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by

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ABSTRACT

This paper explores the interrelationship between poverty, risk, and deforestation by small farmers in the low-income tropics. A nonseparable household model reveals how exogenous shocks to the mean or variance of a food price distribution affect peasants’ incentives to clear forest. The resulting links between food price policy, farmer behavior, and deforestation offer an innovative explanation of the vicious cycle of peasant immiserization and tropical deforestation. An intriguing, testable hypothesis also emerges: market-oriented reforms that increase the mean and variance of food prices may inadvertently stimulate deforestation in economies in which a sizable proportion of farmers are net buyers.

Key words: agricultural liberalization, deforestation, food security, nonseparable household modeling, peasant agriculture, price risk
STOCHASTIC FOOD PRICES AND SLASH-AND-BURN AGRICULTURE

Food security and deforestation in the low-income economies of the tropics are interrelated concerns of global importance. Despite significant increases in recent years in global per capita income, an increasing number of people—better than one billion in the low- and middle-income countries alone—lack access to adequate nutrition; most of these are rural inhabitants, mainly peasant farmers (UNDP). Meanwhile, the best available estimates indicate that the rate of tropical deforestation increased significantly during the 1980s and into the early part of this decade (FAO; Myers 1992; Amelung and Diehl). These facts are related, for the poor are both agents and victims of tropical deforestation. Indeed, leading researchers assert that clearing by poor, small-scale farmers is the primary cause of deforestation worldwide (Southgate 1990, 1994; Myers 1992, 1994; Pearce and Warford).

The literature is replete with analyses of the various connections between peasant agriculture and deforestation. These particularly emphasize inappropriate settlement, migration, and infrastructure development patterns (Jones and O’Neill; Myers 1994; Chomitz and Gray, Southgate 1990), land tenure regimes (Allen; Larson and Bromley 1990), pricing of forest products (Repetto and Gillis; Larson and Bromley 1991; von Amsberg), government subsidy and tax policies (Binswanger; Deacon), and human population pressures (Cleaver and Schreiber). But the literature on deforestation generally fails to explain adequately how the economic incentives created by food price distributions influence peasant choices to clear forest. Some authors have considered the relation between (deterministic) commodity pricing and deforestation (Cleaver; Southgate 1990,

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1This paper has benefitted from discussions with and comments on an earlier draft by Brad Barham, Michael Carter, and Jean Paul Chavas and was supported by the Utah Agricultural Experiment Station and approved as journal paper #__.
1994; Larson and Bromley 1990, 1991; Ehui and Hertel; Elnagheeb and Bromley; Pearce and Warford), while others have explored the interrelation between poverty, risk, and deforestation (Perrings). But no one has yet explored how poverty and stochastic commodity prices jointly influence peasant deforestation. This paper thus helps fill that void by formally establishing, using nonseparable household modeling techniques, how exogenous shocks to the mean or variance of a food price distribution can lead to deforestation through slash-and-burn cultivation.

Slash-and-burn cultivation was long associated with migratory agricultural production commonly referred to as shifting cultivation. Farmers would burn and clear a plot of land, cultivate it for a few seasons, then move on to another plot, abandoning the first to regenerate naturally over a period often measured in decades. In an environment of low human population densities, shifting cultivation based on long fallow periods can be an ecologically sustainable and economically optimal practice in tropical forests (Peters and Neuenschwander). In recent decades, however, human population densities have grown—due to the growth or displacement of human populations—to the point where shifting cultivation is no longer sustainable in many locations. Slash-and-burn agriculture is now commonly a manifestation not of migratory agriculture but of the extensification of sedentarized peasant agriculture. While the data are not as reliable or comprehensive as one might like, slash-and-burn peasant agriculture seems to account for a large and increasing share of contemporary tropical deforestation; indeed, some estimates suggest peasant production accounts for most deforestation today (Myers 1994). A key feature of slash-and-burn practices is that cultivable area is purchased not with cash or output shares but with labor time invested in clearing and preparing the land, as captured in the model presented in the next section.

