# The Aggregate Impact of Household Saving and Borrowing Constraints: Designing a Field Experiment in Uganda*

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**Abstract**

What is the nature of the financial needs and constraints that households in developing countries face and what is the impact of relaxing them? We develop a model of households with multiple financial needs (smoothing shocks, financing investment) and constraints (limited credit, self-control issues). We show that increased access to credit has very different implications for the aggregate model economy depending on whether the credit is in the form of asset-financing loans or cash loans. We illustrate how a short-term increase in access to credit leads to very distinct behavior across the two credit types in the short run. The relevance of the model can be evaluated and key parameters identified using a field experiment, which we are currently implementing in Uganda.

*Keywords*: household savings, borrowing constraints, irreversible investment, non-convexities, quasi-geometric discounting.

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# 1 Introduction

Broadly speaking, financial deepening and increased access to savings and credit are associated with macroeconomic development, and a vast theoretical and empirical literature has shown this to, at least in part, reflect a causal relationship.[1] Much less is known about how different types of financial access affect the the micro-behavior of households and the aggregate development of an economy.

We examine the impact of access to credit of different types on the micro-behavior of households in the context of a model where households face several different financial needs and constraints, typical of economic environments of many developing countries. [2] Specifically, in the model elaborated in Section 2, households face income uncertainty and have a desire to smooth consumption through saving and/or borrowing. They also face potentially high returns to entrepreneurial investments giving them additional motives to save and/or borrow. We also model low returns on savings and potentially limited self-control because of acute impatience (quasi-hyperbolic discounting).[3]

In Section 3, we map the model to key moments of microdata from Uganda, and evaluate the macroeconomic impacts of relaxing the borrowing constraints. In the aggregate, the model produces very different predictions for increased access to cash loans than it does for asset-financed (ie., in-kind) loans. The flexibility of cash loans allows them to more easily be used for current consumption purposes. Consequently, cash loans lead to large increases in output, consumption, investment and entrepreneurship at the time they are made available, but the majority of this impact is only transitory. In the long run, the largest impacts of cash loans are an increase in indebtedness and a decline in net worth. These dynamics are driven largely by the interaction of low interest rates (so people desire to dissave) balanced by high income uncertainty which gives some demand for precautionary savings. In contrast, asset-financed loans lead to smaller initial impacts on consumption and borrowing but larger increases in investment. In the long run, asset-financed loans lead to higher output, consumption, investment, net worth and entrepreneurship rates, and less indebtedness. These results are driven primarily by the presence of high yield entrepreneurial investments. These predictions are overwhelmingly robust to whether or not households discount geometrically (in a time-consistent fashion) or quasi-hyperbolically (time-inconsistent), but whether or not households suffer from time inconsistency problems greatly changes the welfare implications of increased access to the two types of credit. Hyperbolic discounters strongly prefer investment

[1] A review of this literature is available in Levine (2005)

[2] Similar environments are examined in Buera, Kaboski and Shin (2011, 2012), Kaboski and Townsend (2011), Midrigan and Xu (forthcoming), Townsend and Ueda (2006), and Gine and Townsend (2004).

[3] Constraints on savings is another, closely related, issue. See, for example, Dupas and Robinson (2012), and Ashraf, Karlan and Yin (2006)

loans, which help them commit more easily.

Long term access to credit is difficult to manipulate, but a short-term increase in access to the two types of credit also yields distinguishable patterns. In Section 4, we show that one period access to both cash and asset-financed loans leads to increases in investment and indebtedness, but for cash loans, the increase in borrowing is over four times while the increase in investment is less than one-fifth as high. Moreover, cash loans lead to a one period increase in consumption, while investment loans lead to an initial decline as households lower consumption to help finance investment.[4]

Using these results of the model for short-term access, we have designed a field experiment which we are currently conducting in Uganda. The results will allow us to evaluate the relevance of the model for microbehavior, which will allow us to better assess the macroeconomic implications of increased access on development.

# 2 Model

The economy is populated by a continuum of households who face idiosyncratic income risk and can either operate a traditional technology or a modern technology. The modern technology requires a one-time irreversible investment of a fixed size and provides an efficiency advantage over the traditional technology. Households have CRRA preferences with quasi-hyperbolic discounting, of the form studied by Laibson (1997) and Krusell and Smith (2003).

## 2.1 Preferences

A household's objective function is:

$$V_t = \frac{c_t^{1-\sigma}}{1-\sigma} + \beta E_t \sum_{\tau=1}^{\infty} \delta^t \frac{(c_{t+\tau})^{1-\sigma}}{1-\sigma}$$

where $c_t$ is the household's consumption at date $t$. The parameter $\beta$ governs the extent to which the household discounts next period's utility, while $\delta$ governs the extent to which it discounts all future periods.

We assume that $\beta < 1$ so that agents are relatively more impatient in the short-run (the discount factor between $t$ and $t+1$ is $\beta\delta$), but relatively patient (with a discount rate of $\delta$) between period $t+1$ and $t+2$ and thereafter. This creates a conflict with the period $t+1$ self, who discounts at a rate of $\beta\gamma$ between periods $t+1$ and $t+2$. We model quasi-hyperbolic

[4] Kaboski and Townsend (2011) compare an actual cash loan policy in Thailand with a counterfactual simulation in which credit is contingent on investing. Fafchamps (2011) compare differential responses of cash and in-kind grants on microentrepreneurs in Ghana.

agents who are "sophisticated" in that they realize the conflict with their future selves. As is standard, although unable to commit, they play a game with their future selves.

## 2.2 Technology

There is a single consumption good in this economy. Agents operating the traditional technology receive output

$$y_t = e_t$$

where $e_t$ is the household's efficiency and follows a Markov process.

Agents operating the modern technology receive output

$$y_t = z_m e_t$$

where $z_m > 1$ is the relative efficiency of the modern sector.

Entry into the modern sector requires a one-time fixed irreversible investment $\kappa$. This irreversible investment suffers from "one hoss shay" depreciation with a constant hazard $\pi$ in any given period. In this case, the agent switches to operating the traditional technology and must invest again to re-enter the modern sector. The expected life of the investment is thus $1/(1-\pi)$ periods. Finally, we assume that investment opportunities arrive infrequently, with a constant hazard $\pi_m$. The agent can only invest in the modern technology upon arrival of such an investment opportunity, otherwise she remains in the traditional sector.

## 2.3 Finance

Agents in our economy can save and borrow by issuing or purchasing long-term securities. Long-term credit is critical in this environment since investments are long-term and returns mostly accrue in future periods, making it difficult for agents to finance them with short-term debt, especially since the availability of credit will fluctuate.

A tractable way to model a long tem security (see Hatchondo and Martinez, 2009, and Arellano and Ramanarayan, 2012) is as a perpetuity contract with coupon payments that decay geometrically. The contract specifies a price $\omega$ and a face value $l_t$, the latter of which is freely chosen by the borrower. An agent that issues $l_t$ units of the security (a borrower) receives $\omega l_t$ units of the good in period $t$ and must repay $\gamma^{s-1} l_t$ units in all future periods $t+s$ : $l_t$ next period, $\gamma l_t$ in two periods, $\gamma^2 l_t$ in 3 periods. Here $\gamma$ determines the length of the contracts: the higher $\gamma$, the longer the maturity.

Let $d_t = \omega l_t$ be the amount an agent borrows at date $t$. Given a history of borrowing in past periods, the total amount that the household must repay at $t$ is $b_t/\omega$, where:

$$b_t = d_{t-1} + \gamma d_{t-2} + \gamma^2 d_{t-2} + ... = \sum_{j=1}^{t} \gamma^{j-1} d_{t-j}$$

is the total debt of the household. Given new borrowing at date $t$, the total debt of the household evolves over time according to:

$$b_{t+1} = d_t + \gamma b_t \tag{1}$$

## 2.4 Budget and Borrowing Constraint

We assume a borrowing constraint of the form:

$$b_{t+1} \leq \max(\gamma b_t, 0) + \lambda_t.$$

The parameter $\lambda_t$ acts as a limit on the amount of new debt an agent can issue. [5] For an agent who invests , $\lambda = \lambda_1 + \lambda_2 \kappa$, while for an agent who doesn't $\lambda = \lambda_1$. We therefore view $\lambda_1$ as governing the availability of cash loans and $\lambda_2$ as governing any additional funds available for investment purposes (i.e,. asset-financed loans).

