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Debt, Poverty and Resource Management in a Rural Smallholder Economy

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Abstract This paper develops a model to capture the key features of poverty, credit constraints and resource management faced by poor rural households. We assume that, due to the existence of asymmetric information and moral hazard, the household faces an increasing cost of credit as its debt/equity ratio rises. A household exploiting a natural resource may fall into a poverty trap, but only if it is unable to afford the increasing borrowing costs implied by increasing debt to allow it to avoid such a trap, or if it discounts future utility so much that a balanced growth path cannot be financed at any level of long-run borrowing. In contrast, along an optimal balanced growth path, the household's asset wealth, purchased inputs, resource stock and consumption increase at the same constant rate. However, over the long run there may be carrying capacity limits that prevent the resource from improving further. The household may then direct its savings to accumulating financial assets, and eventually under certain conditions may become a net creditor with resource exploitation becoming a less and less important source of its income.

Keywords Debt · Land degradation · Poverty traps · Less favoured agricultural land · Rural credit · Rural households

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1 Introduction

In his review of the case study literature on the relationship between, poverty, income distribution and the environment in developing countries, Markandya (1998, p. 460) concludes that "the linkages between poverty/income distribution and environmental policy are complex and not as well understood as they need to be… The biggest gaps arise because of our limited understanding of the role of institutions in shaping the linkages, and the way in which institutions evolve in response to changes in the economic and policy environment."

In the present paper we illustrate this key theme. In particular, we focus on the role of an important institutional constraint faced by many poor smallholders who live on marginal, and often remote, agricultural lands in developing countries: the lack of access to financial markets that offer affordable credit. These households often face problems of resource degradation and are frequently forced to borrow from informal credit markets at high effective interest rates. Under certain conditions, the outcome is to reinforce further the "poverty–environment trap", which is often prevalent for these marginal farmers (Barbier 2010). Or, as Kraay and McKenzie (2014, p. 143) state: "The evidence most consistent with poverty traps comes from poor households in remote rural regions".

In this paper we develop a model of smallholder behavior to capture these fundamental relationships between poverty, credit constraints and resource management that may be faced by a typical poor farming household in a marginal agricultural area. We assume that the household income is dependent on a natural resource (e.g. land) and purchased factors of production (e.g. capital), but the household is unable to borrow in formal markets to finance such purchases. The credit constraint is modelled by assuming that the household must borrow in the informal credit market paying an increasing interest rate as its level of debt/equity increases.[1] We focus on natural resources that are subject to well-defined property rights, mostly derived from the private ownership of the land. Finally, by obtaining more capital and working the land harder, the household increases production but also may cause more resource degradation (e.g. soil erosion and land degradation).

Such a model allows us to explore the conditions that influence the poor rural smallholder's decision to manage its debt and its natural resource asset over time. In particular, we show that, despite the smallholder being constrained by an increasing cost of borrowing, in the long run a balanced growth path in terms of consumption, household wealth and the resource stock is feasible. Not only does the household's level of borrowing dictates whether a balanced growth path is attainable in the long run but higher, rather than lower, borrowing is associated with the household achieving balanced growth. The reason for this result is that, for smallholders to succeed in expanding their levels of investment in both natural and man-made assets, and hence raise consumption over time, then these households must also be able to increase their level of borrowing to achieve this outcome.

By contrast, households that face a credit supply curve that is too steep may not be able to borrow enough as they would have to pay too high costs for borrowing. This implies that the household may need to rely in an ever more intense exploitation of their natural capital causing constant losses of natural capital and are not able to substitute it for man-made

[1] Alternatively, one may assume that households face quantitative constraints on credit availability instead of increasing cost of borrowing as we do here. Both assumptions yield similar results, and thus it is common to represent credit rationing in economic models as increasing the cost of borrowing (Jaffee and Stiglitz 1989; Stiglitz and Weiss 1981).

productive assets; thus they remain in a poverty trap. Similarly, households that are initially too poor may have very high time discount rates that would prevent them to save in the form of resource preservation or accumulation of other assets are also forced to remain in a poverty trap (López 1997).

Thus, by modeling the key aspects of the poverty, debt and resource management decisions faced by a typical poor household in a rural smallholder economy, our analysis is able to demonstrate how increasing borrowing costs add an important dimension to the poverty–environment "trap" faced by the household. For example, current growth models with poverty traps focus on the structural imbalances of a developing economy (Kraay and McKenzie 2014; Kraay and Raddatz 2007; López and Schiff 2013; Matsuyama 1992; Murphy et al. 1989; Sachs and Warner 2001; van der Ploeg 2011). Alternatively, exogenous rises in interest rates are often blamed for causing both increased household debt service obligations causing financial restrictions and resource degradation in rural areas of the developing world (Lipton 1997).

In contrast, our model suggests that neither structural imbalances nor exogenously increasing credit costs are necessary to generate poverty traps. We allow for the cost of capital to be endogenous showing that households whose initial endowments are not too poor and whose access to credit markets is not too unfavorable, their management of its long-term debt may determine whether or not it is caught in a long-run poverty trap. That is, the household may fall into a poverty trap, but only if it is unable to borrow more due to the increasing cost of borrowing that would allow it to avoid such a trap, or if it discounts future utility so much that a balanced growth path cannot be financed at any level of long-run debt.

However, we also show that high levels of the cost of debt service, dependence on resource exploitation, and the threat of a poverty trap may not necessarily be a permanent outcome for the rural smallholder. Over the long run, when the natural resource reaches carrying capacity limits and cannot improve any further, under certain conditions the household will attain a new balanced growth path in which it directs all savings to accumulating financial assets. Eventually, the household becomes a net creditor, earns asset income at the market rate of interest, and accumulates sufficient assets to progressively reduce its dependence on exploitation of the renewable resource, whether it be soil, fuel-wood, grazing land for livestock fodder, an agroforestry stand, or simply biomass.

The outline of our paper is as follows. The next section provides background on the problem of the concentration of poor households in fragile environments and on marginal agricultural lands prone to degradation. We also discuss the problem of the high indebtedness of and lack of access to formal credit by these households. We then develop our model of a rural smallholder household to capture the key linkages between natural resource degradation, indebtedness and poverty. We derive the balanced growth conditions for the rural smallholder, and use them to analyze the resource management decisions of the chronically indebted household and its tendency to fall into a poverty trap. We show the conditions under which the smallholder might escape this trap and become a net creditor. Our conclusion summarizes the key results of our analysis, and discusses their implications for policy.