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2Commercial logging, urban sprawl, livestock ranching, and other activities are likewise of considerable importance, but lay beyond the scope of this paper. Brown and Pearce includes a range of empirical studies of (primarily macroeconomic and demographic) correlates of deforestation. Pearce and Warford provide good discussions of the complex socioeconomic etiology of deforestation.
It has long been recognized that human population or income growth stimulates aggregate demand for food, in turn enhancing the derived demand for crop and grazing lands by profit-maximizing producers. This can induce commercial farmers to extensify cultivation, perhaps clearing forest to do so (Hosier). But this sort of profit-driven deforestation is qualitatively different than the survival-driven slash-and-burn practiced by semisubsistence peasants perhaps responding less to profit opportunities than to threats to their food security and welfare. If one talks to peasants stripping the forests of Madagascar, Peru, or the Philippines, one does not hear them talking about the need to increase their output to satisfy increased market demand. Instead, they tell a story of increased need to insure themselves against the prospect of needing to buy food at potentially prohibitive prices. I do not mean to suggest that peasant farming is purely a subsistence activity, insulated entirely from markets, nor that peasants are irrational.\footnote{Dvorak models a pure subsistence situation.} Yet markets often fail at the household level due to significant transactions costs, creating incomplete market settings in which some prices are endogenous and others are exogenous (DeJanvry, Fafchamps, and Sadoulet). Adverse exogenous shocks to terms of trade or market price risk can force poor farming households to reduce leisure consumption and to reallocate labor time to clearing land for cultivation. Poverty and market-mediated risk are thus central to peasant deforestation (Perrings; Larson and Bromley 1991).

This issue has considerable relevance to contemporary policymaking because those countries whose tropical forests are of greatest concern to conservationists (e.g., Brazil, Côte d’Ivoire, Indonesia, Madagascar, Peru, the Philippines) have also been liberalizing food price policy over the past decade or are presently undertaking market-oriented reforms. As Bromley emphasizes, economic policies invariably interrelate with natural resource use patterns, if often in unintended
ways. By making explicit the link between deforestation, peasant poverty, and shocks to exogenous food price distributions, the paper also suggests how incentives to deforest might have been inadvertently increased by widespread recent episodes of market-oriented reforms, which appear to have significantly altered food price distributions in low-income economies in which many farmers are desperately poor (Barrett and Dorosh; Barrett 1997). The irony, of course, is that the very international organizations and donors most vigorously sponsoring market-oriented agricultural price policy reforms have been simultaneously working to improve tropical forest conservation. In the absence of explicit coordination between the two activities, the former may be working at cross-purposes with the latter.

The Model

Peasant food insecurity results from either yield risk, price risk, or both that threaten a household's ability to obtain sufficient nutrition through production or exchange. Stochastic prices form the base for the present model, although one can reproduce the general results by modeling stochastic output instead (following Srinivasan). This by no means denies the importance of yield risk to household behavior in peasant agriculture. Rather, contemporary market-oriented policy reforms appear to have had significant effects on food price distributions (Barrett 1997), thereby giving particular policy relevance to analysis that considers how changing food prices affect incentives facing peasant producers.

Where the effects of food prices have been explored in literature on deforestation, it has primarily been within a framework of farmers as firms, based on an assumption that agriculturalists are necessarily net sellers of food. A growing body of evidence, however, reveals that many small farmers are net food buyers and may suffer significant welfare losses from food price policy reforms (Weber et al.; Deaton; Barrett and Dorosh) and that incomplete markets may cause
utility-maximizing household behavior to diverge from profit-maximizing behavior (DeJanvry et al.). Moreover, only Perrings models food prices as uncertain, but his is a recursive formulation in which prices affect activity only after their realization. The *ex ante* impacts of price risk remain uninvestigated in the literature on tropical deforestation despite the fact that the biological lags inherent to agricultural production and the absence of contingency (e.g., futures or options) markets combine to subject peasant farmers to considerable temporal price risk. Given the manifest importance of smallholder agriculture to tropical deforestation and the obvious primacy of food commodity prices and associated food security risk to smallholder decision-making, this seems an important omission and one worth addressing.

