Closing the Eyes on a Gloomy Future: Psychological Causes and Economic Consequences

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"*My third maxim was to endeavor always to conquer myself rather than fortune, and change my desires rather than the order of the world*"

Rene Descartes, Discours de la Méthode (1637), III, p. 595 596, Translated by John Veitch 1901

Abstract

This paper provides a bounded rationality model where a long term planning horizon improves economic decisions but also increases the salience of anticipated future utility. Hence a gloomy future induces the agent to shorten her time horizon in order to reduce distress caused by the anticipation of poverty, at the cost of worsening her realized future consumption, resulting in a behavioral poverty trap. The paper also provides some primary empirical evidence of the endogenous determination of time discounting. I use a randomized control trial in Mozambique that provided agro-input subsidies and matched savings among 1,546 rural households and show that improvement in economic prospects resulted in a significant increase in the planning horizon of the poor beneficiaries.

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1 Introduction

The microeconomic literature provides many examples of under-use of profitable investments (Duflo et al., 2008; Conley and Udry, 2010), and low adoption of investments, even when technology is accessible, remains one of most challenging issues in the field. Some researchers attribute low adoption to heavy discounting on distant payoffs. The pioneering work of Strotz (1955) and Pollak (1968) led to a burgeoning literature on inconsistent time preference and its consequence on long term well-being (e.g., Laibson, 1997, O'Donoghue and Rabin, 1999 and Banerjee and Mullainathan, 2010), which inspired interventions such as commitment savings (Ashraf et al. 2005, Brune et al. 2011) qualified by Loewenstein et al. (2008) as "light paternalism". However, because economists generally take time discounting as exogenous, they may design interventions that address the symptom rather than the source of the issue, which limits the chances of generating a permanent change in the economic path of the beneficiaries. Among the few publications investigating the possibility of an endogenous determination of time preference, Becker and Mulligan (1997) represent an agent who can invest in "forward looking capital" in order to build patience, finding that the discount factor is increasing in the initial wealth of the individual[1]. More recently, Bernheim et al. (2013) use a model where the agent has quasi-hyperbolic preferences. In their model, the ability to exert self-control is determined by history-dependent equilibrium strategies in an intrapersonnal dynamic game, which results in a behavioral poverty trap. By contrast, this paper attributes the behavioral poverty trap to distress generated by anticipation of future poverty, which increases the cost for the poor to have a long term planning horizon.

A different body of literature explains the underinvestment of the poor by the aspiration gap (Appadurai, 2004; Ray, 2006; Macours and Vakis, 2009; Bernard et al., 2011; Beaman et al., 2012). Aspirations are affected by economic opportunities, social interactions, role models and other socioeconomic conditions. Although the concept of aspiration varies among theses papers, it always includes some orientation towards the future. For example, in Macours and Vakis's experiment in Nicaragua, according to a beneficiary's own words, "Before the program, I just thought about working in order to eat from day to day. Now I think about working in order to move forward through my business". High aspirations refer to the belief that a better future is possible, which encourages the individual to take initiatives in the present in order to reach this goal. However, scholars have not yet provided a theoretical framework positing how change in aspiration (and orientation towards the future) occurs. This article aims at filling this gap.

After observing particularly low levels of asset accumulation among the poor, Duflo and

[1] The model in this paper shares some similarities with the one of Becker and Mulligan (1997), but also many differences resulting from the introduction of insights from the literature on cognitive dissonance and time inconsistencies. The cause of the shortsightedness differs. A comparison of the two models is provided in section 3.3.

Banerjee (2007) conclude that "one senses a reluctance of poor people to commit themselves psychologically to a project of making more money. Perhaps at some level this avoidance is emotionally wise: thinking about the economic problems of life must make it harder to avoid confronting the sheer inadequacy of the standard of living faced by the extremely poor". The intuition of the authors is very close to the one presented in this paper, which builds on insights from the literature on cognitive dissonance and neuro-imaging. The contradiction between the poor's concern for their future and their gloomy prospects generates a cognitive dissonance, which can be reduced by shortening their time horizon. However, this coping strategy leads to less asset accumulation, which worsens the long term prospects of the poor, creating a behavioral poverty trap where poverty and shortsightedness are mutually reinforced. This paper is the first attempt to understand and evaluate the cause and consequences of the psychological mechanisms through which gloomy economic prospects discourage a poor individual from being forward looking. It also offers (to the best of my knowledge) the first empirical evidence of the endogenous determination of time horizon. The time horizon is defined as the extent to which the individual identifies with future selves at any given point in time, hence a time horizon that fades away rapidly indicates that the individual is very present biased[2].

