Debt, Poverty and Resource Management in a Rural Smallholder Economy

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Non-Technical Summary

Poor rural smallholders in developing countries are frequently affected by credit constraints that are due to their limited access to the formal credit market (Binswanger and Sillers 1983; Zeller *et al.* 1997). Access to the formal market is greatly restricted because of the small size of their credit operations that, given significant fixed cost per credit operation, provide little incentives to potential lenders. Additionally, poor households have limited assets and face institutional problems, such as lack of land title security, which reduces their capacity to collaterize, increases the risks for lenders, and is translated into higher costs of credit. Most small holders therefore have to rely on lenders in the informal market, who run credit operations at low fixed costs and are willing to take relatively large risks. These informal lenders will to extend credit to poor small holders, but at extremely high interest rates. The most important implication of this situation is that small holders' resource allocation decisions are largely affected by their wealth.

The model of this paper explores the link between poverty and resource allocation, including the management of natural resources by small holders. The paper proposes a formal intertemporal model of a credit constrained farm household that can invest in wealth accumulation to relieve its long run indebtedness or conserve resources. The model of the indebted rural household is an adaptation of the approach developed by Chambers and López (1987), although we extend the latter model significantly by including an additional economic asset - the amount of natural resource stock available to the household. Wealth accumulation increases productivity in the short run but it also imposes greater natural resource degradation. This pressure can, in turn, be alleviated by allowing the resource to regenerate, but this in turn implies lower investments in wealth accumulation. So the household must decide on an optimal combination of investments in the two forms of capital given their savings capacity, indebtedness and costs of obtaining credit.

The evolution of the natural resource base is closely dependent on the investment strategy followed by the household.

The model is also used to analyse how policy-related variables may affect the household's investment strategy and, consequently, resource management and household poverty: (i) Changes in output and input prices due, for example, to macroeconomic and agricultural reforms, and (ii) changes in the functioning of the rural credit markets due to increased competitiveness or more liquidity, that may lead to increased access to credit. These comparative static results suggest caution in assuming that, in response to policy changes that influence input prices and credit availability, chronically indebted households will adjust their long run behavior in similar ways as debt free households. Our analysis also shows that chronically indebted households that retain less debt in the long run are more likely to benefit from such policy changes. Clearly, the poverty-environment-debt ‘trap’ is a vicious cycle that poor smallholders find difficult to escape, once caught in it, and equally difficult to overcome through the design of so-called ‘win-win’ agricultural and credit policy prescriptions.

Abstract

This paper explores the link between poverty and resource allocation, including the management of natural resources, by chronically indebted rural smallholders in developing countries. The paper proposes a formal intertemporal model of a credit constrained farm household that can invest in wealth accumulation to relieve its long run indebtedness or conserve resources. The household must decide on an optimal combination of investments in the two forms of capital, given their savings capacity, indebtedness and costs of obtaining credit. The evolution of the natural resource base is closely dependent on the investment strategy followed by the household. The model is also used to analyse how policy-related variables may affect the household's investment strategy and, consequently, resource management and household poverty: (i) Changes in output and input prices, and (ii) changes in the liquidity available in rural credit markets.

JEL classification: Q0, Q2, O1.

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Debt, Poverty and Resource Management in a Rural Smallholder Economy

Around 370 million of the developing world's poorest people are estimated to live in 'marginal' agricultural areas (Leonard *et al.* 1989). These less favorable agricultural lands, with lower productivity potential, poorer soils and physical characteristics, and more variable and often inadequate rainfall, are easily prone to land degradation due to overcropping, poor farming practices and inadequate conservation measures. Although improved land and resource management, as well as investment in appropriate inputs and farming systems, are necessary for sustained agricultural development of poor rural areas, the endemic poverty faced by smallholder farmers severely constrains their ability to manage the scarce resources at their disposal, particularly arable land (Barbier 1998).

Poor rural households in developing countries have generally only land and unskilled labour as their principal assets, and thus few human or capital endowments. These households are also dependent on agricultural production as their main source of income, but the importance of off-farm income increases as the size of holdings declines. For example, in Latin America, the landholdings of the poorest farmers range between one and five hectares, and this amount of land, if not irrigated and intensively farmed, cannot support levels of consumption above the extreme poverty line without other sources of income (López and Valdés 1998). In Mexico, the 1.3 million farm households (34% of all producers) with holdings of less than 2 hectares (ha) display a high dependence on off-farm income coupled with extreme poverty (Deininger and Heinegg 1995). Their agricultural systems are highly unproductive and lack diversity. Almost two thirds of output value is derived from maize and beans, which occupy on average 84% of the land area available to these producers. Throughout the developing world, poverty, small and poor quality land holdings and resource degradation appear to be highly correlated (Barbier 1994).

The unfortunate consequence of this situation is that poor households with limited holdings often face important labour, land and cash constraints on their ability to invest in land improvements. For example, in discussing their review of farmer adoption of agroforestry systems in Central America and the Caribbean, Current *et al.* (1995) conclude that “poorer farmers may find agroforestry profitable, but their rate and scale or adoption is often constrained by limited land, labour, and capital resources and their need to ensure food security and reduce risks.”

A recent study in Malawi highlights how the poorest rural households face unique incentives and constraints in combatting serious problems of erosion and soil fertility decline (Barbier and Burgess 1992b). In Malawi, female-headed households make up a large percentage (42%) of the 'core-poor' households. They typically cultivate very small plots of land (< 0.5 ha) and are often marginalised onto the less fertile soils and steeper slopes (> 12%). They are often unable to finance agricultural inputs such as fertilizer, to rotate annual crops, to use 'green manure' crops or to undertake soil and water conservation. As a result, poorer female-headed households generally face declining soil fertility and crop yields, further exacerbating their poverty and increasing their dependence upon the land.

Poor farming households may be able to overcome such constraints if they have access to credit, but usually such access is denied them because of their low level of investment collateral. Often the only asset available for collateral is their land, and this may not always be allowed as the basis for acquiring loans (Zeller *et al.*1997). 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. 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 (Feder and Onchon 1987; López and Valdés 1998).