The gist of the present model is that households’ land endowments and the available production technology jointly determine households’ vulnerability to food price shocks and the way they insure against such shocks. The model is thus in the spirit of Finkelshtain and Chalfant or Barrett (1996). In the absence of complete contingency markets and given a uniform production technology, heterogeneous land endowments across households can generate behavioral differences derived from different marketed surplus positions—net buyer or net seller—and related differential capacities to self-insure against risk. Incomplete markets thereby generate cross-sectional behavioral differences. In this respect, poverty manifest in poor land endowments affects tropical forests through a different channel than in the conventional literature, in which poverty typically contributes to deforestation by increasing decision-makers’ discount rate (Perrings).

Assume that a representative agricultural household exhibits non Neumann/Morgenstern utility defined over consumption of leisure \((L^L)^4\) in the first (growing) period and staples \((S)\) and

\[4\] Superscripts distinguish among goods across subcategories. Subscripts denote partial derivatives.
nonstaples ($N$) in the second (post-harvest) period.  $^5$  $U(.)$ is quasi-concave, but concave in each argument individually, with $U_X|_{X=0} = \infty$ with respect to each argument $X$. The staple can be either produced or purchased; the nonstaple is available only through market purchase.

The household has an endowment of land ($T^0$) and of labor time ($L^0$). Deterministic staple commodity production is strictly increasing in land and agricultural labor and (weakly) concave in each. Agricultural labor is a function of household labor ($L^H$) and hired labor ($L^D$), but these may be imperfect substitutes. Just as the household can hire labor in, so can it hire out its time ($L^S$) at a parametric wage rate, $w$. Although no land market exists, additional land, $T^S$, can be brought into production through clearing uncultivated forest using just labor (i.e., a slash-and-burn technique). The cultivable land stock is thus a function of a particular labor activity: land clearing, $L^T$, which maps into cleared land by the concave production technology $T^S(L^T)$. The household faces a time constraint, $L^0 \geq L^H + L^S + L^L + L^T$. Exogenous transfers ($I$) supplement net wage earnings and agricultural revenues.

All product prices are unknown when production decisions (i.e., labor allocation decisions) are made, but post-harvest prices are revealed before staple and nonstaple consumption decisions are made. The household’s utility maximization problem can thus be expressed as

$$\begin{align*}
\text{Max}_{L^0, L^H, L^L, L^S, L^T} & \quad E \text{Max}_{N, S} \quad U(L^0, N, S) \\
\text{s.t.} & \quad P^S S + P^N N \leq Y^* \\
& \quad Y^* = w[L^S - L^D] + P^SF(L, T) + I \\
& \quad L^0 = h(L^D) + L^H \\
& \quad T = T^0 + T^S(L^T) \\
& \quad L^0 \geq L^H + L^S + L^L + L^T \\
& \quad h(L^D) \in [0, L^D] \\
& \quad L^D, L^H, L^L, L^S, L^T, N, S \geq 0,
\end{align*}$$

$^5$The model follows the basic construction of Finkelshtain and Chalfant or Barrett (1996).
where $E$ is the mathematical expectation operator, $P^S$ is the staple price, $P^N$ is the nonstaple price, $Y^*$ is endogenous income, and the function $h(.)$ is a hired labor efficiency index used to convert hired labor units into household labor units. It takes the value zero if hired labor is completely inefficient, and $L^D$ if hired labor is as efficient as household labor. By the strict monotonicity of $U(.)$, the budget and time constraints will bind at any optimum. Productive efficiency is assumed.

