Financial Access, Technical Transformation and Poverty Traps among Poor Farmers in Developing Countries

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Abstract

Poor farm households in developing countries can often find themselves trapped in a state of persistent poverty due to the inability to make the transformative investments needed to secure a higher sustainable income. The introduction of microcredit over the past thirty-five years has helped millions in the developing world to access credit, allowing many to invest in higher income-generating enterprises. However, microcredit has failed to have the large-scale sustainable impacts among the rural poor hoped my many. Microcredit in rural areas of developing countries today is typically unavailable, or available only in small rationed quantities that carry prohibitively high interest rates. In this paper, we analyze a dynamic life-cycle model of a poor agricultural household that can invest in an advanced production technology, provided it can secure the needed financing through credit or accumulated savings. We find that access to secure deposit facilities can offer a more effective and sustainable alternative to borrowing as a means to emerge from poverty, particularly if the required investment is high or loans are subject to stringent borrowing limits. We also find that the benefits of financial services depend primarily on access to such services, and vary little with the interest rates offered on savings deposits and charged on production loans.

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1 Introduction

A poverty trap is a state of persistent poverty that a household is unable to escape. Poverty traps can arise among the poor in developing countries for a variety of reasons, but are often attributable to the household's inability to make the transformative lumpy investment that can lead to a substantially higher sustainable income. These transformative investments can take many forms, including securing an education or training, migration, change of income producing enterprise, or major capital investment in a current productive enterprise.

The introduction of microcredit technologies over the past thirty-five years has helped millions in the developing world to access credit, allowing them to invest in higher income producing activities (Reed, 2015). However, microcredit has failed to have the large-scale sustainable impacts hoped by many, particularly among the rural poor (Tarozzi, Desai, and Johnson, 2015; Banerjee, Karlan, and Zinman, 2015; Attanasio et al., 2015). Microcredit in rural areas of developing countries today is typically unavailable, or available only in small rationed quantities that carry prohibitively high interest rates (Conning and Udry, 2007). Lack of access to financial services in rural areas can be attributed to a multiplicity of factors that contribute to high transactions costs and limit opportunities to take advantage of economies of scale (Lopez and Winkler, 2018). As such, many microcredit programs in developing countries typically have proven sustainable only with substantial external donor support or government subsidies.[1]

In this paper, we examine how access to borrowing and financial savings affect the ability of a poor farm household to adopt an advanced technology, such as irrigation equipment or a farm tractor, that would allow it to substantially increase its income, but which requires a large initial investment.[2] To this end, we develop and analyze a dynamic life-cycle model of a poor agricultural household that could achieve a higher sustainable income if they could access financing, either by borrowing or from accumulated sav-

[1]The notion that reliance on subsidies diminishes with time has also been discredited (Cull, Demirgüç-Kunt, and Morduch, 2018).

[2]Between 1970 and 2000, the number of tractors employed in high-income countries grew from 3.1 to 4.2, while average cereal yields grew from 2,736 to 4,695 kg per hectare; over the same period, the number of tractors employed in low-income countries actually dropped from 0.076 to 0.060, while average cereal yields changed little, from 1,016 to 1,084 kg per hectare.

ings, to make a sizeable investment in an advanced production technology. In our model, it is the discrete and lumpy nature of the investment and the lack of access to suitable financing required to adopt an advanced technology that fosters poverty traps. We explore how individual borrowing, saving, investment, and technology adoption decisions vary with access to financial services. We find that access to safe and reliable deposit facilities can prove superior to access to credit, particularly if credit carries high interest rates or is otherwise quantity constrained.

In section 2, we summarize published findings regarding the impact of financial access on technology adoption and emergence from poverty among the poor in developing countries. In section 3, we introduce a life-cycle model of a "representative" dynamically optimizing household that can either employ a traditional production technology or, subject to making a sizeable lumpy investment, adopt an advanced production technology that generates a greater sustainable income. In section 4, we parameterize the model to fit the stylized facts for a typical subsistence farm household in a developing country. In sections 5 and 6, we solve and simulate the model numerically under alternative assumptions regarding access to credit and deposit facilities to explore how financial access affect technology adoption, income, and consumption. In section 7, we summarize our findings and draw conclusions regarding the impact and sustainability of financial policies designed to promote technology adoption and poverty reduction among the poor of the developing world. An appendix provides an analysis of the sensitivity of our model's implications to less important behavioral parameters.

2 Financial Access in Developing Economies

Deterrents to advanced agricultural technology adoption among poor farmers in developing countries has been studied extensively in the literature, much of it centered on the lack of access to the financing required to make the needed investment.[3] Lack of access to financial services by poor farmers in developing countries is often blamed on high transactions costs attributable to a variety of structural impediments, including asymmetric information, incompatible incentives, and poor contract enforcement (Keeton, 1979; Stiglitz and Weiss,

[3] Extensive reviews of this literature include Feder, Just, and Zilberman (1985); Sunding and Zilberman (2001); Doss (2006); Suri (2011); Zimmerman and Carter (2003); Dercon and Christiaensen (2011).

1981; Besley, 1994; Levine, 2005; Conning and Udry, 2007). Covariance among the incomes of agricultural borrowers due to systemic shocks such as drought, which render agricultural loan portfolios susceptible to widespread defaults, also lead to highly restrictive borrowing limits and high rates of interests on loans, making borrowing prohibitively expensive (Miranda and Gonzalez-Vega, 2011; Farrin and Miranda, 2015; Brock and Rojas Suarez, 2000; Gelos, 2009).