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 (Feder 1985). Estimates suggest that only 5 percent of farmers in Africa and around 15 percent in Latin America and Asia have access to formal credit. Moreover, around 5 percent of all borrowers receive 80 percent of all 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 rural credit, only 9.6% had holdings of 0-2 ha (Deininger and Heinegg 1995). In Malawi, although approximately 45% of rural smallholders have holdings of less than 1 ha and over 21% are 'core poor' households with less than 0.5 ha, only 17% of medium-term credit is allocated to households with less than 2 ha of land (Barbier and Burgess 1992b). 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 (Zeller *et al.* 1997).

Existing credit policies and institutions in developing countries are often biased against poor smallholders obtaining formal credit for long-term investments in land improvements and conservation, and further increase the dependence of these farmers on informal lending sources. In El Salvador, the lack of an agricultural credit policy tailored to subsistence smallholders affects land management in two ways: i) the Central Bank does not allot disbursements without proof of input purchases, which favours the use of credit for the buying of pesticides and fertilizers rather than for obtaining additional labour for soil conservation investments; and ii) there are no special incentives or provisions for smallholders to obtain credit to help diversify their cropping systems away from less erosive annual crops. As a result, less than 20% of small farmers use agricultural credit, and only 0.3% of total credit from the publicly funded Agricultural Development Bank is used for reforestation, soil conservation, irrigation and drainage, and on-farm improvement works. Instead, small farmers rely heavily on the use of suppliers of credit from agricultural products wholesalers, to whom they sell their products as collateral at below-market prices (World Bank 1994). Throughout Indonesia, public liquidity credit meets only 15%of the demand for credit by farmers - and more than half of this is subsidized credit targeted at lowland sugar producers. Small farmers, particularly those outside of lowland irrigated areas, are dependent on informal credit markets, which can generate interest rates as high as 60% (Barbier 1989).

Hence, because of the limited income-earning potential from their small holdings, many poor rural households find themselves in chronic debt to finance basic consumption and production needs. However, imperfections in the rural capital market often limit households' options for smoothing consumption from one period to the next, accumulating capital, and financing lump-sum investments, especially for land improvements (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, and conversely the greater its overall chronic indebtedness, the lower its access to formal credit and insurance services. Informal lending along kinship and community lines may provide some substitute services, such as pooling the risks borne by individual farmers and insurance through reciprocal gift and loan exchange systems. For the chronically indebted household, borrowing from friends, relatives and within the local community is limited and can only satisfy a few specific credit needs. As a household's level of indebtedness 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; Chaves and Sánchez 1998; Zeller *et al.* 1997).

To summarize, poor rural smallholders can easily find themselves caught in a vicious cycle between debt, poverty and resource degradation. Although dependent on their limited land holdings for agricultural income, these households engage in low-productive farming practices that often exacerbate problems of land degradation and fertility decline. Given their low incomes, poor smallholders are often unable to finance investments in land improvements from their own resources, and face prohibitively high costs of borrowing to fund such investments. In fact, many households may be forced into debt just to finance essential inputs for their existing production systems. However, the more these households have to borrow, the more indebted they become, and the higher the interest rates they have to pay. Generating greater savings means increasing household income, but in the short run this means both working the land harder, which leads to more land degradation and lower agricultural productivity in the long run, and increasing purchases of inputs, which leads to higher household indebtedness over time. Moreover, this 'vicious cycle' between poverty, environmental degradation and chronic indebtedness is not limited to a few isolated rural households and communities but appears to be endemic to the poor smallholder rural economy in the marginal agricultural regions of developing countries.

In the following paper we develop a model of smallholder behavior to capture these fundamental relationships between poverty, indebtedness and resource management that may be faced by a typical poor farming household in a marginal agricultural area. The household is dependent on a natural resource (e.g. land) and purchased inputs for production, but is chronically in debt in order to finance input purchases. Moreover the greater the household's level of indebtedness, the higher the interest rate on increased borrowing. Finally, by obtaining more inputs and working the land harder, the household increases production but also causes more degradation.

Such a model allows us to explore the conditions that influence the poor rural smallholder's decision to manage its chronic indebtedness and its essential land asset over time. In particular, we show that a household's optimal strategy over the long run will depend on its initial level of resource stocks relative to other wealth assets. That is, a household with relatively more abundant resources to assets initially will increase resource degradation over time in order to reduce its chronic indebtedness. On the other hand, a household with higher initial assets to resource stocks would draw down its assets, and increase its indebtedness, over time to allow its semi-renewable resource to increase in the long run. To illustrate further the effects of indebtedness on the rural smallholder's resource management decision, we contrast the results of this model with the outcome of the standard farm-level model of optimal resource use for a rural household that is not indebted.

Our model is also used to explore the effects of policies on the long-run strategy of the poor rural smallholder to manage both its debt and resource stocks. Certain policies, such as increases in agricultural producer prices, reduced input prices and the improved availability of rural credit, have been advocated in recent years as potential 'win-win' prescriptions that can lead to long-term improvements in both the economic welfare of poor rural households and their management of resources. The comparative static results of our model indicate that such policies may not always result in 'win-win' outcomes for chronically indebted smallholders that face high costs of increased borrowing. We are also able to show explicitly the important role of indebtedness in influencing the long-run behavior of the household in response to specific price and credit policies.

Thus, by modelling 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 chronic indebtedness and its impact on the household's cost of borrowing add a critically important dimension to the poverty-environment 'trap' faced by the household. Previous analyses of this 'trap' have tended to focus on the economic incentives of rural households to manage their resources without considering the problem of chronic indebtedness. Recent empirical evidence suggests that the latter is very much a part of the poverty-environment 'trap' faced by poor rural smallholders on marginal agricultural land. Our analysis illustrates how increasing borrowing costs as a result of indebtedness will influence the long run resource management and wealth accumulation strategy of the poor rural household, as well as the household's incentives to respond as expected to price and credit policies.

