model, adapted to reflect environmental variables of interest. Hypotheses about changes in the use of the forest during transition are generated from the model. Section 5) presents some comparative statics that are derived from the model. Section 6) tests these hypotheses using household survey data on the Tsimane (a.k.a. Tsimane) People of Bolivia. Finally, Section 7) draws policy conclusions from the findings.

2 Background

Recent approaches to rural development emphasize the development of stronger links between the traditional and modern sectors. Grabowsky and Sheilds (1996), describe the traditional village and rural sector as islands of economic activity isolated from the modern sector by prohibitively high transactions costs (Grabowsky and Shields, 1996). To counter this isolation, an institutional approach to development, especially the New Institutional Economics, focuses on removing obstacles that inhibit the development of markets – markets that serve as a mechanism to integrate the rural and modern sectors of the economy. Modern development strategies encourage market integration by reducing the transaction costs that separate rural and modern sectors. Road and other transportation improvements, technological transfer, and the provision of rural credit all contribute to the integration effort. Bringing modern and rural economies together by reducing transaction costs, it is thought, could help traditional smallholders move from primarily subsistence-based economies into a more modern cash society and in doing so will raise rural incomes and improve access to market goods.

Market integration and rapid technological change indeed have had major impacts on the rural economy and the rural environment – both good and bad. New and improved roads are known to bring with them new smallholder development and concomitant widespread forest clearance. The impacts of market integration, however, are not limited to migrant smallholders and colonists. Traditional rural populations, including indigenous subsistence economies, have undergone rapid change in the face of market integration and the transition to cash economies. Technological expansion gradually has changed incentive structures in the village thereby affecting how land, labor and cash are used (Godoy et. al., 1996). The conversion of forest to arable land in and around these transitional sectors continues unabated[1].

In the paper that follows, we begin to explore the ways in which market integration influences the economic decisions made by households in transitional economies. Unlike other more "descriptive models" of smallholder forest clearance, we develop a simple agricultural household model in which we explicitly consider the balance between cash crops and subsistence agriculture, the links between standing forest and the provision of subsistence goods, the

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[1] Arlid Angelson (1995) indicates that estimates of the share of deforestation from shifting cultivators range from 45% to 60%.

tradeoffs between forest clearance labor and off-site wage, and the role of time preference in the smallholder's allocation of time across farming, wage labor, and forest clearance. We also recognize and model the fact that many rural farmers have the option of converting both old growth and secondary growth forests. We show how differences in the productivity of old growth and secondary growth forests for both non-timber products and agricultural land influence the rates at which each type of forest should be cleared for agriculture. The model also highlights the roles that technological change, especially improvements in the farmer's ability to clear forest, influences agricultural and forest clearance decisions at the household level. Finally, we offer rigorous insights into the way that shrinking transaction costs, a hallmark of market integration, influence forest clearance.

3 Smallholder Forest Clearance

Understanding the subsistence economies of indigenous peoples is critical to understanding linkages between forest clearance and traditional agriculture. In contrast to market economies in which property is largely privately held and sold, indigenous people often are able to augment private smallholdings through the acquisition (usually by clearing) of open access forests. For the region specific to our empirical analysis, landed smallholders traditionally add to their arable land through the conversion of (essentially open access) forests to arable land. Once cleared, tenure to this arable land is largely secure. Time and effort are the household's main constraints to increasing arable land.

Understanding the causes of forest clearance in Latin America is particularly important. Latin America and the Caribbean alone are home to approximately 27.5% of the world's forests (FAO, 1999). Given the relative size of Latin American forests, forest clearance levels have been among the highest in the developing world. The change in forest area from 1980 to 1995 in Latin America was -9.7% (compared to an average -9.1% for the developing world during the same period; FAO, 1999). Tropical forest clearance in tropical South America accounts for the majority of forest clearance in the Latin American region. Regional forest clearance from 1990 to 1995 was estimated to be 5.3 million hectares per year, of this amount, the loss of tropical forests in South America averaged nearly 4.7 million hectares per year (FAO, 1997); smallholders account for the majority of this forest clearance.

To our knowledge, market integration and forest clearance have never been modeled explicitly. Nevertheless, Godoy et al. (1996 and 1998) explore linkages between development and forest clearance among South American indigenous peoples. In their paper, "The effects of economic development on neotropical forest clearance: household and village evidence from Amerindians in Bolivia" (Godoy et al. 1996) the authors explore the relation between income growth and forest clearance among the Tsimane, Mojeno, and Yuracare People of Bolivia. The descriptive model of Godoy et. al. identifies several features of household decision making that are sensitive to increasing modernization. The authors claim that increases in the demand for crops produced by the household may lead to more forest clearance, but increases in technology may offset the need for additional land. Godoy et al. show that income from agriculture is used for the purchase of consumption goods. Also, household decisions concerning labor allocation change because of higher opportunity costs for subsistence farming due to increases in the demand for off-farm labor. Village economies also move from using barter as a means of exchange to cash. Finally, the authors hypothesize that as household incomes rise, impatience falls.[2] Initially, the household increases savings in physical assets; as the economy modernizes they increase holdings of financial assets.