In addition, agents face budget constraints depending on whether they are in the traditional sector and not investing, in the traditional sector but investing to move to the modern sector, or operating in the modern sector, respectively:

An agent that resides in the traditional sector and does not invest in the modern technology faces a budget constraint:

$$c_t + (1 + r) b_t = e_t + b_{t+1}$$

An agent that currently resides in the traditional sector, but is paying the investment cost to join the modern economy faces the budget constraint:

$$c_t + (1 + r) b_t + \kappa = e_t + b_{t+1}$$

An agent that currently resides in the modern sector, and is remaining in the modern sector faces the budget constraint:

$$c_t + (1 + r) b_t = z_m e_t + b_{t+1}$$

We model sophisticated quasi-hyperbolic problem who are aware that they play a game between current and future selves. In general, such set-ups lead to both multiple equilibria

[5] The max operator captures the idea that lenders cannot force borrowers to repay existing debt obligations faster than what is specified by the perpetuity contract.

and indeterminacy. Following Krusell, Kuruscu, and Smith (2002), we focus on a particular set of equilibria: equilibria of Markovian strategies that are the limits of finite horizon problems. The solution to this problem gives decision rules $c^m(a,e)$, $b'^m(b,e)$ for agents already in the modern sector, $c^{\tau,\tau}(b,e)$, $b'^{\tau,\tau}(b,e)$ for agents that stay in the traditional sector, and $c^{\tau,m}(b,e)$, $b'^{\tau,m}(b,e)$ for agents that switch to the modern sector, and a switching rule, $s(b,e)$ for agents in the traditional sector that receive an investment opportunity.

These policy functions have several important features. First, the decision to invest and enter the modern sector is characterized by a minimum level of assets above which the agent invests. Second, the more productive the agent (i.e., the higher the $e$), the lower this threshold level. Third, consumption is everywhere increasing in assets and concave, except at this threshold level of assets where consumption jumps down as the agent makes the high yield, indivisible investment. Fourth, the concavity of consumption leads to a steady state desired level of savings. Poor agents save for precautionary reasons, and rich agents dissave for impatience, leading to a steady state level of desired assets. In addition, however, the modern sector gives agents an additional self-financing motive for saving. For sufficiently high productivity agents, this motive is large enough that a steady state exists only in the modern sector, while steady states for lower productivity agents exist in both the modern and traditional sectors. That is, a low productivity agent who starts out with a low level of assets will not save up to eventually enter the modern sector.

Details of the recursive set-up of the problem and policy functions are available in the on-line appendix.

# 3 Results

## 3.1 Calibration

In order to evaluate the model's predictions, we must parameterize our income process and calibrate the model parameters. Summary details are given in Table 1. Setting the period to one quarter, we assume an AR(1) process for income:

$$\ln e_t = \rho \ln e_{t-1} + \sigma_\varepsilon \varepsilon_t$$

Several values are assigned using standard values in the literature: the discount factor for future selves, $\delta$, of 0.98; a risk aversion parameter, $\sigma$, of 2, and $\delta$ equal to 0.75, implying a duration of loans of 4 quarters.

The remaining seven parameters are chosen endogenously to match specific features of a developing country context, in our case Uganda. These seven data moments are derived from a baseline pilot survey of 399 households in Fort Portal, Uganda. We assign an interest rate on savings of $r = 0$, consistent with very low availability of formal savings. Similarly, the values of the parameters governing the borrowing constraint, $\lambda_1 = \lambda_2 = 0$ in our baseline analysis approximate the fact that the households we surveyed have very little debt.[6] Household responses to questions about the likelihood of various income realizations in the future imply an income variance equal to 0.25, which maps directly into our value of $\sigma_\varepsilon$.

The remaining six parameters are chosen to simultaneously match the following moments. Responses about the average desired investment imply an average investment size of about one quarter of average household income in the data.[7] The households we surveyed save very little: their level of liquid savings is equal to only about one-fourth of their quarterly income.[8] We target a fraction of agents in the modern sector of 0.36, equal to the fraction of households who own a business in the data, and a fraction of agents that enter the model sector of 1.9% per quarter, consistent with 7.6% of households having opened up their business in the previous year. Finally, the median consumption of those households that own a business (which we interpret in the model as having joined the modern sector) is about 37% larger than that of households that do not. Our last moment is taken from the work of de Mel et. al (2008) who estimate returns to capital in micro-enterprises in Sri-Lanka and find these to be around 5% per month or 15% per quarter. Absent such an estimate for our Uganda data, we use this additional target to pin down the productivity advantage of the modern sector, $z_m$. Intuitively, the relative consumption (income) of agents in the modern sector is greater than that of agents in the traditional sector for two reasons. First, such agents operate with the higher efficiency $z_m$. Second, such agents have a higher productivity, $e$. The importance of this second selection effect is pinned down by $\rho$, the parameter that governs the persistence and thus cross-sectional variability of productivity across households. By using direct estimates of the returns to capital, we are able to disentangle the extent to which differences in consumption across agents that own and do not own businesses is driven by selection vs. efficiency differences. [9]

For the remaining values, chosen to jointly minimize the distance between the moments and the data, the results are as follows. A fairly low discount factor between periods $t$ and $t + 1$, $\beta = 0.547$, is necessary for the model to simultaneously match the low savings rates observed in the data and the high returns to investment. The probability that an agent exits the modern sector, $\pi$=0.054: the average duration of the modern technology is thus 18.5

[6]The mean debt in our sample is 53,000 UGX or about 21 USD.

[7]The mode of the projected investment sizes of households we surveyed is equal to 500,000 UGX, or approximately 200 USD. Trimming the top and bottom 5% of the outliers, the mean projected investment size is 823,000 UGX. The per-capita quarterly income of agents in our sample is 600,000 UGX.

[8]The mean net financial assets are 177,000 UGX or 28 percent of quarterly income.

[9]Since investments in our model are long-lived and irreversible, computing returns to investment in the model is nontrivial. Details are in the online appendix.

quarters. The efficiency advantage of the modern sector is equal to $z_m = 1.17$. This number, together with our estimate of $\rho$ of 0.75, is necessary to simultaneously match the returns to investment of 15% and the consumption gap between agents that own a business and those that do not. Finally, investment opportunities arrive fairly infrequently, with a probability of $\pi_m = 0.30$.

Overall, the fit is fairly good, owing to the fact that the model is exactly identified. However, we report several additional predictions of the model. First agents in the modern sector hold three times more financial savings than agents in the traditional sector, even though they produce only 30% more output on average. The reason these agents save more is that they face the risk of exiting the modern sector and thus a stronger precautionary-savings motive. Also note that a large fraction (70%) of households are borrowing constrained, an artifact of the very low rates of time preference.

Comparative static simulations with the model's key parameters underscore the identification in the model by illustrating how these parameters affect on the moments we target. (See Appendix for more details.) First, an increase the short-run discount factor, $\beta$, from 0.55 in our baseline to 0.65 causes agents to save too much now in this economy: more than doubling their financial savings, and increasing their physical assets by more than one-third relative to the data. Second, if we reduce the persistence of productivity from 0.75 to 0.5, the selection effect becomes weaker and the gap between the consumption of agent in the modern and traditional sector falls (by 15 percentage points) along with fraction entering the modern sector and the return to investment. These last two moments are affected more directly, however, by a reduction in the productivity advantage of the modern sector, $z_m$: lowering this advantage from 1.17 to 1.085 lowers the fraction of agents adopting the modern technology by more than half and the returns to investment by more than two-thirds. Finally, eliminating the assumption that investment opportunities arrive infrequently (increasing $\pi_m$ from 0.3 to 1) increases somewhat the fraction of agents that adopt the modern technology.[10]

## 3.2 Aggregate Long Run Implications of Credit

We next show that access to cash or investment-financing lines of credit have different long run implications for the aggregates in our economy by illustrating the impact of increases in $\lambda_1$ and $\lambda_2$, respectively, on the steady state values of consumption, investment, income and entrepreneurship rates in the population.