The Indebted Smallholder Model

The following model of the indebted rural household is an adaptation of the approach developed by Chambers and López (1987), although we extend the latter model significantly by including an additional economic asset - the amount of natural resource stock available to the household. This extension is of fundamental importance to our model, as we are interested in analyzing 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, fuelwood, 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. For simplicity, the land holding and the labor of the household are fixed, and only one output is produced. Alternatively, if there are multiple outputs of the household, their combined production can be explained by a single production function. Output and inputs are expressed in aggregate, but could also be denoted in per hectare or per capita terms. By combining the resource stock with purchased inputs, the household generates production that can either be consumed or saved to accumulate wealth in the form of an interest-earning asset. Income from this asset therefore adds to the income stream from producing and selling output.

The behavior of the smallholder rural household is therefore determined by the impact of resource management and asset accumulation on overall income generation and consumption.[1] Thus the objective of the household is to maximize utility from consumption:

$$Max_{c,z} \quad U = \int_0^{T \to \infty} e^{-\delta t} U(c)\, dt \tag{1}$$

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

subject to degradation of the resource stock:

$$\frac{dx}{dt} = \dot{x} = k_0 - az, \qquad x(0) = x_0,\ k_0 \geq 0,\ a > 0, \tag{2}$$

where c = consumption

δ = household's private rate of discount

x = the renewable resource stock

z = purchased inputs

p = price of output

$F(z, x)$ = production function, where $F_1 > 0$, $F_{11} < 0$, $F_2 \geq 0$, $F_{22} \leq 0$, $F_{12} > 0$

w = price of purchased inputs.

Equation (2) indicates that the resource stock will grow at a constant rate, k_0; however, the stock is also depleted through its use in production. To simplify the analysis, the rate of depletion is proportional to the employment of purchased inputs in production, *z*.[2]

We assume that the household has to purchase inputs through expenditure *wz*, which is financed in two ways:

- the household can accumulate a stock of net savings, or asset wealth, *A*

[2]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. See, for example, McConnell (1983), and for applications to developing countries, 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 decisions (Grepperud 1997) and the soil erosion problem in the context of a common property bush-fallow rotation system (López 1997). We also do not consider the potential impacts of varying property right regimes on the resource degradation problem (Larson and Bromley 1990).

- the household can 'borrow' money in the local rural credit market.

However, we additionally assume that the smallholder household is a chronic net borrower; that is, the household never accumulates enough wealth, A, through net saving in order to purchase all its input requirements. Defining D as the household's stock of debt, then:

$$A + D = wz \tag{3}$$

Thus, the smallholder household always finds itself in debt, and its degree of indebtedness will in turn affect its ability to obtain credit to finance the purchase of inputs for production. By re-arranging (3), the debt-equity ration of the household can be defined as:

$$\frac{D}{A + D} = \frac{wz - A}{wz} \tag{4}$$

In our model, it is convenient to approximate (4) by the ratio A/wz, which indicates the degree of indebtedness of the household.

Following the discussion in the introduction, we assume that the rate of interest that the smallholder household must pay on debt will be affected by its debt-equity ratio.[3] That is, the greater the degree of indebtedness, i.e. A/wz decreases, the higher the rate of interest the household must pay on its outstanding debt. However, as the ratio of accumulated wealth to total purchased inputs rises, the debt-equity ratio of the household falls, and the household becomes

[3] Chambers and López (1987) apply a similar, but more general, relationship between the cost of obtaining credit and the debt-equity ratio of the borrowing household to analyze the implications of income, profit and consumption taxes on the economic decisions of financially constrained farm households in the United States.

less dependent on borrowing to finance its input purchases. Consequently, although the chronically indebted rural household always pays an interest rate 'premium' to finance its input purchases, a decrease in the household's level of indebtedness would reduce its borrowing rate in credit markets. We represent this effect of household indebtedness on the interest rate cost of borrowing, r, as:

$$r = r^{M}\left(\frac{A}{wz}\right)^{\epsilon}, \quad \epsilon < 0, \tag{5}$$

where r^M is the prevailing rate of interest in commercial credit markets and $(A/wz)^{\epsilon}$ is a factor determining the additional premium on this rate.[4] Equation (5) indicates that the indebted smallholder rural household is either considered a 'credit risk' in commercial markets and most pay a high 'premium' above the prevailing rate in these markets, or as is more likely the case in rural areas of developing countries, the indebted household is generally unable to obtain loans in commercial markets and hence must borrow at higher rates from 'informal' credit lending sources.

Finally, any income from production by the household that is not consumed must pay off its outstanding debt:

$$\dot{A} = pF(z,x) - r^{M}\left(\frac{A}{wz}\right)^{\epsilon}(wz - A) - c, \qquad A(0) = A_o \tag{6}$$

Although the household can accumulate wealth, A, following our previous assumption, it is always in debt, i.e. $wz > A$.

[4] 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.

Denoting λ and μ as the current value costate variables corresponding to A and x respectively, then the Hamiltonian of the household's maximization problem is

$$H = U(c) + \lambda[pF(x,z) - r^M\left(\frac{A}{wz}\right)^{\epsilon}(wz - A) - c] + \mu[k_0 - az] \tag{7}$$

The first order conditions are (2) and (6) plus the following:

$$U' = \lambda \tag{8}$$

$$\lambda pF_z = \lambda wr^M\left(\frac{A}{wz}\right)^{\epsilon}\left[1 - \epsilon + \frac{A\epsilon}{wz}\right] + \mu a \tag{9}$$

$$\dot{\lambda} = \delta\lambda - \lambda r^M\left(\frac{A}{wz}\right)^{\epsilon}\left[1 + \epsilon - \frac{wz\epsilon}{A}\right] \tag{10}$$

$$\dot{\mu} = \delta\mu - \lambda pF_x. \tag{11}$$

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

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

$$\lim_{t\to\infty} [\mu(t)x(t)] = 0. \tag{13}$$

Equation (8) is the standard condition that the marginal utility of consumption for the household must equal the (shadow) value of foregone wealth or savings, in the form of asset A. Equation

(9) determines the optimal allocation of purchased inputs, z; that is, the household equates the value marginal product of these inputs with their two 'costs', the marginal debt impacts of an increase in inputs plus the marginal cost of input use in terms of resource depletion, $\mu a/\lambda$. Equations (10) and (11) indicate respectively the optimal allocation rules for holding on to wealth, A, and the renewable resource, x, as economic assets. Thus wealth is accumulated by the household up to the point where any capital gains plus the marginal changes in the debt position of the household equal the discount rate. Similarly, the household exploits the resource up to the point where any capital gains plus the current value marginal productivity changes attributed to the resource, $\lambda p F_x/\mu$, 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 want to have any remaining assets left over at the end of the planning horizon.