Lack of financial access in developing countries can be discerned from table 1. It shows the percentage of adults with an account at a financial institution in selected regions of the developing world. East Asia and the Pacific exhibits the greatest degree of financial inclusion, with 69% of adults participating in formal financial markets, a figure that is nonetheless well below higher income countries, where financial inclusion exceeds a 90%. This is followed by East Europe and Central Asia (51%), Latin America and the Caribbean (51%), Sub-Saharan Africa (29%), and the Middle East (14%). Young adults between the ages of 15 and 24 years participate in formal financial markets in fewer numbers that older adults; in Latin America and the Caribbean and Europe and Central Asia the gap can be as great as 20 percentage points. Lack of financial inclusion is more prevalent among the poorest and those who live in rural areas. Between the richest 60% and the poorest 40%, the gap is in the double digits in every developing region, while the gap between richest and rural dwellers the difference is around 10 percentage points.

Table 1: Percentage of Adults with an Account at a Financial Institution in Developing Countries, by Region, 2014.

Region	Total	Young (15-24)	Older (>24)	Richest 60%	Poorest 40%	Rural
East Asia & Pacific	69	60	71	74	61	64
East Europe & Central Asia	51	36	56	56	44	46
Latin America & Caribbean	51	37	56	58	41	46
Middle East	14	7	17	19	7	11
Sub-Saharan Africa	29	21	33	36	25	24

Source: Global Financial Inclusion Database, World Bank (2018b).

Overall, the evidence suggests that achieving high rates of inclusion in formal financial markets remains an ongoing challenge. Table 2 sheds light on whether the obstacles to financial inclusion are primarily attributable to demand or supply factors. Focusing only on the poorest and rural sectors, table 2 separates use of formal borrowing and saving from the total (including formal and informal) borrowing and saving. Demand for formal and informal credit services indeed exists. Even in the Latin American region, where the portion of adults who borrow is lowest, participation is as high as 28% among the poorest and 31% among those residing in rural areas. Participation is higher in other regions. For instance, in Sub-Saharan Africa, more than half of the poor and rural dwellers reported taking loans. However, the proportion of those who borrowed from formal financial institutions is quite low, barely reaching 10% in any region. Participation in savings tells a similar story. The poor and rural inhabitants save. However, very few do so through formal mechanisms. In general, table 2 suggests that lack of inclusion in formal financial markets may be more a matter of supply than demand restrictions.

Table 2: Percentage of Population Participating in Credit and Savings Markets in Developing Countries, by Region, 2014.

	Credit				Saving			
Region	Poorest Total	Poorest Formal	Rural Total	Rural Formal	Poorest Total	Poorest Formal	Rural Total	Rural Formal
East Asia & Pacific	42	8	43	10	60	26	67	33
East Europe & Central Asia	42	10	37	11	32	4	37	7
Latin America & Caribbean	28	7	31	11	33	7	39	12
Middle East	48	5	46	5	22	2	26	2
Sub-Saharan Africa	54	5	54	6	53	9	58	13

Source: Global Financial Inclusion Database, World Bank (2018b).

The spread between rates offered on savings deposits and those demanded on loans reflects frictions in financial markets arising from transactions costs. In an ideal frictionless market, the spread would equal the difference between the cost of funds for the marginal borrower and the net return on savings deposits for the marginal saver (Gonzalez-Vega, 1977). However, in real markets, the spread must further reflects borrower non-interest transaction costs for borrower and saver. Underdeveloped markets, characterized by limited physical and institutional infrastructure, particularly in rural areas, will be plagued by higher transaction costs and exhibit comparatively wider spreads (Brock and Rojas Suarez, 2000; Gelos, 2009). As seen in table 3, spreads in low-income countries are more than twice those observed in high-income countries. The lending interest rate reported in the table is that charged by banks on private sector loans and the deposit interest rate is that offered by commercial banks on three-month savings deposits (World Bank, 2018a). The difference is much higher in rural areas.

Table 3: Average Bank Loan-Deposit Interest Rate Spread and Private Credit by Banks as a Percentage of Gross National Product, by Country Income Level, 2016.

Income Level	Percent Interest Rate Spread	Credit as Percent of GDP
High	4.0	95
Upper Middle	6.2	119
Lower Middle	7.0	41
Low	8.6	19

Source: World Development Indicators, The World Bank, 2018c

Lack of adequate collateral and high enforcement costs broaden the gap between the interest rates offered on savings deposits and the interest rates charged on loans (Brock and Rojas Suarez, 2000; Gonzalez-Vega, 2003; Gelos, 2009; Jaffee and Stiglitz, 1990; Gonzalez-Vega, 2011; Demirgüç-Kunt, Beck, and Honohan, 2008). For the same reasons, developing countries also exhibit relatively stringent borrowing limits on agricultural loans. Restrictions imposed by the lenders on loan amounts reflect, in the aggregate, a limited degree of financial depth as measured by the ratio of private sector credit to Gross Domestic Product (GDP). Table 3 shows striking differences in financial depth between low-income and other countries. Domestic credit is only 19% of GDP for low-income economies, about one-quarter of what it is in high income economies.