In another article, Godoy, Jacobson, and Wilkie (1998) more explicitly examine the link between forest clearance and development by exploring time preferences and tenure security. They find that more patient individuals (those with a lower discount rate) engage in more old-growth cutting while less patient individuals work more outside of the village and cut more new growth forest.[3] Old growth and secondary growth forests differ in both the difficulty of clearance and the agricultural productivity of land derived from these types of forests. The authors provide only a descriptive model of forest clearance; an explicit economic model linking impatience and forest clearance is not given.

4 The Model

The model we develop is consistent, yet distinct, from the general agricultural household model outlined by Singh, Squire, and Strauss (1986).[4] Agents in our two period, two season framework maximize utility subject to a cash income constraint, a time constraint, and both agricultural and forest clearance production functions. The model we provide is not a comprehensive model of total forest clearance. Instead, we present a model that allows us to look at the way in which specific policy parameters influence forest clearance decisions. While the model is a two period model, the extension of the model to *n* periods does not change the smallholder's forest clearance behavior at the margin (i.e. the maximum principle is met each year.)

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[2] In arguing that income can change time preferences, reference is made to Benzion, Rapoport and Yagil (1989).
[3] The method used to measure impatience will be discussed in the empirical section of this paper.
[4] See Bardhan and Udry (1999) ch. 2 and Grabowsky and Shields (1996) ch. 3 for an overview of household and agricultural household models.

To begin, household utility is assumed to be a simple linear function of the present amount of the market good consumed in the initial period, X_m^0, and the discounted future value of consumption of the market good, X_m^1,

$$U = U(X_m^0) + \left(\frac{1}{\delta}\right) U(X_m^1) \tag{1}$$

More patient households place a relatively greater weight on the future and thus more patient households have a relatively lower discount rate, δ.

The household maximizes utility subject to a production function, a time constraint, and a budget constraint. Agricultural production at time t, Q_a^t, is a function of the time the household devotes to agriculture at time t, T_a^t, $t = 0,1$ and the total area of land devoted to agriculture, A^t.

$$Q_a^t \;=\; Q(T_a^t, A^t) \tag{2a}$$

New agricultural land can be derived from old growth forest and secondary growth forest. (We denote the absolute level of each type of forest in period 0 as $\bar{F}_O$ and $\bar{F}_S$, respectively.) We can distinguish the contribution to agriculture of land derived from old growth forest (A_o) and secondary or new growth (A_s) and rewrite (2a) for period 0 and 1, respectively, as,

$$Q^0 \;=\; Q(T_a^0, \bar{A}_O, \bar{A}_S) \tag{2b}$$

$$Q^1 \;=\; Q(T_a^1, \bar{A}_O + A_O^1, \bar{A}_S + A_S^1) \tag{2c}$$

where $\bar{A}_o$ and $\bar{A}_s$ represent the accumulated stock of arable land and A_o^1 and A_s^1 represent the addition to arable land in the final period. We assume that the agricultural productivity of land derived from old growth forest differs from that of secondary growth by a factor we call σ, where $\sigma>0$ and in practice usually $\sigma>1$. We represent the relative differences in productivity by arbitrarily taking the agricultural productivity of land derived from secondary growth as the reference (so $dQ/dA_o = \sigma(dQ/dA)$ and $dQ/dA_s = (dQ/dA)$.) Agricultural land can be augmented in the second period by forest clearance (of possibly open access lands) in the initial period. Production is assumed to be a mix of cash crops and staples and excess agricultural goods can be sold at market to acquire market goods.

To specify the household's time constraint, assume that the household uses its time in the initial period for subsistence agriculture, forest clearance or for working outside of the village for a wage rate (T_a, T_F, and T_w, respectively.) The household also chooses how to allocate its time differently in the rainy and dry seasons in each period (rainy seasons precede dry seasons in each period.) In the rainy season (represented by subscript R) the household chooses between time spent working outside of the village (T_{wR}) and time spent on smallholder agriculture (T_{aR}). In the dry season (represented by subscript D), the household allocates time between working for an outside wage rate (T_{wD}) and time devoted to the clearance of primary (T_{FOD}) and secondary (T_{FSD}) forest. For simplicity, we assume that gathering from the forest is done by other members of the household. Therefore, the household's time constraint for the initial period in the rainy season is,

$$T_{aR}^0 + T_{wR}^0 \leq T_R^0 \tag{3a}$$

and in the dry season

$$T_{FOD}^0 + T_{FSD}^0 + T_{wD}^0 \leq T_D^0 . \tag{3b}$$

The household's choices are the same in the rainy season of the second period. However, since the model ends after two periods, households will not choose to clear forest in the second period since there is no gain to forest clearance. The time constraints for the second period are therefore,

$$T^1_{wR} + T^1_{aR} \leq T^1_R \tag{4a}$$

$$T^1_{wD} \leq T^1_D . \tag{4b}$$

Total household income includes income earned from crop sales (see below) and from "outside the village" employment. Agricultural production sells at the market for a price of P^t_a in periods t = 0,1. Similarly, the market good can be purchased in the market for a price of P^t_m in periods t = 0,1. The household, however, does not face the market prices defined above because of the transactions costs that exist between the modern and the rural sectors. In the setting of a remote rural economy it is especially important to consider transactions costs.[5] We define agricultural prices in the village as $(P^t_a - t_a)$ and market prices as $(P^t_m + t_m)$, where transaction costs are captured by t_a and t_m. Also, we assume that the price received for outside the village labor, w^t_m, is influenced by transactions costs. The wage received for labor is defined as $(w^t_m - t_w)$ since transactions costs are incurred when working outside of the village. As mentioned earlier, transactions costs may include transport costs and are thus functions of both the distance to the market and conditions of the roads or paths.