We are interested in exploring the conditions determining the household's management of both its indebtedness and its resource stock in the long run, as well as possible optimal paths that the household could follow to this equilibrium. From the above first order conditions of the model, the long run steady state for the household will occur when $dx/dt = dA/dt = d\mu/dt = d\lambda/dt = 0$, and the system of equations depicting this equilibrium is:

$$z^* = \frac{k_0}{a}, \quad \dot{x} = 0 \tag{14}$$

$$c^* = pF(z^*, x^*) - r^M\left(\frac{A^*}{wz^*}\right)^{\epsilon}(wz^* - A^*), \quad \dot{A} = 0. \tag{15}$$

$$\delta = r^M\left(\frac{A^*}{wz^*}\right)^{\epsilon}\left[1 + \epsilon - \frac{\epsilon wz^*}{A^*}\right] > 0, \quad \dot{\lambda} = \dot{c} = 0 \tag{16}$$

$$F_z - \frac{a}{\delta}F_x = \frac{w}{p}r^M\left(\frac{A^*}{wz^*}\right)^{\epsilon}\left[1 - \epsilon + \frac{\epsilon A^*}{wz^*}\right] > 0, \quad \dot{\mu} = 0. \tag{17}$$

Equation (14) indicates that the steady state level of purchased inputs, z^*, is a constant and always equal to the ratio of the parameters k_0 and a. From equation (15), in the long run consumption of the household is a recursive function of its steady state level of wealth, A^*, and resources, x^*. That is, once the equilibrium levels of the resource stock and assets held by the household are known, then the household's steady state level of consumption can also be determined. The final two conditions can therefore be solved for unique values of A^* and x^*. As x^* does not appear in (16), this equation can be re-arranged to solve for A^* as a function of the parameters of the model, i.e. $A^* = A(\delta, \epsilon, wk_0/a)$. Finally, once the latter expression and $z^* = k_0/a$ are substituted into (17), it is possible to solve this equation for the steady state level of resource stock, x^*. This also implies that the above long run equilibrium for the smallholder household can be fully represented graphically in (x, A) space, once (14) is substituted into (16) and (17):

$$\delta - r^M\left(\frac{aA^*}{wk_0}\right)^{\epsilon}\left[1 + \epsilon - \frac{\epsilon wk_0}{aA^*}\right] = 0 \quad \text{or} \quad A^* = A\left(\delta, \epsilon, \frac{wk_0}{a}\right) \tag{18}$$

$$G(A,x) = F_z\left(x^*, \frac{k_0}{a}\right) - \frac{a}{\delta}F_x\left(x^*, \frac{k_0}{a}\right) - \frac{w}{p}r^M\left(\frac{aA^*}{wk_0}\right)^{\epsilon}\left[1 - \epsilon + \frac{\epsilon aA^*}{wk_0}\right] = 0 \tag{19}$$

Equation (18) is clearly vertical in (x, A) space, and thus determines a unique solution for A^*. It can be easily demonstrated that the $G(A, x) = 0$ curve of (19) is downward sloping. As shown in Figure 1, the household's steady state levels of both A^* and x^* will occur where these two curves intersect, and this equilibrium is a stable saddle point. Once the steady sate values for A^* and x^* are known, then equation (15) yields the steady state value of household consumption, c^*, that is determined recursively by the equilibrium level of household assets and resource stock.

Equation (15) indicates that for any x above the $G(A, x) = 0$ curve the level of household assets will be increasing, i.e. $dA/dt > 0$, and for any x below the curve, $dA/dt < 0$. By definition, any points to the right of the vertical $A^* = A(\delta, \epsilon, wk_0/a)$ line imply that the household is holding on to a stock of assets greater than the equilibrium level, i.e. $A > A^*$. However, for this to occur equation (16) shows that, if the parameters of the model remain constant, then the household must be acquiring less than the equilibrium level of inputs, i.e. $z < z^*$. It therefore follows from condition (14) that the resource stock will be increasing, i.e. $dx/dt > 0$, for any A to the right of A^*. Similarly, for $A < A^*$ also requires that $dx/dt < 0$.

As depicted in Figure 1, this suggests two possible optimal trajectories to the stable steady state, (A^*, x^*). The smallholder household could be endowed initially with a high level of resource stock relative to assets. In this case, the household can afford to acquire more purchased inputs, z, and degrade its resource stock, x, so long as more asset wealth is also accumulated over time to avoid increasing the costs of borrowing to finance these additional input purchases. Under these conditions, resource depletion is an optimal strategy for the household, and it is directly related to the need of the household to manage its indebtedness and costs of borrowing in the long run. Alternatively, the smallholder could be endowed with a high initial level of wealth relative to resource stock, in which case it would reduce its assets over time while simultaneously purchasing less inputs and allowing its land resource and productivity to improve. By purchasing less inputs, the household can afford to reduce its stock of wealth over time without increasing its indebtedness and costs of borrowing in the long run. Hence, under these second set of conditions, resource conservation is an optimal strategy for the household, and its resource management strategy is again related to the smallholder's management of the long run impact of its indebtedness on the costs of financing input purchases.

The 'Debt Free' Household

Further insights into the optimal long run strategy of the indebted rural smallholder household can be gained by contrasting the long run economic behaviour of this household with that of a 'debt free' smallholder.

