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Financial Intermediation and Poverty Trap Dynamics over the Life Cycle

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Summary

In this paper, we analyze poverty traps that emerge because farmers are unable to afford the adoption and retention of higher-productivity technologies that are risky and require lumpy investments. Although access to deposit facilities and credit play an important role in breaking up poverty traps, farmers' stage in the life cycle and underlying market conditions like credit limits and interest rates on deposits and loans determine the effect of the financial policies. First, our numerical results show that in economies with scant financial development (stringent loan-size limits and large gap between interest rates), the access to only savings deposits represents a superior policy (relative to only access to credit) to increase the sustained adoption of advanced technologies and that its effectiveness is even higher when the target population is young. Additionally, the results indicate that only if the demographic structure is young and farmers have simultaneous access to both deposit facilities and credit, full financial transformation can be achieved through credit expansion. Otherwise, the effects of larger credit-limits vanish. Finally, the results indicate that policies of loan rates in credit-constrained economies have null effects on technology transformation, irrespective of the demographic structure. In contrast, sustained adoption rates increase with higher deposit rates, in young and credit-constrained economies. In aging economies, however, an opposite effect can be realized due to substitution between the yields of deposits and of the advanced technology.

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1 Introduction

The literature asserts that financial systems stimulate technological change via the allocation of resources from surplus to deficit units (Gonzalez-Vega, 1977, Levine, 1997; McKinnon, 1973; Shaw, 1973; Levine, Loayza and Beck, 2000). At the household level, technological change serves as a basis for increasing incomes, and, therefore, it accelerates the transition out of poverty. Following this principle, this paper investigates the role of different financial policies in the decisions of farm-households for both adopting and abandoning higher-productivity technologies, considering the life cycle. We focus, in particular, on policies of credit limits and of loan and deposits interest rates. The outcomes of this research improve our understanding of the role of financial intermediation as a mechanism for poverty reduction.

Poorly developed markets are ubiquitous in developing countries. Numerous problems hinder the development of the financial system. In addition to inappropriate policy interventions (McKinnon, 1973; Shaw, 1973), problems of asymmetric information, incompatible incentives, and incomplete institutions for contract enforcement discourage the mobilization of command over resources (Keeton, 1979; Stiglitz and Weiss, 1981; Jaffee and Stiglitz, 1990; Besley, 1994; Conning and Udry, 2007). Prohibitively high transaction costs and the strong covariance of incomes further prevent the emergence of formal financial markets. If the market exists, the ability of the financial system to transfer purchasing power across agents is quite limited, typically resulting in restrictive borrowing limits and comparatively large gaps between interest rate on loans and deposits.

This paper characterizes economies with scant financial development by setting relatively large wedges between loan and deposit rates, and by imposing restrictive borrowing limits. The influence of financial intermediation on poverty reduction is captured through the technological choices of the household-farmers. In particular, poverty rates in the economy are measured in the long run as the proportion of farmers producing with a traditional or low-productivity

technology as opposed to with an advance or higher-productivity technology.

Poverty reduction then is possible through the adoption and retention of the advanced technology. This process, however, is not straightforward since, compared to the traditional technology, the advanced technology generates more volatile incomes, and its operation requires a lumpy investment, which farmers who produce with the traditional technology are unwilling or unable to afford. Thus, traditional farmers are caught in poverty traps.

Financial intermediaries play the primary role of providing borrowing and deposit facilities that allow individuals to better cope with risk and accumulate the wealth required to afford the investment. In particular, the credit could influence the choice of crops and of production technologies, by reducing the household-farms vulnerability to idiosyncratic shocks (Deaton, 1990; Deaton, 1992; Alderman and Paxson, 1992; Morduch, 1995; Kochar, 1999, Dercon and Christiansen, 2011) or by directly providing liquidity for adoption (Salasya, et al., 1998; Ouma et al., 2002; Croppenstedt, Demeke, and Meschi, 2003; Gine and Yang, 2009). Savings constraints, resulting from the absence of deposit facilities, may also affect the efficiency of production (Von Pischke, Adams and Donald, 1983; Adams, Graham and Von Pischke, 1984; Robinson, 1998; Yaron, Benjamin and Charitonenko, 1998; Karlan et al., 2010; Brune et al., 2011; Dupas and Robinson, 2013). Then the deposit facilities might incentivize the adoption of technology by facilitating the accumulation of financial assets and by addressing the limitations of holding precautionary reserves in kind (Fafchamps, Udry and Czukas, 1998; Jalan and Ravallion 2001; Kazianga and Udry 2006; Gomez-Soto, 2007).

Access to either credit or deposit facilities, per se, may not always be effective in reducing poverty (Adams, 1998; Gonzalez-Vega, 1998). In particular, as assumed in this research, when emerging from poverty entails the sustained adoption of advanced production technologies that are highly risky and require a lumpy investment to operate. The effect of the financial intermediation on technology choices depends critically upon the borrowing limit policies and upon interest rates on deposits and loans adopted by lenders. In particular, highly restrictive

borrowing limits, high loan rates, and low deposit rates could restraint the ability of the farmer to afford the technological investment.

Highly developed financial systems do not guarantee poverty reduction either. By setting the maximization problem of the representative farmer in finite horizon models, we show that farmers stage in the life cycle determine the success or failure of the financial intervention. In particular, our results show that in the periods preceding retirement, the farmers will be increasingly less willing to sacrifice current consumption by investing in the advanced technology. Similarly, in these periods, adopters will be prompted to abandon the technology when experiencing income shortcomings.