3 A Model of Credit, Saving and Technology Adoption

We now develop an annual life-cycle model of a "representative" dynamically optimizing "farmer" who begins each year t of his productive life employing a pre-determined production technology and possessing a pre-determined stock of wealth w, and who must decide how to apportion his wealth among consumption over the coming year, savings, production costs, and, potentially, investment in an advanced technology.

The farmer may employ one of two production technologies, a "traditional" technology $i = 0$ that produces a random income $\tilde{y}_0$ with expectation $\bar{y}_0$ the following year, or an "advanced" technology $i = 1$ that produces a random income $\tilde{y}_1$ with higher expectation $\bar{y}_1$ the following year. There is a annual cost $\kappa_j \geq 0$ associated with employing technology j, where $\kappa_1 \geq \kappa_0$. Moreover, acquiring advanced technology in perpetuity requires a one-time lumpy capital investment $K > 0$.[4] We summarize these costs by letting

$$\kappa_{ij} = \kappa_j + Kj(1 - i) \tag{1}$$

denote the total cost of adopting technology j in any given year, given technology i was used the preceding year.

The farmer may borrow up to a borrowing limit $b \geq 0$, provided he has invested in the advanced technology, which serves as collateral. Loans command an interest rate r_b and savings deposits earn an interest rate r_s, where $r_b \geq r_s$. As such, if the farmer holds net savings x this year, with $x < 0$ denoting the farmer carries debt and $x > 0$ denoting that holds positive savings deposits, it obtains a gross return

$$g(x) \equiv \begin{cases} (1 + r_b)x, & x \leq 0 \\ (1 + r_s)x, & x \geq 0 \end{cases} \tag{2}$$

at the beginning of the following year.

The farmer maximizes the present value of current and expected future utility of consumption over a finite decision horizon of T years, followed by an indefinite period in retirement over which the farmer finances consumption using wealth accumulated prior to retirement and additional family financial

[4]For example, the farmer could invest in durable irrigation equipment.

support. Assuming that the technology-specific incomes $\tilde{y}_0$ and $\tilde{y}_1$ are serially independent and identically distributed over time, the farmer's dynamic decision problem is characterized by a recursive Bellman equation whose age-specific value functions specify the maximum expected present value of lifetime utility $V_{ti}(w)$ attainable by the farmer from age t onward, given his wealth w and technology i at the beginning of the year:

$$V_{ti}(w) = \max_{\substack{w-\kappa_{ij} \geq x \geq -jb \\ j=0,1}} \{u(w - x - \kappa_{ij}) + \delta E_t V_{t+1,j}(\tilde{y}_j + g(x))\} \tag{3}$$

for $t = 0, 1, 2, \ldots, T$. Here, $\delta \in (0, 1)$ is the farmer's annual subjective discount factor and u is the farmer's utility, a twice continuously differentiable function of current consumption, with $u' > 0$, $u'' < 0$, and $u'(0) = -\infty$. Each year, consumption equals wealth w, less net savings x, less production and technology adoption costs κ_{ij}. Wealth next year equals production income $\tilde{y}_j$ plus gross returns on net savings $g(x)$.

The farmer retires at age $T + 1$, at which time he sells the advanced technology, if he acquired it, recovering a portion $\rho < 1$ of its original cost, supplementing his accumulated wealth w_{T+1}.[5] He then converts his entire cash holdings into a perpetual annuity that provides him with a fixed income $r_s(w_{T+1} + i\rho K)$ every year over his indefinite remaining lifetime, an amount that is further supplemented by a modest annual financial support P provided by his family. Thus, the Bellman functional equation is subject to the terminal condition

$$V_{T+1,i}(w_{T+1}) = \frac{1}{1-\delta} u(r_s(w_{T+1} + i\rho K) + P)). \tag{4}$$

We denote the *action-contingent value function* as

$$V_{tij}(w) = \max_{w-\kappa_{ij} \geq x \geq -jb} \{u(w - x - \kappa_{ij}) + \delta E_t V_{t+1,j}(\tilde{y}_j + g(x))\}, \tag{5}$$

if $w - \kappa_{ij} > -b$, and $V_{tij}(w) = -\infty$, otherwise. We denote the solution to 5 by $X_{tij}(w)$ and refer to X_{tij} as *action-contingent optimal savings policy.*

The action-contingent value function is directly recoverable from knowledge of the underlying value function. Conversely, the value function is related to the action-contingent value function through

$$V_{ti}(w) = \max\{V_{ti0}(w), V_{ti1}(w)\}. \tag{6}$$

[5]Note that $\rho = 0$ indicates the investment in the advanced technology a fully irreversible, and $\rho = 1$ indicates it is a fully reversible.

A farmer possessing wealth w and invested in the traditional technology at the beginning of year t will adopt the advanced technology if, and only if, $V_{t01}(w) > V_{t00}(w)$, implying that its *willingness-to-pay* to acquire the advanced technology in period t, $\pi_t(w)$, is characterized by

$$V_{t01}(w - \pi_t(w)) = V_{t00}(w). \tag{7}$$

As defined, a farmer possessing wealth w and invested in the traditional technology at the beginning of year t will adopt the advanced technology if, and only if, $\pi_t(w) > K$, that is, if, and only if their willingness to pay for the advanced technology exceeds its cost.