The household allocates labor across the alternative uses conditional on anticipated ex post optimal choices of consumption volumes. Thus, by duality, we can work with the variable indirect utility function (Epstein). $V(.)$ is homogenous of degree zero in the relevant prices and income and, therefore, invariant to units of measurement. So let $P^N$ be a numéraire, with $P = P^S/P^N$ and $Y = Y^*/P^N$. Assume the household exhibits Arrow/Pratt income risk aversion ($V_{YY} < 0$).

The peasant's labor allocation decisions can thus be represented by the optimization problem

\[ \max_{L^D, L^H, L^L, L^T} EV(L^L, P, Y) \]

\[ \text{s.t. } Y = w[L^0 - L^D - L^L - L^H - L^T] + PF(L, T) + I, \]

for which the first-order necessary conditions for an optimum are

\[ \text{w.r.t. hired labor, } L^D : E(V_y[P_{L^D} - w]) \leq 0 \quad (= 0 \text{ if } L^D > 0) \]  
\[ \text{w.r.t. household labor, } L^H : E(V_y[P_{L^H} - w]) \leq 0 \quad (= 0 \text{ if } L^H > 0) \]  
\[ \text{w.r.t. leisure, } L^L : E(V_y - V_yw) \leq 0 \quad (= 0 \text{ if } L^L > 0) \]
\[ \text{w.r.t. land clearing labor, } L^T : E(V_y[P_{L^T} - w]) \leq 0 \quad (= 0 \text{ if } L^T > 0) \]

\[ \text{where } \quad D = (\partial F/\partial T)(\partial T^S/\partial L^T) \]

Since the focus of this paper is on peasant deforestation decisions, I focus on the implications of relation (6). If the marginal revenue product of forest-clearing labor ($L^T$), evaluated at $L^T = T^S = 0$, is at least as great as the market wage, then slash-and-burn agriculture is a rational
activity. Deforestation is thus more likely the lower the wage rate, the higher the marginal product of land in agriculture, the more efficient the land clearing technology, the lower the household’s land endowment and the greater its labor endowment. This aptly describes peasant agriculture in many poor regions where modern input use is low, cleared land is scarce, families are large, and slash-and-burn techniques clear land remarkably quick.

If peasant deforestation is optimal, then following Barrett’s (1996) propositions 1 and 2, it can be shown that net seller (buyer) households will “underemploy” (“overemploy”) land-clearing labor relative to the certainty equivalent rate at which the expected marginal revenue product equals the parametric wage rate. That is, if μ is the mean of \( P \), then

\[
w < (>) \mu D
\]  

for net sellers (buyers) of \( S \). Given a single, parametric wage rate facing all households and a common set of concave production and land-clearing technologies, the implication is clear that households with a smaller endowment of cultivable land will devote more labor to deforestation and thereby clear more land. This fits the conventional wisdom: it is the poorest farmers who most threaten tropical forests through slash-and-burn cultivation.

The key concern of this paper is to understand how rational peasants’ optimal decisions with respect to deforestation respond to shocks to the exogenous staple food price distribution, \( P \). A natural way to proceed follows the mean-variance analytical approach of Meyer, which is consistent with the expected utility maximization hypothesis maintained in (1). By this approach, \( P \) can be specified as

\[
P_t = \mu_t + \sigma e_t,
\]  

where \( \mu \) is the mean price (a “location” parameter), \( \sigma > 0 \) is a mean-preserving spread (a “scale”
parameter), and \( e \) is a mean zero, iid random shock. Both \( \mu \) and \( \sigma \) may be subject to nonstationary structural shocks, such as those induced by policy reforms including exchange rate realignment, price (de)control, the introduction or termination of subsidies or taxes, or changed marketing arrangements.