For example, assume that the latter household is also managing a single resource, i.e. land or topsoil, for production, and subject to the same conditions as described by equations (1) and (2) above. However, as this household is not in chronic debt, equations (3) to (6) do not apply. Instead, any income that is not consumed by the household or used to purchase inputs leads to accumulation of asset wealth, and the smallholder is able to obtain a rate of return on this wealth equivalent to the commercial market rate of interest, r^M. That is, asset accumulation by the debt-free household is depicted by:

$$\dot{A} = pF(z,x) + r^M A - wz - c, \qquad A(0) = A_o. \tag{6'}$$

Note that, in comparison with (6), assets can be accumulated by this household to yield an additional source of savings income, $r^M A$, and as the household is 'debt free', it is assumed that $A \geq 0$ throughout the planning period.

The Hamiltonian (7) of the maximizing problem is therefore modified for the debt-free household to become:

$$H = U(c) + \lambda[pF(x,z) + r^M A - wz - c] + \mu[k_0 - az], \qquad (7')$$

which yields the following long run steady state conditions for the household:

$$\lim_{t\to\infty} [\lambda(t)A(t)] = \lim_{t\to\infty} \left[A(t)\lambda_0 \exp\left(-\int_0^t [r^M(\tau) - \delta]\, d\tau\right)\right] = 0 \qquad (12')$$

$$\lim_{t\to\infty} [\mu(t)x(t)] = 0 \qquad (13)$$

$$z^* = \frac{k_0}{a}, \quad \dot{x} = 0 \qquad (14)$$

$$c^* = pF(z^*,x^*) - wz^*, \quad \dot{A} = 0. \qquad (15')$$

$$\delta = r^M > 0, \quad \dot{\lambda} = \dot{c} = 0 \qquad (16')$$

$$F_z(z^*,x^*) - \frac{a}{\delta}F_x(z^*,x^*) = \frac{w}{p} > 0, \quad \dot{\mu} = 0. \tag{17'}$$

If the biophysical parameters, a and k_0, are the same for the indebted and debt free households, then the steady level of inputs, z^*, will also be the same. However, in comparison to condition (15) for the indebted household, the steady state level of consumption, c^*, for the debt free household will be determined by steady state income from crop production and assets, $pF(z^*, x^*) + r^M A^*$, less any purchases of inputs, wk_0/a. Although in the long run the debt free household may hold a positive stock of wealth ($A^* > 0$) to generate interest income, the transversality condition (12') ensures that the value of this asset wealth is zero in the long run.[5] In contrast, the indebted household must retain a long run positive stock of assets, A^*, not to generate income but because it must use this stock to finance its steady state level of inputs, wk_0/a. As is clear from (13), if the household's assets fell to zero, then the interest rate on outstanding debt would tend to infinity. Long run consumption would therefore be zero.

Condition (16') shows that, if consumption is constant in the long run for the debt free household, then its rate of return on accumulated wealth, r^M, must equal the household's rate of discount, δ. In comparison, from (16), the indebted household will have constant consumption in the long run if the household's marginal cost of borrowing equals its discount rate. The latter terms consists

[5] The transversality condition ensures that the household has no valuable assets left over, as any remaining assets in infinite time could instead have been used to increase consumption, and thus utility, during some period of finite time. See Barro and Sala-I-Martin (1995) for further discussion.. In (12'), the value of the shadow price $\lambda(t) = \lambda_0 e^{-\int[rM(\tau) - \delta]d\tau}$ is derived from integrating with respect to time the first-order condition $d\lambda/dt - \delta\lambda = -dH/dA = -r^M$ for maximizing the Hamiltonian (7'). Note that, unless r^M changes over time, condition (15') will hold for both finite time as well as for when time approaches infinity, i.e. there will be no growth in consumption for the household. That is, the household will determine whether consumption grows, falls or is constant in finite time depending on whether r^M is greater than, less than or equal to δ. Since we wish to allow for changes in consumption over time for the debt free household, we assume that r^M is exogenously determined but not fixed over time (Barro and Sala-I-Martin 1995).

of the equilibrium interest rate on household borrowing, $r^* = r^M(A^*/wz^*)^\epsilon$ times the marginal change in the equilibrium debt position of the household, $(1 + \epsilon(1 - wz^*/A^*)$. Thus the long run marginal cost of borrowing of the indebted household will always exceed the market rate of interest, r^M.

This result may have important implications for the respective discount rates chosen by the two types of households. For example, suppose that both households have the same constant intertemporal elasticity of consumption, and at initial time $t = 0$ both the indebted and debt free households know that the long run market rate of interest will be some value, $r^M = r^{M*}$. The debt free household will therefore choose a discount rate equal to this value, but the indebted household will discount future utility at a much higher rate, equal to its long marginal cost of borrowing. Intuitively, it makes sense that a chronically indebted household would discount the future more heavily than a debt free household. Because of the premium it faces on market rate of interest and because it is chronically in debt, the indebted household can never accumulate enough assets over the planning period so that its marginal cost of borrowing is reduced to the market rate of interest, r^M. Thus this household will never be able to attain a consumption-saving path that would allow it to discount future utility at the rate r^M in the long run.

Despite having a higher rate of discount than the debt free household, the indebted household will not necessarily have a lower long run resource stock, x^*. Once $z^* = k_0/a$ and $\delta = r^M$ are substituted into equation (17'), it will yield a singular solution for x^* for the debt free household. Note that (17') will now be similar to condition (17) that can be solved for x^* for the indebted household, except that in the latter expression the value of δ will be defined by (16), which is greater than r^M (as discussed above), and the ratio of input to output prices, w/p, will be weighted by the additional term $r^M(A/wz)^\epsilon[1 - \epsilon(1 - A/wz)]$.[6] We can get an indication of how changing (17') to resemble (17) will affect the long run resource stock level, x^*, by differentiating condition (17') with respect to δ and w/p:

$$dx^* = \frac{d(w/p) - \frac{a}{\delta}F_x d\delta}{F_{zx} - \frac{a}{\delta}F_{xx}}, \quad \frac{dx^*}{d(w/p)} > 0, \quad \frac{dx^*}{d\delta} < 0. \tag{20}$$

Thus, equation (20) indicates that dx^* will only be unambiguously negative (i.e. x^* is lower for the indebted household) if either $0 < d(w/p) < aF_x/\delta$ or $d(w/p) < 0$. As discussed above, the indebted household is likely to have a higher discount rate than the debt free household, and (20) suggests that this change will lead to a lower x^*. Effectively, a higher discount rate means a greater opportunity cost of conserving the resource for future income and utility. However, this negative effect of an increase in the discount rate on equilibrium x^* may be offset by a change in the input-output price ratio, unless $d(w/p)$ is either very small or negative. The latter condition, which suggests that the 'weighted' w/p term in (17) for an indebted household is less than w/p in (17') for the debt free household, is in turn determined by the following:

$$d(w/p) < 0 \quad \text{if} \quad r^* = r^M\left(\frac{A}{wz}\right)^\epsilon < \frac{1}{1 - \epsilon(1 - A/wz)} < 1. \tag{21}$$

[6] In what follows, we assume as before that in the long run the parameters a, k_0 and r^M are the same for both households, and now that w and p are also the same.

