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STOCHASTIC FOOD PRICES AND SLASH-AND-BURN AGRICULTURE

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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 might 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: that 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, Madagascar, nonseparable household modeling, peasant agriculture, price risk

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Non-Technical Summary

This paper develops a model that shows how the mean and variance of food price distributions influence semi-subsistence farmers' 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 semi-subsistence food production, and they are often net buyers of the staple foods they grow. 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, not because of greater profit opportunities, but rather due to decreased welfare and increased food insecurity. This qualitative results differs from those found in the existing literature linking farmer behavior and deforestation, offering an innovative interpretation of the vicious cycle relating smallholder poverty, risk coping, and tropical deforestation, three issue sets of considerable current interest to policymakers and researchers in tropical agrarian nations.

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, and the Philippines) have also been liberalizing food price policy over the past decade and a half, and contain considerable populations of semi-subsistence farmers. It has been well established, across a broad range of countries, that previous state control of marketing channels, trade, exchange rates, etc., generally reduced the mean and variance of food price distributions. If removal or reduction of those same state controls—the thrust of liberalization efforts

worldwide—increases both the mean and variance of food price distributions, as limited empirical evidence suggest has been the case, this raises an intriguing hypothesis: do market-oriented reforms that increase the mean and variance of food prices inadvertently stimulate deforestation in low-income economies in which a sizable proportion of farmers are net food buyers? 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 hard to improve tropical forest conservation. In the absence of explicit coordination between the two activities or of models to understand how they might relate to one another, the former may be working at cross-purposes with the latter. While data are not available with which to test the model's hypotheses directly, empirical evidence from Madagascar is consistent with this story. Interventions that stimulate rural labor markets (and thereby wage rates), provide safety nets for net food buyers, or both (such as food-for-work schemes), may effectively mitigate the negative deforestation externalities perhaps created by food price liberalization.

Stochastic Food Prices and Slash-and-Burn Agriculture

1. Introduction

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 peasant producers in the low- and middle-income countries lack access to adequate nutrition (UNDP 1996). Meanwhile, the best available estimates indicate that the rate of tropical deforestation increased significantly during the 1980s, with mixed evidence across years and continents in the 1990s (FAO 1992; Myers 1992; Amelung and Diehl 1992; unpublished FAO data). These facts may be related, for the poor are both agents and victims of tropical deforestation. While there are other important sources of deforestation worldwide (e.g., logging, extensive ranching), leading researchers assert that a primary cause is clearing by the 300 million or so small-scale farmers who practice shifting cultivation on roughly half the land area of the world's tropical and mountain ecosystems (Dove 1983; Southgate 1990, 1994; Myers 1992, 1994; Pearce and Warford 1993). This paper focuses on smallholder incentives to slash and burn tropical forest and how these might be influenced by changing the moments of food price distributions.

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 1992; Myers 1994; Chomitz and Gray 1996; Southgate 1990), land tenure regimes (Allen 1985; Larson and Bromley 1990), pricing of forest products (Repetto and Gillis 1988; Larson and Bromley 1991; von Amsberg 1994), government subsidy and tax policies (Binswanger 1991; Deacon 1995), and human population pressures (Cleaver and Schreiber 1994). 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 1985; Southgate 1990, 1994; Larson and Bromley 1990, 1991; Ehui and Hertel 1989; Elnagheeb and Bromley 1994; Pearce and Warford 1993), while others have explored the interrelation between poverty, risk, and deforestation (Perrings 1989). But no one has yet explored how poverty and stochastic commodity prices jointly influence peasant deforestation. Madagascar's experience, described in section 2, suggests this may be an important oversight. This paper uses a nonseparable household model to establish formally how exogenous shocks to the mean or variance of a food price distribution might lead to slash-and-burn deforestation.