The model presented allows the agent to determine her own time horizon, and shows that when an individual is poor, a small reduction in her time horizon leads to a first order gain due to the reduction of the weight on the anticipated disutility and a second order loss in realized consumption due to the reallocation. A parallel can be drawn between the approach of this paper and the one of Brunnermeier and Parker (2005), who build a structural model of endogenous beliefs on the return of future investments. They find that a small optimistic bias in belief leads to a first order gain in anticipated utility but a second order loss in investment decisions, and, thus, that the optimal solution is not the one that corresponds to the optimal behavior based on purely economic outcomes.

The predictions of the model are tested using an experiment including 1,546 rural households in the Manica province of Mozambique. I analyze the planning horizon of randomly selected poor and non-poor recipients of an agro-input subsidy and a matched savings intervention. As predicted, both the subsidy and the intervention significantly increased the planning horizon of the initially poor, but not the non-poor. Our measurement of the planning horizon is inspired by Ameriks et al. (2003), who find that financial planning substantially increases savings and asset accumulation. They instrument the financial planning with attitudes that determine the individual's propensity to plan, but do not examine the impact of wealth on financial planning due to the absence of exogenous instrument for wealth. I adapt their question to a population with a lower level of wealth and education and obtain a proxy

[2]Section 2.4 more formally decomposes the time discounting into time preference and time horizon. The former is consistent across time, while the latter is a psychological bias towards selves that are "closer".

of the individual's time horizon, which tells how much time ahead the respondent plans her future expenditures. At the time of the survey, each treatment offered an exogenous variation in the economic prospects of the beneficiaries (but not in their current economic conditions), which is shown to affect their time horizon. The timing of the survey, after the household are involved in the projects, but before they ripe the economic benefits, ensure that the results are not driven by the fact that some household would be "too hungry to think". Furthermore, the theoretical model shows that it is unlikely to be driven by the fact that some households are "too poor to save" and that more money naturally leads to a longer planning horizon, because the economic cost of a short term horizon is as high for the poor as it is for the rich. The fact that the gain from planning is reduced when one has less money is compensated by the fact that the marginal utility is higher, and thus the consequence of a misallocation of consumption across time is more acute for the poor. The results do not reject the model's prediction that one can prefer closing the eyes on a gloomy future to reduce the disutility from the anticipation of future poverty. The results are also compatible with some other models that lead to a behavioral poverty trap (Bernheim et al., 2013; Banerjee and Mullainathan, 2010), and reinforce the findings of Mani et al. (2013), according to which the stress related to poverty impedes one's cognitive capacity. The findings of this paper and other new evidence point to a "behavioral multiplier" effect of some interventions, that has the potential to change long term poverty dynamics, and, thus, should be taken into account in the design of interventions that aim to reduce poverty.

2 The psychological causes of the endogeneity of time discounting

The burden of poverty comes not only from poverty itself, but also from the anxiety that is generated by the anticipation of future poverty. For the poor, the contradiction between the desire to have a better future and the realization of gloomy prospects generates a cognitive dissonance. Previous research in psychology has shown that 1) when compelled to punish others, one can reduce altruism toward others in order to reduce cognitive dissonance, and 2) the decision making process involving a tradeoff between our current and future selves is similar to the one between ourselves and other individuals. These two findings together indicate that if poverty induces an individual to leave harsh conditions for the benefit of future selves, this individual can decide to detach from these future selves in order to reduce the cognitive dissonance and the anxiety that it generates. This reasoning is explained in more detail in this section.

2.1 Anxiety and the anticipation of poverty

This paper argues that anxiety from future poverty can be such that individuals may prefer to be shortsighted in order to avoid it, even though they are aware of the negative economic consequences of shortsightedness. Narayan and Ebrary (2000) asked 20,000 poor people across the developing world about their perception of poverty and found that anxiety represents a large part of the burden, in particular in Africa, where the sources of anxiety "are closely related to basic agriculture and survival that depend on the vagaries of nature, rains, droughts". The book includes many quotes that describe the anxiety of the poor:

> *Mental health problems—stress, anxiety, depression, lack of self-esteem and suicide—are among the more commonly identified effects of poverty and ill-being by discussion groups. In some African communities, people often describe a mental condition associated with poverty as "madness."*
>
> *"As if land shortage is not bad enough we live a life of tension worrying about the rain: will it rain or not? There is nothing about which we say, ' this is for tomorrow.' We live hour to hour." — A woman, Kajima, Ethiopia*
>
> *"These agonizing decisions take their toll. People cope by focusing on one day at a time, becoming indifferent, apathetic or hovering near losing their mind." — A member of the research team, Ghana*
>
> *In Malawi, ukavu means a state of constant deprivation. It is explained that households described in this group lack peace of mind because they are always worried about how to make ends meet. In most ukavu households, couples quarrel and fight a lot because they desire good lifestyles (umoyo uwemi), but they lack the means. "It is not surprising that most men from these households are drunkards because they drink to forget home problems."*

These quotes mark a distress caused by the inability to reach better economic prospects. The toll of anxiety is omnipresent, yet the most striking feature of these testimonies is the apparently irrational reaction to poverty by living day to day rather than making all possible efforts to plan a long-term exit strategy.