2 Background

Since 1950, the estimated population in developing economies on "fragile lands" prone to land degradation has doubled (World Bank 2003). These fragile environments consist of upland areas, forest systems and dry-lands that suffer from low agricultural productivity, and areas that present significant constraints for intensive agriculture. Barbier (2010) shows that, for a sample of 92 low and middle income economies, the incidence of rural poverty rises

Table 1 Rural population on less favored agricultural lands, 2010

	Population in 2010 (millions)		
	Rural population (1)	Rural population on less favored agricultural land (2)	% Share (2)/(1)
Developing country	4248.6	1499.7	35.3
East Asia and Pacific	1499.1	709.4	47.3
Europe and C. Asia	180.7	97.7	54.1
Latin America and Caribbean	336.1	109.2	32.5
Middle East and N. Africa	237.2	50.4	21.3
South Asia	1284.0	309.7	24.1
Sub-Saharan Africa	711.4	223.2	31.4
Developed country	415.3	166.9	40.2
World	4663.9	1666.6	35.7

Less favored agricultural land consists of irrigated land on terrain >8 % median slope; rainfed land with a length of growing period (LGP) of more than 120 days but either on terrain >8 % median slope or with poor soil quality; semi-arid land (land with LGP 60–119 days); and arid land (land with LGP <60–119 days). These various land areas were determined by employing in Arc GIS 10.1 the datasets from the FAO Global Agro-Ecological Zones (GAEZ) Data Portal version 3 (http://gaez.fao.org/) combined with national boundaries from the Gridded Population of the World, Version 3 (GPWv3) of the Center for International Earth Science Information Network (CIESIN) and Centro Internacional de Agricultura Tropical (CIAT). Agricultural land extent was obtained from the Pilot Analysis of Global Ecosystems (PAGE) (http://www.ifpri.org/dataset/pilot-analysis-global-ecosystems-page), and rural population determined from the rural-urban extent dataset that was published as part of CIESIN Global Rural Urban Mapping Project (GRUMPv1). GIS estimates are for people per km^2 in 2010

Developing countries are all low and middle income economies with 2012 per capita income of $12,615 or less (World Bank 2014)

with the share of the total population concentrated on fragile lands, as defined by the World Bank (2003). Although the average poverty rate across all economies is 45.3 %, the rate falls to 36.4 % for those countries with <20 % of their population in fragile environments. For those with more than 50 % of their population in marginal areas, however, the incidence of rural poverty rises to 50 % or more.

Using spatial data sets from several sources, Table 1 provides estimates in 2010 of the share of rural population on less favored, or “marginal”, agricultural land. This consists of land that is susceptible to low productivity and degradation, because it is constrained by slope, poor soil quality or limited rainfall. Globally, around 1.7 billion people, or approximately 36 % of the rural population, can be found on less favored agricultural land. Almost all the rural population on marginal land, about 1.5 billion, is located in developing countries, and consists of over 35 % of the rural population. However, this share varies considerably by region. For example, East Asia and the Pacific has both the largest number of people on less favored agricultural land (709 million), and nearly half the rural population located on such land. Middle East and North Africa has 50 million people on marginal land, which is just over one fifth of its rural population.

The rural population on marginal lands of developing economies also tend to be concentrated in remote areas. Around 430 million people in developing countries live in locations with poor market access that require five or more hours to reach a market town of 5000 or more, and nearly half (49 %) of this population is located in arid and semi-arid regions characterized by frequent moisture stress that limits agricultural production (World Bank 2008).

Table 2 Rural population on less favored agricultural land, remoteness and poverty, 2010

	Population in 2010 (millions)			
	Rural population on less favored agricultural land	% Remote	National poverty headcount (%)	National poverty gap (%)
Developing country	1499.7	21.5	20.63	6.30
East Asia and Pacific	709.4	24.4	12.48	2.82
Europe and C. Asia	97.7	12.6	0.66	0.21
Latin America and Caribbean	109.2	13.5	5.53	2.89
Middle East and N. Africa	50.4	14.2	2.41	0.55
South Asia	309.7	16.0	31.03	7.09
Sub-Saharan Africa	223.2	29.4	48.47	20.95
Developed	166.9	5.9		
World	1666.6	19.9		

Less favored agricultural land consists of irrigated land on terrain >8 % median slope; rainfed land with a length of growing period (LGP) of more than 120 days but either on terrain >8 % median slope or with poor soil quality; semi-arid land (land with LGP 60–119 days); and arid land (land with LGP <60–119 days). These various land areas were determined by employing in Arc GIS 10.1 the datasets from the FAO Global Agro-Ecological Zones (GAEZ) Data Portal version 3 (Available online: http://gaez.fao.org/) combined with national boundaries from the Gridded Population of the World, Version 3 (GPWv3) of the Center for International Earth Science Information Network (CIESIN) and Centro Internacional de Agricultura Tropical (CIAT). Agricultural land extent was obtained from the Pilot Analysis of Global Ecosystems (PAGE) (http://www.ifpri.org/dataset/pilot-analysis-global-ecosystems-page), and rural population determined from the rural-urban extent dataset that was published as part of CIESIN Global Rural Urban Mapping Project (GRUMPv1). GIS estimates are for people per km^2 in 2010. Market accessibility was used to identify remote areas using Nelson (2008) as released by the Global Environment Monitoring Unit of the Joint Research Centre of the European Commission. Market access is identified as <5 h of travel to a market city with a population of 50,000 or more. Poverty data from PovcalNet: the on-line tool for poverty measurement developed by the Development Research Group of the World Bank (Available online: http://iresearch.worldbank.org/PovcalNet/). Poverty headcount is the percentage of population with consumption or income per person below the $1.25 per day poverty line. Poverty gap is the mean distance below the $1.25 per day poverty line as a proportion of the poverty line
Developing countries are all low and middle income economies with 2012 per capita income of $12,615 or less (World Bank 2014)

As indicated in Table 2, around 22 % of the rural population on marginal lands in developing countries are located five or more hours from a market city with a population of 50,000 or more. The regions with the largest share of their rural population in marginal and remote areas are Sub-Saharan Africa (29 %), East Asia and Pacific (24 %) and South Asia (16 %). These three regions also tend to have the highest incidence of national poverty.