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 1988). 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, especially in places characterized by low-income agriculture and small remnant forests (Myers 1994; Rudel and Roper 1997).[1]

The theory of the firm shows that increased food prices stimulate derived demand for cropland by profit-maximizing producers. This can induce commercial farmers to extensify cultivation, perhaps clearing forest to do so (Hosier 1988). But this sort of profit-driven deforestation is qualitatively different than the survival-driven slash-and-burn practiced by semi-subsistence peasants perhaps responding less to profit opportunities than to increased need to insure themselves against the prospect of needing to buy food at potentially prohibitive prices. 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. Adverse exogenous shocks 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 patterns (Perrings 1989; 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, and the Philippines) have also been liberalizing food price policy over the past decade and a half. It has been well established, across a broad range of countries, that previous state control of marketing channels, trade, exchange rates, etc., generally reduced the mean and variance of food price distributions (Krueger et al. 1988). The natural prediction is that removal or reduction of those same state controls—the thrust of liberalization efforts worldwide—should

[1]Commercial logging, urban sprawl, livestock ranching, and other activities are likewise of considerable importance, but lie beyond the scope of this paper. Brown and Pearce (1994) includes a range of empirical studies of (primarily macroeconomic and demographic) correlates of deforestation. Pearce and Warford (1993) provide good discussions of the complex socioeconomic etiology of deforestation.

increase both the mean and variance of food price distributions. Limited available evidence suggests this has indeed been the case (Barrett and Dorosh 1996; Barrett 1997b), raising an intriguing, testable hypothesis: do market-oriented reforms that increase the mean and variance of food prices inadvertently stimulate deforestation in low-income economies in which a sizable proportion of farmers are net food buyers?[2] As Bromley (1986) 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, this paper suggests how incentives to deforest might have been inadvertently affected by widespread recent episodes of market-oriented reforms. 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 hard to improve tropical forest conservation. In the absence of explicit coordination between the two activities or of models to understand how they might relate to one another, the former may be working at cross-purposes with the latter.

2. The Case of Madagascar

For both environmental and development reasons, slash-and-burn cultivation is a grave concern in Madagascar.[3] The vast majority of Madagascar's exceptional biodiversity is concentrated in the less than 20% of the island that remains forested. Forest degradation and fragmentation in Madagascar is therefore of tremendous concern to environmentalists (Kull 1996). Steep relief, heavy

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[2]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 (Barrett and Carter forthcoming).

[3]Slash-and-burn *tavy* is a longstanding concern. Precolonial and colonial rulers issued bans on the burning and clearing of forests and on shifting cultivation in the 18th through the early 20th centuries (Jarosz 1993; Kull 1996).

episodic rainfall and ferruginous soils also make the country's agriculture-based economy vulnerable to soil erosion, nutrient leaching and siltation in the wake of deforestation, imperiling the small farmers who comprise a large majority of the island's poor (World Bank 1989). A recent World Bank study argues that "probably the most important land use affecting deforestation and soil erosion in Madagascar . . . is the traditional shifting slash-and-burn agriculture, known locally as *tavy*" (Keck et al. 1994).

Madagascar's government initiated several ill-conceived policies in the 1970s that led to unsustainable macroeconomic imbalances and ultimately to the introduction of a wide variety of reforms in the 1980s, enacted under the rubric of a structural adjustment program supported by the International Monetary Fund and the World Bank. Madagascar was considered a star pupil by the Bretton Woods institutions due to its relatively rapid and comprehensive pursuit of market-oriented reforms (Pryor 1990; Barrett 1994). Among the most significant reforms were massive exchange rate devaluation and decontrol of food marketing and pricing, particularly for rice, the staple crop. These measures led to sharp increases in the mean and variance of rice prices (Barrett 1997b).

Rice is the dominant crop throughout most of the island, grown by 83% of the nation's agricultural households and accounting for 55% of all cultivated area (MPARA/FAO 1988). The Malagasy are among the world's leading rice consumers per capita. Indeed, Madagascar's rice farmers consume more rice than they produce, in aggregate, with roughly 60% of all rice producing households nationwide being net rice buyers (Barrett and Dorosh 1996; Barrett 1998).[4] The greatest net rice importing production areas in the country are the eastern escarpment, the southern drylands

[4]Many Malagasy rice producers do not meet own subsistence needs because of large families, small farms (1.2 hectare national mean) and rudimentary production technologies yielding about two metric tons/hectare, on average, less than half the world mean (MPARA/FAO 1988).

and the northern highlands, areas where deforestation is generally thought most rapid and where concerns about biodiversity loss are most acute.