[10] If we fix $\pi_m = 1$ and rather reduce $z_m$ to match the fraction of agents in the modern sector, the returns to investment decline to about 10%, thus much lower than the estimates of de Mel et. al (2008).

### 3.2.1 Cash lines of credit

Consider an increase in the cash credit limit, $\lambda_1$, from 0 to 0.20. Given that $\lambda_1$ constrains the amount the agent can borrow in any given period, the maximum amount of debt an agent can take on is given by $\lambda_1/(1-\delta) = 0.8$, thus about two-thirds of per-capita income.[11] The second column of Table 2 shows that a large fraction, 86%, of agents indeed take up these loans: the debt to income ratio thus increases to about 50%. Since agents are now poorer (the asset to income ratio falls from 0.25 to -0.36), those that receive investment opportunities are less able to undertake them and the fraction of agents that operate the modern technology falls from 36% to 28%. Consequently consumption and output fall by 0.9% and 1.4%, respectively. Interestingly, overall steady state welfare, defined as the constant amount of additional consumption $\bar{c}$ in the ergodic steady state of the no credit world that would the same level of life-time utility as that of the average household in the world with borrowing, only falls by 0.09% in this experiment.[12] Welfare falls much less than aggregate consumption because agents are better able to smooth consumption now that they have access to cash lines of credit. Only 11% of agents are borrowing-constrained in this setup, compared to 70% in our baseline model and consumption is thus somewhat less sensitive to changes in income, as the last two rows of Table 2 indicate. Figure 1 shows the dynamics of consumption, output, investment, debt, net worth, and the activity in the modern sector after an unanticipated permanent increase in the cash credit limit.

Of course, the reduction in steady state utility associated with an increase in the cash lines of credit only ignores the transitional welfare gains. An unanticipated increase in the cash credit limit from 0 to 0.20 leads to a sharp increase in consumption that only gradually returns to the somewhat lower new steady state level. Welfare therefore increases in the short-run and decreases in the long run, but overall agents are better off with the relaxed constraint, equivalent to a 1.93% permanent increase in consumption.

### 3.2.2 Investment lines of credit

Consider instead an increase in the investment credit limit, $\lambda_2$, from 0 to 0.50, which allows agents to finance up to 50% of the cost of their investment. In contrast to the cash line of credit, the investment line of credit leads to an increase in steady state consumption (by 1.8%) and welfare (2.6%) as shown in Table 2. This is a result of the higher fraction of

[11] The field experiment we conduct has a 500 USD loan cap, or twice the quarterly income.

[12] That is, our consumption equivalent welfare measure solves:

$$\left(1 + \frac{\beta\delta}{1-\delta}\right)\frac{\bar{c}^{1-\sigma}}{1-\sigma} = \int V_0^m(b,e)dn^m(b,e) + \int V_0^\tau(b,e)dn^\tau(b,e),$$

where $n^m()$ and $n^\tau()$ are the steady-state measures of agents in the modern and traditional sectors.

agents operating the modern technology compared to baseline (52% compared to 36% in the baseline). Similarly, steady state welfare increases by 1.2%, despite the fact that agents hold less financial savings and are unable to smooth consumption as well as in the baseline model. Figure 2 shows the transition dynamics in response to a permanent increase in the investment credit limit: consumption and output increase gradually to their new steady state levels. Because consumption only increases gradually, the welfare of agents on impact increases by less (0.8%) than it does once the economy converges to the new steady state.

### 3.2.3 Comparison with model with geometric discounting

We next compare our model's steady-state implications with that of a model with geometric discounting by setting the short-run discount factor, $\beta$, equal to 1, and the long-run discount factor, $\delta$, equal to 0.88 so that the model reproduces the financial savings to output ratio of 0.25 in the data and in our baseline model, while leaving all other parameters unchanged.

The welfare implications of the two different policies depend strongly on whether households discount geometrically or quasi-hyperbolically, although – consistent with earlier literature (e.g., Barro, 1999) – the predicted patterns for observables do not differ dramatically. We find similar output, consumption and investment responses to increased access to credit in the model with hyperbolic and geometric discounting. With cash loans, the welfare of households when the policy change is announced increases much more on impact when preferences are geometric, by 6.9%, compared to 1.9% when preferences are hyperbolic. Relative to geometric discounters, the hyperbolic agents put less weight on their consumption increase in the near future (after the initial period) but they place higher weight on the lower long run consumption in the steady state under our parameter choices.[13]. Under investment loans, this difference is much smaller (0.15% for geometric vs. 0.9% for hyperbolic) because the transition path is smoother, and steady state consumption is higher with investment loans.

Another way to see the welfare impacts is to measure the utility value of access to the modern technology, which acts as a commitment device for hyperbolic agents. Steady state consumption increases by 4.2% in the economy with hyperbolic preferences and by only 3.2% in the economy with geometric discounting. Similarly, steady-state welfare increases by 4.8% in the economy with hyperbolic preferences and by only 2.8% in the economy with hyperbolic discounting.

Our welfare calculations so far are computed from the perspective of the self that makes the decision in the period when the credit line is introduced. Of course, to the extent to which the planner weighs places a higher weight on the welfare of future selves, cash lines of credit

[13]For example, with $\delta = 0.98$ and $\beta = 0.547$ as in our hyperbolic model, the weight on a self 20 periods from now is equal to 0.365, much higher than the weight of 0.078 of an agent with $\delta = 0.88$ and $\beta = 1$

may not necessarily be welfare-improving. Only investment lines of credit unambiguously increase the welfare of current future generations.

# 4 Designing a Field Experiment

We have emphasized that the aggregate implications of permanent access to cash and investment loans are quite different in the long run, and may have very different welfare implications. Lacking the ability to run long run experiments, we now use the model to design a logistically feasible short-term experiment that leads to observable predictions that can help assess the relevance of the model. Such an assessment will help determine how seriously we should take the long run predictions. The experiment uses the differential responses to temporary increases in cash and investment loans to distinguish hyperbolic from geometric responses. Feasibility is key, since we are implementing this model-designed experiment in continuing research based on actual field experiment in Uganda.

## 4.1 Simulated Experiment

Figure 3 shows the what happens if we increase the cash credit limit, $\lambda_1$, for one period. We rescale all series (except for debt) relative to their pre-intervention steady-state values so as to make the responses of hyperbolic and geometric consumers comparable. We see that households take advantage of the increase in availability of cash loans mostly to finance consumption. Although investment increases by about 40%, the absolute level of investment is very small to begin with so about 90% of the increase in credit is absorbed by the increase in consumption. Consequently, output increases little and households gradually repay the initial consumption increase by cutting consumption in future periods. Consider next a one period increase in the investment credit limit, $\lambda_2$ as in Figure 4. Not surprisingly, such an intervention mostly affects investment and thus leads to a protracted increase in output. Interestingly, aggregate consumption falls in the period when the credit limit increases as those households that invest find it optimal to reduce consumption to finance investment.

## 4.2 Implementing the Field Experiment: Current and Next Steps

We are currently implementing a field experiment approximating the simulated experiment as a pilot in Fort Portal, Uganda. The baseline survey, which we referenced earlier, involved a sample of 399 households, randomly selected from a census of 2168 households collected around 40 GIS coordinates randomly selected from 100 gridded points across the municipality of Fort Portal, Uganda. The sample was stratified based on job type, whether they had taken loans in the past, whether they had a savings account, the gender of the head of household, whether they wanted to take a loan, and household income in order to ensure a representative sample. We collected data on household composition and demographics, consumption, savings, investment, income from various sources including business, desired investments, perceived income risk, and time and risk preferences. At baseline, all households were offered free savings accounts in the institution. Realized take-up of savings accounts was low: 203 households stated that they would like to open the savings accounts at the time they were offered, but only 40 households had opened an account as of 2 months later.

After two months, credit offers were extended to participants. Eleven percent of the least creditworthy participant households were eliminated from the participant pool as subjects to which the partner NGO, Pride, did not want to extend credit. One-third of the remaining households are being notified and given an open offer of a credit line for a cash loan available for a 3-month period, one-third are being given an open offer of a credit line for an asset-financed loan available for a 3-month period, and one-third are being kept as a control. Of those being offered a cash loan, half are asked to pledge collateral if they take the loans and half are not asked for collateral. We are surveying the households at the time they are notified that they are eligible for the credit, and at the end of the 3-month period to assess take up and household debt, as well as consumption, investment and income responses.