Households receive the prices defined above for excess agricultural production and for wage labor. All income earned is spent in the same period for market goods, X^t_m. There is no savings or storage in the model across periods. Excess agricultural production is the amount of production beyond subsistence agricultural production, $Q^t - X^t_{aR}$, where subsistence agriculture, X^t_{aR}, is a means of satisfying a minimum nutritional level.

Subsistence consumption, *s*, is the households minimum nutritional level and is met by gathering from the forest, S^t_{FR}, and by subsistence agricultural production X^t_{aR} in the rainy seasons of both periods. Products gathered from the forest (herein referred to simply as gathering) substitute for subsistence agriculture at a fixed rate α, thus subsistence agriculture can be written as,

$$X^{t}_{aR} = s - \alpha[S^{t}_{FR}]. \tag{5}$$

If no gathering occurs agricultural production must at least be equal to *s* to support a basic nutritional level. If the quantity of products gathered from the forest is an increasing function of the amount of primary and secondary forests available, gathering can be represented as,

$$S^{0}_{FR} = \theta\bar{F}_{O} + \bar{F}_{S}, \tag{6a}$$

in the initial period and

$$S^{1}_{FR} = \theta(\bar{F}_{O} - F^{1}_{O}) + \bar{F}_{S} - F^{1}_{S}, \tag{6b}$$

in the final period, where $\bar{F}_{O}$ and $\bar{F}_{S}$ are initial levels of old growth and secondary growth forest areas respectively, F^{1}_{O} and F^{1}_{S} (which are functions of forest clearance labor, as will be defined) indicate the loss of forest due to forest clearance, and θ is a constant that indicates that old growth forest and secondary growth forests differ in productivity for gathering (in practice $\theta > 1$.) Reducing the size of the forest reduces the subsistence value of gathering.

Equating spending in each period to earned income and substituting (6a) and (6b) into equation (5), the household's budget constraint for period 0 and 1 can be rewritten as,

$$(P^{0}_{m} + t^{0}_{m})X^{0}_{m} = (P^{0}_{a} - t^{0}_{a})[Q(T^{0}_{aR}, A_{O}, A_{S}) - X_{aR}(\bar{F}_{O}, \bar{F}_{S})] + (w^{0}_{m} - t^{0}_{w})(T^{0}_{wD} + T^{0}_{wR}) \tag{7a}$$

$$\begin{aligned}(P^{1}_{m} + t^{1}_{m})X^{1}_{m} = (P^{1}_{a} - t^{1}_{a})[Q(T^{1}_{aR}, \bar{A}_{O}, \bar{A}_{S} + A^{1}_{S}) - X_{aR}(\bar{F}_{O} - F^{1}_{O}, \bar{F}_{S} - F^{1}_{S})]\\ + (w^{1}_{m} - t^{1}_{w})(T^{1}_{wD} + T^{1}_{wR})\end{aligned} \tag{7b}$$

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[5] See Omamo (1998a, 1998b) and Oczkowski and Philp (1994).

In both periods expenditures are equal to earned income (i.e. there is no savings in the model.)

In our model, forest clearance essentially is an investment in future agriculture. The cost of the investment is foregone wage earnings, but the payoff is increased agricultural production. If we were to model the farmer's problem for more than two periods, we would need to include costs of protecting this investment (e.g. markers, fences, vigilance). Furthermore, we take only the opportunity cost of the farmer's time as the cost of investment. If forest clearance required material investment, we would need to incorporate these costs. Similarly, if the farmer were to borrow to pay for this investment, we also would include the cost of interest. The traditional Tsimane tend to clear forest areas for short-term agricultural production (e.g. one or two years.) More modern Tsimane, however, will use cleared areas for longer-term agricultural production and will protect tenure to these areas through the use of markers.

The changes in arable land and consequently the relative size of the forest in the second period are both functions of time spent clearing forest in the initial period. Specifically, the amounts of old growth and secondary growth forest cleared are defined as linear functions of the time allocated to forest clearance,

$$F_{o}^{1} = \varphi T_{FOD}^{0} \tag{8a}$$

$$F_{s}^{1} = \gamma T_{FOD}^{0}, \tag{8b}$$

where φ and γ are exogenous parameters that describe the efficiency of forest clearance and $\varphi < \gamma$ since clearance of primary forest requires more time to clear than secondary growth forest.

The change in arable land is equal to the area of forest cleared,

$$A_{O}^{1} = F_{O}^{1} = \varphi T_{FOD}^{0} \tag{9a}$$

$$A_S^1 = F_S^1 = \gamma T_{FOD}^0 \qquad (9b).$$

Since forest clearance only occurs in the initial period, equations (8) and (9) indicate that the household's time allocation to forest clearance in the initial period determines the amount of new arable land available in the second period.