The farmer's value functions lack known closed-form expressions. However, if the functional forms are explicitly specified and parameterized, it is possible to compute arbitrarily accurate numerical approximations for the value functions and the farmer's optimal net savings and technology adoption policies using functional equation collocation methods (Miranda and Fackler, 2002; Judd, 1998). The collocation method calls for the value functions $V_{ti}(w)$ to be approximated using a linear combination of m prescribed basis functions ϕ_k:

$$V_{ti}(w) \approx \sum_{k=1}^{m} c_{tik}\phi_k(w) \tag{8}$$

and fixing the unknown $n = 2m(T+1)$ basis coefficients c_{tik} by requiring the value function approximants to exactly satisfy the Bellman equation at m prescribed collocation nodes $w_1, w_2, \ldots, w_m$. This requires solving a system of n nonlinear equations

$$\sum_{k=1}^{m} c_{tik}\phi_k(w_l) = \max_{\substack{w-\kappa_{ij} \geq x \geq -jb \\ j=0,1}} \left\{ u(w_l - x - \kappa_{ij}) + \delta E \sum_{k=1}^{m} c_{t+1,jk}\phi_k(\tilde{y}_j + g(x)) \right\} \tag{9}$$

for $t = 0, 1, \ldots, T$, $i = 0, 1$ and $l = 1, 2, \ldots, m$. For the purposes of this study, we employ cubic spline basis functions with equally spaced break points 0.001 units apart and discretize the admissible net saving levels x by confining them to a grid of equally-spaced nodes 0.001 units apart. The continuous income random variables were discretized using a 15-node Gaussian quadrature scheme. Computations were performed in Matlab using the CompEcon Toolbox (Miranda and Fackler, 2002).[6]

4 Model Parameterization

The parameter values selected for the baseline model, documented in table 2, reflect the stylized facts of rural financial markets in developing economies. The time-preference δ is set to 0.9, which describes impatient decisionmakers, as assumed by Fafchamps and Pender (1997).[7] The interest rate paid on savings deposits r_s is set to 5% to preclude excessive accumulation of liquid wealth, something rarely seen among poor farmers in developing countries (Deaton, 1991). The bank lending-deposit spread is set to 20%, double the economy-wide average observed in low-income countries (see table 3) to reflect the greater financial frictions that exist in the rural sectors. The borrowing limit b is set to 20% of expected annual income with the traditional technology. The cost of the lumpy investment K is set equal to the expected annual income with the advanced technology. Annual incomes with both technologies are assumed to be serially independent and identically log-normally distributed with common volatility (i.e., log standard deviation) $\sigma = 0.15$. For ease of interpretation, and without loss of generality, we normalize the expected income with the traditional technology to 1 and set the expected income with the advanced technology to 1.3.

The farmer is assumed to possess a utility of consumption function that exhibits constant relative risk aversion $\alpha > 0$:

$$u(c) \equiv \frac{c^{1-\alpha} - 1}{1 - \alpha}. \tag{10}$$

The values assumed for relative risk aversion in the literature vary widely. In a study encompassing 52 developing countries, Gandelman and Hernández-Murillo (2014) find coefficients of relative risk aversion vary from zero to three; Fafchamps and Pender (1997) find coefficients of relative risk aversion between 1.8 and 3.1 for poor farm households in India. Our assumed value of 2.5 is near the midpoint of the latter range.

[6] The Matlab code and CompEcon Toolbox used to solve and simulate the model are available from the authors upon request.

[7] This corresponds to a subjective annual discount rate of approximately 11%.

Table 4: Base Case Parameter Values

Symbol	Value	Description
T	41	Number of decision years
r_s	5%	Annual interest rate paid on savings deposits
r_b	25%	Annual interest rate charged on loans
R	30%	Annual rate of return on advanced technology investment
b	20%	Borrowing limit as a percent of advanced technology cost
ρ	50%	Salvageable portion of advanced technology cost
K	1.00	Cost of acquiring advanced technology
δ	0.90	Annual subjective discount factor
α	2.50	Coefficient of relative risk aversion
σ	0.15	Annual income log standard deviation
P	0.50	Annual post-retirement income

5 Optimal Borrowing, Saving and Technology Adoption

We begin by analyzing the representative farmer's optimal savings and technology adoption decisions under the base case parameterization, assuming that the farmer has access to both credit and savings. We then simulate how different scenarios regarding access to financial services affect the farmer's probability of adopting the advanced technology. We refer to a farmer who has adopted the advanced technology as an "advanced farmer" and one who has not as a "traditional farmer".

5.1 Optimal Behavior with Access to Credit and Savings

Figure 1 illustrates the present value of expected remaining lifetime utility for a younger traditional farmer, contingent on retaining the traditional technology (blue) or adopting the advanced technology (red). For low levels of wealth, the farmer does not adopt the advanced technology, given that doing so would exact a high opportunity cost in terms of forgone utility of consumption. As the farmer's wealth increases, it reaches a critical level w^*