Thus, the previous evidence shows that a large segment of the rural population of developing economies are often concentrated in ecologically fragile and remote locations, which makes them prone to fall in poverty traps. To understand why, it is important to identify the typical conditions facing the poor in such regions, and how these conditions are influenced by the lack of access to formal credit.

Land is one of the few assets owned by the rural poor, and almost all households engage in some form of agriculture, but the size of landholdings tends to be small (Banerjee and Duflo 2007). The range of choices and tradeoffs available to the poor, and their dependence on the surrounding environment, is also affected by their access to key markets, such as for land, labor, and especially credit, as well as the quality and state of the surrounding environment on which their livelihoods depend (Banerjee and Duflo 2010; Barbier 2010; Carter and Barrett 2006; Caviglia-Harris 2004; Gray and Mosley 2005; Pattanayak et al. 2003; World Bank 2008). As summarized by Dasgupta (1993, p. 475) "in rural communities of poor countries a great many markets of significance (e.g. credit, capital, and insurance) are missing, and a number of commodities of vital importance for household production (potable water, sources of fuel and fodder, and so forth) are available only at considerable time and labour cost." In the absence of local labor markets capable of absorbing all the poor and landless households looking for work, or well-functioning rural credit markets to lend needed capital, the landless and near landless in rural communities often fall back on the use of common-property and open access resources for their income and nutritional needs (Barbier 2010). This is especially the case in remote rural areas, where local markets are isolated from larger regional and national markets and essential public services are lacking (Barrett 2008).

López (1997, 1998) have shown that environmental degradation and poverty are connected through two mechanisms: first, households struggling to survive need to over exploit their natural resources causing their degradation. This over the long run reduces even further their capacity to generate income thus making even harder their ability to survive. An additional mechanism is that poor households may not be able to invest in man-made assets that could compensate or even be used to repair the degraded natural assets, which worsen their poverty situation making the poverty trap even deeper. One potential way out of the poverty trap is the credit market. If households can have access to credit in reasonable conditions they could then gradually start rebuilding their natural assets thus increasing their income, saving capacity and in turn improving the conditions to credit access. That is, favorable credit market conditions could in principle transform a vicious cycle of poverty, environmental degradation and more poverty into a virtuous cycle of poverty reduction, increasing natural and man-made assets, further improvement in access to credit and income growth.

Unfortunately, credit market is perhaps one of the most important "missing markets" that is critical to the natural resource management decisions of poor rural smallholders. Throughout the developing world, the ability of poor farmers to obtain credit for land improvements is limited either by restrictions on the availability of rural credit for this purpose, or because insecure property rights mean that poor farmers are not eligible for credit programs (Barbier 2010; Binswanger and Deininger 1997; Carter and Barrett 2006; Feder 1985; Pattanayak et al. 2003; Zeller et al. 1997). In particular, legal land titles prove to be significant in helping alleviate liquidity constraints affecting the purchase of working inputs, as well as land improvements generally, yet many smallholders do not have legally recognized titles to their land (Besley 1995; Brasselle et al. 2002; Deininger and Jin 2006; Feder and Onchan 1987; López and Valdés 1998). In any case, often the only asset available to poor rural households for collateral is their land, and this may not always be allowed as the basis for acquiring loans (Banerjee and Duflo 2010; Boucher and Guirkinger 2007; Zeller et al. 1997). In addition, for many poor rural households, "imperfect insurance markets, spatial dispersion, and covariant incomes add to the difficulties of obtaining access to credit" (Binswanger and Deininger 1997, p. 1971; see also Boucher and Guirkinger 2007; Carter and Barrett 2006; Hoff and Stiglitz 1990; Stiglitz 1987).

Thus even if formal credit is available in rural areas, poor smallholders usually are not eligible or unable to take advantage of it to finance the inputs needed for improved land management and productivity (Barbier 2010; Binswanger and Deininger 1997; Feder 1985; Pattanayak et al. 2003). Estimates suggest that only 5 % of farmers in Africa and around 15 % in Latin America and Asia have access to formal credit. Moreover, around 5 % of all borrowers receive 80 % of all formal credit (Hoff et al. 1993). A study across five countries in Latin America indicates that access to either extension assistance or credit for input purchases by smallholders ranges between 13 and 33 % (López and Valdés 1998). Of the rural producers surveyed across Mexico who received credit from formal sources, only 9.6 % had holdings of 0–2 ha (Deininger and Minten 1999). Many poor smallholders in developing countries are therefore forced to meet both consumption and input needs by borrowing from informal credit sources, often at much higher effective rates of interest (Banerjee and Duflo 2010; Binswanger and Sillers 1983; Boucher and Guirkinger 2007; Chaves and Sánchez 1998; Zeller et al. 1997). For example, a survey of poor households across 13 developing countries revealed that with the exception of Indonesia (where there has been a large expansion of government-sponsored microcredit), no more than 6 % of the funds borrowed by the poor came from a formal source (Banerjee and Duflo 2010).

Because of the limited income-earning potential from their smallholdings, many poor rural households reach debt/equity ratios that are so high that they must pay exorbitant costs of borrowing which impede them to adequately finance basic consumption and production needs. Imperfections in the rural capital market often limit households' options for smoothing consumption from one period to the next, accumulating capital, and financing investments, especially for land improvements (Carter and Barrett 2006; Zeller et al. 1997). In addition, in formal capital markets, access to credit and the cost of borrowing is mostly determined by either the household's capacity to save or its ownership or control of assets (usually other than land). The lower the household's wealth and risk-bearing ability relative to its debt, the lower its access to formal credit and insurance services. As a household's debt/equity ratio rises, it is forced to borrow from other informal sources, such as money lenders, traders, merchants and processors, but at higher interest rates and transaction costs, leading to effective real interest rates that can increase to as much as 100 % per year (Binswanger and Sillers 1983; Banerjee and Duflo 2010; Boucher and Guirkinger 2007; Chaves and Sánchez 1998; Zeller et al. 1997).