Given (8) and (9), the budget equations can be rewritten as,

$$X_m^0 = \frac{(P_a^0 - t_a^0)}{(P_m^0 + t_m^0)}[Q(T_{aR}^0, \overline{A}_o, \overline{A}_s) - (s - \alpha(\theta \overline{F}_0 + \overline{F}_S))] + \frac{(w_m^0 - t_w^0)}{(P_m^0 + t_m^0)}(T_{wD}^0 + T_{wR}^0) \qquad (10a)$$

$$\begin{aligned} X_m^1 = {} & \frac{(P_a^1 - t_a^1)}{(P_m^1 + t_m^1)}[Q(T_{aR}^1, \overline{A}_O + \varphi T_{FOD}^0, \overline{A}_S + \lambda T_{FOD}^0) - (s - \alpha(\theta(\overline{F}_O - \varphi T_{FOD}^0) + \overline{F}_S - \gamma T_{FSD}^0))] \\ & + \frac{(w_m^1 - t_w^1)}{(P_m^1 + t_m^1)}(T_{wD}^1 + T_{wR}^1) \end{aligned} \qquad (10b)$$

Assuming utility is a linear function that follows

$$U = X_m^0 + \frac{1}{\delta} X_m^1 \qquad (11)$$

where X_m is defined by (10a) and (10b), the household chooses $T_{aR}^0, T_{wR}^0, T_{FOD}^0, T_{FSD}^0, T_{wD}^0, T_{aR}^1, T_{wR}^1, T_{wD}^1$ to maximize utility subject to time constraints (3), (3)', (4), (4)'. The Lagrangian can be formulated as,

$$\begin{aligned} L = {} & X_m^0 + \frac{1}{\delta} X_m^1 - \lambda_R^0(T_{aR}^0 + T_{wR}^0 - T_R^0) - \lambda_D^0(T_{FOD}^0 + T_{FSD}^0 + T_{wD}^0 - T_D^0) \\ & - \lambda_R^1(T_{aR}^1 + T_{wR}^1 - T_R^1) - \lambda_D^1(T_{wD}^1 - T_D^1) \end{aligned} \qquad (12)$$

where (10a) and (10b) substitute for X_m. Taking the first order conditions with respect to the choice variables and indicating the first order derivative with respect to A by subscripts, we have:

$$\frac{dL}{dT^0_{aR}}: \quad \frac{P^0_a - t^0_a}{P^0_m + t^0_m}\frac{dQ}{dT^0_{aR}} - \boldsymbol{l}^0_R = 0 \tag{13a}$$

$$\frac{dL}{dT^0_{wR}}: \quad \frac{w^0_m - t^0_w}{P^0_m + t^0_m} - \boldsymbol{l}^0_R = 0 \tag{13b}$$

$$\frac{dL}{dT^0_{FOD}}: \frac{1}{\text{ä}}[\frac{P^1_a - t^1_a}{P^1_m + t^1_m}\{\sigma\varphi\frac{dQ}{dA} \text{-}\alpha\theta\varphi\}]\text{-}\ \boldsymbol{l}^0_D = 0 \tag{13c}$$

$$\frac{dL}{dT^0_{FsD}}: \frac{1}{\text{ä}}[\frac{P^1_a - t^1_a}{P^1_m + t^1_m}\{ \frac{dQ}{dA} - \text{ã} \quad - {}^{0}_{D}\text{ãã}=\}] \tag{13e}$$

$$\frac{dL}{dT^0_{wD}}: \quad \text{ë}\frac{w^0_m - t^0_w}{P^0_m + t^0_m}0 - {}^{0}_{D} = \tag{13f}$$

$$\frac{dL}{dT^1_{aR}}: \frac{1}{\text{ä}}\frac{P^1_a - t^1_a}{P^1_m + t^1_m}\{\frac{dQ}{dT^1_{aR}}\} - \text{ë}^1_R = 0 \tag{13g}$$

$$\frac{dL}{dT^1_{wR}}: \quad \frac{1}{\text{ä}}\frac{w^1_m - t^1_w}{P^1_m + t^1_m} - \text{ë}^1_R = 0 \tag{13h}$$

$$\frac{dL}{dT^1_{wD}}: \quad \frac{1}{\text{ä}}\frac{w^1_m - t^1_w}{P^1_m + t^1_m} - \text{ë}^1_D = 0\,, \tag{13i}$$

in addition to the time constraints.

5 Comparative Statics

If the smallholder maximizes utility, he will continue to add new arable land to his holdings up to the point where the marginal benefits of doing so just equal the marginal costs. By simplifying the above first order conditions we see this directly in (14a and b),

$$\frac{1}{ä}(P^1_a - t^1_a)[ó j(\frac{dQ}{dA}) - áè j] = (\frac{w^0_m - t^0_w}{P^0_m + t^0_m})(P^1_m + t^1_m) \qquad (14a)$$

$$\frac{1}{ä}(P^1_a - t^1_a)[ã[\frac{dQ}{dA}) - áã] = (\frac{w^0_m - t^0_w}{P^0_m + t^0_m})(P^1_m + t^1_m)\,. \qquad (14b)$$

In (14a) the left hand side represents the discounted benefits of newly added land; in this case the village price for the cash crop times additional agricultural output less the reduction in subsistence production from lost forest which must be replaced from additional output. The right hand side is the marginal cost of forest clearance in the initial period in terms of the foregone wage, weighted by the proportional change in prices for consumer goods.