Observed increases in the mean or variance of Malagasy rice prices reduced smallholder welfare (Barrett and Dorosh 1996). In response, many peasants reduced leisure time. Some turned to petty trading or wage labor, although rural unemployment rates ranging from 20-55% during the reform era sharply limited labor market opportunities in Madagascar (Barrett 1997a, P. Andrianomanana, personal communication). Others turned to the forest, for the Malagasy rightly perceive deforestation as a labor activity (Keck et al. 1994). Indeed, when the French colonial state banned shifting cultivation in the early 20th century, "peasants interpreted the ban as a form of labor control" (Jarosz 1993, p. 374). There is little spare, cleared land suitable for rice cultivation in Madagascar,[5] so most areal expansion comes through clearing forest, with relatively little captured from shortened fallows or pasture conversion (Oxby 1985; Keck et al. 1994; Raison 1994; Kramer et al. 1995). Rice production at the extensive (deforested) margin generally yields lower output, so one would expect to find lower yields in rice production areas expanding rapidly due to deforestation.

There are no reliable data available with which to establish whether deforestation has accelerated or decelerated in Madagascar since the mid-1980s' economic reforms. However, most observers claim deforestation has accelerated over the past decade (Sussman et al. 1994; Kramer et al. 1995; P. Andrianomanana, personal communication), exceeding the 0.8% annual rate Green and

[5]Steep slopes (*tanety*) are often clear but in fallow. Considerable investment is needed to irrigate such lands in order to provide sufficient water for rice cultivation. Thus, unless they intend to maintain cultivation on the plot for a long enough period to recoup the sunk costs of terracing and irrigation (land markets that might capture these capital improvements in land values are thin or missing in most regions), Malagasy farmers rarely grow rice on such plots, opting instead for vegetables and tubers.

Sussman (1990) estimated from satellite imagery for 1973-85. Deforestation has many different causal factors, including land tenure regimes, forestry policy, changes to the prices of nonwood fuels, human population growth, etc. The claim here is not that changes to the rice price distributions are *the sole* factor responsible for deforestation in Madagascar, just that market-oriented reforms may have inadvertently stimulated deforestation among Madagascar's sizable community of net rice buying farmers by increasing the mean and variance of staple food prices, causing welfare losses that induced peasants to deforest.

These basic characteristics are precisely what one finds in the aggregate data from the regions of Madagascar where deforestation is of concern and for which the necessary data are available (Table 1).[6] Those regions with larger than average net rice buyer subpopulations (Antsohihy, Taolagnaro, Toamasina, Fianarantsoa) experienced higher than average increases in the mean and variance of rice prices, more rapid than average expansion in paddy area cultivated, and lower than average paddy yields. Using more localized data, Raison (1994) documents the expansion of cultivated areas at the expense of tropical forests during the 1980s, citing increased rice prices and greater intra-annual rice price variability that threatened the food security of Malagasy smallholders, especially during the December-March hungry season (*soudure*), as a primary cause of environmental predation by peasants. In open-ended interviews with me in 1992 and 1993, many Malagasy farmers likewise reported increased work effort in response to changes in food prices and their households' food security situation. Among those respondents with access to previously uncultivated forests, expansion of cultivated area through land clearing was the most common reported method of such

[6]Household data necessary to estimate the proportion of net buyers in a region are not available nationwide. Table 1's figures are from a 1990 national survey of 825 rice farming households (Barrett and Dorosh 1996).

expansion.[7] While this quantitative and qualitative evidence from Madagascar do not prove that changes to the rice price distribution increased incentives to slash-and-burn, these data are consistent with the analytical story developed in the next section.