Together the pilot and model will assist in the development of the design for a larger scale experiment across the regional capitals of Uganda. Access and use of formal savings accounts and credit is rare outside of Kampala, so the treatment represents an important change in the access of households to financial tools. In designing the experiment, we use the model to generate predictions on the key variables that we identified in the experiment. Simulations across various levels of income uncertainty and risk aversion, and various entrepreneurial productivities, use parameters identified in our experiments. Moreover, these simulations give us a way of better predicting the sample sizes needed to get tight estimates. Finally, variation in loan terms and savings accounts in our field experiment will allow us to identify the hyperbolic discounting parameter. Such evidence, gained in a model where credit constraints are present, will help us assess the usefulness of standard questions designed to elicit such preferences. This is important given the relevance to normative evaluation.

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# A Appendix

This appendix contains the details of the recursive formulation, computed policy functions, and the computation of the returns to investment.

## A.1 Recursive Formulation

Because the quasi-hyperbolic problem involves a game between current and future selves, there are, in general multiple, equilibria and indeterminacy. Following Krusell, Kuruscu, and Smith (2002), we will focus on a particular set of equilibria: equilibria of Markovian strategies that are the limits of finite horizon problems. To solve for such equilibria, we write the problem recursively.

Let $V_0^m(b,e)$ be the value of an agent in the modern sector. Let $V_0^\tau(b,e)$ be the value of the agent in the traditional sector. Similarly, let $V^m(b,e)$ and $V^\tau(b,e)$ be the continuation values of future selves.

The Bellman equation is:

$$V_0^m(b,e) = \max_{c,b'} \frac{c^{1-\sigma}}{1-\sigma} + \beta\delta \int \left[(1-\pi)\, V^m(b',e) + \pi V^\tau(b',e')\right] dG(e'|e)$$

s.t.

$$c + (1+r)\, b = z_m e + b'$$

$$b' \leqslant \max(\gamma b, 0) + \lambda_1$$

Similarly, we have:

$$V_0^\tau(b,e) = \begin{cases} \max\left[V_0^{\tau,m}(b,e), V_0^{\tau,\tau}(b,e)\right] \text{ with prob. } \pi_m \\ \\ V_0^{\tau,\tau}(b,e) \text{ witj prob. } (1-\pi_m) \end{cases}$$

where $V_0^{\tau,m}(b,e)$ is the value of switching to the modern sector and $V_0^{\tau,\tau}(b,e)$ is the value of staying in the traditional sector and recall that $\pi_m$ is the probability that an investment opportunity arrives. We have

$$V_0^{\tau,m}(b,e) = \max_{c,b'} \frac{c^{1-\sigma}}{1-\sigma} + \beta\delta \int V^m(b',e')\, dG(e'|e)$$

s.t.

$$c + (1+r)\, b + \kappa = e + b'$$

$$b' \leqslant \max(\gamma b, 0) + \lambda_1 + \lambda_2 \kappa$$

and

$$V_0^{\tau,\tau}(b,e) = \max_{c,b'} \frac{c^{1-\sigma}}{1-\sigma} + \beta\delta \int V^\tau(b',e')\, dG(e'|e)$$

s.t.

$$c + (1+r)\,b = e + b'$$

$$b' \leqslant \max(\gamma b, 0) + \lambda_1$$

The solution to this problem gives decision rules $c^m(a,e)$, $b'^m(b,e)$ for agents already in the modern sector, $c^{\tau,\tau}(b,e)$, $b'^{\tau,\tau}(b,e)$ for agents that stay in the traditional sector, and $c^{\tau,m}(b,e)$, $b'^{\tau,m}(b,e)$ for agents that switch to the modern sector. Moreover, we have a switching rule, $s(b,e)$ for agents in the traditional sector that receive an investment opportunity:

$$s(b,e) = 1 \text{ if } V_0^{\tau,m}(b,e) \geqslant V_0^{\tau,\tau}(b,e)$$

The continuation values of future selves are defined as follows:

$$V^m(b,e) = \frac{\tilde{c}^m(b,e)^{1-\sigma}}{1-\sigma} + \delta \int \left[(1-\pi)\,V^m\left(\tilde{b}'^m(b,e), e'\right) + \pi V^\tau\left(\tilde{b}'^m(b,e), e'\right)\right] dG(e'|e)$$

$$V^\tau(b,e) = \begin{cases} \tilde{s}(b,e)\,V^{\tau,m}(b,e) + (1-\tilde{s}(b,e))\,V^{\tau,\tau}(b,e) \ \text{ with prob. } \pi_m \\ \\ V^{\tau,\tau}(b,e) \ \text{ with prob. } (1-\pi_m) \end{cases}$$

$$V^{\tau,m}(b,e) = \frac{\tilde{c}^{\tau,m}(b,e)^{1-\sigma}}{1-\sigma} + \delta \int V^m\left(\tilde{b}'^{\tau,m}(b,e), e\right) dG(e'|e)$$

$$V^{\tau,\tau}(b,e) = \frac{\tilde{c}^{\tau,\tau}(b,e)^{1-\sigma}}{1-\sigma} + \delta \int V^\tau\left(\tilde{b}'^{\tau,\tau}(b,e), e\right) dG(e'|e)$$

Note that there is no maximization in this last set expressions for the continuation values of future selves. We use instead the policy functions $\tilde{s}(a,e), \tilde{c}(a,e)$ and $\tilde{b}'(b,e)$, which are the Markov reaction functions of future selves. Denoting these joint reaction functions as $\tilde{\Gamma}(a,e)$ and the counterpart policy functions of the current self as $\Gamma(a,e)$, the Markov Perfect equilibrium is the solution of the fixed point problem, $\Gamma = \tilde{\Gamma}$.

Figure 1.A reports the decision rules of a household with a relatively high level of productivity. The left column of the figure illustrates the savings rule, $a' = -b'$, for agents residing in the modern and traditional sectors, respectively, as a function of the agents' beginning of period assets. The right column illustrates the associated consumption choices. Superimposed on the savings rules is the 45-degree line: whenever the savings choice is above the 45-degree line, the agent increases its stock of savings: the intersection of the two lines thus shows the steady-state level of assets that would prevail absent any changes in productivity. Finally, the vertical line in the lower panels of the figures shows the switching cutoff: the minimum level of assets at which, given the opportunity to do so, the agent pays the fixed cost and joins the modern sector.

The upper panel of the figure is typical for Bewley-Aiyagari models of the type we study here: the consumption function is concave, poor agents save for precautionary reasons, and rich agents dissave because of impatience. The lower panel of the figure shows that the agent must have accumulated a sufficiently large level of savings to find it worthwhile to join the modern sector. When they do switch, their level of financial savings goes to 0 (the assumed borrowing limit in this example) and consumption experiences a discrete fall. Notice that in this particular example the agent's savings choice when poor is above the 45 degree line: the agent thus builds up a stock of asset and eventually switches to the modern sector.

Figure 2.A contrasts the decision rules of the relatively productive agent in Figure 1 with those of a relatively unproductive agent and focuses on the savings choices of those in the traditional sector. Notice that the cutoff level of assets necessary to switch to the modern sector is higher for the less productive agent. Moreover, less productive agents save less. Indeed, an agent that always receives the lower productivity realization does not save enough to build up the stock necessary to enter the modern sector (the 45-degree line intersects the savings rule before the cutoff is reached) and stays permanently in the traditional sector. Figure 3.A summarizes this discussion by illustrating the time-series paths of consumption and savings for the productive and unproductive agents. The more productive agents builds up the necessary stock of savings in 5 periods, switches to the modern sector and experiences a sharp increase in consumption after the initial investment period. The less productive agent, in contrast, saves little and never switches sectors.