Thus, a farmer who has been beset by poor fortunes early in life may never reach the point at which adoption of the advanced technology is optimal. And a farmer who has adopted the advanced technology will find optimal a sell off of the investment in the elderly periods. Although this behavior varies with distinct policies of interest rates and credit limits, the pattern remains resilient to them. As the trend cannot be reversed with a financial policy, timely designed financial interventions result critical in hopes of poverty reduction. The results demonstrate that in economies with scant financial development (stringent loan-size limits and large gap between interest rates), the access to only savings deposits represents a superior policy (relative to only access to credit) to increase the sustained adoption of advanced technologies and that its effectiveness is even higher when the target population is young.

Assuming absence of default risk, the results also show that policies of credit expansion can lead to full financial transformation only in young demographic structures and conditional on simultaneous inclusion into deposit markets. Otherwise, promoting policies of credit expansion would fail in achieving technological change and poverty reduction. Furthermore, the results indicate that policies of loan interest rates, in loan-constrained economies, would have null effects on technology transformation, irrespective of the demographic structure. In contrast, policies of deposit rates encourage technology adoption in economies with young populations

and constrained credit limits. As the economies age, however, increased deposit rates compete with the income generated by the advanced technology, which discourage the adoption and encourage the abandonment of the advanced technology.

2 Conceptual Framework

Each agents decision over a potentially large number of technology choices are simplified by assuming that, in every period, the agent engages in one of two productive activities available: one based on a traditional technology, $i = 0$, or one based on an advanced technology, $i = 1$. For example, an agent produces a crop using either a traditional or a new improved variety. The new variety is, however, more susceptible to water availability and it requires a sophisticated sprinkler irrigation system, for which the farmer must make an initial relatively large investment, K .

Farmers face an uncertain income stream, \tilde{y}_i , which depends on his choice of technology, i . We assume that farm incomes are lognormally distributed and serially independent, with mean \bar{y}_i and volatility $\sigma_i > 0$. The advanced technology generates a higher expected income, $0 < \bar{y}_0 < \bar{y}_1$; however, since it is more vulnerable to water availability, while the farmers are experienced in the production of the traditional variety, production with the advanced technology is riskier, $\sigma_1 > \sigma_0$. The farmers then face a trade-off between income-earning and risk.

2.1 The representative agent

The representative farmer, of age a , begins each period possessing a pre-determined wealth, s , and invested in a given technology, i , which generates his production income for the current period. He must then decide whether to continue using the current technology or to adopt the alternative technology for the following period. This choice of technology is designated by j , and it requires the farmer to use a portion of his current wealth in anticipation of its use. We

further assume, that age, a , is independent of the income the technology generates.

There is a per-period operational cost, κ_j , associated with employing each technology, j , and the advanced technology is more costly, $\kappa_1 > \kappa > 0$, as it, for example, is energy intensive. These costs are incurred in the current period, for use of a technology, j , in the next period. As in Duflo, Kremer, and Robinson (2011), for example, the farmer purchases a stock of fertilizer now, to be able to produce and generate an income the next period.

In turn, the advanced-technology requirement for the irrigation equipment is a fixed capital investment to be made (once, at the time of adoption) in the current period, $K > 0$, for use in the next and future periods. A portion $\rho \in (0, 1)$ of this investment may subsequently be recovered, if switching back to producing with the traditional technology.

The total cost of choosing technology j for the following period, given that the farmer begins the current period employing technology i , is thus:

$$\tau_{ij} = \begin{cases} \kappa_j, & \text{if } i = j \\ \kappa_j + K, & \text{if } i = 0, j = 1 \\ \kappa_j - \rho K, & \text{if } i = 1, j = 0 \end{cases} \quad (1)$$

The farmer's utility function, u , exhibits constant relative risk aversion and it is a twice, continuously differentiable function of current consumption, with $u'(c) > 0$, $u''(c) < 0$, and $u'(0) = -\infty$.

The farmer maximizes the present value of current and expected future utility of consumption over a finite decision period of A periods, at a per-period discount factor, $\delta \in (0, 1)$. The optimization problem solved by the farmer is summarized by the Bellman equation:

$$V_{ai}(s) = \max_{j \in \{0,1\}} u(s - \tau_{ij}) + \delta EV_{a+1j}(\tilde{y}_j) \quad (2)$$

For $a = 1, 2, \dots, A$. Where the unknown age-specific value function, $V_{ai}(s)$, represents the

maximum expected present value of lifetime utility attainable by the farmer currently engaged in technology i , from age a onwards. Given his current wealth, s , and his choice of technology for the following period, j , the difference $s - \tau_{ij}$ represents the farmer's choice of current consumption. Since the farmer is using technology i , switching his technology for the next period, j , is feasible only if $s > \tau_{ij}$.