We assume that the marginal returns to agriculture are a decreasing function of land, that is, $\frac{dQ}{dA} > 0, \frac{d^2Q}{dA^2} < 0$. Since we defined the rate at which forest clearance labor produces arable land as a linear relationship, we also know that $\frac{dQ}{dT_F} > 0, \frac{d^2Q}{dT_F{}^2} < 0$. Additional time allocated to forest clearance increases agricultural production at a decreasing rate.

Substituting in A=F and simplifying equations (14a) and (14b) yields the contribution to agricultural output of the marginal unit of arable land and of time spent clearing forest,

$$\frac{dQ}{dF_o ó} = \frac{1}{j ó}[ä\frac{(w^0_m - t^0_w)}{(P^1_a - t^1_a)}\frac{(P^1_m + t^1_m)}{(P^0_m + t^0_m)} + áè j] = \frac{1}{j}Ù_O \qquad (15a)$$

$$\frac{dQ}{dF_s} = \frac{1}{ã}[ä\frac{(w^0_m - t^0_w)}{(P^1_a - t^1_a)}\frac{(P^1_m + t^1_m)}{(P^0_m + t^0_m)} + áã] = \frac{1}{ã}Ù_S \qquad (15b)$$

$$\frac{dQ}{dT_{FOD}} = \Omega_O \qquad (16a)$$

$$\frac{dQ}{dT_{FSD}} = \Omega_S\,. \qquad (16b)$$

Figure One demonstrates that forest will be converted to agriculture as long as $\grave{U}\frac{dQ}{dF_{O}ó} > \frac{1}{\boldsymbol{j}} \quad _{O}$

and $\grave{U}\frac{dQ}{dF_{S}ã} > \frac{1}{} \quad _{S}$. In Figure One, $F_{O}^{*1} = A_{O}^{*1}$ represents the equilibrium amount of old growth forest a utility maximizing household would choose to clear. Also following from above, Figure Two shows that labor is invested in forest clearance as long as $\grave{U}\frac{dQ}{dT_{FOD}} > \quad _{O}$ and $\grave{U}\frac{dQ}{dT_{FSD}} > \quad _{S}$. The equilibrium amount of time spent clearing primary growth forest is given by T_{FOD}^{*0} in Figure Two.

We examine the way in which policy and economic variables influence forest clearance by examining the way in which $\frac{1}{ó\,\boldsymbol{j}}\grave{U}_{O}, \frac{1}{\boldsymbol{g}}\grave{U}_{S}, \grave{U}_{O}, \grave{U}_{S}$ change with changes in these variables. If any of these quantities fall, forest clearance increases. In Figure Two, such a change is illustrated by a move from Ω to Ω’ and a subsequent change in forest clearance effort from T_{F}^{*} to $T_{F}^{*\prime}$.

Forest Clearance and Market Integration

An important result of market integration is that transaction costs, especially those associated with distance to and from the market, tend to decline. All things being equal, declining transaction costs increase the prices earned for cash crops and reduce the prices paid for market goods. If we think of market integration in terms of transaction costs, the model shows clearly how market integration influences the decision to clear forest or to participate in agricultural production. In particular, when the first order conditions are satisfied, transaction costs affect equilibrium levels of forest clearance in two separate ways. First note that $\frac{P_{m}^{1} + t_{m}^{1}}{P_{m}^{0} + t_{m}^{0}}$

represents the (undiscounted) relative future price of consumption goods at the village level compared to current prices. Declining transactions costs, associated with increased market integration (e.g. decreasing distances to markets or decreasing transport costs), cause the ratio $\frac{P_m^1 + t_m^1}{P_m^0 + t_m^0}$ to decline (since t_m^1 falls) thus increasing the (expected) future buying power of farmers and thus the relative value of income derived from future agricultural production. In addition, note that the ratio of wages to prices, $\frac{w_m^0 - t_w^0}{P_a^1 - t_a^1}$, also falls with increased integration (since t_a^1 falls), causing the amount of time allocated to forest clearance to rise. Wages foregone during time spent clearing forest in the initial period can be offset by higher prices for cash crops in the following period. In a sense, $\frac{w_m^0 - t_w^0}{P_a^1 - t_a^1}$ represents the relative opportunity cost of foregone wages. Individuals will substitute away from wage labor and toward forest clearance labor in the initial period since the relative value of future agricultural production increases[6]. Summarizing these two effects we see that the inverse of their product, $\left[\left(\frac{P_m^1 + t_m^1}{P_m^0 + t_m^0}\right)\left(\frac{w_m^0 - t_w^0}{P_a^1 - t_a^1}\right)\right]^{-1} = \text{ç}$, is a good proxy for market integration, where η represents the <u>rate </u>of market integration.