3. An Analytical Model of Peasant Deforestation

Peasant food insecurity arises in part from yield risk, price risk, or both, that threaten a household's ability to obtain sufficient nutrition through production or exchange.[8] Stochastic prices form the base for the present model, although one can reproduce the general results by modeling stochastic output instead (following Srinivasan 1972). 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 1997b), 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 the literature on deforestation, it has primarily been within a framework of farmers as firms, based on an implicit 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. 1988; Deaton 1989; Barrett and Dorosh 1996), and that incomplete markets may cause utility-maximizing household behavior to diverge from profit-maximizing behavior

[7] Petty trading, casual labor for larger farmers in the area, and seasonal migration to cities (especially by teenage and adult males) were commonly cited by all respondent groups.

[8] Food security is a complex concept related to risk. See Barrett (forthcoming) for a review.

(Singh et al. 1986; DeJanvry et al. 1991). Only Perrings (1989) 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 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 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 (1991), Fafchamps (1992), 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 (Singh et al. 1986). Incomplete markets are thereby one source, among several, of 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 1989).

Assume that a representative agricultural household exhibits von Neumann-Morgenstern utility defined over consumption of leisure (L^L)[9] in the first (growing) period and staples (S) and

[9]Superscripts distinguish among goods across subcategories. Subscripts denote partial derivatives.

nonstaples (N) in the second (postharvest) period.[10] U(.) is quasi-concave, 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 (L^H) and concave in each.[11] Not only can the household work its own farm, it can also hire out its time (L^S) at a parametric wage rate, w.[12] 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), L^T, which maps into cleared land by a monotone, concave production technology. 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 postharvest prices are revealed before staples and nonstaples consumption decisions are made. The household's utility maximization problem can thus be expressed as

where E is the mathematical expectation operator, P^S is the staple price, P^N is the nonstaple price,

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[10]The model follows the basic construction of Finkelshtain and Chalfant (1991) or Barrett (1996).

[11]Fafchamps (1992) offers a model with multivariate risk, in which the household produces a food crop, a nonconsumable cash crop, or both. The basic results of his model are identical to those presented here, so I present a simpler, single output model.

[12]The possibility of hiring labor was included in an earlier version of this paper, with no change in the qualitative results. It has been omitted to streamline the model and since the farm units of greatest interest are small and far more likely to hire out than to hire in labor.

$$\underset{L^H, L^L, L^S, L^T}{Max} \; E\left[\underset{N,S}{Max}\; U(L^L, N, S)\right] \tag{1}$$

$$\begin{aligned} s.t.\;\; & P^S S + P^N N \le Y^* \\ & Y^* \equiv wL^S + P^S F(L^H, T^0, T^S(L^T)) + I^* \\ & L^0 \ge L^T + L^S + L^L + L^H \\ & L^H, L^L, L^S, L^T, N, S \;\ge\; 0, \end{aligned}$$

and Y* is endogenous income. 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 1975). 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 $P = P^S/P^{N,}$ $Y = Y^*/P^N$, and $I=I^*/P^N$. Assume the household exhibits Arrow-Pratt income risk aversion ($V_{YY} < 0$), characterized by decreasing absolute risk aversion.

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

$$\underset{L^H, L^L, L^T}{Max} \; EV(L^L, P, Y) \tag{2}$$

$$s.t.\;\; Y = w[L^0 - L^L - L^H - L^T] + PF(L^H, T^0, T^S(L^T)) + I$$

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

$$w.r.t.\;\; household\;\; labor,\; L^H\!: \quad E\Big(V_Y\big[PF_{L^H} - w\big]\Big) \le 0 \quad (= 0 \;\; if \;\; L^H > 0) \tag{3}$$

$$w.r.t.\;\; leisure,\; L^L\!: \quad E\big(V_{L^L} - V_Y w\big) \le 0 \quad (= 0 \;\; if \;\; L_L > 0) \tag{4}$$

$$w.r.t.\;\; land\;\; clearing\;\; labor,\; L^T\!: \quad E\Big(V_Y\big[PD - w\big]\Big) \le 0 \quad (= 0 \;\; if \;\; L_T > 0) \tag{5}$$

$$where \quad D \equiv \big(\partial F/\partial T\big)\big(\partial T^S/\partial L^T\big)$$