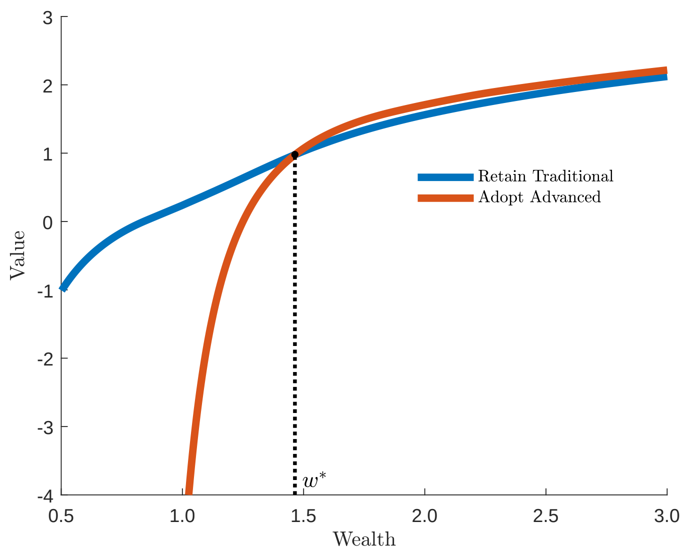

Figure 1: Action-Contingent Value Functions, Young Traditional Farmer

at which the farmer is indifferent between adopting and not adopting the advanced technology. At greater levels of wealth, the farmer adopts the advanced technology, given that diminishing marginal utility of consumption implies a lower opportunity cost from doing so. The figure is typical of traditional farmers throughout their productive lifetime, and begins to change only as the farmer approaches retirement, as the financial returns to adoption decline due to a diminishing productive horizon.

Figure 2 illustrates optimal net savings policies for younger traditional and advanced farmers. Consider first the savings policy for a traditional farmer (blue). At low levels of wealth, the traditional farmer lacks the resources required to invest in the advanced technology, and is thus unable to borrow due to lack of collateral. His optimal policy is to consume his limited wealth and save nothing, given that his current marginal utility of consumption exceeds that expected the following year without saving. Beginning at wealth level w_1, the farmer has sufficient wealth to merit saving some of it, with the amount saved rising with wealth, in order to equate marginal utility between years; however, the farmer still lacks sufficient wealth to merit acquiring the advanced technology. Once his wealth reaches the critical level w^*, the farmer adopts the advanced technology, entering into debt and borrowing the maximum allowable amount b in order to finance the investment.

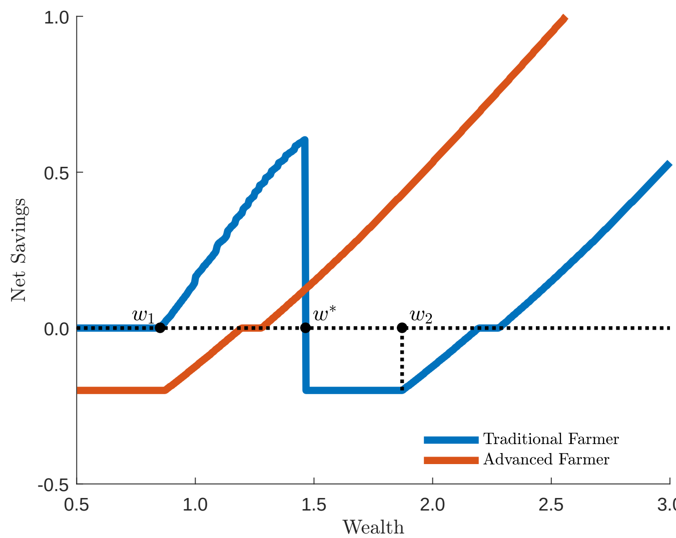

Figure 2: Optimal Net Savings Policy, Young Traditional and Advanced Farmer

Once wealth rises beyond w_2, the farmer borrows less than the allowable amount, choosing to finance the investment partly through borrowing and partly from what would otherwise be held as savings. Beyond that level of wealth, the net amount saved strictly rises with wealth, except over a short interval over which his net savings is zero, which is a natural consequence of having distinct interest rates earned by savings deposits and charged on loans.

Consider now the savings policy for an advanced farmer (red). Unlike the traditional farmer, the advanced farmer is able to borrow, given that, having adopted the advanced technology, he possesses the required collateral. For low levels of wealth, the advanced farmer borrows the maximum allowable amount to finance current consumption in excess of his current wealth. As his wealth rises, he eventually reaches a level at which it is optimal for him to reduce the amount he borrows, and ultimately reaches a level beyond which he net saves more as his wealth increases.

Figure 3 illustrates a traditional farmer's willingness to pay to adopt the advanced technology at ages 1 (blue) and 38 (red). The traditional farmer's willingness to pay for the advanced technology rises with wealth, regardless of age. At lower levels of wealth, the farmer's willingness to pay for the advanced technology does not exceed its cost K, and the farmer does not

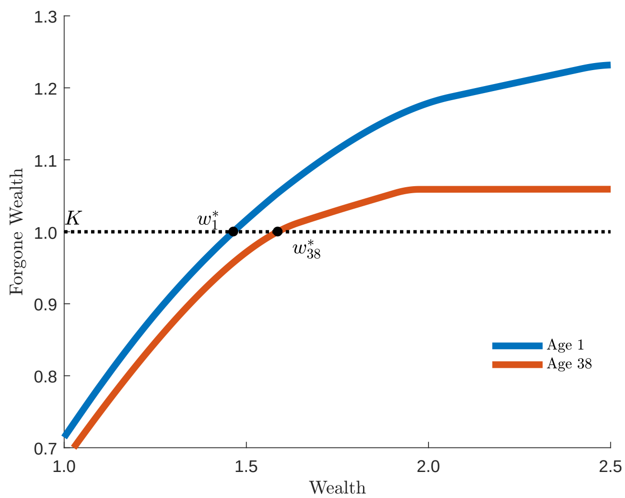

Figure 3: Traditional Farmer Willingness to Pay for Advanced Technology vs Wealth, Ages 1 and 38