The idea that future disutility is a source of distress is closely related to utility (or disutility) from anticipation, a concept that goes as far back as Bentham (1838). It was first applied in intertemporal choice by Jevons (1879) and his son Jevons (1905), and has been formalized by Loewenstein (1987)[3]. While Jevons (1905) assumes that individuals always maximize their present utility, which incorporates utility from the anticipation of pleasure or pain,

[3]For more historical background, Loewenstein and Elster (1992) provide an excellent review of the history of the economics of intertemporal choices.

Loewenstein analyzes an agent that maximizes her intertemporal utility, given that the utility at each period incorporates the anticipation of future consumption.

With an exogenous preference for the present, the inclusion of anticipated utility makes individuals more willing to save. However, if one has the possibility to alter her focus toward the future, then she may close her eyes on the future to avoid the permanent distress of gloomy prospects. Whether the anticipation of future poverty can be such that individuals prefer a more acute, but myopic, poverty is an empirical question that is investigated in section (4) of this paper.

Caplin and Leahy (2001) show how anticipatory utility can provide an explanation for many time inconsistencies by analyzing a model that incorporates the anxiety caused by uncertainty into the utility function. They claim that the cost of uncertainty about the future includes not only the loss caused by risk aversion, but also the psychological effect of this uncertainty. They provide an example of its impact on portfolio management, yet one can imagine that anxiety is likely to be even higher when one's food security depends on rainfall.

2.2 Cognitive dissonance and endogenous time discounting

Since Festinger (1957), cognitive dissonance has been one of the most influential theories in social psychology. It was introduced into economics by Hirschman (1965) and was first modeled by Akerlof and Dickens (1982). Cognitive dissonance is the feeling of uncomfortable tension which comes from holding conflicting thoughts in the mind at the same time. As a consequence, an individual's mind alters her beliefs or preferences in a way that reduces this dissonance. Bramel (1962) relates cognitive dissonance with ego-defensive processes, showing that in some situations, an individual can attribute undesirable characteristics to other people in order to preserve self-esteem. In a well-known illustration of this mechanism, Glass (1964) found that students who were asked to give electric shocks to victims tended to attribute undesirable characteristics to the victims in order to preserve their self-esteem.

Leibow (1967)'s classic ethnographic book on street corner men is revisited by Montgomery (1994) to explain their behavior using the concept of cognitive dissonance. The contradiction between the social values that dictate that a man must financially support his family and the inability of the street-corner man to do so generates a cognitive dissonance that causes him major distress. In Montgomery's model of endogenous altruism, a man receives a positive utility from supporting the members of his family, but a negative utility from the resulting cognitive dissonance, both proportional to his attachment to his family. Hence, through an unconscious process, the man who cannot afford to support his family detaches himself from them in order to limit this cognitive dissonance (and the feeling of failure). Similarly, the poor can either face anxiety and low self-esteem, or close their eyes on the future, which

harms their long-term economic development. The quotes from Narayan and Ebrary (2000) in the introduction indicate that, at least in some cases, the poor opt for the latter option. This paper provides a model of endogenous time horizon that formalizes this change in attitude toward the future and empirical evidence that it is a widespread phenomena among households that are not self-sufficient in their maize production in the Manica province in rural Mozambique .

2.3 Getting into the brain

Recent progress in neuroscience has helped us to understand and model the human decision making process. Van Veen et al. (2009) provide new evidence that supports the existence of cognitive dissonance activity in the brain. In asking participants to state that the uncomfortable scanner environment was a pleasant experience, the authors found not only that cognitive dissonance engages certain regions of the brain, but also that the extent to which these regions are activated predicts participants' change in attitude toward their experience in the scanner. This study directly demonstrates how a contradiction generates a tension in the brain, resulting in a change in preference in order to reduce dissonance.