## A.2 Computing Returns to Investment

We comput returns to (the long-lived, irreversible) investment in the model as a risk-neutral equivalent retunr. Assume a risk-neutral investor who faces an interest rate $r$. Such an investor is indifferent between adopting the modern sector and not doing so as long as the project has a net present value of zero. Let $V_i$ denote the expected present value of the output produced by the modern technology. This value satisfies:

$$V_i = (z_m - 1)\, e_i + \frac{(1-\pi)}{1+r} \sum_j P_{i,j} V_j$$

where $P_{i,j}$ is the probability that a household with productivity $e_i$ in the current period draws productivity $e_j$ next period. Letting $V$ denote the vector of values for each productivity level, we have

$$V(r) = (z_m - 1) \left[ I - \frac{1-\pi}{1+r} P \right]^{-1} e$$

where $P$ is the matrix describing the Markov transition probabilities and $e$ is vector of productivities. Since entering the modern sector requires paying a fixed cost $\kappa$ one period in advance, the interest rate that makes an investor indifferent between investing in a project of type $i$ solves:

$$\frac{1}{1+r_i} V_i(r_i) - \kappa = 0$$

We compute the returns to investment as the weighted average of $r_i$, weighting each productivity type by the fraction of households of that particular type that switch to the modern sector in the ergodic steady state of the economy.

## A.3 Details of Computed Results

The remaining tables and figures give more details of the analyses described in Section 3.

Table 1: Parameterization

Panel A: *Moments*

| | Data | Model |
|---|---|---|
| *Moments used in calibration* | | |
| mean investment to per-capita income | 1.00 | 1.06 |
| financial assets to income ratio | 0.25 | 0.25 |
| fraction in modern (own business) | 0.365 | 0.36 |
| fraction entering modern sector | 0.019 | 0.020 |
| median consumption modern/tradit. | 1.37 | 1.40 |
| average return to investment at entry | 0.150 | 0.132 |
| *Additional model predictions* | | |
| mean fin. assets modern/tradit. | | 3.19 |
| mean consumption modern/tradit. | | 1.32 |
| mean output modern/tradit. | | 1.30 |
| mean productivity modern/tradit. | | 1.11 |
| mean productivity switch/don't | | 1.62 |
| Fraction borrowing constrained | | 0.70 |
| Fraction traditional constrained | | 0.76 |
| Fraction modern constrained | | 0.60 |

Panel B: *Parameters*

| | |
|---|---|
| *Endogenously chosen* | |
| $\beta$, current self discount factor | 0.547 |
| $\kappa$, investment / per-capita output | 1.06 |
| $\pi$, probability exit modern | 0.054 |
| $z_m$, modern efficiency advantage | 1.17 |
| $\pi_m$, prob. receive investment opportunity | 0.30 |
| $\rho$, AR(1) coefficient productivity | 0.75 |
| *Assigned* | |
| $\delta$, future selves discount factor | 0.98 |
| $\sigma$, CRRA | 2 |
| $\sigma_\varepsilon$, std. dev. shocks | 0.25 |
| $r$, interest rate | 0 |
| $\delta$, persistence coupon payments | 0.75 |

All moments are based on the survey conducted in Uganda, except for the returns to capital estimate which are taken from de Mel et. al (2008).

Table 2: Steady State Comparisons: Hyperbolic vs. Geometric Discounting

| | *Hyperbolic* | | | *Geometric* | | |
|---|---|---|---|---|---|---|
| | Baseline | $\lambda_2 = 0.20$ | $\lambda_2 = 0.50$ | Baseline | $\lambda_1 = 0.20$ | $\lambda_2 = 0.50$ |
| assets to income | 0.25 | -0.36 | 0.17 | 0.25 | -0.46 | 0.21 |
| fraction in modern | 0.36 | 0.28 | 0.52 | 0.27 | 0.16 | 0.42 |
| fraction borrowers | 0 | 0.86 | 0.22 | 0 | 0.89 | 0.09 |
| fraction constrained | 0.70 | 0.11 | 0.77 | 0.39 | 0.08 | 0.44 |
| Consumption | 1.119 | 1.109 | 1.139 | 1.108 | 1.095 | 1.128 |
| Output | 1.143 | 1.127 | 1.173 | 1.126 | 1.105 | 1.156 |
| Debt to Output | 0 | 0.49 | 0.03 | 0 | 0.52 | 0.02 |
| Welfare, $\bar{c}$ | 0.9876 | 0.9867 | 0.9990 | 0.9853 | 0.9717 | 1.000 |
| elasticity $\Delta \ln(c_{it})$ to $\Delta \ln(y_{it})$ | 0.845 | 0.825 | 0.867 | 0.847 | 0.868 | 0.850 |
| std. dev. $\Delta \ln(c_{it})$ / std. dev. $\Delta \ln(y_{it})$ | 0.907 | 0.880 | 0.923 | 0.882 | 0.897 | 0.884 |

Figure 1: Dynamics after an unanticipated increase in cash credit limit, $\lambda_1$, from 0 to 0.2

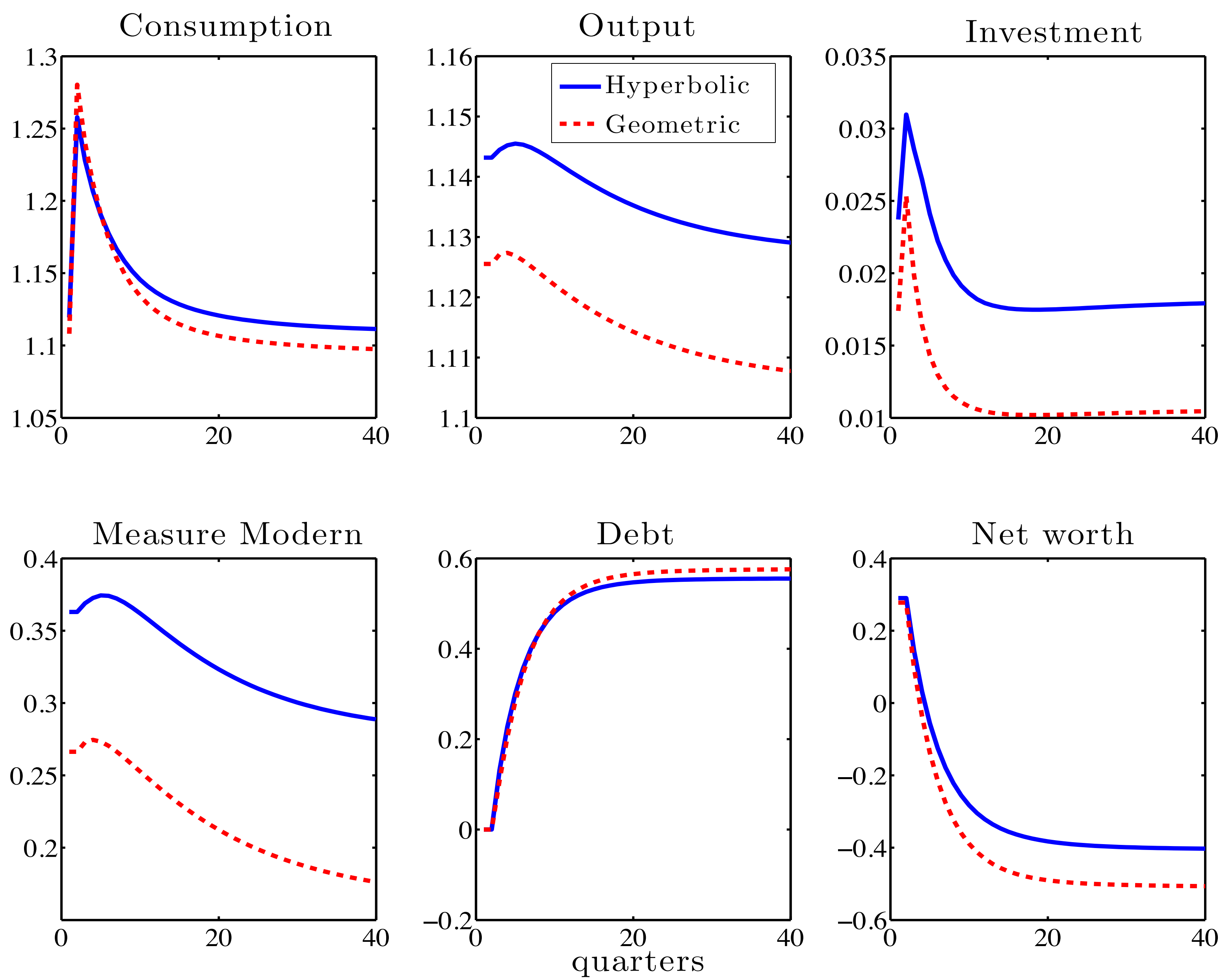

Figure 2: Dynamics after an unanticipated increase in investment credit limit, $\lambda_2$, from 0 to 0.5