Given these difficulties faced by poor rural smallholders in financing land improvement and other expenditures, degradation of agricultural land is a serious and growing problem across the developing world. Estimates indicate that over 1.5 billion people are affected by land degradation worldwide, with almost all located among the rural population of developing countries (Bai et al. 2008; de Jong et al. 2011). Over 2000–2030, the area of degrading agricultural land is expected to increase globally by 1–2.9 million hectares (ha) annually, with much of this expansion occurring in the developing countries (Lambin and Meyfroidt 2011). As a result, at least 135 million ha of forests, wetlands and other non-cultivated land will be converted to cropland by 2030, with some of this serving to replace land lost to degradation (Lambin and Meyfroidt 2011).

But as this new land converted forest and wetlands for agriculture is likely to be more ecologically fragile and marginal (Barbier 2010; World Bank 2003), the problems posed by the lack of access to affordable credit markets, increased land and resource degradation, and persistent poverty will continue to plague many rural smallholders for some time.

3 The Rural Smallholder Model

The following model analyzes the behavior of a representative household of a smallholder rural economy, in which the household exploits a renewable or semi-renewable resource for production. The resource could be soil, fuel-wood, grazing land for livestock fodder, an agroforestry stand, or simply biomass, but as we are interested mainly in the problem of land degradation, it can be assumed that the resource stock is topsoil. In addition to managing its available resource stock, the household may also either accumulate a stock of asset wealth to finance purchases of production inputs, or alternatively borrow money in a local informal rural credit market to cover these purchases. Purchased inputs could be capital goods or any other factor of production.

There are two possible debt-equity scenarios for the rural smallholder. Under some circumstance, the household will accumulate enough wealth through net saving in order to self-finance the purchases of all its production factor requirements, in which case the household will be a "net saver" or "creditor". However, we focus on the more interesting and realistic scenario when the household initially needs to complement its savings with borrowing.

To sharpen the analysis, we assume that the land holding and the own labor of the household are fixed in supply; the household may produce several outputs. By combining the resource stock with the stock of purchased productive assets, the household generates an aggregate quantity of productive assets used in production to maximize profits. Let z be the vector of purchased productive factors and x the resource stock available to the household, and let p be vector of output prices. Denoting R as the maximized net revenues, or profit, of the household with respect the use of z and x, for convenience we write this profit function as

$$R = R(p; z, x) = \varphi(z, x)\tilde{R}(p), \quad \varphi_i > 0, \varphi_{ii} < 0, i = z, x, \tag{1}$$

where the function φ represents a quantifiable index of the aggregate combination of z and x used in production by the household. We assume that this function is increasing, concave and to assume it is linearly homogenous (constant returns to scale).[2] $\tilde{R}(p)$ is the profit per unit of the aggregate combination of z and x. Unless price change, per unit profit is assumed to be constant; hence, for the sake of saving notation we can choose the units of the exogenous prices so that $\tilde{R} = 1$.

The behavior of the smallholder is therefore determined by the impact of resource management and asset accumulation on overall income generation and consumption.[3] Thus the objective of the household is to maximize utility from consumption, c, and choice of variable inputs, z

$$\underset{c,z}{Max} \int_0^\infty e^{-\delta t} U(c) dt \tag{2}$$

subject to changes in the renewable resource stock,

$$\dot{x} = k_0 x - az. \tag{3}$$

In addition the household maximization is also constrained by the budget constraint which we specify below. In the objective function (2), δ is the household's private rate of discount, and the utility function is assumed to be strictly concave with a constant elasticity of marginal utility. Equation (3) indicates that the resource stock, which is a semi-renewable, will naturally replenishes at a constant rate, k_0; however, the stock is also depleted through its use in agricultural production. To simplify the analysis, the rate of depletion is proportional to the employment of purchased production factors used in production relative to the stock of natural assets, z/x.[4] Because we focus on natural resources that are subject to well defined

[2] The assumption of constant returns to scale considerably reduces algebraic clutter but does not affect the qualitative results.

[3] To simplify the analysis we assume that the household population is constant.

[4] The assumption that optimal depletion is a function of the level of inputs used in production is particularly common for models of optimal depletion of soils in developing countries, which also generally assume that this semi-renewable resource that replenishes at a constant rate; e.g. see Barbier (1990), Barrett (1991) and Grepperud (1995). However, we have simplified our analysis of the rural smallholder resource degradation problem to abstract from such problems as the role of climate variability in influencing land degradation

property rights, we assume in (2) that the household considers the dynamics of the natural resource as a relevant constraint.

In addition to productive factors z, the household also accumulates a stock of financial asset wealth, A, which may be used to finance purchases of productive factors through expenditure, wz, where w is the unit price of productive factors of production. Without loss of generality and solely to save notation we pick the units of z so that its exogenous price $w = 1$. The household may also borrow money in the local rural credit markets to complement its own financial assets to purchase productive factors. Defining D as the household's stock of debt, then $A + D = z$, and all financial assets available to the household are invested in z. The debt-equity ratio of the household is therefore,

$$\frac{D}{A + D} = \frac{z - A}{z} = 1 - \frac{A}{z}. \tag{4}$$

It follows that if $A/z < 1$ then the household is *indebted*. If $A/z \geq 1$, the household is a *net saver*.

Following the discussion in the introduction, we assume that any rural smallholder that is initially indebted (i.e. $A/z < 1$) is either considered a "credit risk" in commercial markets, or as is more likely the case in rural areas of developing countries, is generally unable to obtain loans in commercial markets and hence must borrow at higher rates from "informal" credit lending sources. As a result, the household will pay a "premium" over the prevailing commercial market rate of interest. The greater the degree of indebtedness, i.e. as A/z decreases, the higher the interest rate premium the household must pay on its outstanding debt. Alternatively, a decrease in the household's level of indebtedness would reduce the premium.

We therefore represent the effect of household indebtedness on the cost of borrowing ($\tilde{r}$) as

$$\tilde{r} \equiv r\left(1 + \beta\left(1 - \frac{A}{z}\right)\right), \quad \beta > 0, \quad \beta\left(1 - \frac{A}{z}\right) > 0 \text{ for } \frac{A}{z} < 1, \tag{5}$$

where r is the prevailing rate of interest in commercial credit markets, and β is the interest rate premium multiplier for the indebted household.[5] Finally, the change in the financial asset wealth, A, or budget constraint of a representative household is determined by

$$\dot{A} = \varphi(z, x) - \tilde{r}(z - A) - c, \tag{6}$$

where we have assumed that $\tilde{R} = 1$. Thus, the budget constraint (6) says that the household's consumption plus asset accumulation ($c + \dot{A}$) must be equal to its income net of borrowing costs ($\varphi(z, x) - \tilde{r}(z - A)$). Denoting λ and μ as the current value costate variables corresponding to A and x respectively, then the current-value Hamiltonian of the household's maximization problem is

$$H = U(c) + \lambda\left[\varphi(z, x) - \tilde{r}(z - A) - c\right] + \mu\left[k_0 x - az\right]. \tag{7}$$

Footnote 4 continued
decisions (Grepperud 1997) and the soil erosion problem in the context of a common property bush-fallow rotation system (López 1997) or shifting cultivation (Pascual and Barbier 2007). We also do not consider the potential impacts of varying property right regimes on the resource degradation problem (Larson and Bromley 1990).