Rewriting (15a) through (16b) in terms of the rate of market integration illustrates this more clearly,

$$\frac{dQ}{dF_{O}\text{ó}} = \frac{1}{\text{ç}\boldsymbol{j}}[-\overset{\text{ä}}{+}\quad \boldsymbol{j}_{\text{ó}} = \text{áè}\frac{1}{\boldsymbol{j}}]\ {}_{O} \tag{17a}$$

$$\frac{dQ}{dF_{S}\text{ã}} = \frac{1}{\text{ç}}[-\overset{\text{ä}}{+}\quad {}_{\text{ã}}\ \text{áã}]^{1}\ {}_{S} \tag{17b}$$

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[6] Note that a change in the degree of market integration in the second period does not affect wages in the first period.

$$\frac{\text{dQä}}{\text{dTç}_{\text{FSOD}}} = [-+ \quad j \ \text{á=è}\Omega]_{\text{O}} \tag{17c}$$

$$\frac{\text{dQä}}{\text{dTç}_{\text{FSSD}}} = [-+ \quad \text{=á}\tilde{\Omega}]_{\text{S}} \, . \tag{17d}$$

Taking the derivative of Ω with respect to the rate of market integration we find $\frac{\text{d}\grave{\text{U}}}{\text{dç}} = \frac{-\text{ä}}{\text{ç}^{2}} < 0$.

From Figures One and Two it can be seen that declining Ω results in increased levels of both forest clearance and time spent clearing the forest. Increased rates of market integration unambiguously increase rates of forest clearance.

Forest Clearance and Impatience

The model shows that in our two period world, forest clearance is an investment in future agricultural production and thus consumption. Not surprisingly, the value of this future pay-off will vary across smallholders depending on how much they discount the value of future consumption. The literature on discounting and time preference for consumption is immense and will not be summarized here. Nevertheless, we posit that an important component of an individual's discount rate, or their time preference for consumption, depends critically on their general level of patience/impatience (see Godoy et al. 1998). The comparative statics of the model show quite clearly that increased levels of impatience diminish the value of future consumption and thus decrease the benefit of forest clearance. Specifically, we see that $\frac{\text{d}\grave{\text{U}}}{\text{dä}} = \frac{1}{\text{ç}} > 0$. Once again, from Figures One and Two we see that increased levels of impatience, increasing δ, cause the farmer to stop clearing the forest when marginal products of arable land and time are higher than levels chosen by more patient farmers. The result is that impatient farmers clear less land for agriculture, patient farmers clear more[7].

The model also predicts that there is a synergistic effect between the rate of market integration and time preference. The influence of patience on forest clearance is exacerbated by higher rates of market integration. Taking the derivative of Ω with respect to impatience and the rate of market integration gives $\frac{d(\frac{d\Omega_s}{d\delta})}{d\eta} = -\frac{1}{\eta^2} < 0$.

Forest Clearance, Technology, and Productivity

The efficiency with which farmers convert forest to farmland and the productivity of that land in agriculture also influence the optimal rate of forest clearance for the smallholder. Comparative statics can be derived to examine explicitly the way in which tree cutting efficiency on old growth and secondary forests, φ and γ respectively, influences forest clearance. Similarly, we can derive comparative statics that relate changes in forest clearance to different levels of agricultural productivity, subsistence production, and the relative differences in these levels between old growth and secondary forest. While we leave the simple calculus to the reader, we note several interesting outcomes here.

Not surprisingly, anything that increases the efficiency with which forest is converted to farmland increases forest clearance. Recalling that our production function for forest clearance models the relationship between effort and forest clearance as a simple linear relationship $F_O^1 = \varphi T_{FOR}^0$, $F_s^1 = \gamma T_{FSR}^0$, $\frac{dF_O^1}{dT_{F_O}^0} = \varphi$, and $\frac{dF_s^1}{dT_{F_s}^0} = \gamma$. Changes in the marginal productivity of

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[7] We leave a full discussion of the sources of impatience for another paper.

forest clearance effort can come about through the introduction of chainsaws, logging roads, and tractors. Furthermore, the marginal productivity of effort also can vary across farmers and may depend on relative experience and knowledge of forested areas. Anything that increases the productivity of forest clearance effort will influence forest clearance in two ways. Most obviously, anything that makes it easier to clear the forest increases forest clearance

($\frac{dQ^2}{dF_O d\boldsymbol{j}} = \frac{d\grave{U}\left(\frac{1}{\acute{o}\,\boldsymbol{j}} \quad {}_{O}\right)}{d\boldsymbol{j}} < 0$.) Deriving the comparative statics for forest clearance effort,

however, shows that the optimal level of forest clearance <u>effort</u> actually declines

($\frac{dQ^2}{dT_{FOD} d\boldsymbol{j}} = \frac{d\Omega_O}{d\boldsymbol{j}} > 0$.)

Finally, increased agricultural productivity unambiguously increases forest clearance, while increased subsistence productivity by forests decreases forest clearance.

6 Data and Analysis

To empirically test the relationships explored above, we use data from a household survey conducted among the Tsimane People of Bolivia. The survey was conducted in 1996 among Tsimane villages of differing degrees of proximity to the closest market town of San Borja, Bolivia. In all, 209 households in 18 villages are included in the data set.

The Tsimane are, in many ways, an emerging subsistence economy. The Tsimane people satisfy their dietary requirements by hunting, gathering, and subsistence farming. Additionally, cash income is earned from limited commercial agriculture, outside the village wage labor, and from contracted sales of mahogany from Tsimane lands. Villages are located in highly varying degrees of proximity to the market. As seen in Table 2, distances from the villages to the nearest market center of San Borja range from less than a one-hour walk to nearly 84 hours (in the dry season.) Finally, the Tsimane have relatively secure tenure to land cultivated and forest cleared for future cultivation.