In the absence of any financial means to transfer wealth across periods, wealth next period, s , equals production income, \tilde{y}_j . Financial intermediation would allow the farmer to hold a financial instrument either to make deposits or borrow. The model incorporates the opportunity for financial transactions by introducing a continuous variable, x . A non-negative value of x represents a deposit, while a negative value of x indicates the farmer is carrying a loan. Debt commands an interest rate r_b and deposits earn an interest rate r_d , where $r_b \geq r_d$. The one-period gross return on net farmer's financial holdings then is:

$$g(x) = \begin{cases} (1 + r_b), & x < 0 \\ (1 + r_d) & x \geq 0 \end{cases} \quad (3)$$

The farmer may deposit an unlimited amount, but he may borrow only up to a limit, $\bar{b}_i \geq 0$. Because the irrigation equipment represents collateral, the limit for the traditional producer is lower than for the advanced producer, $\bar{b}_1 \geq \bar{b}_0$. The assumption that $\min \{\tilde{y}_j\} > r_b \bar{b}_j$ implies that the farmer is not allowed to borrow so much that he might not be able to cover the minimum required interest payment the following period. In this setting an economy with incipient financial markets can be well represented by relatively large gaps between the interest rates (Gonzalez-Vega, 2003) and stringent borrowing limits (Gonzalez-Vega, 1976; Stiglitz and Weiss, 1981; Bester, 1985; Jaffee and Stiglitz, 1990).

The farmer's dynamic decision problem now is characterized by a recursive Bellman equation, whose age-specific value functions specify the maximum expected present value of lifetime

utility $V_{a,i}(s)$ attainable by the agent from age a onward, given his wealth, s , and technology, i :

$$V_{ai}(s) = \max_{j=\{0,1\}, x_a \geq -\bar{b}_i} [u(s - \tau_{ij} - x) + \delta EV_{a+1j}(\tilde{y}_j + g(x))] \quad (4)$$

for $a = 1, 2, 3, \dots, A$. Each period, wealth, s , is allocated to consumption, net financial holdings, x , and the cost of investment and operation of the next periods technology, τ_{ij} . Wealth in the next period equals production income \tilde{y}_j plus the gross returns on net financial holdings, $g(x)$, which may be positive or negative, depending on the balance-sheet position of the farmer. We let $x_{a,i}(s)$ denote the optimal net financial holdings carryover for an agent of age a , invested in technology i , and with wealth s . And $g_{ai}(s) = g(x_{ai}(s))$ denotes the agents optimal gross return on net savings at the beginning of the following period for an agent currently of age a invested in technology i with wealth s .

Consumption, borrowing, deposit, and technology use decisions each period, depend on the farmers age a . The farmer retires at age $A + 1$, converting his accumulated wealth (just his financial holdings, once he is retired), s_A , into a perpetual annuity with income \hat{y} . As no further production income will be generated, each period this annuity is supplemented, instead, by a pension P_i (for instance, a government cash transfer). If his financial holdings are positive (a deposit), $\hat{y} = r_d s_A$. If these holdings are negative (debt), $\hat{y} = r_b s_A$. He derives utility $u(P_i + \hat{y})$ each period over his indefinite remaining lifetime. Thus, the Bellman equation is subject to the terminal condition:

$$V_{A+1,i}(s) = \frac{1}{1 - \delta} u(P_i + \hat{y}) \quad (5)$$

The farmer's inter-temporal optimization in this finite horizon for his production capacity will determine his ability and willingness to adopt or abandon the advanced technology. The incentives to choose either technology are given by the differential in lifetime utility obtained from either technology. In particular, If $V_{a,i}(s, j)$ denotes the value function of a farmer of age a with wealth s who is currently engaged in the technology i and decides to produce with

technology j the next period, the farmer will optimally adopt when the value of the remaining life time utility is larger with the advanced technology, that is, whenever

$$V_{a,0}(s, 1) - V_{a,0}(s, 0) \geq 0 \quad (6)$$

The decision of abandon is similarly found when

$$V_{a,1}(s, 0) - V_{a,1}(s, 1) \geq 0 \quad (7)$$

The farmer then optimally decides to switch technologies as soon as the incentive, given by the differential of the lifetime utility, becomes positive. The results will suggest the impact of financial services on technology choices that lead to poverty traps in a particular economy depending on the demographic structure of its population.

2.2 The economy with heterogenous farmers

At the aggregate level, the economy is composed of a large number of household-farms who behave as the representative farmer described so far, but who otherwise are heterogeneous with respect to wealth and technology state, as a result of having experienced distinct, idiosyncratic production shocks over time. We assume that the income shocks are independent across farmers in the economy and that the population is sufficiently large that the shocks are perfectly diversifiable across the entire economy.

Farmers in the economy advance in age with the passage of time. Each period, retiring agents of age $a = A + 1$ are replaced by an equal number of new agents of age $a = 1$. Thus, the overall working population remains constant over time, with an equal number of agents in each age cohort at all times. New entrants into the population are presumed to have no net savings and be invested in the traditional technology.

In the steady state, there is a well-defined distribution of wealth and technology use across

farmers within each age cohort. Let $F_{ai}(s)$ denote the proportion of farmers in the economy who in the steady state are of age a , are invested in technology i and have wealth less than or equal to s . Then, given that idiosyncratic shocks to production are fully diversifiable across agents in the economy, it must be that:

$$F_{a+1,j}(s') = \sum_i \int_{S_{aij}} G_j(s' - g_{ai}^*(s)) dF_{ai}(s) \quad (8)$$

where G_j is the cumulative distribution associated with production income \tilde{y}_j and S_{aij} denotes the set of all wealth levels, s , such that, at age a , it is optimal for the agent to adopt technology j , given that he begins the period with wealth s and invested in technology i .

3 Numerical Approximations

The value functions are solved by backward recursion using the collocation method. This method converts the Bellman functional equation with no known analytical solution into a finite-dimensional nonlinear equation that can be solved using nonlinear equation approaches such as Newton's or Broydens method.