5 Thus the analysis presumes that the rural economy is part of a larger economy that includes a financial market, with r^M the prevailing interest rate determined in the latter market. We therefore assume in our model that r^M is exogenously determined, but as will be discussed further below, not necessarily fixed over time.

The first order conditions are (3) and (6) plus the following

$$U_c(c) = \lambda \tag{8}$$

$$\varphi_z(z/x) = r\left[1 + \beta\left(1 - \frac{A}{z}\right)\left(1 + \frac{A}{z}\right)\right] + \frac{\mu}{\lambda}a \tag{9}$$

$$\frac{\dot{\lambda}}{\lambda} = \delta - r\left(1 + 2\beta\left(1 - \frac{A}{z}\right)\right) \tag{10}$$

$$\frac{\dot{\mu}}{\mu} = \delta - k_0 - \frac{\lambda}{\mu}\varphi_x(z/x). \tag{11}$$

The corresponding necessary transversality conditions for this infinite time horizon problem are

$$\lim_{t\to\infty}[\lambda(t)A(t)] = 0;\ \lim_{t\to\infty}[\mu(t)x(t)] = 0. \tag{12}$$

A subscript on a function denotes first derivative with respect to the corresponding argument. We note that given the assumption of constant returns to scale, the marginal products of z and x, $\varphi_z(z/x)$ and $\varphi_x(z/x)$ respectively, are homogenous of degree zero and hence are functions solely of the factor ratios. Concavity and gross complementarity mean that the function $\varphi_z(z/x)$ is decreasing while the function $\varphi_x(z/x)$ is increasing in the z/x ratio.

Equation (8) is the standard condition that the marginal utility of consumption for the household must equal the (shadow) value of foregone wealth, in the form of asset A. Condition (9) determines the optimal allocation of purchased productive factors, z. The indebted smallholder equates the marginal profit contribution of increased use of purchased factors of production with the marginal cost of the factor use in terms of resource depletion, $\frac{\mu}{\lambda}a$, plus the costs associated with the additional indebtedness required to finance productive asset purchases. The latter costs consist of the increase in overall household debt as well as the higher interest rate premium on borrowing that the smallholder faces due to greater indebtedness.

Conditions (10) and (11) indicate respectively the optimal allocation rules for holding on to financial wealth, A, and the renewable resource, x, as economic assets. As Eq. (10) indicates, for the indebted household wealth is accumulated up to the point where any capital gains plus the marginal changes in the debt position of the household equal the discount rate, which represents the opportunity cost to the household of holding on to wealth today. Similarly, the household will exploit the resource up to the point where any capital gains plus the current marginal profit attributed to the resource, $\varphi_x\lambda/\mu$, equal the discount rate. Finally, the transversality conditions indicate that the value of the household's assets and resource stocks must tend to zero as time approaches infinity, which will ensure that the household does not have any remaining assets left over at the end of the planning horizon.[6]

Differentiating Eq. (8) with respect to time and then using (10) we obtain the rate of growth of consumption of the household along the optimal path,

$$\frac{\dot{c}}{c} = \frac{1}{\sigma}\left[r\left(1 + 2\beta\left(1 - \frac{A}{z}\right)\right) - \delta\right] \tag{13}$$

where $\sigma \equiv -\frac{cU_{cc}}{U_c} > 0$ is the elasticity of marginal utility, which is assumed to be constant. That is, the rate of consumption growth is proportional to the gap between the marginal return to the asset A, which in turn is equal to the marginal cost of credit, and the time discount rate.

[6] The transversality condition implies that the value of the assets converges to zero as time approaches infinity, but it does not necessarily imply that the physical level of the asset asymptotically converges to zero.

4 Long Run Growth Equilibrium

Equations (3), (6) and (8)–(11) govern the optimal dynamic path of the representative smallholder with respect to changes over time in household consumption, purchased productive factors, wealth and the resource stock. In the long run, under certain conditions, this dynamic system may converge to a balanced growth path if $\dot{A}/A, \dot{x}/x, \dot{c}/c,$ and $\dot{z}/z$ are positive and constant over time. Moreover, if this path entails a positive and constant growth of consumption, there is constant growth in household wealth and the resource stock; it then follows that $\dot{\lambda}/\lambda$ and $\dot{\mu}/\mu$ must also be declining at a constant rate.

In the following section we demonstrate that such a balanced growth path is feasible. The conditions determining long run consumption growth for the rural smallholder are endogenously determined by the household's long run level of indebtedness. In fact, depending on its level of indebtedness in the long run, the household may be able to attain constant consumption growth as opposed to constant or declining consumption levels over time.

From (10) and (11) $\dot{\lambda}/\lambda = \dot{\mu}/\mu$ suggests

$$r\left(1+2\beta\left(1-\frac{A}{z}\right)\right) = k_0 + \varphi_x(z/x)\frac{\lambda}{\mu}. \tag{14}$$

Also, the condition $\frac{\dot{c}}{c} = \frac{\dot{x}}{x}$ implies that

$$\frac{1}{\sigma}\left[r\left(1+2\beta\left(1-\frac{A}{z}\right)-\delta\right)\right] = k_0 - \frac{z}{x} \tag{15}$$

In addition, Eq. (9) is still valid in the long run. Finally, the balanced growth path also implies that $\frac{\dot{A}}{A} = \frac{\dot{c}}{c}$. Using (6) and (13) we then have

$$\frac{x}{A}\varphi\left(1,\frac{z}{x}\right) - r\left(1+\beta\left(1-\frac{z}{A}\right)\right)\left(\frac{z}{A}-1\right) - \frac{c}{A} = \frac{1}{\sigma}\left[\delta - r\left(1+2\beta\left(1-\frac{A}{z}\right)\right)\right] \tag{16}$$

Equations (9), (14) and (15) can be solved simultaneously for three endogenous variables, $\frac{A}{z}$, $\frac{x}{z}$ and $\frac{\lambda}{\mu}$. In addition, using these values in (16) we can solve for the long run level of the consumption to financial asset ratio, $\frac{c}{A}$. Note that, given the values for $\frac{A}{z}$ and $\frac{x}{z}$ derived from the simultaneous solution of (9), (14) and (15), the equilibrium level for $\frac{x}{A}$ is also found. Therefore, the only remaining unknown endogenous variable to be determined by (16) is $\frac{c}{A}$. Thus, in the long run balanced growth equilibrium all four endogenous ratios are fixed.