Unless 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 the optimal choice is not to undertake slash-and-burn agriculture is a rational activity; i.e., a corner solution will result. 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 are widely used. As in Bluffstone (1995) or Barrett and Arcese (1998), labor market conditions—wage rates and employment prospects—are intimately connected with the probability and rate of exploitation of an open access resource, in this case forest.

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 (1987), which is consistent with the expected utility maximization hypothesis maintained in (1). By this approach, P can be specified as

$$P = \mu + \sigma e \qquad (6)$$

where μ 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.[13] Both μ and σ may be subject to nonstationary structural shocks, such as those induced by recent policy reforms in low-income agrarian economies, including exchange rate realignment, price (de)control, the introduction or termination of subsidies or taxes, or changed marketing arrangements.

[13]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.

Given a concern about how exogenous changes in the staple food price distribution affect peasant incentives to deforest, the natural way to proceed is to apply comparative statics analysis. Totally differentiating the three first-order conditions (3)-(5) with respect to μ and σ, assuming no change in other exogenous parameters (in particular dw = 0), arranging these derivatives into a linear system of equations, and applying Cramer's rule yields the following two results:

$$\frac{\partial L^T}{\partial \mu} = \frac{-D\,E[V_Y]}{F_{T^S} T^S_{LL}\big(COV[V_Y, P] + E[V_Y]E[P]\big)} \tag{7}$$

$$\frac{\partial L^T}{\partial \sigma} = \frac{-D\,COV[V_Y, e]}{F_{T^S} T^S_{LL}\big(COV[V_Y, P] + E[V_Y]E[P]\big)} \tag{8}$$

The monotonicity and concavity of V, F and T^S and the fact that sign(COV[V_Y,e]) = sign(COV[V_Y,P]) combine to imply that COV[V_Y, P]>0 is a sufficient condition for both (7) and (8) to be positive. The covariance between the marginal utility of income and price is negative for net food sellers and positive for net food buyers (Finkelshtain and Chalfant 1991; Barrett 1996). So for the subpopulation of net buyer producers, the optimal response to a positive shock to either the mean or variance of the food price distribution is to increase labor devoted to deforestation, and the optimal response to a negative shock is to decrease land-clearing labor.[14] For net buyer households, a rise in μ induces reduced leisure consumption via the income effect and therefore an unambiguous increase in deforestation activity. Conversely, a fall in μ induces greater leisure and so decreased deforestation. For net seller households, by contrast, a change in μ or σ has ambiguous effects on deforestation activity. So only the poorest, small farmers respond unambiguously to higher mean or

[14]Note that (3) and (5) imply that an increase in L^T implies an increase in L^H, a point confirmed by comparative statics results not reported here. Increased time spent on one's own farm—whether employed in land clearing or cultivation—comes at the expense of leisure, off-farm labor, or both.

variance in the staple food price distribution by clearing more forest. This highlights the relationship between food security stress and incentives to deforest.

This is a more qualified finding than that which emerges from conventional models of agricultural supply response under risk, which predict increased labor use, including forest-clearing, in response to an increase in the mean or decrease in the variance, unconditional on whether the farmer is a net buyer or a net seller (Behrman 1968; Just 1974; Chavas and Holt 1990; Elnagheeb and Bromley 1994). Three features of the present model generate the different results presented here. First, producer utility maximization generally does not reduce to profit maximization in the presence of risk or missing or imperfect markets—conditions affecting essentially all tropical farmers—and the present model uses the more general form (Singh et al. 1986; DeJanvry et al. 1991). Second, net buyer producers respond differently to price risk than do net sellers (Finkelshtain and Chalfant 1991; Fafchamps 1992; Barrett 1996). Food producer households with rudimentary production technologies and meager land endowments are commonly net food buyers in the low-income tropics. Third, in much of the world, land is "purchased" with labor, not with cash. The (negative) welfare effects experienced by price risk averse small farmers following an increase in μ, σ, or both, thereby induce a reallocation of time from leisure to forest-clearing labor. The implication is that changes to stochastic food price distributions—an explicit objective in most liberalization programs of the past two decades—will have less severe effects on tropical forests where farmers have enough land or sufficiently advanced technologies to be net food sellers. Conversely, where land is scarce and production technologies rudimentary, yielding a sizable population of net food buyer farmers, shocks to food price distributions may indirectly put additional pressure on tropical forests.