That is, if the long run interest rate on borrowing by the indebted household is small, then this household is likely to hold a smaller stock of resources than the debt free household. Once again this result makes intuitive sense, as it is indicative of how the chronically indebted household's resource management strategy is related to managing the long run impact of indebtedness on the costs of financing input purchases. In order to reduce its indebtedness in the long run, and thus face a lower cost of borrowing, the indebted smallholder must accumulate a larger stock of assets. However, to do this, the smallholder must increase its income, which requires purchasing more inputs, working the land harder and increasing long run degradation. In short, as discussed above, the indebted household has the choice of having a larger steady state level of assets in the long run, and thus less indebtedness and a lower cost of borrowing, or a larger resource stock. As shown in Figure 1, it cannot both have greatly reduced indebtedness and a large resource stock.

In sum, condition (20) suggests that the long run level of resource stock for the chronically indebted household will not necessarily always be lower than $x*$ for the debt free household. Condition (21) indicates that, whether the steady state amount of resources held by the indebted household will in the long run be less than the amount held by the debt free household, will in turn be a function of the long run debt position and borrowing rate faced by the indebted household. These conditions once again indicate that the household must trade off resource conservation and reduced indebtedness in the long run. Compared to the debt free household, it is optimal for the indebted smallholder to conserve more of its resource in the long run, provided that it is willing and able to have a lower level of wealth and thus greater debt.

The Effects of Policy Changes

In recent years, policies such as increases in agricultural producer prices, reduced input prices and the improved availability of rural credit, have been advocated as potential 'win-win' prescriptions that can lead to long-term improvements in both the economic welfare of poor rural households and their management of resources. The indebted smallholder model developed in this paper can be used to explore the effects of such policies on the long-run strategy of the poor rural smallholder to manage both its debt and resource stocks. We are able to show explicitly the important role of indebtedness in influencing the long-run behavior of the household in response to specific price and credit policies. Finally, our analysis of policy changes may shed some light on the findings emerging from recent empirical studies of resource management by poor and indebted rural smallholders.

For example, a considerable empirical literature now exists on the impacts of agricultural input and output price changes on the incentives for rural households in developing countries to conserve or degrade their land holdings (see, for example, Alfsen *et al.* 1997; Anderson and Thampapillai 1990; Barbier 1990 and 1998; Barbier and Burgess 1992b; Coxhead and Jayauriya 1994; Freeman *et al.* 1997). Most reviews of this literature have concluded that the impacts of price changes on farmers' incentives to degrade their land will be influenced by a variety of economic factors, but generally an increase in aggregate input or output prices will not affect these incentives as much as changes in relative prices that influence the returns to less erosive, compared to more erosive, cropping systems (Anderson and Thampapillai 1990; Barbier 1998; Barbier and Burgess 1992a). Similarly, there is evidence that expanding the general availability of rural credit for indebted smallholders may make some households better off, especially those with secure land tenure, but the impacts on land degradation are more ambiguous, and in fact often ignored in the analysis (Binswanger and Sillers 1983; Chaves and Sánchez 1998; Feder and Onchon 1987; Zeller *et al.* 1997). Developing and targeting rural credit policies specifically to overcome the economic constraints faced by poor and indebted smallholders that prevent them from investing in conservation measures and land improvements may be a more effective means of improving land management and reducing degradation in the long run (Barbier 1989; Barbier and Burgess 1992b).

We can examine how these policy changes might affect the long run behavior of smallholder rural households in our model by exploring the comparative static effects resulting from changes in three key parameters: output price, p, input price, w and credit liquidity, l. The first two parameters appear explicitly in our model. The latter appears implicitly, and can be included in our analysis by modifying the asset accumulation equation (5).

The results of the analysis of changes in p, w and l are summarized in Table 1. We discuss each of these comparative static effects in turn.

The effects of a change in output price, p

As Table 1 indicates, an interesting feature of our indebted smallholder model is that a change in output price, p, will have no effect on the amount of assets accumulated by the household in the long run, i.e. $dA^*/dp = 0$. As noted previously, the household's steady level of assets is determined uniquely by equation (18), and this expression is independent of the level of output price. In fact, the only factors influencing the long run level of assets accumulated by the indebted household are the rate of discount, δ, the responsiveness of the costs of borrowing to changes in the household's degree of indebtedness, ϵ, and the equilibrium level of expenditure on purchased inputs, wz^*.

However, a change in output price, p, will influence the $G(A, x) = 0$ curve. Table 1 indicates that this curve will shift down as p increases; that is, an increase in the output price will reduce the long run equilibrium resource stock held by the chronically indebted household. Effectively, the household can afford to hold onto less of the resource in the long run, because the higher output price means that the household will receive a greater return for its production. Note, though, that this comparative static effect is not unique to the chronically indebted household. Close inspection of steady state condition (17') shows that $dx^*/dp < 0$ always holds for the debt free household as well. Thus the negative influence of policy induced price changes on the amount of resource stock held by a rural household appears to be a general result, although of course in the case of the indebted household the magnitude of this impact will be 'weighted' by the additional cost of indebtedness in the long run, $r^*[1 - \epsilon(1 - A/wz)]$.