Neuroscientists have also paid particular attention to time preferences. McClure et al. (2004) recorded neuro-images of subjects who were asked to select from options that may or may not include immediate gratification. The researchers distinguished a "delta part" of the brain, which includes regions that are related to cognitive functions, from a "beta part" of the brain, which has consistently been implicated in impulsive behavior, such as drug addiction. While the delta part is activated similarly for all decisions and was found to be more active in individuals more likely to opt for delayed gratification, the beta part is significantly more active in decisions that involve immediate gratification. Jamison and Wegener (2010) later compared the neural activity during decision making between immediate and delayed gratification to the neural activity during decision making between oneself and others, concluding that "the decision making process involving a tradeoff between our current and future selves is substantially the same as the decision making process involving a tradeoff between ourselves and other individuals". The findings of Jamison and Wegener (2010) confirm Parfit (1971)'s claim that *psychological connectedness* determines the level of altruism both toward other individuals and towards future selves. Hence, since Glass (1964) found that students asked to give electric shocks to victims increased their unfriendliness towards the victims, the same phenomena may occur between present and future selves. When the pressing needs of the present push a poor individual to "punish" future selves by saving very little money for them, distancing herself from these future selves allows her to reduce cognitive dissonance. This, in turn, makes the poor more vulnerable in the long run, generating a behavioral poverty trap.

In addition to indicating that the attitude toward future selves is likely to be affected by

the individual's economic conditions, these findings from neuroscience corroborate not only economic models with a distinction between present and future selves (e.g., Laibson (1997) and O'Donoghue and Rabin (1999)), but also models that incorporate two selves with different preferences at any single point in time. For example, Thaler and Shefrin (1981) model a farsighted principal who controls the myopic agent through the alteration of incentives and limitations of his opportunities. More recently, Fudenberg and Levine (2006) show that this dual self model gives a unified explanation for several observed forms of time inconsistencies. This paper also presents a dual self model that separates the consumption decision from the endogenous determination of time horizon.

2.4 Decomposition of time discounting into time preference and time horizon

The effective time discounting of an individual is a combination of two distinct elements: the time preference and the time horizon. The time preference tells the real valuation of different time periods if the individual were able to extract himself from any present-bias. The discounting does not need to be positive, given that some individuals would not prefer a consumption path that is decreasing over their life. The time horizon is a function that designates the psychological connectedness between current and future selves. As the time span increases between now and a perceived future, the psychological connectedness toward this future self decreases and, with it, altruism toward the future self, affecting both the planning of consumption and the utility from anticipation. In other words, the time horizon expresses the bias towards the present due to a neglect of future selves because one tends to identify more with her current self than her future selves. In the following model, the time preference is exogenous and the time horizon H is endogenously determined. This contrasts with Becker and Mulligan (1997), who did not distinguish between these two components, allowing the real time preference to vary. The implications of this important difference are discussed in section 3.3.

The time preference must be time consistent; the discounting between a consumption at time t and time $t + \theta$ should not change between time $i < t$ and time t and should only be a function of θ. Hence, it should be represented by an exponential function (or the power function in discrete time). By contrast, the time horizon function can vary; the discounting between time t and time τ can change depending on i, the point in time where the current self is located.

Formally, the discount factor is obtained by the multiplication of the time preference and the time horizon. In continuous time the discount factor is given by:

$$d(\theta) = e^{-\rho\theta} \; h(\theta, H) \tag{1}$$

and in discrete time:

$$d(\theta) = \ \delta^{\theta} \ h(\theta, H) \tag{2}$$

where $d_i(\theta)$ is the discount factor that multiplies the value of the reward, θ is the delay in the reward, ρ is a parameter governing the degree of discounting in real time preference, and $h(\theta, H)$ is the time horizon function which is decreasing in θ and increasing in H and must satisfy $d(\theta) \geq 0$ and $d(0) = 1$ (given that the current self fully connects with himself at the current time). Effective time discounting at any given time can thus be divided into two elements. The objective time preference ($e^{-\rho\theta}$ in the case of continuous time), consistent over time, and $h(\theta, H)$ indicates how much individual i cares about his future self $i+\theta$, which is driven by the extent to which one identifies with his future self.

When an individual is not myopic, then psychological connectedness remains equal among present and future selves: $h(\theta, H) = 1 \ \forall\theta$, which recovers the exponential utility function. Perhaps the most intuitive perception of the distinction between the time preference and the time horizon is associated to the quasi-hyperbolic utility function, used in discrete time, where $d(\theta) = \begin{cases} 1 \ \ if\, \theta = 0 \\ \beta\, \delta^{\,\theta} \ \ if\, \theta > 0 \end{cases}$.