For each age and technology choice, the value function $V(s)$ is approximated using a linear combination of M basis functions ϕ defined on the state space S , whose coefficients c are set by requiring the value function approximant to satisfy the Bellman equation at M collocation nodes s_1, s_2, \dots, s_M . That is, $V(s) \approx \sum_{w=1}^M c_w \phi_w(s)$, where

$$\sum_{m=1}^M c_w \phi_w(s_m) = \max_{x \in (-b_i, \infty)} \left[u(s_m, x) + \delta \sum_{h=1}^H \sum_{w=1}^M q_h c_w \phi_w(g(x) + \tilde{y}_{j,h}) \right] \quad (9)$$

where the continuous random income is replaced with a discrete approximation constructed by using Gaussian quadrature, such that H is the number of quadrature nodes and q_h is the probability of income \tilde{y}_h .

The collocation equation (9) is written as a root-finding problem and solved through Newton’s method. In the process we employ polynomial splines basis functions. Because of the interest rate gap and the credit limit in the Bellman equations, the solution for the maximization problem with respect to x are not stable using derivative-based methods. In order to find a solution, we specify a finite set of possible values of x . The optimal x is found after solving the maximization problem (4) for all possible values of x . The optimal policies at each age

Table 1: Baseline Parameter Values

Parameter	Base Value	Description
δ	0.85	Per-period discount factor
α	2	Relative risk aversion
$[\bar{y}_0, \bar{y}_1]$	[0.90, 1.10]	Expected incomes
$[\sigma_0, \sigma_1]$	[0.25, 0.33]	Income volatility
$[\kappa_0, \kappa_1]$	[0.11, 0.13]	Production costs
K	1.0	Lumpy Investment
ρ	0.50	Investment irreversibility
r_d	0.02	Per-period deposit rate
r_b	0.17	Per-period loan rate
A	40	Number of periods
$[\bar{b}_0, \bar{b}_1]$	[0.1, $(\bar{b}_0 + 0.25K)$]	Borrowing Limits

are obtained by backward recursion. That is, given the terminal condition in equation (5), we obtain the policy and value functions for period A , whose optimal values are in turn used to solve the maximization problem for the preceding period, $A - 1$, subsequently for period $A - 2$, and so on until period 1. All the computations are done in Matlab and using the CompEcon Toolbox (Miranda and Fackler, 2012) using the parameter shown in Table 1. The parameters are chosen to reflect a rural economy. The discount factor is reflective of impatience farmers and the risk parameter displays a high degree of risk aversion, both values are in the range of the models of Fafchamps and Pender (1997). The deposit rate is kept lower than the interest rates on credit, which is set at an arbitrarily large value (Dercon, 1998; Gomez-Soto, 2007).

4 Results and discussion

The first set of results show the preferences of the 40 working-years representative farmer towards the two technologies. Next, given the individual behaviour, we explore the implications of different intermediation policies and lifecycle status in a complete economy.

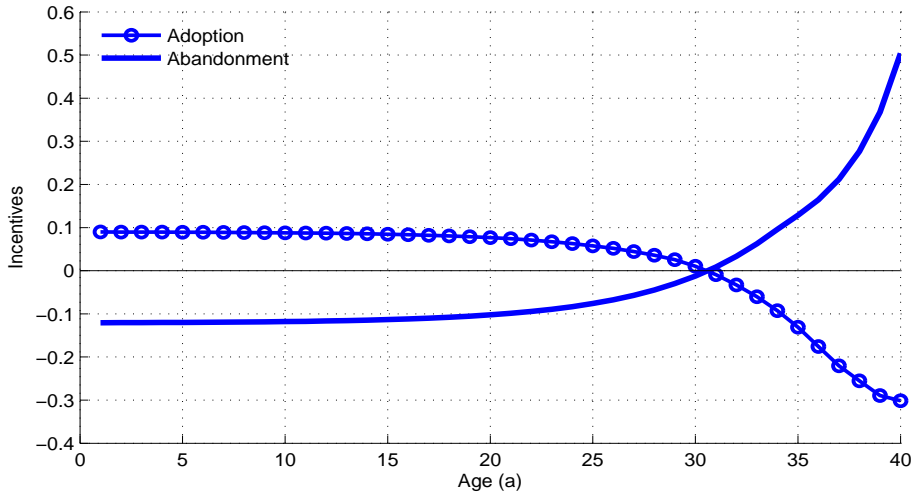
4.1 The representative farmer

Given the concavity of the utility function, as wealth grows, the agents marginal utility of consumption decreases. Thus the individual will be more willing to render current for future consumption by financing the new technology as wealth rises. Following the same principle, the incentives to abandon the advance technology must decrease with wealth. A key finding, resulting from allowing the value functions to depend on age, indicate that for any given level of wealth, these incentives to adopt and to abandon are geometrically offset by farmer's age (Figure 1).

Decreasing adoption incentives over the life cycle indicate that a subsistence farmer who is in the initial periods of the working cycle is willing to sacrifice more current consumption in order to adopt the technology than a farmer in latter stages because the remaining utility is larger. Symmetrically, decreasing incentives to retain the technology indicate that the utility derived from producing with the advanced technology when the retirement period approaches are not sufficiently large to prevent the abandonment.