These conditions are necessary but not sufficient for the indebted household to attain positive balanced growth. This can be seen most clearly from (13), which implies that

$$\frac{\dot{c}}{c} \gtreqless 0 \quad \text{if r}\left(1+2\beta\left(1-\frac{A}{z}\right)\right) \gtreqless \delta, \tag{17}$$

where $\frac{A}{z}$ is evaluated at its long-run equilibrium level obtained from the solution to the system (9), (14), (15) and (16).

The rate of interest in the long run is endogenously determined by the household's level of indebtedness. Over the long run, the household is only able to generate positive growth if it is willing to increase its borrowing and pay the higher interest rate premiums resulting from this greater borrowing. This in turn is possible if the marginal products of the factors of production are sufficiently high to make increased debt optimal. The household will make this sacrifice of current for future consumption, if it considers the interest rate cost associated with this increased borrowing to be greater than the discount rate that the household applies to future utility. The household values future utility sufficiently to incur greater indebtedness

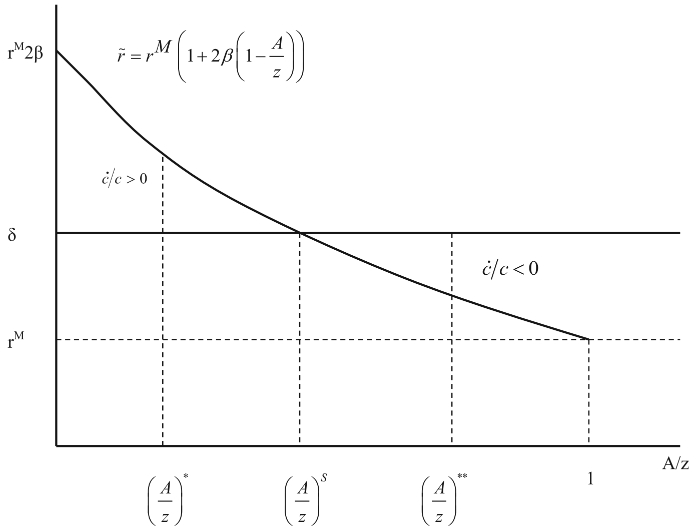

Fig. 1 Long run outcomes for the chronically indebted household

and borrowing costs today in order to finance increased future consumption as well as wealth accumulation. In effect, increased future consumption is the compensation for incurring higher debt and borrowing costs today.

Figure 1 illustrates the possible long run outcomes for the chronically indebted household. As discussed above and shown in the figure, balanced growth (i.e., $\dot{c}/c > 0$) occurs only if the household is prepared to incur higher debt, $(A/z)^*$, and thus increased borrowing costs today relative to the discount rate, δ. The household will do so if the marginal benefit of investing in its assets (A and x), which are required to be equalized as an optimization condition, is higher than its time discount rate.

However, if the returns to its assets are low enough or if its discount rate is too high due to, for example, extreme poverty then the household is unwilling to borrow more and pay higher interest rates in the long run to finance its investments on the financial and productive assets. In this case the household may lower its long-run debt level to $(A/z)^S$ until its consumption is at a steady state (i.e., $\dot{c}/c = 0$); that is, the household income stagnates.

5 Long Run Growth When the Resource Stock Reaches a Maximum Level

The previous analysis is valid for households that have an initial stock of natural resources that is highly degraded. In this case, a household whose discount rate is not too high relative to its productivity (that is, is not too poor) and uses the (informal) credit market efficiently may be able to exhibit balanced growth where the resource stock and the financial assets continuously grow at the same rates. However, after growing for a period of time (which could be quite long) the resource may reach its maximum carrying capacity at which point it ceases to grow. In this case,

$$\dot{x} = k_0 x - az = 0 \tag{18}$$

Hence, both x and z reach steady-state fixed levels. Denote the steady state of these variables as $\bar{x}$ and $\bar{z}$, respectively. Also, from (18), the long run level of the factor input to resource ratio is

$$(z/x)^* = k_0/a \tag{19}$$

Then given that the natural resource stock cannot grow any further, it follows that consumption growth must rely exclusively on the expansion of the financial assets. Eventually, given that z is constant while A is increasing over time, the A/z ratio becomes >1, the household becomes a net creditor. At this point the relevant opportunity cost of capital ceases to depend on the asset position of the household and becomes equal to the market interest rate, r. It follows that $\frac{A}{z} \geq 1$ and $\beta\left(1 - \frac{A}{z}\right) = 0$. The new long-run balanced growth conditions of the household are

$$\frac{\dot{\lambda}}{\lambda} = \delta - r, \tag{20}$$

$$\frac{\dot{\mu}}{\mu} = \delta - \frac{\lambda}{\mu}\varphi_x(\bar{z}/\bar{x}) \tag{21}$$

$$\frac{\dot{A}}{A} = \frac{\varphi(\bar{z},\bar{x})}{A} - r\left(\frac{\bar{z}}{A} - 1\right) - \frac{c}{A}, \tag{22}$$

Still condition (8) holds as before. Differentiating (8) with respect to time and using (20) we obtain the consumption growth rate for the creditor household,

$$\frac{\dot{c}}{c} = \frac{1}{\sigma}\left[r - \delta\right] \tag{23}$$

Equalizing (22) and (23), and noting that $\lim_{t\to\infty} \frac{\varphi(\bar{z},\bar{x})}{A} = \lim_{t\to\infty} \frac{\bar{z}}{A} = 0$, the long run c/A ratio for the net creditor household is

$$(c/A)^* = \left(1 - \frac{1}{\sigma}\right) r + \delta/\sigma. \tag{24}$$

The most important implication of this analysis is that as long as the market rate of return to the financial assets of the household is above its discount rate ($r - \delta > 0$) the household can continue increasing its consumption indefinitely even if the natural resource stock becomes fixed at its maximum carrying capacity. Farm production becomes a progressively a smaller fraction of the household income. The household growth becomes more and more dependent on its financial assets and eventually will tend to grow exclusively on the basis of expanding its financial assets.