Which can be rewritten:

$d(\theta) = \ \delta^{\theta} \ h(\theta, \beta)$ with $h(\theta, \beta) = \begin{cases} 1 \ \ if\, \theta = 0 \\ \beta \ \ if\, \theta > 0 \end{cases}$. in which case $H = \beta$

It is commonly understood that in the "beta-delta" preferences, the delta refers to the real time preference, and the beta represents the bias for the present. In a similar but less tractable way, in continuous time, the horizon function $h(\theta, \beta) = \frac{e^{\rho\theta}}{1+H\theta}$ will result in a hyperbolic discounting function.

In the empirical section, the respondents are asked "How much time ahead do you plan your future expenditures?" in order to approximate the horizon function. This can be literally interpreted as the following degenerate horizon function: $h(\theta, H) = \begin{cases} 1 \ \ if\, \theta \leq H \\ 0 \ \ if\, \theta > H \end{cases}$, which means that an individual at time i fully identifies with her future self until time $i + H$ and not at all with her future self after $i + H$[4]. Keeping a more general horizon function as defined initially, it can be considered that the individual will plan for future consumption and investments as long as $h(\theta, H)$ is above a certain threshold; hence, the answer to this question is increasing in the time horizon. Therefore, for any initial horizon function, up to a monotonic transformation, the variable H can also be literally interpreted as the planning horizon.

[4]This function does not belong to the set of functions previously defined because the horizon function is not continuous and differentiable in H; it is, instead, a limit of the set of possible functions, and a previously circulated version of this paper demonstrates the same propositions for this degenerate function.

2.5 Cognitive dissonance and the decency norm

This model incorporates a utility from anticipation which, like Loewenstein (1987), is proportional to the actualized utility to be derived from future consumption. The cognitive dissonance is a source of disutility when a decent living condition will not be achieved in the future. Let z be the "decent" level of consumption, which can be interpreted as a local poverty line in a way that is similar to Montgomery (1994). Below z, the lack of basic food, shelter, clothes and the needs resulting from social expectations, creates anxiety as a result of anticipation. Above z, resources are used for other goods and services of which the anticipation is a savoring[5]. Also, let $\bar{u} = u(z)$ with $u(c)$ being an increasing and concave utility function derived from immediate consumption. When $c = z$, the utility from anticipation should be null. The utility from anticipation of consumption at period t is proportional to $u(c_2) - \bar{u}$. Hence, for a poor individual, the loss in utility from anticipation caused by cognitive dissonance is proportional to the loss in utility caused by the poverty gap in period t. By normalizing $u(z) = 0$, the utility from anticipation is proportional to $u(c_t)$; it is negative when the individual will be poor at time t and positive when she will be above the poverty line. For models in which the possibility to experience (or not experience) a utility is given, anchoring the utility function is key (e.g., Becker and Posner 2005), as adding a constant increases the willingness to experience this period.

3 A model of cognitive dissonance and endogenous time horizon

This section presents a model where cognitive dissonance generates tensions that can be attenuated by a reduction in the time horizon. A utility (or disutility) from anticipation of consumption is incorporated. Hence, when future consumption is expected to be below a decent living condition, its anticipation generates cognitive dissonance, which reduces the utility of the individual. The model assumes multiple selves. At any given time, the "outer self" makes the consumption decision, taking his time preference as exogenous, and the "inner self" determines the outer self's time horizon. Although primarily unconscious, the determination of the time horizon is rational since the inner self maximizes the intertemporal utility of the "whole self" without being present biased. The time horizon is the extent to which the individual identifies with future selves at any given point in time. A long term planning horizon requires the individual to face potential distress caused by his gloomy economic prospects, which increases cognitive dissonance. Consequently, even though the inner self is farsighted, she may opt for a short time horizon in order to reduce the permanent burden of cognitive dissonance, which results in a vicious cycle between poverty and myopia.

[5]Savoring commonly refers to a positive utility derived from the anticipation of consumption

3.1 The decision process

The game describes an agent's consumption decision from period 0 to T, with the succession of actions as follows:

Step 1: The inner self chooses the time horizon $H \in (0, \bar{H}]$ which will determine the horizon function $h(\theta, H)$, defined in section 2.4. θ is the distance between a present and given future self, H is the horizon parameter and $h(\theta, H) \in (0, 1]$ is decreasing in θ and increasing in H. When $H < \bar{H}$, the outer self i is myopic, and the consumption plan is consistently updated.

Step 2: The outer self i (starting with $i = 0$) makes the consumption plan $\{c_t^i\}_{t=i}^{t=T}$ that maximizes his (myopic) intertemporal utility function which incorporates, for every period t, the utility from consumption at time t and the utility from the anticipation of consumption from period t to T. c_t^i is the consumption at time t planned at time i (*i.e.,* planned by the outer self i). Only immediate consumption c_i^i actually occurs in the consumption plan of the outer self i. The remainder of the consumption plan of the outer self i $\{c_t^i\}$ affects only the utility from anticipation at time i.