adopt the advanced technology; at sufficiently higher levels of wealth, however, the farmer's willingness to pay exceeds its cost, and the farmer adopts the advanced technology. As seen in figure 3, a young traditional farmer's willingness to pay for the advanced technology is greater than that of an older traditional farmer, at all wealth levels, given the older farmer faces a shorter productive horizon over which to recover his investment. As a consequence, the critical minimum level of wealth needed to induce a traditional farmer to invest in the advanced technology rises with age.

5.2 Effects of Financial Access on Advanced Technology Adoption

If and when a traditional farmer adopts the advanced technology will depend on his access to financing. It will also depend on the realizations of random incomes. Traditional farmers who enjoy good fortune early in their productive life will be able to adopt the advanced technology sooner than those who suffer bad fortune. In order to assess the timing of advanced technology adoption, the optimal decisions of a representative farmer was simulated for 100,000 independent hypothetical income streams under alternate assumptions regarding financial access.

Figure 4 illustrates the probability of initial advanced technology adoption

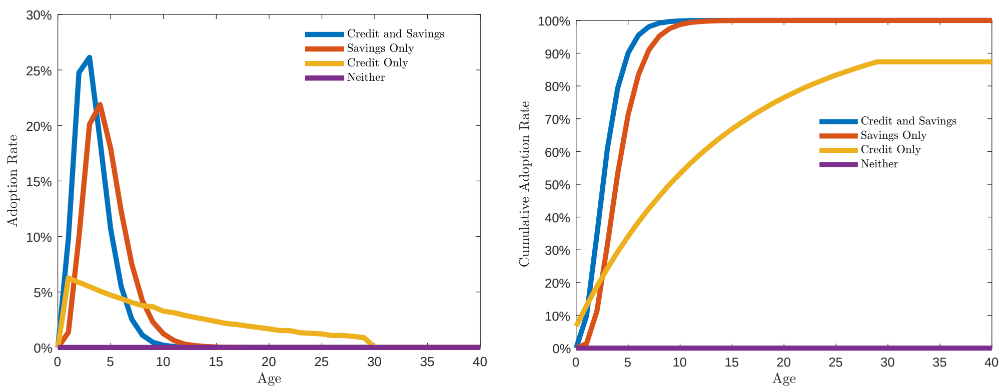

Figure 4: Probability of Initial Advanced Technology Adoption and Cumulative Probability of Advanced Technology Adoption vs Age, by Financial Access

(left panel) and cumulative probability of sustained adoption of the advanced technology (right panel) by age, under four financial access scenarios: the farmer has access to both credit and savings (blue); the farmer has access only savings (red); the farmer has access only to credit (yellow); and the farmer has access neither to credit nor savings (purple).

Consider first a traditional farmer who lacks access to both credit and savings. Under the base-case parameterization, in which acquisition of the advanced technology requires a sizeable lumpy investment equal to average annual income with the traditional technology, the farmer will occasionally realize incomes that exceed the cost of the advanced technology. However, even when his income is greater than normal, investing in the advanced technology will leave little for consumption. The opportunity cost of forgone consumption will be too great for the farmer to bear. As such, the farmer will never adopt the advanced technology and will remain snared in a poverty trap for his entire productive life.

Access to credit, savings or both will provide the traditional farmer with the means to invest in the advanced technology, something he will prefer do earlier rather than later in his productive life in order to secure maximum lifetime gains from adoption. However, the timing of adoption will depend on the types of financial service available to him.

Consider a farmer who has access to credit, but not to savings. Given the farmer cannot borrow the entire cost of the advanced technology, he will invest in the advanced technology only when he has been favored by a sufficiently high income from the traditional technology. With luck, such an opportunity will arise early. However, given that the long-term benefits of adoption erode as the farmer's productive horizon diminishes, the probability of adoption declines as the farmer ages, eventually falling to zero as the end of his productive horizon approaches. Under the base-case parameterization, the probability that the traditional farmer will ultimately adopt the advanced technology at some point during his productive lifetime, given access to credit alone, is 90%. However, adoption occurs at a median age of 10 years. Moreover, with probability 10%, a farmer with access to credit alone will never adopt the advanced technology and live out his life in relative poverty.

Consider now a farmer who has access to savings, but not to credit. Given that the farmer cannot borrow, he will be able to adopt the advanced technology only after he has accumulated sufficient savings to make adoption possible. This occur at a median age of three years, substantially earlier than if the farmer had access only to credit. Moreover, with access to savings alone, the farmer is virtually certain to adopt the advanced technology by year 9. The access to a deposit facility, however, would force the traditional farmer to choose whether to invest in the advanced technology that yields random returns or to hold a greater amount of deposits that offer a certain return. The comparatively greater benefit of the advanced technology shrinks as farmers productive period shortens. Under the baseline parametrization, the probability of adopting the technology then collapses to zero very early in life. If the farmer has access to both credit and savings, adoption occurs slightly earlier, at a median age of 2, and with near certainty by year 8. Clearly, access to savings, not credit, is the primary driver of early adoption of the advanced technology.