Thus, this model illustrates the transition of a successful household able to manage its natural resources optimally from a mostly agricultural-dependent household to one in which non-agricultural income becomes more and more important. All of this occurs while allowing the natural resources to be conserved. The long-run optimal path for the household thus replicates the economy-wide stylized fact so often documented in the literature, in which the share of agriculture in national income secularly falls with economic development. Of course this does not occur in the case where the household is initially too poor with a discount rate that is too high relative to its asset productivity. These household simply stagnate or may even fall into a poverty spiral.

6 Conclusions

Several notable results emerge from the analysis of our model.

First, smallholder indebtedness per se is not an obstacle to the household attaining a balanced growth path. In fact, as is clear from Fig. 1, higher and not lower indebtedness is associated with the household achieving balanced growth. The reason is that a household will get a higher debt only if the rate of return to its assets is high enough. That is, only households that have high asset productivity will face effective cost of capital above their discount rates and therefore be able to grow its consumption over the long run. By contrast, low productivity households will have a relatively lower cost of capital because they will borrow very little and consequently their consumption may stagnate over the long run. Thus, a high cost of capital is not necessarily bad for the household; it will simply reflect that the household is able to borrow more because its assets have a high productivity.

Second, our model has demonstrated that, for such a household, increasing its long-run debt and thus the cost of borrowing can be an optimal strategy resulting in balanced growth in consumption, asset accumulation and resource improvement. These results therefore suggest caution in supporting broad policy statements, such as "rising real interest rates of interest, transmitted to LDCs and to their developing rural areas, are likely to cause rising rates of resource degradation, via private incentives and public capacities" (Lipton 1997, p. 147). Our model makes it clear that interest rates are endogenous and that a high cost of capital may either be due to high market rates, in which case Lipton's statement is correct, or to merely high levels of household debt, in which case such a statement may be wrong. High costs of capital in the case of imperfect credit markets may be a reflection of high household productivity which lead them to increase debt. As we have seen in the case of indebted households, this trade-off between high interest rates and balanced growth is endogenously determined by the long-run debt strategy of the household. For the indebted households of a rural economy, increased future consumption and an improved resource stock is the compensation for incurring higher debt and borrowing costs today, or alternatively, the costs of consumption growth and resource improvement is incurring greater current debt and borrowing costs.

Our analysis suggests that the real threat to improved long-run resource management in the rural economy of developing countries is not necessarily higher *ex-post* costs of capital but a high rate of private discount applied to households' future utility. As is easily seen from Fig. 1, if δ is sufficiently high that no intersection occurs with the r curve, then the indebted household will always choose a long-run strategy that leads to consumption decline, wealth disinvestment and resource degradation.

Finally, at least for a rural smallholder economy, our model provides an alternative explanation of the existence of a possible *poverty trap*, or more accurately a poverty–debt–environmental degradation trap, than suggested by the existing growth literature. Current growth models with poverty traps focus on the structural imbalances of a developing economy (Kraay and McKenzie 2014). For example, the big-push model of the poverty trap focuses on the inability of developing countries to move from a structural dependence on an agricultural sector that exhibits diminishing returns to a permanent transition to an industrial and service-based economy that displays increasing returns in the long run (Murphy et al. 1989). Similarly, Dutch disease theories suggest that resource-price booms in a resource-abundant developing country will lead to expansion of primary sectors at the expense of more dynamic and growth-enhancing industrial sectors (Matsuyama 1992; Sachs and Warner 2001; van der Ploeg 2011). Other theories stress the influence of inadequate savings and investment in a subsistence-dominated economy or the presence of structural anomalies, such as open access resource exploitation (Kraay and Raddatz 2007; López and Schiff 2013).

In our model, declining consumption, wealth and resource stocks may occur in a rural smallholder economy without assuming diminishing returns or any other structural imbalance in that economy, such as open access conditions or subsistence consumption. Chronically indebted households will face a long-run poverty–debt–environmental degradation trap if they are unwilling or unable to incur the greater debts (and, consequently, borrowing costs) necessary to avoid such a trap, or if they discount future utility so much that a balanced growth path cannot be financed at any level of long-run debt. Of course a reason for a high discount rate is extreme poverty in which case its discount rate will naturally be very high. In this case if its asset productivity is low enough such household will remain stagnated in a poverty trap.

However, we also show the conditions under which a household can permanently escape the threat of a poverty–debt–environmental degradation trap. Our model assumes that the indebted rural household is managing a highly degraded resource (e.g. marginal and low productivity land). The optimal balanced growth for the household involves both a constant rate of asset accumulation and resource improvement. However, as we have shown, there may be carrying capacity limits on the ability of the resource to improve indefinitely, thus suggesting that the resource stock should attain a steady state eventually over the long run. But once the natural resource reaches a steady state, the household is likely to become a net creditor. Along this new balanced growth path where the resource is at its maximum carrying capacity, all household savings are directed to increase financial assets. Thus, this wealth A continues to increase until the ratio of assets to purchased inputs A/z becomes >1. At this point the household becomes a net creditor, and its financial wealth continues to grow as long as the market interest rate exceeds the household's discount rate. Consumption continues to grow at a constant rate, which is the same rate of growth in the household's financial wealth. Income from agricultural production over the very long run becomes a negligible fraction of the household's overall income. That is, our model is able to show explicitly the conditions for the successful transition of a chronically indebted rural smallholder farming marginal land to a household that is a net creditor that eventually accumulates sufficient assets to eliminate its dependence on exploitation of the renewable resource, whether it be soil, fuel-wood, grazing land for livestock fodder, an agroforestry stand, or simply biomass.