The optimal solutions for the representative are shown in Appendix. The results indicate that about ten periods preceding retirement, farmers are increasingly less willing to sacrifice current consumption by investing in an advance technology. Similarly, in this period, the farmer is increasingly more willing to abandon the technology whenever there is an income shortcoming. Although differences in regards to the optimal level of wealth for adoption and abandonment emerge with distinct policies of interest rates and credit limits, the pattern remains resilient to them. At the individual level, this trend cannot be reversed, but a careful design of financial

Figure 1: Incentives for adoption and abandonment over the life cycle



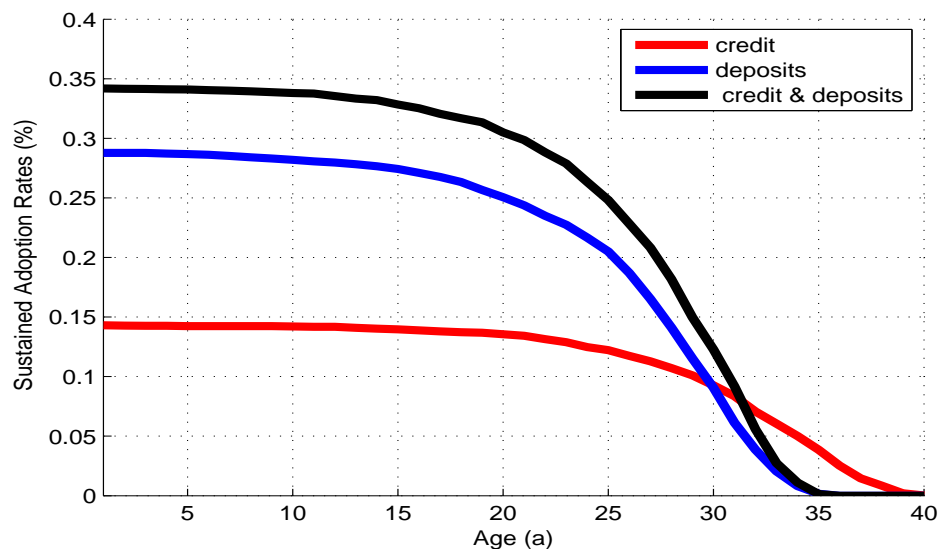
policies might have an impact in a whole economy.

4.2 The economy with heterogenous farmers

The rates of sustained technology adoption in the economy are measured as the proportion of farmers engaged in the advanced production in the long run, as described in equation (9). Figure 2 shows the sustained adoption of the advanced technology for hypothetical economies where all farmers are of a given age. In order to identify the individual effect of financial policies, we simulate economies where farmer have only access to deposits, only access to credit, and access to both. The results, first, confirm that sustained rates of adoption decay in older economies; second, reveal that in economies with severe credit rationing and gaps in the interest rates between deposits and loan rates (Table 1), not only policies of only access to deposits represent superior interventions (Guizar, Gonzalez-Vega, and Miranda, 2014), but also that the effectiveness of deposit policies is relatively larger when the target population is young. In the last fourth of the lifecycle, when financial policies loose relevance, sustained adoption is slightly superior with only access to credit than with only deposits, because with the later farmers are more willing to abandon (the adoption rates decline) as they can use the deposit facility to increase future consumption. In contrast, with only credit the technology is the only mean to

transfer income across periods.

Figure 2: Rates of sustained adoption of the advanced technology in economies with scant financial development, for different financial policies and farmers' age



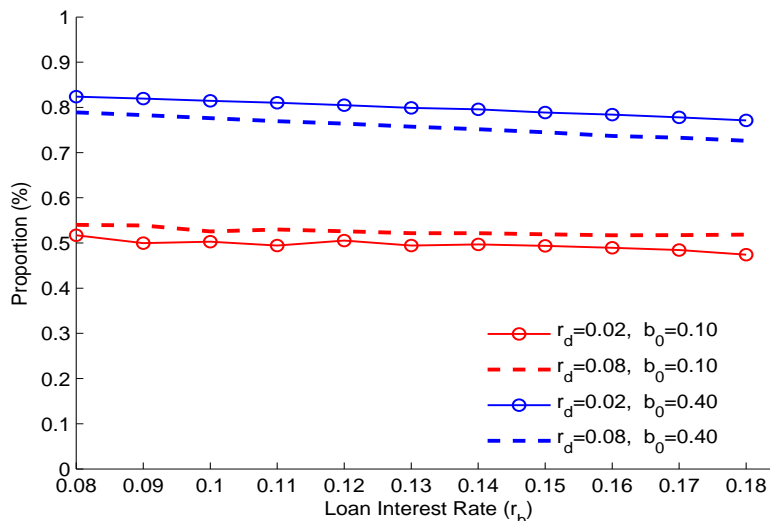
Finally, figure 2 shows that rates of sustained adoption increase when there is access to both credit and deposits. In this case the farmers withdraw the benefits of liquidity and wealth that credit and saving deposits offer (Guizar, Gonzalez-Vega, and Miranda, 2014). Therefore, despite credit rationing and the interest rates wedge, policies of full financial inclusion represent a more effective financial intervention. Then, in what follows, we analyze policies of interest rates and credit limits in economies where the farmers have access to both financial services. Our analysis focuses on the effects of extending credit limits and on changes in deposit and loan rates. For simplicity, we first assume the distribution of the population across ages is uniform, so every retiree is replaced by a new farmer of age one. We then allow for changes in the demographic structure.