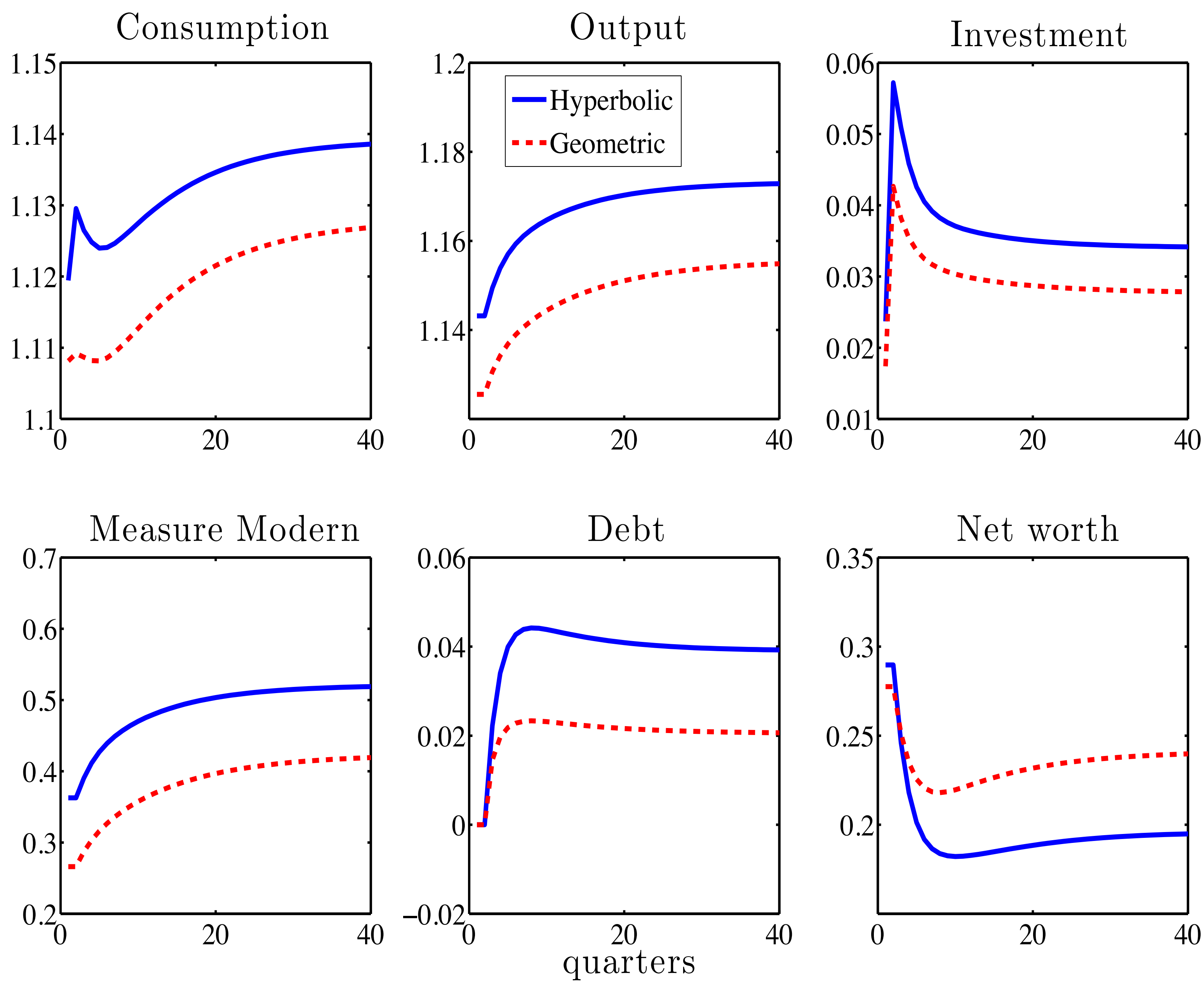

Figure 3: Dynamics after a transitory increase in cash credit limit, $\lambda_1$, from 0 to 0.2

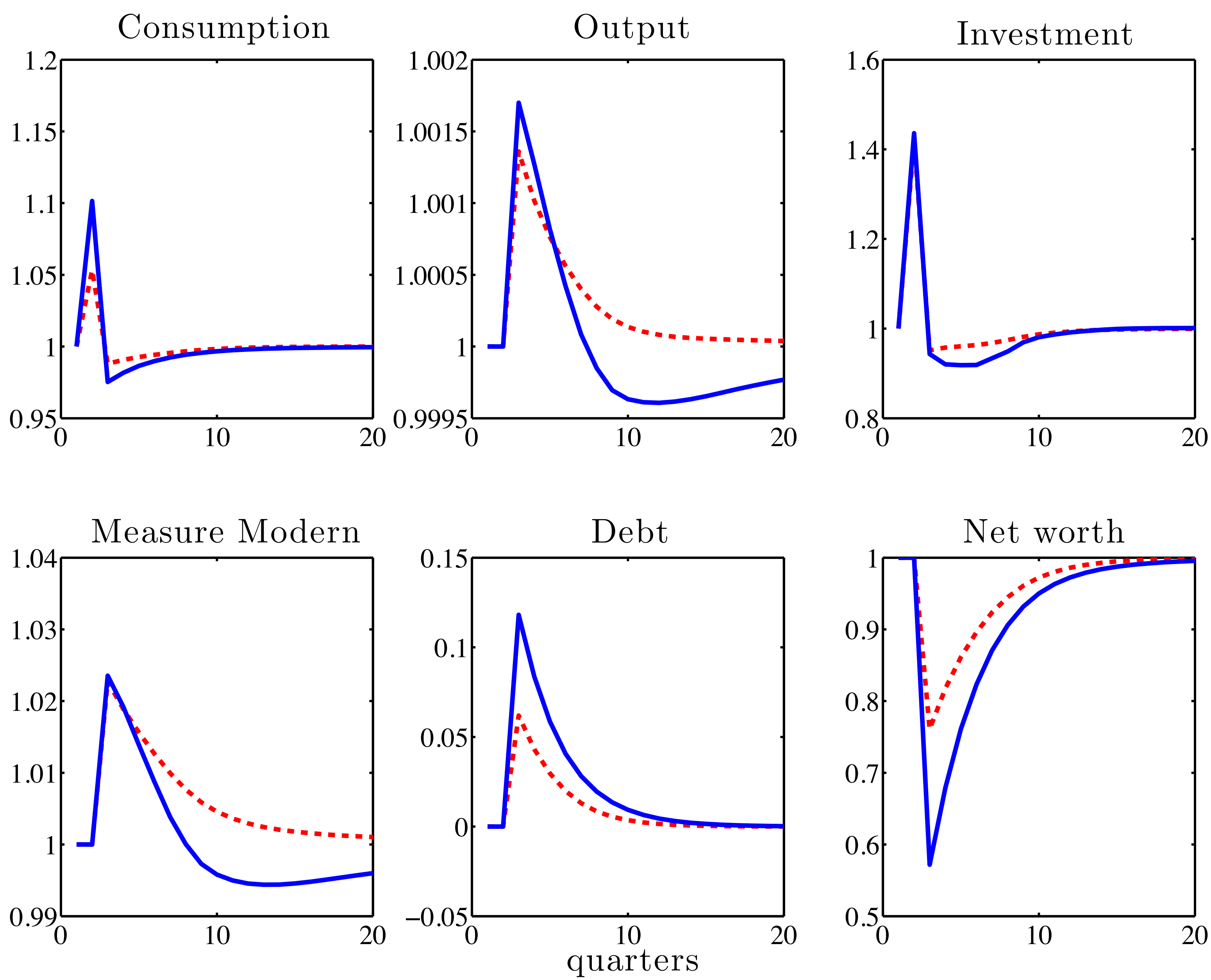

Figure 4: Dynamics after a transitory increase in investment credit limit, $\lambda_2$, from 0 to 0.5