6 Aggregate Impacts of Financial Services

We now examine the effects of access to financial services on the agricultural sector as a whole. To this end, we assume the agricultural sector consists of a large population of farmers who behave as the representative farmer, but who otherwise experience independent idiosyncratic income shocks, thereby generating cross-sectional heterogeneity in advanced technology adoption and wealth at harvest for every age cohort. To further simplify the analysis, we assume that the number of farmers who enter the agricultural sector each year exactly equals the number of farmers who retire, implying that, in steady-state, the distribution of working farmers is uniform across ages.[8]

Table 5: Steady-State Aggregate Rate of Advanced Technology Adoption, Per-Capita Wealth and Net Savings at Harvest, Per-Capita Annual Consumption, Net Savings at Retirement, and Willingness to Pay for Access to Financial Services, by Financial Access.

	Financial Access			
Variable	Both	Deposits Only	Credit Only	Neither
Advanced Technology Adoption	92%	89%	67%	0%
Wealth at Harvest	1.71	1.77	1.15	1.00
Net Savings at Harvest	0.50	0.56	−0.03	0.00
Annual Consumption	1.18	1.18	1.17	1.00
Net Savings at Retirement	3.17	3.20	0.00	1.00
WTP for Financial Services	0.48	0.46	0.22	

Table 5 presents the steady-state aggregate rate of advanced technology adoption, per-capita wealth and net savings at harvest, annual consumption, and net savings at retirement under alternate assumptions regarding the financial services available to the agricultural sector as a whole. Without access to financial services, that is, without access to either savings or credit, no farmer adopts the advanced technology and per-capita wealth at harvest and annual consumption both equal expected income with the traditional technology, which we have normalized to 1.

Access to credit alone increases per-capita wealth at harvest by 15%, access to savings alone increases it by 77%, and access to both credit and savings increases it by 71%. In steady-state, the advanced technology is employed by 67% of farmers, given access to credit alone, by 89% of farmers, given access to savings alone, and by 92% of farmers, given access to both credit and savings. Given access to savings alone, approximately 32% (0.56/1.77) of farmers wealth at harvest derives from past savings, and the remainder

[8]If the population of farmers exhibits a positive rate of growth, and the number of farmers entering exceed those exiting, the age distribution will be skewed toward younger farmers. This would affect the numerical results we are about to present; however, it would do so in predictable and otherwise unremarkable ways.

from current income; given access to both credit and savings, approximately 29% (0.50/1.71) of farmers wealth at harvest derives from past savings, and the remainder from current income.

Access to financial services increases farmers' annual consumption during their productive life between 17% and 18%, varying little across different financial service combinations. However, access to savings, with and without an accompanying access to credit, allows farmers to accumulate by the time they retire approximately 3.2 years of annual income with the traditional technology, ensuring a substantially higher post-retirement standard of living.

Table 5 also presents the willingness to pay for access to different financial services. Willingness to pay is defined as the lump-sum a beginning traditional farmer would be willing to accept in lieu of access to the prescribed financial service. The representative farmer values access to credit alone at 22% of average annual income from the traditional technology. He values access to savings alone at 46% of average annual income from the traditional technology, more than twice the value he ascribes to access to credit alone. Given access to savings, the farmer would only be willing to pay an additional 2% of average annual income from the traditional technology in order to have access to both savings and credit.

Tables 6 and 7, respectively, present the steady-state aggregate rate of advanced technology adoption and willingness to pay for financial access by an entering traditional farmer, under different forms of financial access and varying levels of key financial parameters. The parameters are set below, at, and above their base case levels. More specifically, the borrowing limit is varied between 0% and 40% of the cost of the advanced technology, the annual interest rate offered on savings deposits is varied between 0% and 10%, the annual rate charged on loans is varied between 10% and 30%, the annual rate or return on the amount invested in the advanced technology is varied between 20% and 40%, and the lump sum investment required to acquire the advanced technology is varied between 0.50 and 1.50 (i.e., 50% and 150% of expected annual income with the traditional technology, respectively).

Farmers generally receive greater value and adopt the advanced technology at a greater rate given access to savings deposits rather than access to credit alone. Moreover, providing access to credit in addition to access to savings deposits only marginally increases value and adoption. The difference in value and adoption between access to savings deposits and access to credit alone will be quite pronounced if the borrowing limit is stringent, the rate of return on advanced technology investment is low, or the cost of the

Table 6: Aggregate Percentage Rate of Advanced Technology Adoption by Financial Access, Alternate Financial Parameter Values

		Financial Access		
Parameter	Parameter Value	Both	Deposits Only	Credit Only
Borrowing Limit as Percent of Advanced Technology Cost	0%	89	89	0
	20%	92	89	67
	40%	95	89	90
Annual Interest Rate Paid on Deposits	0%	92	88	66
	5%	92	89	67
	10%	92	89	67
Annual Interest Rate Charged on Loans	10%	92	89	67
	25%	92	89	67
	40%	92	89	67
Annual Rate of Return on Advanced Technology Investment	20%	87	80	0
	30%	92	89	67
	40%	93	91	68
Cost of Acquiring Advanced Technology	0.50	98	97	98
	1.00	92	89	67
	1.50	78	54	0

advanced technology is high. Access to credit alone can produce value and adoption rates comparable to access to savings deposits only if the borrowing limit is liberal or the cost of the advanced technology is low.