References

Bai ZG, Dent DL, Olsson L, Schaepman ME (2008) Proxy global assessment of land degradation. Soil Use Manag 24:223–234

Banerjee AV, Duflo E (2007) The economic lives of the poor. J Econ Perspect 21(1):141–168

Banerjee AV, Duflo E (2010) Giving credit where it is due. J Econ Perspect 24(3):61–80

Barbier EB (1990) The farm-level economics of soil conservation: the uplands of Java. Land Econ 66(2):199–211

Barbier EB (2010) Poverty, development and environment. Environ Dev Econ 15:635–660

Barrett S (1991) Optimal soil conservation and the reform of agricultural pricing policies. J Dev Econ 36:167–187

Barrett CB (2008) Smallholder market participation: concepts and evidence from eastern and southern Africa. Food Policy 33:299–317

Besley T (1995) Property rights and investment incentives: theory and evidence from Ghana. J Polit Econ 103(5):903–907

Binswanger HP, Deininger K (1997) Explaining agricultural and agrarian policies in developing countries. J Econ Lit 35:1958–2005

Binswanger HP, Sillers DA (1983) Risk aversion and credit constraints in farmers' decision-making: a reinterpretation. J Dev Stud 22:504–539
Boucher S, Guirkinger C (2007) Risk, wealth, and sectoral choice in rural credit markets. Am J Agric Econ 89(4):991–1004
Brasselle A-S, Gaspart F, Platteau J-P (2002) Land tenure security and investment incentives: puzzling evidence from Burkina Faso. J Dev Econ 67:272–418
Carter MR, Barrett CB (2006) The economics of poverty traps and persistent poverty: an asset-based approach. J Dev Stud 42(2):178–199
Caviglia-Harris JL (2004) Household production and forest clearing: the role of farming in the development of the Amazon. Environ Dev Econ 9:181–202
Chaves RA, Sánchez SM (1998) Poverty, entrepreneurs and financial markets in the rural areas of Mexico. In: López R, Valdés A (eds) Rural poverty in Latin America. The World Bank, Washington DC
Dasgupta P (1993) An inquiry into well-being and destitution. Oxford University Press, Oxford
de Jong R, de Bruin S, Schaepman M, Dent D (2011) Quantitative mapping of land degradation using Earth observations. Int J Remote Sens 32:6823–6853
Deininger K, Minten B (1999) Poverty, policies and deforestation: the case of Mexico. Econ Dev Cult Change 47(2):313–344
Deininger K, Jin S (2006) Tenure security and land-related investment: evidence from Ethiopia. Eur Econ Rev 50(5):1245–1277
Feder G (1985) The relation between farm size and farm productivity: the role of family labor, supervision and credit constraints. J Dev Econ 18:297–313
Feder G, Onchan T (1987) Land ownership security and farm investment in Thailand. Am J Agric Econ 69:311–320
Gray LC, Mosley WG (2005) A geographical perspective on poverty–environment interactions. Geogr J 171(1):9–23
Grepperud S (1995) Soil conservation and governmental policies in tropical areas: does aid worsen the incentives for arresting erosion? Agric Econ 12:129–140
Grepperud S (1997) Poverty, land degradation and climatic uncertainty. Oxford Econ Papers 49(4):586–608
Hoff K, Stiglitz JE (1990) Introduction: imperfect information and rural credit markets—puzzles and policy perspectives. World Bank Econ Rev 4(3):235–250
Hoff K, Braverman A, Stiglitz JE (eds) (1993) The economics of rural organization: theory, practice and policy. Oxford University Press, Oxford
Jaffee D, Stiglitz J (1989) Credit rationing. The Macmillan Press Ltd, London
Kraay A, McKenzie D (2014) Do poverty traps exist? Assessing the evidence. J Econ Perspect 28:127–148
Kraay A, Raddatz C (2007) Poverty traps, aid, and growth. J Dev Econ 82:315–347
Lambin EF, Meyfroidt P (2011) Global land use change, economic globalization, and the looming land scarcity. Proc Natl Acad Sci 108:3465–3472
Larson BA, Bromley DW (1990) Property rights, externalities, and resource degradation. J Dev Econ 33:235–262
Lipton M (1997) 'Exogenous' interest rates, technology, and farm prices versus 'endogenous' conservation incentives and policies. In: Vosti SA, Reardon T (eds) Sustainability, growth and poverty alleviation: a policy and agroecological perspective. The Johns Hopkins University Press, Baltimore, pp 146–153
López R (1997) Environmental externalities in traditional agriculture and the impact of trade liberalization: the case of Ghana. J Dev Econ 53:17–39
López R (1998) The tragedy of the commons in Côte d'Ivoire agriculture: evidence and implications for evaluating trade policies. World Bank Econ Rev 12:105–131
López R, Schiff M (2013) Interactive dynamics between natural and man-made assets: the impact of external shocks. J Dev Econ 104:1–15
López R, Valdés A (eds) (1998) Rural poverty in Latin Amercia. The World Bank, Washington DC
Markandya A (1998) Poverty, income distribution and policy making. Environ Resour Econ 11:459–472
Matsuyama K (1992) Agricultural productivity, comparative advantage, and economic growth. J Econ Theory 58:317–334
Murphy KM, Shleifer A, Vishny RW (1989) Industrialization and the big push. J Polit Econ 97:1003–1026
Pascual U, Barbier EB (2007) On price liberalization, poverty, and shifting cultivation: an example from Mexico. Land Econ 83(2):192–216
Pattanayak SK, Mercer DE, Sills E, Yang J-C (2003) Taking stock of agroforestry adoption studies. Agrofor Syst 57:173–186
Sachs JD, Warner AM (2001) The curse of natural resources. Eur Econ Rev 45:827–838
Stiglitz JE (1987) Some theoretical aspects of agricultural policies. World Bank Res Obs 2(1):43–53
Stiglitz JE, Weiss A (1981) Credit rationing in markets with imperfect information. Am Econ Rev 71:393–410

van der Ploeg R (2011) Natural resources: curse or blessing? J Econ Lit 49:366–420

World Bank (2003) World Development Report 2003. World Bank, Washington DC

World Bank (2008) Word Development Report 2008: Agricultural Development. The World Bank, Washington DC

World Bank (2014) Word Development Indicators. The World Bank, Washington DC. Available from the World Databank at http://databank.worldbank.org/data/views/variableselection/selectvariables.aspx?source=world-development-indicators

Zeller M, Schreider G, von Braun J, Heidhues F (1997) Rural finance for food security for the poor. Food Policy Review No. 4, International Food Policy Research Institute, Washington DC