Market wage rates influence the optimal allocation of labor to land clearing activities, affecting both the probability of a corner solution with no deforestation, and the extent of deforestation activity in the event of an interior solution. Repeating the same comparative statics analysis as was used to generate (7) and (8), we can obtain a rather complicated expression relating exogenous changes in the wage rate to optimal deforestation effort:

$$\frac{\partial L^{T}}{\partial w} = \frac{wDE[V_{Y}]\left(COV[V_{YY},P]+E[V_{YY}]E[P]\right) - \Psi \cdot \Upsilon}{\Psi \cdot \Lambda} \tag{9}$$

$$\begin{aligned} where\ \Psi &= E[V_{LL}]+E[V_{YY}]w^{2} \\ \Upsilon &= DL^{S}\left(COV[V_{YY},P]+E[V_{YY}]E[P]\right) - E[V_{Y}] \\ \Lambda &= F_{T^{S}}T^{S}_{LL}\left(COV[V_{Y},P]+E[V_{Y}]E[P]\right) \end{aligned}$$

Recognize that Λ is simply the denominator from (7) and (8), which is negative for net buyers, and of ambiguous sign for net sellers. Ψ will be negative for all types of agents, given the assumptions with respect to preferences and Arrow-Pratt risk aversion. So the denominator of (9) is positive in the case of net buyers. Under decreasing absolute risk aversion, $COV[V_{YY},P] < 0$ for net buyers, implying that both Υ and the numerator are negative in the case of net buyers. So for the subset of net buyer producers, $\partial L^{T}/\partial w < 0$, confirming the intuition that as market wage rates increase, farmers substitute labor supplied to the market ($L^{S} = L^{0}-L^{H}-L^{L}-L^{T}$) for labor allocated to clearing forest for own cultivation. Wage increases thus have the opposite effect on peasant farmers' deforestation patterns of increased mean and variance of food prices.

The policy problem is that real wages have generally fallen, not risen, in the course of market-oriented reforms in low-income agriculture. Mitigating adverse environmental spillovers may require ancillary interventions to stimulate demand for unskilled labor. In the present context, a promising prospect is food-for-work schemes directed toward improving the supporting infrastructure for sedentarized agriculture (e.g., constructing or rehabilitating irrigation and windbreaks, bunding and ridging). It is relatively easy to identify communities with substantial net staples buyer subpopulations likely to be hurt by shocks to food price distributions. Providing such communities with safety nets that absorb surplus labor time can not only reduce adverse welfare effects on the poor, but also place a floor on the opportunity cost of labor time spent exploiting open access resources such as forests or wildlife (Bluffstone 1995; Barrett and Arcese 1998). Moreover, microeconometric evidence from food-for-work schemes in rural Kenya shows that temporary safety nets can relieve working capital constraints, increasing smallholder capital formation, on-farm labor productivity, and wage employment, akin to technology improvements in the model above (Bezuneh et al. 1988; Bezuneh and Deaton 1997). By effectively absorbing labor and potentially indirectly stimulating increased demand for labor, public employment schemes targetted toward the poor can make use of the inverse relation between wage rates and deforestation effort identified in (9).