Sensitivity analysis of the first-order conditions, with respect to changes in \( \mu \) and \( \sigma \), offers some insight as to how peasants' incentives to clear tropical forest change in response to exogenous shocks to food prices. First, considering changes with respect to \( \mu \), rearrange (6) and substitute in (8), then partially differentiate the resulting expression with respect to \( \mu \), as follows

\[
EV_{yw} = EDV_y (\mu + \sigma e) 
\]

(9)

\[
\Upsilon = \frac{EV_{yw}}{D} = EV_y (\mu + \sigma e) 
\]

(10)

\[
\frac{\partial \Upsilon}{\partial \mu} = E(V_y + PV_{yy}). 
\]

(11)

The concavity of output in land-clearing labor suffices to define the optimal reallocation of labor time. If \( \partial \Upsilon/\partial \mu > (<) 0 \), this indicates that in response to a positive shock to the mean food price, it is optimal to increase (decrease) labor devoted to deforestation, either through a reduction in market labor supply, if \( L^S \) was positive, or through a reduction in leisure time, \( L^L \). The first term on the right-hand side of (11) is a substitution effect and is always positive. This captures the increased derived demand for acreage in response to an increase in the expected food price. The second term is an income effect and can be of either sign. It is positive (negative) if and only if an increase in \( \mu \) increases (decreases) the marginal utility of income, which, by the assumption of income risk aversion, implies that increasing the expected food price lowers (raises) real income, which is true

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6 This framework does not impose restrictions on risk preferences, on the joint distribution of \( P \) and \( Y \) (an endogenously random variable), or on the functional form of the cumulative density function describing any particular random variable.
if and only if the household is a net food buyer (seller). For net buyer households, a rise (fall) in $\mu$ induces reduced (expanded) leisure consumption via the income effect and therefore an unambiguous increase (decrease) in deforestation activity. For net seller households, by contrast, the income effect of an increase (decrease) in $\mu$ leads to greater (less) leisure consumption—a "wealth effect" in the jargon of the household modeling literature—and therefore ambiguous effects on deforestation activity since the income and substitution effects on $L^T$ are opposite in sign. So it is only the poorest farmers who respond unambiguously to higher expected food prices by clearing more forest.

Similar sensitivity analysis with respect to $\sigma$ enables investigation of the impact of shocks to food price variability on peasant deforestation activity. Again, working from (10), differentiation with respect to $\sigma$ yields another Slutsky-type expression:

$$\frac{\partial Y}{\partial \sigma} = \text{sign} \left[ \text{COV}(V_y, P) + E V_y P \right]$$

Again, $\partial Y/\partial \sigma > (\leq) 0$ indicates that it is optimal to increase (decrease) labor devoted to deforestation in response to a positive shock to the variance of the staple food price. The first term on the right-hand side of (12) is the substitution effect. The covariance between the marginal utility of income and price is negative (positive) for net food sellers (buyers), as Finkelshtain and Chalfant and Barrett (1996) demonstrate.

The second term on the right-hand side of (12), the income effect, depends on whether the expected marginal utility of income increases or decreases with respect to changes in $\sigma$. This depends on whether agents are price risk averse, as represented locally by the curvature of indirect

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$^7$The precise relationship is $\frac{\partial Y}{\partial \sigma} = \text{COV}(V_y, e) + E V_y P$, where $e = (P-\mu)/\sigma$. Obviously, sign $\text{COV}(V_y, P) = \text{sign} (\text{COV}(V_y, e))$, since $\mu$ and $\sigma$ are constants.
utility in prices, $V_{pp}$. Barrett (1996) showed that net buyer smallholders are commonly price risk averse. In that case, an increase in $\sigma$ is equivalent to a reduction in real income and hence the income effect on land-clearing labor will be positive. Thus, a positive (negative) shock to the staple food price variance will unambiguously increase (decrease) deforestation activity only among price risk-averse net buyers. For all other producer categories, the effects are ambiguous.