Step 3: Wealth continuously increases (or decreases) by the difference between the returns from assets and the immediate consumption c_i^i , and the following outer self continuously repeats step 2) until $i = T$.

The outer self is not "sophisticated". Both his consumption choice and his utility from anticipation are "naive" since he does not take into account the fact that the preferences of the following selves (at time $t > i$) will potentially be different from the outer self's preference at time i, and thus his consumption plan at time i may not occur. However, consumption c_i^i always occurs immediately, at the time when it is planned. In this model, the "sophistication" of the outer self is replaced by the rationality of the inner self, who chooses H in order to maximize the utility of the whole self, knowing the response function of the outer selves. The following subsection first describes the decision process of the outer selves (step 2 and 3) before describing the decision of the inner self (step 1). In order to distinguish one from the other, I use the feminine for the inner self (i.e., "she") and the masculine for the outer self (i.e., "he").

3.1.1 The succession of outer selves (step 2 and 3)

The outer self i acts as a typical consumer, maximizing his intertemporal utility function, incorporating the utility from anticipation at each period. He applies two forms of time discounting toward a future self at time $t = i + \theta$: the first reflects his real time preference $e^{-\rho(\theta)}$, and the second, the time horizon $h(\theta, H)$, reflects the extent to which he associates with his future selves.

The outer self considers time discounting as exogenous, given that the real time preference ρ is fully exogenous and the time horizon is previously fixed by the inner self. The horizon function affects both the weight of future selves in a given outer self's maximization and the extent to which future consumption generates a utility from anticipation.

The utility to be experienced at time t from the perspective of the outer self i is composed of the utility from the instantaneous consumption c_t and anticipation of future consumption c_τ from time t to time T:

$$v_t^i\left(\left\{c_t^i\right\}, H\right) = e^{-\rho(t-i)}h(t-i,H)\left[u(c_t^i) + \gamma\int_t^T e^{-\rho(\tau-t)}h(\tau-t,H)\,u(c_\tau^i)d\tau\right] \tag{3}$$

where v_t^i is the outer self i's valuation of his utility at time t, which incorporates first $u(c_t^i)$, the utility derived from c_t^i (the consumption at time t planned at time i), and second, the anticipation of consumption c_τ^i for $t < \tau < T$. γ is an exogenous parameter that indicates the weight on utility from anticipation and ρ is the (objective and exogenous) time discount factor[6]

The outer self i maximizes an intertemporal utility function that incorporates, for every period t, the utility from consumption at time t and from anticipation at time $t < \tau < T$:

$$\begin{gathered}\max_{\{c_t\}} U_i\left(\{c_t\}, H\right) = \int_i^T v_t^i dt = \int_i^T e^{-\rho(t-i)}h(t-i,H)\left[u(c_t^i) + \gamma\int_t^T e^{-\rho(\tau-t)}h(\tau-t,H)\,u(c_\tau^i)d\tau\right]dt \\ s.t.\ w_i = \bar{w}_i \\ \dot{w}_t = rw_t - c_t^i \\ w_h \geq 0\end{gathered} \tag{4}$$

A continuum of outer selves i successively solves the maximization problem of equation 4 at time i. Let $\left\{c_t^i(w_i,H)\right\}$ be the consumption at time t planned by the outer self i that solves the intertemporal maximization problem of equation 4, and let $v_t^i(w_i,H) = v_t^i\left(H, \left\{c_t^i(w_i,H)\right\}\right)$.

At any given time i, the utility from consumption $c_i^i(w_i,H)$ and from the anticipation of the consumption plan $\left\{c_t^i(w,H)\right\}$ provide the instantaneous utility:

$$v_i^i(w_i,H) = u\left(c_i^i\right) + \gamma\int_i^T e^{-\rho(\tau-i)}h(\tau-i,H)\,u\left(c_\tau^i\right)d\tau \tag{5}$$

When $H < \bar{H}$, the instantaneous utility v_i^i given in equation 5 is the utility that is actually felt by the agent i at time i, while the instantaneous utility v_t^i for $t \in (i,T]$ is planned at time i, but never realized since the consumption plan is updated before it occurs. When

[6]For simplification, unlike Loewenstein (1987), the same time discount rate ρ applies to discounting at time i of the utility felt at time t and to discounting of the anticipation of c_τ at time t .

$H = \bar{H}$, the consumption plan remains unchanged with time because the individual's time discounting is time consistent.