4.2.1 Uniform distribution of population

The blue lines above the red lines in figure (3) indicate that an increase of 40 percent in the credit limit will increase the economy's rate of adoption by 25 – 32 percentage points. In contrast, the flatness of all lines indicates that these rates are highly insensitive to changes in the loan rates, particularly in the economy with stringent borrowing limits. The major effect of less stringent

loans results from the lower adoption and abandonment thresholds of the representative farmer caused by the credit expansion. The minor effect of loan rates indicate lack of loan interest rate rationing in highly credit restrictive environments.

Figure 3: Effects of loan rates, deposit rates, and credit limits on the sustained adoption of the advanced technology in economies with equally distributed agents across age



Increases of interest rate on deposits (8 percentage points) raises the rates of sustained adoption in the credit-constrained economy, but has the opposite effect in the less credit rationed economy. The increment is expected since the higher interest rate encourages the farmers willingness and ability to accumulate deposits, thus to afford the advance technology and to buffer negative income shocks. The negative effect requires a more elaborate explanation. Loans, financial deposits, and the advance technology may serve as risk coping mechanisms. The latter, however, is illiquid and non-divisible. When the credit limit expands, deposits and the technology loose relevance as risk coping mechanism. They are now only investment mechanisms. As the deposit rates increase, the financial deposit becomes a better investment than the technology. Therefore, the rates of adoptions decline. As it will be explained below, this effect is further magnified in elder demographic profiles.

4.2.2 Non uniform distribution of population across age

Changes in the demographic structure of the economy unveil important effects of the financial policies on the proportion of farmers cultivating with the advance technology. The different panels in figure (4) display the implications of the different financial policies (right) for different demographic profiles (left).

Borrowing limits

Regardless of the credit size, the effect of credit diminishes as the population ages. The different panels are consistent with literature that points out that augmenting borrowing limits will foster technology adoption by expanding farmers opportunities to manage risk and invest. Nevertheless, its influence closes up in older populations. Comparing economies where the deposit rate is 2 percent (dashed lines) the results indicate that, in young populations a less restrictive credit policy guarantees 100 percent of sustained adoption, while a restrictive policy of 80 percent. This gap of 20 percentage points opens up to about 30 points in middle age populations (average age of 20 and 30 years) and closes to less than 10 percentage point in older economies.

The nonlinear outcome results from a more rapid reduction of adoption when credit is highly restrictive than otherwise. For instance, when the average is 20 years, the adoption rate remains at 100 percent with large limits but drops to 70 percent with restrictive borrowing limits. Therefore, creating conditions that allow lenders to expand credit limits are especially important in youthful populations when technological transformation and its inherent increase in income can be achieved. The result does not simply suggest that a flowing of credit into rural production would automatically increase adoption rates and reduce poverty. The result presumes that intermediaries are able to expand credit limits without incurring in default risk. Moreover, the effects observed rely critically on a sustained access to the financial

service. Shortsighted credit policies, then, might fail to achieve technological transformation and poverty reduction.