This last result contrasts with the existing literature on supply response under risk, in which price risk leads producers to reduce, not increase, cultivated area (Behrman; Just; Chavas and Holt; Elnagheeb and Bromley). Two key differences in the present model generate the contrarian result that, for an important subpopulation of producers, food price risk stimulates agricultural extensification through deforestation. First, net buyer producers respond differently to price risk than do net sellers (Finkelshtain and Chalfant; Barrett 1996). Food producer households with rudimentary production technologies and meager land endowments are commonly net food buyers in the low-income tropics. Second, land is “purchased” with labor not with cash. The (negative) wealth effects experienced by price risk-averse small farmers following an increase in $\sigma$ thereby induce a reallocation of time from leisure to forest-clearing labor.

**Policy Implications**

While the present model assumes uniform technologies and allows cross-sectional variation in landholdings, endowments and technologies are jointly central to the analysis, and the results could be replicated by assuming uniform landholdings and permitting technologies to vary. The more realistic arrangement was chosen for modeling purposes, but it is important to recognize that the changes to the land distribution or to production technologies have similar effects on the core results. Holding technology constant, the smaller a household’s land endowment, the less its marketable surplus (which may be quite negative) and thus the greater the welfare loss associated
with increases in the mean and variance of food prices (Deaton; Barrett and Dorosh) and the more
pronounced the induced incentives to clear forest for cultivation. Alternatively, holding land
endowments constant, the less efficient the production technology, the less the household’s
marketable surplus, with the same behavioral consequences in response to an exogenous shock to
the food price distribution. In response to such shocks, decreased welfare (and increased food
insecurity), not greater profit opportunities, prompts peasant deforestation in this model. The
qualitative results are thus quite different than those found in the existing literature linking farmer
behavior and deforestation, offering an innovative interpretation of the vicious cycle by which
peasant immiserization and tropical deforestation are linked.

Do these results offer any insight into the apparent acceleration of peasant deforestation in
the 1980s and early 1990s? Quite possibly, since this has also been a period of unprecedented food
price liberalization in tropical agrarian nations. Previous state control of marketing channels, trade,
exchange rates, etc., generally reduced the mean and variance of food price distributions (Krueger,
Schiff, and Valdés). The natural prediction is that removal or reduction of state controls, as has been
the thrust of liberalization efforts worldwide, should increase both the mean and variance of food
price distributions. Limited available evidence suggests this has indeed been the case (Barrett 1997).
This raises an intriguing, testable hypothesis: market-oriented reforms that increase the mean and
variance of food prices stimulate deforestation in low-income economies in which a sizable
proportion of farmers are net food buyers. Might unintended reductions in poor, net buyer farmer
welfare in the wake of food marketing and price liberalization in the low-income tropics (Weber et
al.; Barrett and Dorosh) also have adverse spillover effects on the natural environment? If so,

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8 This is especially true if economic reforms also lead to lower real wages, as has generally been the case in
much of the developing world, particularly in sub-Saharan Africa.
induced peasant deforestation could be mitigated through either improved peasant production
technologies or through land redistribution. In many countries, however, the latter is either not
politically feasible or, as in the case of countries with small per capita cultivable landholdings (e.g.,
Madagascar, Rwanda, and Sri Lanka), land redistribution would probably not be effective in
converting the mass of peasant producers to net food seller status.

Conclusions

This paper shows how the mean and variance of food price distributions influence
semisubsistence farmer incentives to clear forest to add to cultivated area when markets may be
incomplete. Smaller farmers are more likely than larger farmers to engage in slash-and-burn
cultivation for semisubsistence food production. Moreover, where land is available primarily at the
extensive margin, food insecure, net buyer agricultural households will rationally respond to an
increase in either the mean or the variance of the staple food price distribution by allocating more
labor to land clearing. This finding links food price policy, risk coping, and environmental
protection, three issue sets of considerable recent interest to policymakers and researchers in tropical
agrarian nations. Getting food prices right, as the 1980s’ popular aphorism had it, may have adverse
environmental externalities in settings where rudimentary production technologies and small
cultivable parcels per capita conspire to create food insecurity for a subpopulation whose primary
asset, labor power, is often most lucratively applied to expanding cultivated area through clearing
forest.
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