The wealth continuously changes following $\dot{w}_i = rw_i - c_i^i$, and the following agent continuously repeats the same steps, solving again equation 4. Hence, once all the outer selves have played, the agent (the whole self) receives the actualized utility:

$$U(w_0, H) = \int_0^T e^{-\rho(i)} v_i^i(w_i, H) di \tag{6}$$

This is the utility resulting from the maximization of the succession of outer selves, considering their horizon parameter H as exogenous. The utility of the whole self is subject to objective discounting at rate ρ, reflecting the individual's true time preference, but does not apply the discounting of the horizon function, which is related to present bias.

3.1.2 The inner self (step 1)

Aware of $U(w_0, H)$ and of $c_t^i(w_0, H)$, the response function of the outer selves, the inner self selects the horizon boundary $H \in (0, \bar{H}]$, which maximizes the agent's intertemporal utility given by equation 6 in which I substitute equation 5 to obtain the following:

$$\max_H U(w_0, H) = \int_0^T e^{-\rho(i)} \left[u\left(c_i^i(w_0, H)\right) + \gamma \int_i^T e^{-\rho(\tau - i)} h(\tau - i, H)\, u\left(c_i^i(w_0, H)\right) d\tau \right] di \tag{7}$$

such that $\left\{c_t^i\right\}$ solves the maximization problem of each outer self i for $0 < i < T$, described in equation 4. H represents the horizon parameter of all outer selves i. Notice that the inner self is farsighted in the sense that her objective function is the actualized utility of the whole self. The following propositions analyze the horizon parameter $H(w_0) \in (0, T]$ chosen by the inner self, which is the solution that maximizes equation 7.

3.2 Results

The tradeoff

The appendix provides a detailed resolution of the problem. For an intuitive interpretation of the proof of proposition 1, equation 8 shows the tradeoff, where closing one's eyes on the

future reduces the (dis)utility from anticipation, but improves the allocation of consumption across time.

$$\underbrace{\int_0^T e^{-\rho i} u'\left(c_i^i\right) \frac{dc_i^i}{dH}\left(1+\gamma \int_0^i h(i-\tau, H) d\tau\right) di}_{Marginal\, benefit\, of\, correcting\, the\ misallocation} = \underbrace{-\int_0^T e^{-\rho i} u\left(c_i^i\right) \gamma \int_0^i \frac{dh(i-\tau, H)}{dH} d\tau di}_{Marginal\, benefit\, of\, closing\, the\, eyes} \tag{8}$$

This tradeoff occurs during the determination of the optimal time horizon of the inner self. The tradeoff exists only when the initial wealth is low enough that the RHS of equation 8 is negative. This weighted average of utility from future consumption being negative can be interpreted as the individual being predominantly poor in the future; hence, the anticipation of future consumption generates more anxiety than savoring, and thus ceteris paribus, the agent would prefer reducing the anticipation of future (dis)utility. The forthcoming propositions will show that the tradeoff does not occur with high initial wealth, and that, for the poor, a reduction in initial wealth increases the cost of being forward looking, and thus pushes the agent to opt for a shorter time horizon, creating a behavioral poverty trap.

Propositions

The proofs of the propositions are in the online appendix.

Assumption 1: $u'(c) > 0$, $u''(c) < 0$ and $\lim_{c \to 0} u(c) = -\infty$. This minimal assumption simply ensures the concavity of the utility function and excludes zero consumption as a possible solution.

Proposition 1: *Under assumption 1,* $\exists\, \hat{w_0}$ *such that* $H(w_0) \in (0, \bar{H})\ \forall\ w_0 < \hat{w_0}$ *and* $H(w_0) = \bar{H}\ \forall\ w_0 \geq \hat{w_0}$.

In other words, a level of wealth $\hat{w_0}$ exists such that if the initial wealth is below $\hat{w_0}$, then the inner self decides to be myopic in the sense that she selects a time horizon H lower than $\bar{H}$, and will thus have a time preference that is not consistent across periods. If the initial wealth is above $\hat{w_0}$, an increase in the time horizon increases the weight on the anticipation of positive utility, and the right hand side of equation 8 becomes negative, meaning the possible tradeoff between improving the allocation of consumption versus closing one's eyes on a gloomy future disappears. Hence, in this model, the non-poor has no reason to be myopic.

Assumption 2: $u(c)$ is a log utility function. The log utility function is scale neutral, making the relative allocation of consumption across periods independent of wealth (for a given H). Individuals with different wealth have the same need to smooth consumption across time;

hence, the LHS of equation 8 becomes independent of wealth and the results are purely driven by the fact that poverty increases the benefits of closing one's eyes on the future. The following section provides a discussion on the choice of the log utility function and the use of alternative functions.