Table 1 shows that the impact of an increase in output price on long run consumption, c^*, is ambiguous. The overall gain in returns from production may be offset by the decline in the value marginal productivity of the resource stock. As steady state condition (15') for the debt free household indicates, this result occurs irrespective of whether the household is indebted or not.

In sum, the comparative static effect of a change in output price, *p*, on the optimal long run strategy of the household appears to be only marginally affected by its chronic indebtedness.

The effects of a change in input price, w

In comparison, Table 1 indicates that a change in input price, *w*, will affect both equilibrium assets, A^*, and resource stocks, x^*. An increase in input prices will lead unambiguously to an increase in both the long run assets and resource stock held by the chronically indebted household. Higher input prices mean that the indebted smallholder must accumulate more assets in the long run to avoid any increased debt from purchasing more expensive inputs. However, more expensive inputs will also mean less will be used, and hence there will be more resource stock conserved in the long run.

The overall impact of a higher input price on steady state consumption of the indebted household will be ambiguous, precisely because the smallholder is chronically in debt in the long run, i.e. $wz^* > A^*$. An increase in the price of inputs will cause c^* to rise only if the resource stock effect of the price change on production and thus household income outweighs the negative debt effect of having to purchase more expensive inputs. This is likely to be the case if the household's level of indebtedness is relatively low in the long run.

The effect of a change in liquidity, l

A policy that increases the general availability of formal credit in the rural economy will essentially make more funds, or liquidity, available to indebted rural smallholders. This in turn should reduce the cost of borrowing faced by these households. By denoting an overall liquidity parameter, *l*, we can represent the impacts of a change in the general availability of credit on the interest rate faced by the indebted smallholder through modifying equation (5):

$$r = \frac{r^M}{l}\left(\frac{A}{wz}\right)^{\epsilon}, \quad \frac{dr}{dl} = -\frac{r}{l^2} < 0. \tag{5'}$$

By utilizing (5'), it is possible to determine the comparative static effects of a policy to increase credit availability on the chronically indebted household's steady state level of assets, resource stock and consumption (see Table 1).

The results show that an increase in credit will reduce the level of assets held by the indebted smallholder in the long run. This is expected, as a policy that increases rural credit will mean that the indebted household will not need to accumulate as much wealth in the long run, as the costs of borrowing to purchase inputs will be lower and the household can afford a higher level of indebtedness in the steady state.

However, the impact of a rise in *l* on the steady state resource stock is ambiguous. Note, though, that the direction of this comparative static effect is likely to depend on the magnitude of ρ, which is in turn affected by the household's level of indebtedness, wz^*/A^*, in the long run. For example, if wz^*/A^* is very low then ρ will be relatively large (i.e. $\rho \approx 1$) and dx^*/dl is likely to be positive.

Thus, rural smallholders who are less in debt will in the long run increase conservation of their resource stock in response to an expansion in rural credit. Conversely, severely indebted households may actually degrade the environment more as liquidity is increased.

The impact of an increase in liquidity on the long run consumption of the household is also ambiguous. Because the level of household indebtedness has counteractive effects on dc^*/dl, the direction of this comparative static effect is difficult to determine. On the whole, however, if the household has less debt in the long run, then it is more likely to benefit (in consumption terms) from an increase in liquidity. For example, a low level of household indebtedness will mean that ρ will be relatively large and thus dx^*/dl is likely to be positive. Although the other positive argument in the expression, $(wz^* - A^*)/l$, will also be smaller, the negative argument, $(1 + \epsilon(1 - wz^*/A^*)dA^*/dl$, will also fall.

Conclusion

There is widespread evidence that many poor rural smallholders in developing countries suffer from problems of both resource degradation and chronic indebtedness. Given their low incomes, poor smallholders are often forced into debt just to finance essential inputs for their existing production systems. However, the more these households have to borrow, the more indebted they become, and the higher the interest rates they have to pay. Generating greater savings means increasing household income, but in the short run this means both working the land harder, which leads to more land degradation and lower agricultural productivity in the long run, and increasing purchases of inputs, which leads to higher household indebtedness over time. The purpose of this paper has been to explore how the long run resource management and wealth accumulation strategy of a representative smallholder farming household will be influenced the household's chronic indebtedness, and how policy induced changes in output prices, input prices and credit availability may also affect this long run strategy.

Our analysis indicates that in the long run the chronically indebted household must trade off either accumulating asset wealth to reduce its debt and thus costs of borrowing, or alternatively, conserve its resource stock to increase production and income. It cannot do both. Moreover, the optimal strategy chosen by the household will be determined by the relative size of its initial endowments as well as its long run debt position and costs of borrowing. For example, if the smallholder is endowed initially with a high level of resource stock relative to assets, then resource depletion is an optimal strategy. The household can afford to acquire more purchased inputs and degrade its resource stock, so long as more asset wealth is also accumulated to avoid increasing the long run costs of borrowing. Alternatively, the smallholder could be endowed with a high initial level of wealth relative to resource stock, in which case resource conservation is an optimal strategy. The household can reduce its assets over time while simultaneously purchasing less inputs and allowing its land resource and productivity to improve without affecting the long run costs of borrowing.

We have derived further insights into the optimal strategy of the indebted rural smallholder by contrasting its long run behavior with that of a 'debt free' household. Intuitively, one might think that, without the burden of chronic debt and thus a higher costs of borrowing, the debt free household would be willing to conserve more of its resource stock in the long run than the indebted household. However, our analysis indicates that this may not necessarily be the case. Whether the steady state amount of resources held by the indebted household will in the long run be less than the amount held by the debt free household will depend on the long run debt position and borrowing rate faced by the indebted household. Compared to the debt free household, it is optimal for the indebted smallholder to conserve more of its resource in the long run, provided that it is willing and able to have a lower level of wealth and thus greater debt. Once again, this outcome indicates that the household must trade off resource conservation and reduced indebtedness in its optimal strategy.

Finally, we have examined how policy changes that influence output price, input price and credit liquidity might affect the long run behavior of chronically indebted smallholders. Our results indicate that the household's level of indebtedness has an influence on these comparative static effects, but is particularly important with regard to a change in input price and in the general availability of rural credit.