4. Conclusions

This paper shows how the mean and variance of stochastic food price distributions influence semi-subsistence 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 semi-subsistence 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 is a response to decreased welfare and food security, not to greater profit opportunities, as predicted by the neoclassical theory of the firm. This qualitative result differs from those found in the existing literature linking farmer behavior and deforestation, offering additional insight into a vicious cycle of peasant immiserization and tropical deforestation. Unfortunately, while price data of sufficient frequency and quality are available for several locations, data on deforestation are are simply not available at appropriate spatial and time scales to enable formal, econometric testing of the model.[15] [16] The findings offered in section 3 thus remain hypotheses in need of testing, although the background information presented section 2 is consistent with the model's structure and implications.

If food marketing and price liberalization has negative spillover effects on the environment in the low-income tropics, induced peasant deforestation could be mitigated through either improved peasant production technologies, land redistribution, or interventions that raise labor productivity, and thus wage rates. In many countries, however, land redistribution is either not politically feasible or, as in the case of countries with small per capita cultivable landholdings (e.g., Burundi, Madagascar, Rwanda, Sri Lanka), land redistribution would probably not be effective in converting the mass of peasant producers to net food seller status. Improved peasant agricultural productivity seems essential both to improving the food security of the rural poor and to protecting tropical forests. Unfortunately, technology improvements take time and serious structural economic reforms have been immediately necessary to stem unsustainable macroeconomic imbalances in much of the low-income world. Hence, the earlier emphasis on the potential for labor market interventions such as food-for-work schemes.

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[15]Ideally, one would like to estimate something like a full information maximum-likelihood model with deforestation as one dependent variable—with the conditional mean and variance of the staple food price as regressors in that equation—in a system that also includes a GARCH model of the staple food price.

[16] Existing deforestation series, notably those produced by FAO, are estimated using questionable methods and include only a couple of annual point estimates used to infer trends (Rudel and Roper 1997). Time series constructed from satellite imagery may ultimately prove useful, but as yet these data are not available with sufficient frequency (e.g., annual time series of a few decades) to enable their use in time series models.

The implication of this paper is not that structural adjustment leading to higher and more variable food prices should be abandoned but, rather, that suitable policies must be introduced to mitigate or prevent negative deforestation externalities. Barrett and Carter (forthcoming) make a more general case for the need for ancillary interventions to complement macroeconomic and sectoral reforms with microeconomic correctives to incomplete and missing markets in agrarian environments. Introduction or enforcement of property rights that might restrict forest access might help temper induced deforestation, although the introduction of effective tenurial regimes in previously open access areas can be as slow a process as technological improvement. A more promising prospect is public works projects to stimulate demand for unskilled rural labor, thereby taking advantage of the inverse relation between wage rates and deforestation incentives.

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Table 1: Rice Production, Price Moments, and Farmer Characteristics in Madagascar

Region	Net Buyers as % of Rice Farms (1990)	1986-91/1983-85 % Change in Rice Price		Paddy Yield (tons/hectare, 1991)	Annual Avg. % Change in Paddy Area, 1985-91
		Mean	Variance		
Antsohihy	68	27.7	99.5	1.83	3.9
Taolagnaro	58	16.0	6.3	1.59	3.2
Toamasina	76	4.1	-33.5	1.09	2.2
Fianarantsoa	78	-3.3	30.8	1.93	2.1
Mahajanga	49	25.4	158.6	2.04	1.5
Morondava	48	9.1	20.6	1.68	1.5
Fenerive Est	48	10.9	-40.0	1.32	1.5
Ambatondrazaka	13	10.2	2.8	2.32	1.1
Itasy	41	-4.1	19.8	2.68	0.4
Toliary	36	2.5	-6.8	2.03	0.3
All Madagascar	49	11.3	28.9	1.98	1.9

Note: The above represent only 10 of Madagascar’s 17 agricultural enumeration regions. Household-level data necessary to estimate the proportion of net rice buyers among rice farmers are not available from the other seven regions.

Data sources: First three columns are drawn from Barrett and Dorosh (1996). The last two columns are computed from data provided by the *Service de la Méthodologie et du Traitement des Informations Statistiques*.