Interest rates have no or negligible impact on advanced technology adoption, regardless of the financial services available to the farmer. The value of access to savings deposits naturally increases as the rate earned by savings deposits rises, and the value of access to credit naturally increases as the rate charged on loans falls. However, the impact of interest rates on the value received by farmers from access to financial services remains surprisingly low. The value derived from financial services depends primarily and quite simply on the ability to borrow and/or save to secure the funds needed to invest in the advanced technology. The opportunity costs of taking out a loan or

Table 7: Willingness to Pay for Financial Access, Entering Traditional Farmer, Alternate Financial Parameter Values

Parameter	Parameter Value	Financial Access: Both	Financial Access: Deposits Only	Financial Access: Credit Only
Borrowing Limit as Percent of Advanced Technology Cost	0%	0.46	0.46	0.00
	20%	0.48	0.46	0.22
	40%	0.50	0.46	0.46
Annual Interest Rate Paid on Deposits	0%	0.46	0.44	0.21
	5%	0.48	0.46	0.22
	10%	0.50	0.48	0.22
Annual Interest Rate Charged on Loans	10%	0.49	0.46	0.26
	25%	0.48	0.46	0.22
	40%	0.47	0.46	0.19
Annual Rate of Return on Advanced Technology Investment	20%	0.49	0.31	0.00
	30%	0.48	0.46	0.22
	40%	0.46	0.44	0.39
Cost of Acquiring Advanced Technology	0.50	0.13	0.10	0.09
	1.00	0.48	0.46	0.22
	1.50	0.30	0.16	0.00

dipping into savings to acquire the advanced technology remain relatively inconsequential, provided the rate of return on the investment is substantially higher.

Regardless of the financial services available, farmers adopt the advanced technology at greater rates as the cost of the advanced technology falls and the rate of return on advanced technology investment rises. However, although farmers are generally better off with lower costs and higher rates of return, their impact on the relative value of access to financing can be ambiguous. In our base line simulations, the cost of acquiring the advanced technology is set to the expected annual income with the traditional technology, which has been normalized to 1, and the annual rate of return is set to 30%. If the cost of the advanced technology is lower, so is the gross return provided by investing in it, given a fixed rate of return, reducing the value provided by any form of financing. If the cost of the advanced technology is higher, access to the needed financing, whether via credit or savings deposit accumulation, becomes more difficult, also reducing the value provided by financing. However, regardless of the investment needed to acquire the advanced technology or the rate of return it provides, farmers derive greater value from access to savings deposits than to access to credit alone.

7 Summary and Conclusions

A multitude of microfinancial development initiatives across the globe over the past half century have been motivated by an abundant literature that promotes access to credit as a means to poverty reduction among the poor (e.g., Alderman and Paxson, 1994; Deaton, 1992; Kochar, 1999; Giné and Yang, 2009; Dercon and Christiaensen, 2011). However, these initiatives often ignore warnings regarding the limitations of credit. Adams and Von Pischke (1992), for example, point out that indebtedness exposes the rural poor to significant financial risks that they are ill-equipped to bear, and argue that access to deposit facilities would be a safer and more effective means to promote their ability to invest in advanced technologies. Ahlin and Jiang (2008) also argue that the lasting effects of microcredit depend on the simultaneous provision of saving facilities.

In this paper, we develop and analyze a dynamic life-cycle model of a poor agricultural household that that has an opportunity to emerge from by poverty by making a transformative permanent investment that will generate a higher sustainable income. However, the investment is "lumpy, requiring a one-time commitment of funds that significantly exceeds the households annual income. As such, to make the transformative investment, the household must have access to financial services, either in the form of access to secure savings deposits facilities, which will allow the household to accumulate the funds needed to invest, or in the form of access to credit, which will allow the household to borrow the money needed to make the investment.

We use our model to analyze how access to either savings or credit, or both, affect the households investment decisions and lifetime income profiles. Our key finding is that access to secure savings deposit facilities can offer a more effective and sustainable alternative to borrowing as a means for poor households to emerge from poverty, particularly if the required investment is high or loans are subject to stringent borrowing limits. The benefits of access to credit alone are comparable to those offered by access to savings deposits alone only if the farmer is allowed to borrow amounts significantly exceed annual income, a situation that is unlikely to materialize due to lenders concerns over default. Our results, moreover, are generally insensitive to the interest rates offered on deposits and the interest rates charged on loans.

We also find that the benefits to financial access vary over the lifecycle. In particular, the traditional farmer's incentive to make a transformative investment diminishes as he ages, regardless of the financial services available to him. Moreover, a farmer that has been beset by poor fortunes early in life may never reach the point at which adoption of the advanced technology is optimal. As such, government policies to promote financial access should be aimed at younger farmers and may need to be coupled with promotion of insurance services if general poverty reduction goals are to be met.

Adoption of advanced production technologies arguably provides the most promising pathway for emergence from poverty among poor smallholder farmers of the developing world. Our findings add nuance to the established scholarly literature regarding the role that access to financial services in promoting technical transformation and poverty reduction. For policy purposes, acknowledging that access to savings has a greater potential to drive technical change and emergence from poverty among poor farmers than access to credit challenges the persisting view among development economists and policy makers that credit as the best approach to poverty reduction.

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