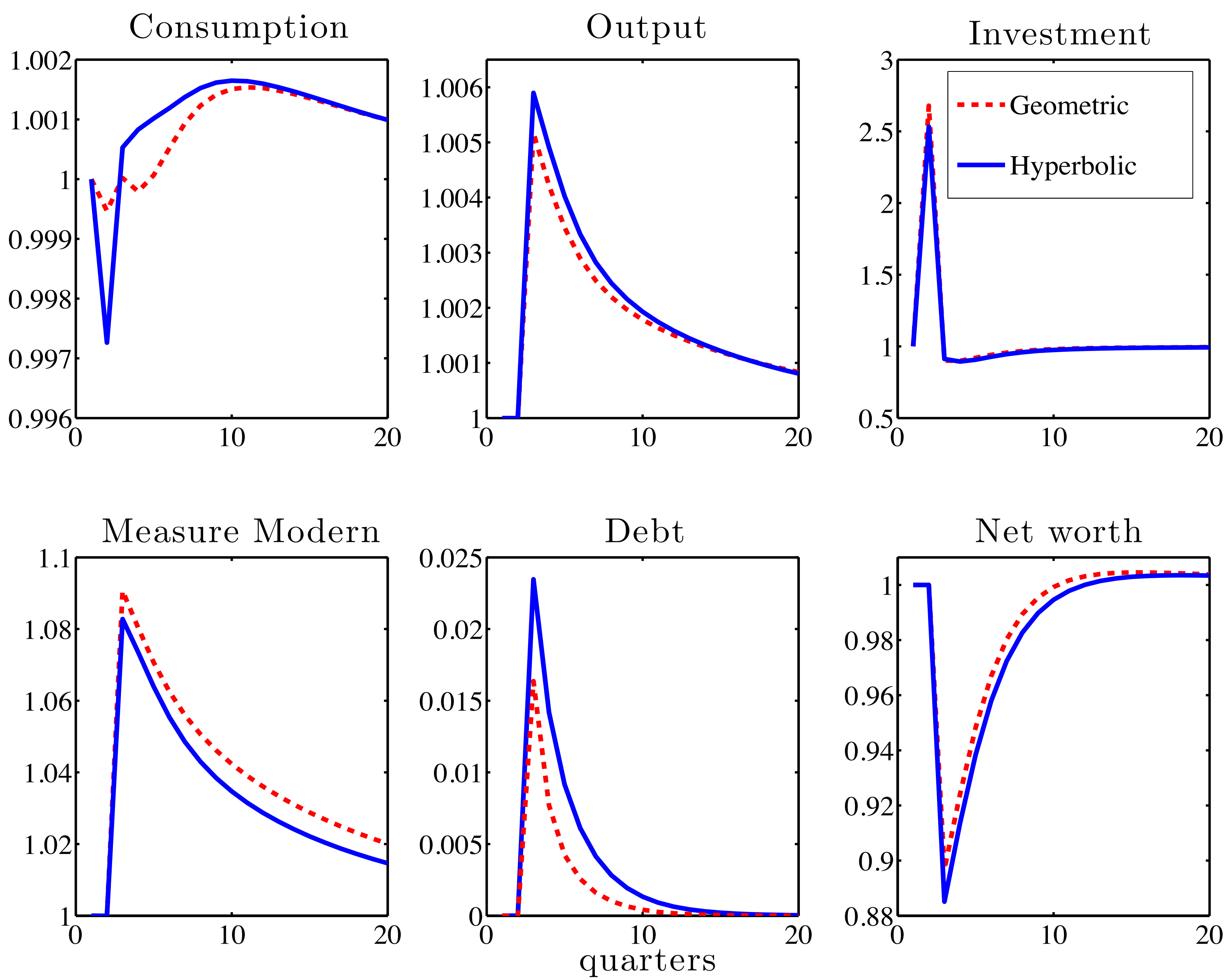

Table 3: Role of key endogenous parameters

| | Data | Model | $\beta' = 0.65$ | $\rho = 0.5$ | $z'_m = 1.085$ | $\pi_m = 1$ |
|---|---|---|---|---|---|---|
| investment to income | 1.00 | 1.06 | 1.04 | 1.12 | 1.11 | 1.05 |
| fin. assets to income | 0.25 | 0.25 | 0.59 | 0.08 | 0.11 | 0.27 |
| fraction in modern | 0.365 | 0.36 | 0.50 | 0.23 | 0.16 | 0.43 |
| fraction entering modern | 0.019 | 0.020 | 0.029 | 0.012 | 0.009 | 0.023 |
| consumption modern/tradit. | 1.37 | 1.40 | 1.35 | 1.228 | 1.300 | 1.402 |
| return to investment | 0.150 | 0.132 | 0.122 | 0.110 | 0.037 | 0.141 |

This table reports the effect of changing the key endogenous parameters, in isolation, away from their baseline values in Table 2.