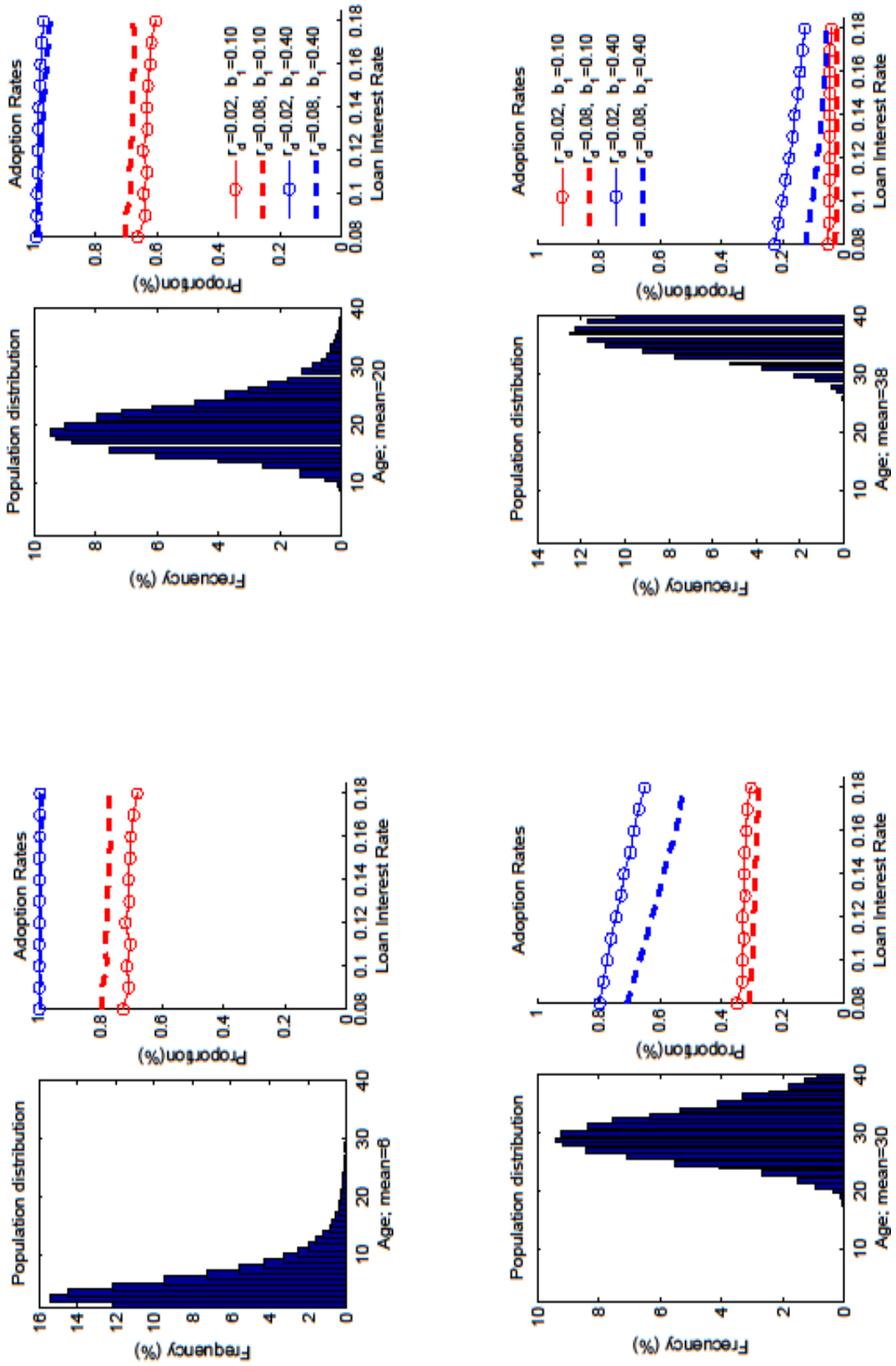
Interest rates

Regarding interest rates on loan, figure (4) indicates that policies of loan interest rates in loan-constrained economies would have minor or null effects on technology transformation, irrespective of the demographic structure, reflecting a situation of genuine non-interest credit rationing. Nonetheless economy's rate of adoption become responsive to the interest charged when the loan size is expanded, particularly as population reaches maturity. Sensitivity in less restricted environment arises from the higher interest burden implicit in a larger loan.

In young populations, however, the interest burden generated by the loan is affordable throughout the life cycle, thus adoption rates are less sensitive to interest rates compare to an economy where the average age is 30 years, where, for instance, the proportion of advance producers drops from 80 to 70 percent, when loan rate grows from 8 to 18 percent. In aging populations this rate increase drops the rates of adoption by less than one percentage point.

The relatively short range of rates considered might also explain the low response to interest rates. It is possible that not even the largest loan rate simulated (18 percent) is expensive enough to significantly influence individuals borrowing behavior. The possibility of observing sensitivity at much larger borrowing interest rates neither can be ruled out nor confirmed with our simulations as the numerical approximations become highly unstable in an upper range. These results then can be deemed as an optimistic reflection of relatively low interest rates on loan.

Figure 4: Demographic structure and financial policies effects on sustained adoption of technology



Policies of deposit interest rates simulate economies where net yield on deposits is low (2 percent) and high (8 percent). Figure (4) adds to our previous analysis of credit and loan rate policies in changing demographic structures the two deposit rates, represented with dotted and dashed lines respectively. The results indicate that in economies with young populations and unconstrained credit limits, the effect of distinctive rates of deposits is insignificant. As the retirement period is far away, farmers would not depend on deposits, but take advantage of the large loan to afford the adoption, therefore the effect of changing deposit rates is negligible.

As the economy ages, however, the higher deposit rate could play a major role either in facilitating the accumulation of wealth, thus maintaining high adoption rates, or in competing with the yield generated by the advance technology, thus reducing adoption rates. The dashed blue line moving below the dotted blue line in the bottom panels indicate the latter is true. Individual farmers maximize lifetime utility investing wealth in a deposit when retirement period approaches, so the higher interest rate discourages technology adoption. At an average age of 30, the increase of 6 percentage points in deposit rates implies a decrease of about 10 percentage points in adoption.

The two deposit rates in credit constrained environments represented by the red lines in figure (4) shed lights on not uniform effects on adoption rates. Given the credit limitation and young demography, the higher yield of deposits show an adoption rate of about 10percentage points higher than the low deposit rate. As demography evolves the higher deposit yield loses relevance regarding technology adoption because individual farmers would rather deposit than invest in the technology; indeed, we observe that adoption rates become higher when yield on deposits is low. Given that rate of adoption are not responsive to changes in loan rates in borrowing constrained economies, it is worth pointing out that different policies of deposit rates show a clear influence in adoption rates, which however, vanishes in an aged demography.

5 Conclusions

This paper develops numerical approximations of dynamic, stochastic models in order to investigate the influence of policies of interest rate and borrowing limits in overcoming poverty traps through the sustained adoption of advanced production technologies. The models take into consideration different stages in the farmers working life by setting the farmers dynamic maximization problem in a finite horizon.

The poverty traps arise from the farmers inability to afford the adoption and retention of an advance production technology. We presume that financial deposits and credit could play a major role breaking up the traps, but it is not uniform. The differences in their roles depend on the life cycle and underlying market primitives, such as the credit limit policies adopted by lenders and interest rates on deposits and loans.

The optimal solutions for the representative farmer shows that about ten periods preceding retirement, farmers are increasingly less willing to sacrifice current consumption by investing in an advance technology. Similarly, in this period, the farmer is increasingly more willing to abandon the technology whenever there is an income shortcoming. Although differences in regards to the optimal level of wealth for adoption and abandonment emerge with distinct policies of interest rates and credit limits, the pattern remains resilient to them. At the individual level, this trend cannot be reversed, but a careful design of financial policies might have an impact on the aggregate.