Of particular interest to our study are variables used in the model section above. The variables are described and related to the model in Table 1. Summary statistics of relevant variables are given in Table 2, where data is based on the responses of male heads of households. Table 1 illustrates that several variables important to the model were not available explicitly. For instance, we do not have a direct measure for market integration. We know distance to the market, but we do not know change in this distance over time; walking time to the nearest market or road is only available for the year the survey was conducted. Earlier, we argued that market integration had a direct impact on transaction costs. We note that transactions costs are included in the village prices of the cash crops and goods. Prices are taken on a village level and vary widely from village to village (as is evident in Table 2). All goods in the study area must be purchased in San Borja, either directly by the household or by a trader. Village prices then reflect market prices in San Borja plus transaction costs. A change in price, therefore, may indicate changes in transactions costs. These price changes also could reflect changes in prices at the market in San Borja, but these changes should be the same for all villages. Therefore, relative differences in changes in prices must reflect village specific differences, the most likely of which is variation in the degree of integration to the market. Similar logic can be followed for agricultural goods sold at the village gate. We use the ratio of future over present prices for bananas (a cash crop) as a unitless proxy for the rate of market integration.

A tobit model, with robust variance estimates, is used for the regressions since forest clearance is censored at 0. Table 3 lists the results of regressing forest clearance in 1995 (total, old growth and secondary growth) on the explanatory variables summarized in Tables 1 and 2. The results of the model estimation are robust, most coefficients are of the expected sign and many are statistically different from zero (using Huber-White sandwiched estimates of variance.) The estimated coefficients of the old growth forest clearance model are significant more often than the model for secondary growth forest clearance.

The model assumes that market integration should lead to higher farmgate prices for cash crops and then hypothesizes that increasing rates of change in these prices in turn should increase forest clearance. Of course, the forest clearance decision is made using expected changes in the farmgate prices of cash crops. While we do not have data about farmer's expectations about crop prices, we do know actual changes in prices from 1995 to 1996. To capture changes in farmgate prices (in a way that is insensitive to the units used), we use a price ratio for the price of bananas (P_{1996}/P_{1995}). The estimated models indicate that increasing rates of market integration (the ratio of future and present banana prices) lead to a large and significant increase in forest clearance of old growth areas. The impact of price changes on secondary growth is insignificantly different from zero. Distance to the road has a negative impact on the forest clearance of old growth areas (and an insignificant, but positive impact on cutting in secondary growth areas.) The empirical estimations also show that forest clearance increases with distance from the closest major town of San Borja. One explanation consistent with these findings is that the availability of old growth forest is itself a function of the distance from major developed areas like San Borja.

Finally, the estimations confirm an important result of the model: patient farmers clear more forest than impatient farmers. While the coefficients for impatience are remarkably similar for forest clearance in both old growth and secondary growth areas, the coefficient on impatience is significant only for secondary growth. As found in other studies, education has a negative impact on forest clearance. The level of subsistence hunting, possibly an indicator of familiarity with the forest, is positively correlated with forest clearance.

7 Policy Implications and Discussion

A two period model shows that traditional development strategies may have mixed impacts on rural forest clearance. Market integration in the long run may, indeed, reduce forest clearance if such integration results in increased levels of education and increased wages off the farm. Our empirical findings support this proposition. While market integration and increasing smallholder income and welfare may slow forest clearance, the rate at which integration occurs could dramatically influence forest clearance in the present; rapid market integration will quicken the pace of rural forest clearance by smallholders.

Market integration could have duel impacts on the personal discount rate of smallholders and thus on rates of forest clearance. Increasing levels of income and declining interest rates for credit both work to reduce the personal discount rates of smallholders. Our two period model and the empirical results reported here and in Godoy et al. (1998) find that more patient farmers are more likely to clear forest. While our empirical results are cross-sectional, the model shows that increasing the patience of farmers over time should also increase their propensity to clear forest over time.

The model shows that access to technology, for both agricultural and forest clearance purposes, will increase forest clearance rates. It has long been known that giving smallholders better tools is one of the surest ways to promote forest clearance. Our model shows additionally, though, that access to agricultural technology will increase forest clearance – even when that technology improves agricultural sustainability. Finally our model suggests that one possible way of reducing rates of forest clearance rates in transitional economies is too improve the productivity of the local forest for subsistence goods. While our model does not explicitly address open access and common property issues associated with forest gathering, it is implicit that increasing the property rights of smallholders to non-timber forest goods could further reduce levels of smallholder forest clearance.