Figure 1.A: Decision Rules

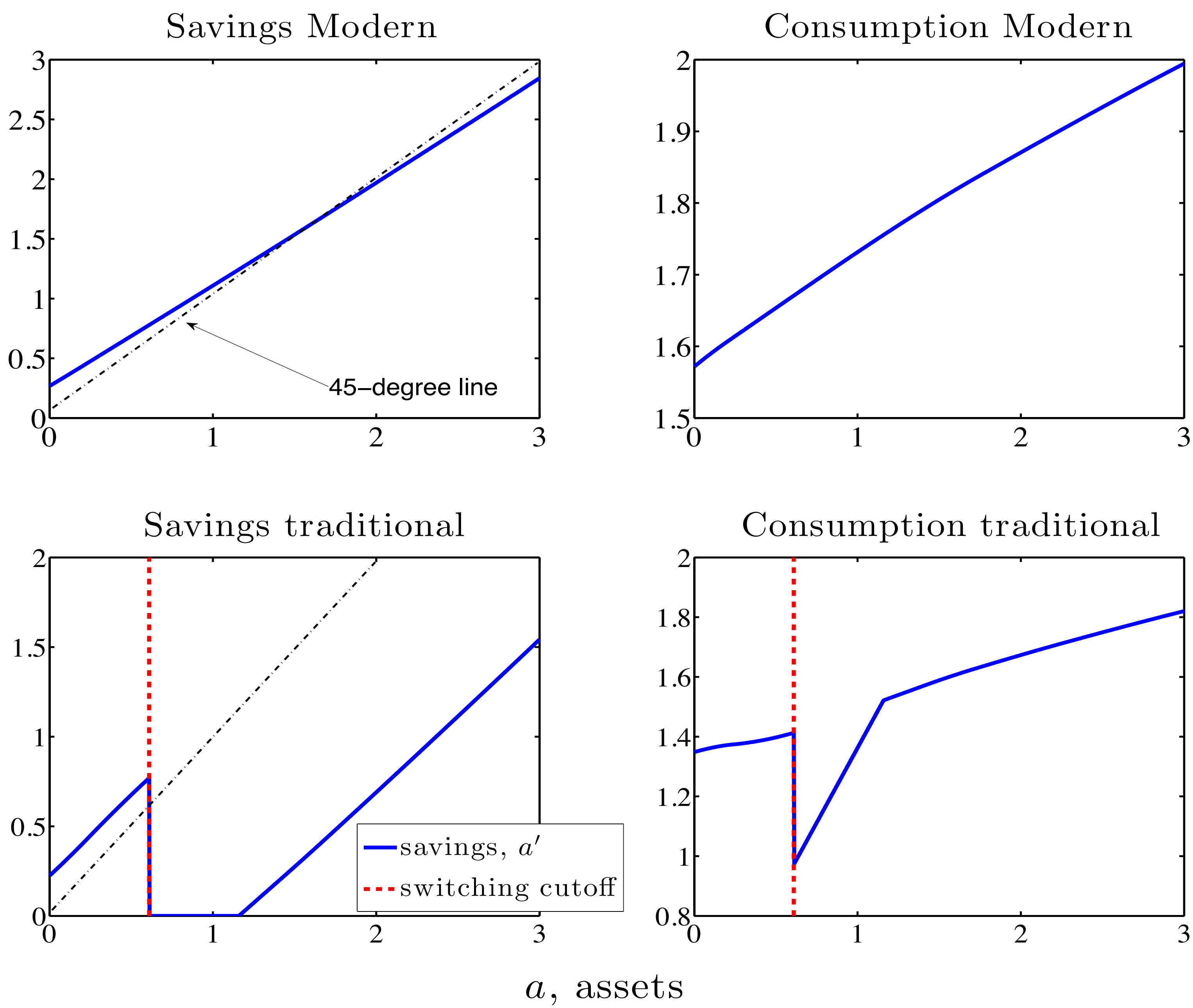

Figure 2.A: Decision Rules: high vs. low productivity agents

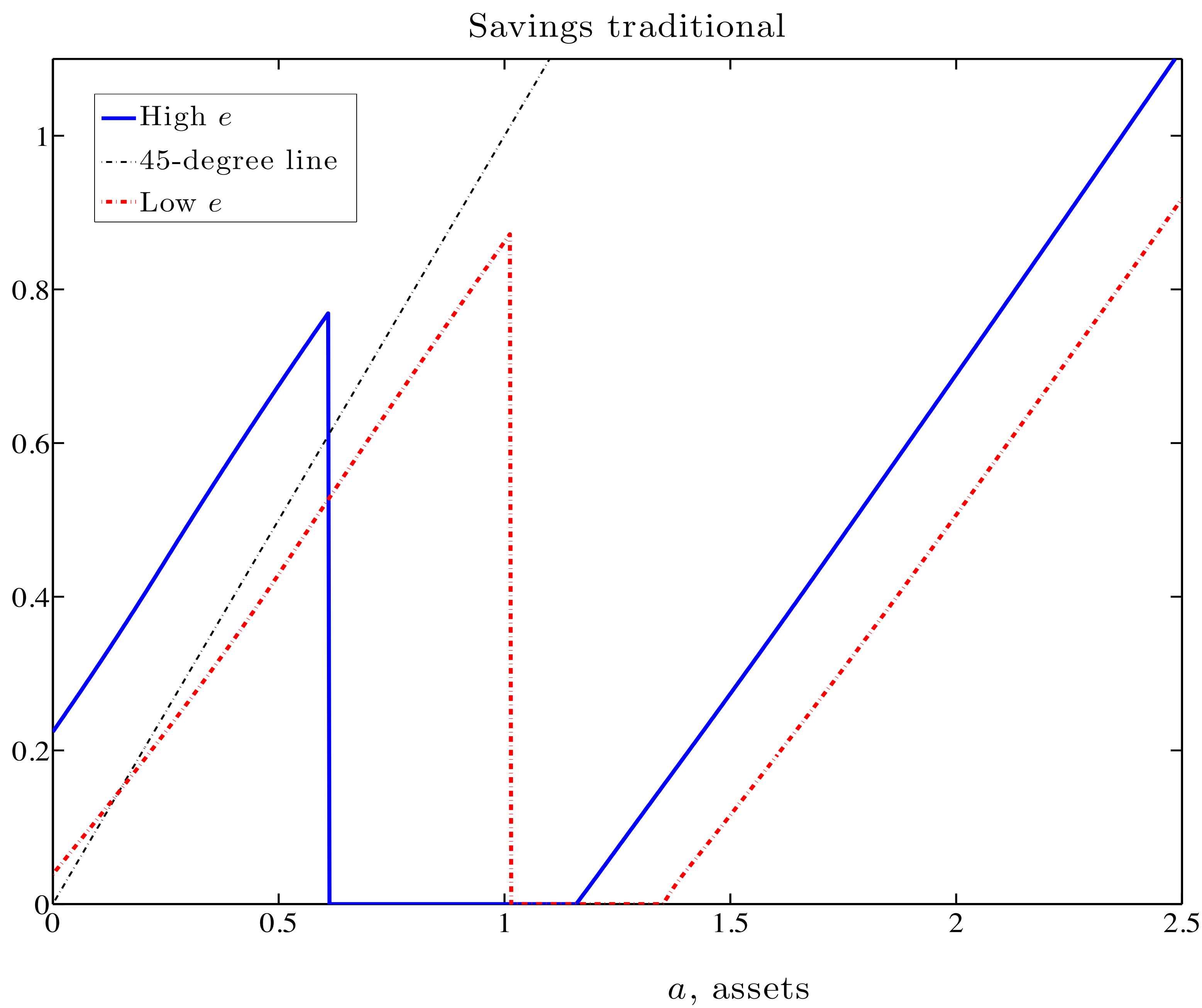

Figure 3.A: Sample paths: high vs. low productivity agents

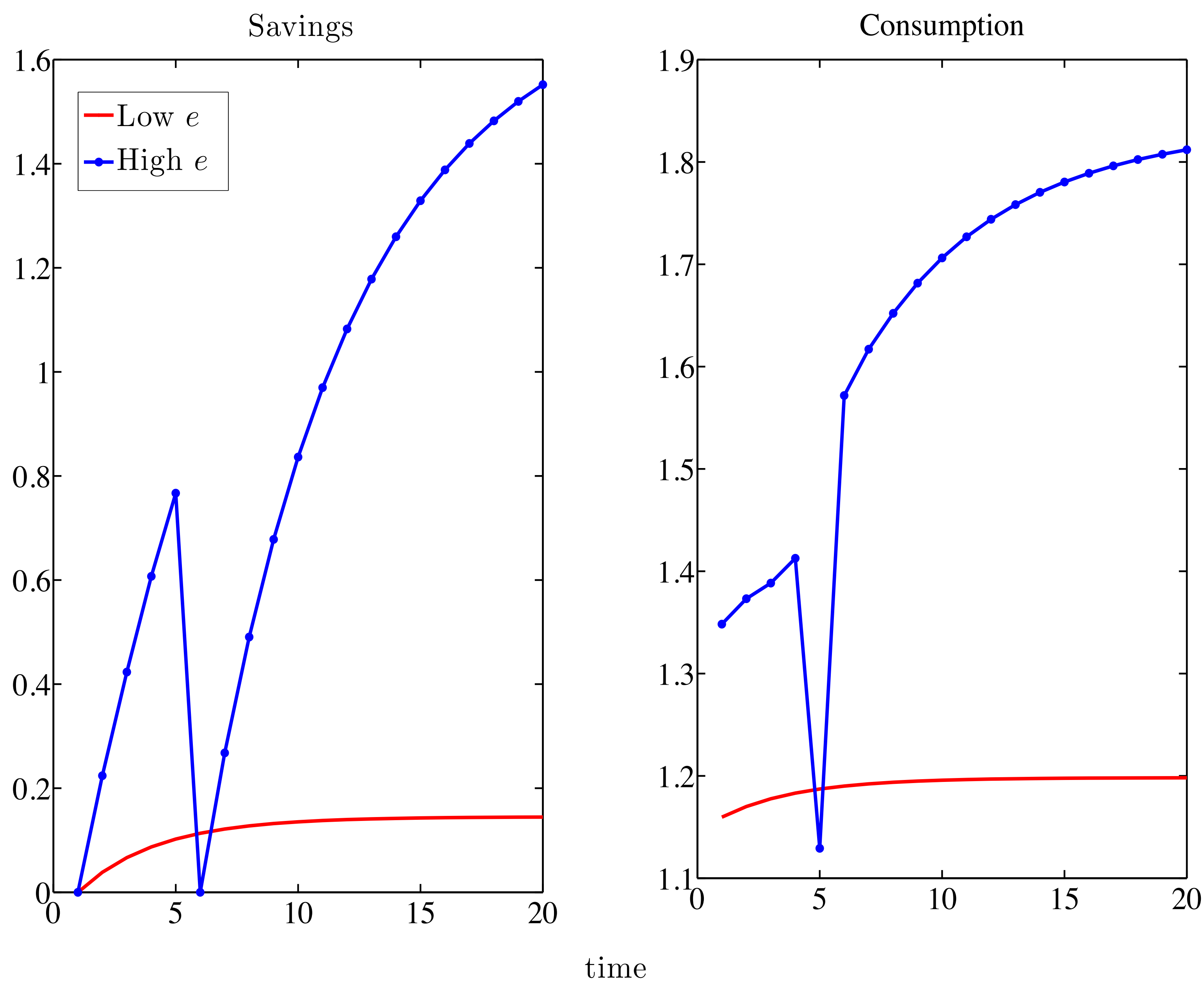

Figure 4.A: Welfare change of selves in current and future periods