By expanding the models to a whole economy, where farmers behave as the representative agent but, as a result of having experienced distinct production shocks, are heterogeneous with respect to wealth and choice of technology, we examine the effects of the different financial policies on the rates of technology use, at the aggregate level. We first, assume a uniform distribution of farmers across each stage in the life cycle, so every retiree is replaced by a newcomer of age one. The demographic structure of the economy is later allowed to change.

Were the distribution of farmers uniform, a 40 increase in the credit limit for traditional farmers would increase the economy's rate of sustained adoption by 25 – 32 percentage points. These rates of adoption are highly insensitive to changes in loan rates, particularly in economies with stringent borrowing limits, suggesting situations of excess credit demand and non-credit interest rationing.

In contrast, changes in deposit rates show a clear influence on sustained adoption, but its effect is not independent of the credit limit. In credit-constrained economies, higher deposit rates raises the rates of sustained technological adoption, but has the opposite effect in less credit rationed economies.

The positive effect in credit constrained economies is expected since the higher interest rate encourages the farmers willingness and ability to accumulate deposits, and thus to afford the sustained use of the advance technology. The negative effect is requires a more elaborate explanation. Loans, financial deposits, and the advance technology may serve as risk coping mechanisms. The latter, however, is illiquid and non-divisible. When the credit limit expands, deposits and the technology loose relevance as risk coping mechanism. They are now only investment mechanisms. As the deposit rates increase, the financial deposit becomes a better investment tool than the technology. Therefore, the sustained rates of adoption decline.

The outcomes of financial intermediation policies differ substantially when the demographic structure is not uniform. Through policies of credit expansion, full financial transformation is achievable, but conditional on demographic structures being young. As the economy ages, the effect of credit vanishes. The result does not suggest that a flowing of credit into subsistence production will automatically increase adoption rates and reduce poverty, it rather suggest conditions to improve the effectiveness of credit policies. For instance, the result presumes that intermediaries are able to expand credit limits without incurring in default risk. Moreover, the effects observed rely critically on a sustained access to the financial service. Shortsighted credit policies, then, might fail to achieve technological transformation and poverty reduction.

Policies of loan interest rates in loan-constrained economies would have minor or null effects on technology transformation, irrespective of the demographic structure, reflecting situations of genuine non-interest loan rationing. Sustained rates of adoption, however, become responsive to loan rates when the loan size is expanded, particularly as population reaches maturity. This is because the interest burden is heavier when the credit size grows. Also, unlike young demographic profile, in a mature population the interest burden might not be affordable throughout the life cycle.

Arguments against the lack of response to loan rates might arise from the relatively short range of loan rates considered. It is possible that not even the largest loan rate simulated is high enough to significantly influence individuals borrowing behavior. The possibility of observing sensitivity at greater borrowing interest rates neither can be ruled out nor confirmed with our simulations as the numerical approximations become highly unstable in an upper range of loan rates. Our results then can be deemed as an optimistic reflection of relatively low interest rates on loan.

We presumed that comparatively high deposit rates would ease farmers wealth accumulation, which in turn will facilitate technology adoption. The results indicate that this holds true only in younger populations where credit is constrained, else the effect might even be the opposite. As the economy ages the higher deposit rate discourages the technology adoption because the yield of the advance technology is not sufficiently high to compensate the cost of adoption and retention of the technology, thus the deposits become a more attractive alternative investment. Moreover, as explained earlier, the potential use of the technology as a risk coping mechanism loses relevance when the credit size grows.

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Appendix

Figure 5: Response of the representative to expansion of credit limits

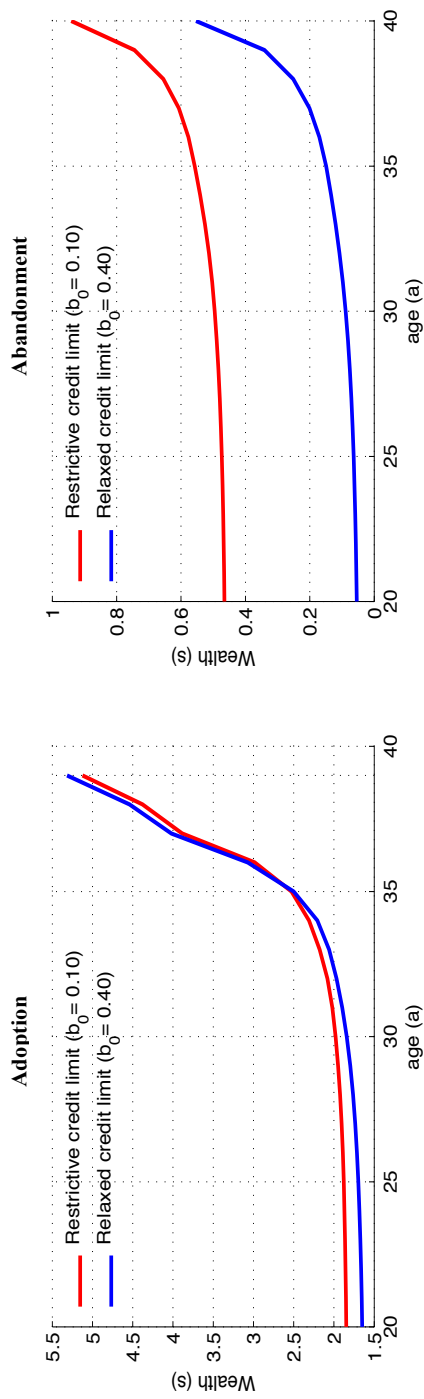


Figure 6: Response of the representative farmer to policies of interest rate