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Tables

Table 1. Regression Variables

Variable	Relation to Model	Description
Clearfo95	F	Total forest cut by the household in 1995
Oldgrw95	F_O	Total old growth forest cut by the household in 1995
Secgrw95	F_s	Total secondary growth forest (fallow) cut by the household in 1995
Avgimpat	δ	Average impatience of the household heads (0 is given for patient household heads, 1 for average impatience, and 2 for impatient household heads)[8]
Prcorn95	P_a^0 (corn)	Village price of corn in 1995
Prrice95	P_a^0 (rice)	Village price of rice in 1995
Banratio	$P_a^1 - t_a^1 \big/ P_a^0 - t_a^0$	Village price of bananas in 1996 over price in 1995
Prsoap	P_m^0 (soap)	Village price of soap in 1995
WalkSB	t^1 (San Borja)	Hours walking from the village to the closest market center of San Borja (1996)
Walkrd	t^1 (road)	Hours walking from the village to the nearest road (1996)
Hunt	X_m^1	Number of days of successful hunting in the past week times the number of household participants (1996)
Hhsize	None	Size of the household in 1996
Avgeduc	None	Average number of years of education of household heads

Table 2. Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Clearfo95	209	13.07	12.94	0	110
Oldgrw95	209	6.61	7.84	0	80
Secgrw95	209	6.46	8.26	0	60
Avgimp	196	0.31	0.53	0	2
Prcorn95	198	11.6	14.7	3	100
Prrice95	201	9.55	3.03	4	20
Banratio	190	1.56	0.38	1	2.5
Prsoap	174	1.16	0.91	0.5	5
WalkSB	209	12.1	13.18	0.6	84
Walkrd	201	2.61	5.89	0	20
Hunt	208	1.29	2.33	0	19
Hhsize	209	4.9	3.05	0	16
Avgeduc	209	1.46	1.77	0	9

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[8] To calculate impatience a method common to social psychologists was used (Godoy et. al. 1998). Survey participants were given the choice of having one candy at the beginning of the survey or two pieces at the end of the survey. Patient individuals waited until the end of the survey for candy, individuals with average impatience needed greater incentive to wait (e.g. more candy), while impatient individuals always opted for candy now.

Table 3. Estimation Results

	Total Deforestation	Primary Forest Deforestation	Secondary Growth Deforestation
Avgimpat	-3.43[b]	-2.21	-2.07[b]
	(1.40)[d]	(1.45)	(1.00)
Prcorn95	0.07[c]	0.05	0.04
	(0.04)	(0.05)	(0.03)
Prrice95	1.99[a]	2.10[a]	0.86
	(0.75)	(0.73)	(0.53)
Banratio	6.08	9.71[b]	-2.70
	(6.20)	(4.93)	(3.96)
Prsoap	-0.66	0.77	-1.28
	(0.80)	(0.71)	(0.89)
WalkSB	0.19[a]	0.24[a]	0.06
	(0.04)	(0.06)	(0.04)
Walkrd	-0.15	-0.36[b]	0.16
	(0.18)	(0.18)	(0.11)
Hunt	1.10[b]	0.56[b]	0.83[b]
	(0.54)	(0.28)	(0.38)
Hhsize	-0.01	0.25	-0.27
	(0.25)	(0.24)	(0.20)
Avgeduc	-2.41[a]	-3.41[a]	-0.46
	(0.88)	(1.08)	(0.48)
Constant	-12.49	-28.65[b]	3.52
	(14.41)	(12.73)	(10.16)
Log Likelihood	-620.69	-448.77	-510.59
Wald Chi^2	42.76[a]	24.19[a]	32.15[a]
Observations	162	162	162
Left censored	7	50	24
Uncensored	155	112	138

[a] significant at the 1% level

[b] significant at the 5% level

[c] significant at the 10% level

[d] robust standard errors in parenthesis

Figures

Figure 1. Choosing the Optimal Level of Forest Clearance

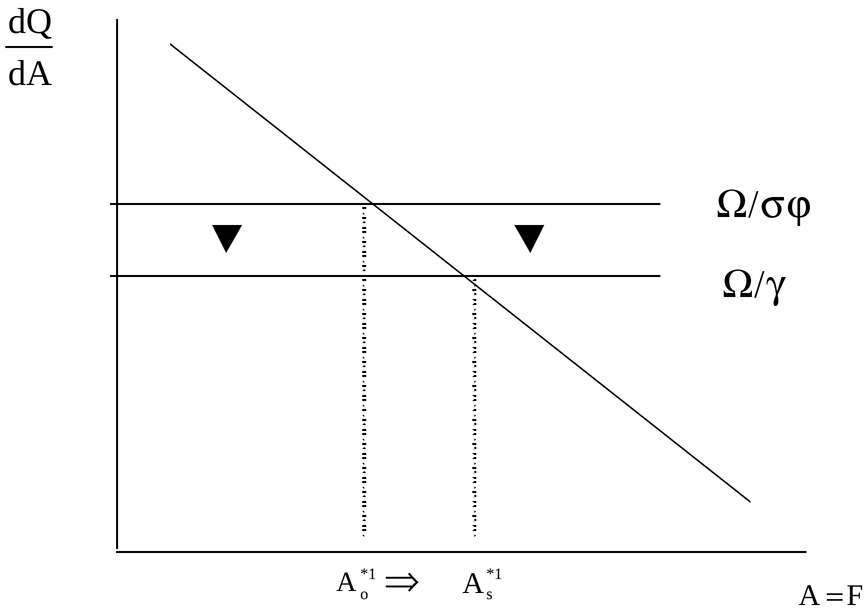

Figure 2. **Choosing the Optimal Level of Forest Clearance EFFORT**