The chronic indebtedness of a smallholder household appears to have only a nominal effect on its overall long run response to a change in output price. This suggests that any policy that influences output price will have more or less a similar impact on the long run behavior of an indebted rural smallholder as on a household that is debt free. The policy conclusions emerging from more general models of household resource management strategies that analyze output price changes may be valid for both debt free and chronically indebted rural smallholders (see, for example, Alfsen *et al.* 1997; Anderson and Thampapillai 1990; Barbier 1990 and 1998; Barbier and Burgess 1992b; Coxhead and Jayauriya 1994; Freeman *et al.* 1997).

However, our analysis of changes in input prices and in liquidity indicates that the long run behavior of an indebted household in response to these policy induced changes will be more significantly affected by its level of indebtedness. For example, an increase in input prices will lead unambiguously to an increase in both the long run assets and resource stock held by the chronically indebted household, and these effects are directly impacted by the household's long run debt position and costs of borrowing. Although the overall impact on steady state consumption is ambiguous, this effect is more likely to be positive if the household's level of indebtedness is relatively low in the long run. In comparison, an increase in credit will reduce the long run level of assets that the indebted smallholder requires to reduce the costs of borrowing, as expected. The impact on steady state resource stocks is clearly also affected by the long run debt position of the household. Rural smallholders who are less in debt will in the long run increase conservation of their resource stock in response to an expansion in rural credit. Conversely, severely indebted households may actually degrade the environment more as liquidity is increased. Finally, if the household has less debt in the long run, then it is more likely to benefit (in consumption terms) from an increase in liquidity.

These comparative static results suggest caution in assuming that, in response to policy changes that influence input prices and credit availability, chronically indebted households will adjust their long run behavior in similar ways as debt free households. Our analysis also shows that chronically indebted households that retain less debt in the long run are more likely to benefit from such policy changes. Clearly, the poverty-environment-debt 'trap' is a vicious cycle that poor smallholders find difficult to escape, once caught in it, and equally difficult to overcome through the design of so-called 'win-win' agricultural and credit policy prescriptions.

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Figura 1 Long Run Equilibrium of the Indebted Household

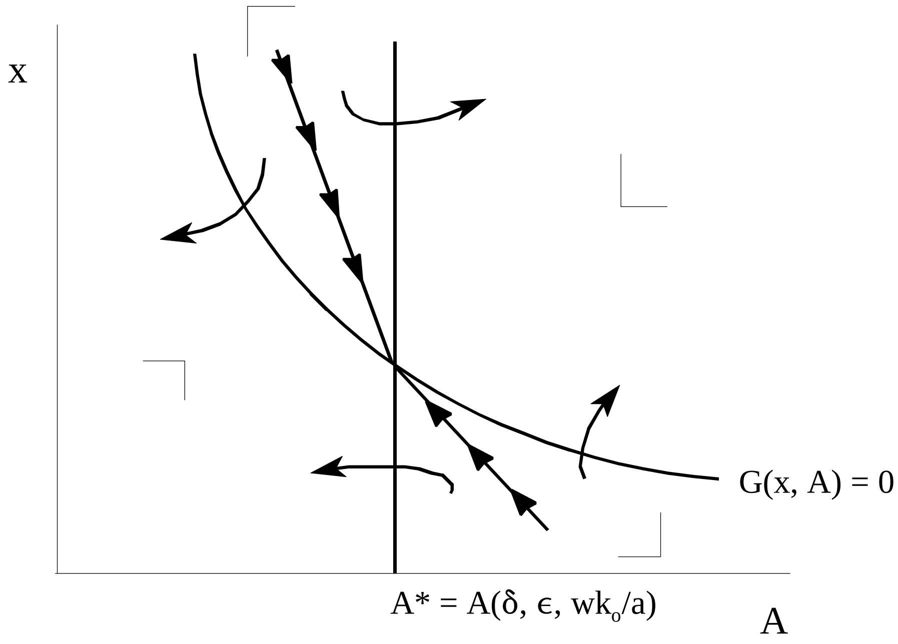

Table 1. Comparative Static Effects of Policy Changes [a/]

The effects of a change in output price, *p*	**The effects of a change in input price, *w***	**The effects of a change in liquidity, *l***
$\frac{dA^*}{dp} = 0$	$\frac{dA^*}{dw} = \frac{A^*}{w} > 0$	$\frac{dA^*}{dl} = \frac{A^*\rho}{\epsilon l} < 0$
$\frac{dx^*}{dp} = -\frac{wr^*\left[1 - \epsilon\left(1 - \frac{A^*}{wz^*}\right)\right]}{p^2\left[F_{zx} - \frac{a}{\delta}F_{xx}\right]} < 0$	$\frac{dx^*}{dw} = \frac{r^*\left[1 - \epsilon\left(1 - \frac{A^*}{wz^*}\right)\right]}{p\left[F_{zx} - \frac{a}{\delta}F_{xx}\right]} > 0$	$\frac{dx^*}{dl} = \frac{\frac{w}{p}r^*\left[\rho\frac{A^*}{wz^*} - (1 - \rho)[1 - \epsilon(1 - A/wz^*)]\right]}{l^2\left[F_{zx} - \frac{a}{\delta}F_{xx}\right]}$
$\frac{dc^*}{dp} = F(z^*,x^*) + pF_x\frac{dx^*}{dp}$	$\frac{dc^*}{dw} = pF_x\frac{dx^*}{dw} - \frac{r^*}{w}[wz^* - A^*]$	$\frac{dc^*}{dl} = pF_x\frac{dx^*}{dl} + \frac{r^*}{l}\left[1 + \epsilon\left(1 - \frac{wz^*}{A^*}\right)\frac{dA^*}{dl} + \frac{wz^* - A^*}{l}\right]$

Notes: a/ In the following table, the parameter ρ and the variable r^* are defined respectively as:

$$\rho = \frac{[1 + \epsilon(1 - wz^*/A^*)]}{[1 + \epsilon(1 - wz^*/A^*) + wz^*/A^*]} < 1$$

$$r^* = r^M\left(\frac{A^*}{wz^*}\right)^{\epsilon}.$$