Proposition 2: *Under assumption 2, for any $w_0 < \hat{w}_0$ then any local maximum $H(w_0)$ satisfies* $\frac{dH(w_0)}{dw_0} > 0$

This proposition states that, for any individual with a level of initial wealth below $\hat{w}_0$, the time horizon of that individual is increasing in the initial wealth of the individual. This results from the fact that the marginal benefit of closing one's eyes on the future decreases with w_0, and with a log utility function, the marginal benefit of correcting the misallocation is unchanged.

Proposition 3: *Under assumption 2, for any given i, $w_0 < \hat{w}_0$ then $\frac{\partial \frac{\dot{w}_i}{w_i}}{\partial w_0} > 0$ $\forall r$ and when $w_0 < \hat{w}_0$ and $\underline{r}(i) < r < \bar{r}(i)$, then $\exists \tilde{w}_0$ such that when $w_0 < \tilde{w}_0$ then $\partial \frac{\dot{w}_i}{w_i} < 0$, and when $\partial \frac{\dot{w}_i}{w_i} \geq 0$ then $\partial \frac{\dot{w}_i}{w_i} \geq 0$.*

$\underline{r}(i) = \frac{1}{\int_i^T k_\tau^i(\overline{H})\, d\tau}$ is the interest rate such that an individual with $H = \bar{H}$ would choose $\partial \frac{\dot{w}_i}{w_i} = 0$

Let $H_l = \lim_{w_0 \to 0} H(w_0)$, then $\overline{r}(i) = \frac{1}{\int_i^T k_\tau^i(H_l)\, d\tau}$ is the interest rate such that an individual with $H = H_l$ would choose $\partial \frac{\dot{w}_i}{w_i} = 0$.

The condition $\underline{r}(i) < r < \bar{r}(i)$ ensures that for sufficiently high level of w_0, the asset accumulation would be positive, and for a sufficiently low level of w_0, the asset accumulation becomes negative. Note that the conditions on r vary with i and that $\frac{\underline{r}(i)}{\bar{r}(i)} \to 1$ when $i \to T$. The range of values of r for which a tipping point exists shrinks because the individual's time horizon matters less when the remaining time is small.

Proposition 3 highlights the divergence in the accumulation of assets. Individuals who are initially richer (starting with a higher w_0) will accumulate assets at a pace that is higher than individuals who are initially poorer. It also confirms the existence of a behavioral poverty trap, given that there is a tipping point $\tilde{w}_0$ above which asset accumulation becomes positive.

3.3 Interpretation of the theoretical findings and comparison with previous literature

The results show that when the time horizon is endogenously determined–and this horizon determines both the consumption plan and the utility from anticipation–then the gloomy prospect caused by poverty discourages people from being forward looking. The poor individual would decide to reduce her time horizon in order to reduce the distress associated

with the combination of poverty and a long term horizon. As a consequence of the shorter time horizon, the poor will have a lower accumulation of assets, which creates a behavioral poverty trap. The proof of proposition 1 is methodologically close to Brunnermeier and Parker (2005), who show in an endogenous belief model that a small optimistic bias in beliefs about the returns to one's investments leads to a first order increase in utility from anticipation but only a second order loss in utility from realized outcome.

The framework of this model shares some similarities with that of Becker and Mulligan (1997), who posited that the individual can invest in a "forward looking capital" in order to build patience, finding that the discount factor is increasing in the initial wealth of the individual. The present study shows similar findings, but for different reasons. While Becker et al did not distinguish between time preference and time horizon, allowing the true time preference to vary, it is important to note that though one can decide to disregard the future today, it cannot be prevented from happening. Therefore, it is unclear why, when reaching future periods, the individual with low "forward looking capital" (equivalent to the horizon in this paper) will not regret having consumed less in the previous periods. This weakens the authors' assumption of rational agents.

In a previous version of this paper, keeping the same framework as Becker and Mulligan (1997) with a constant cost to increase the horizon, but allowing only the time horizon to vary (not the true time preference), I show that the optimal time horizon becomes independent of the initial wealth[7]. In this paper's version, the fixed cost to increase the horizon is replaced by utility from anticipation, which makes the cost higher for the poor and explains why the optimal time horizon is increasing in initial wealth. Even when an individual reaches future periods, she will not regret having chosen a low time horizon because it reduced the distress caused by poverty. The model of Becker and Mulligan (1997) provided the core reasoning on endogenous time discounting; this paper complements his work by using recent insights from the literature on time preference, time inconsistencies, cognitive dissonance and neuroimaging in order to better pinpoint the mechanisms behind the endogenous determination of time preference.

4 Empirical analysis

This section briefly describes the use of two randomized interventions implemented in "Savings, subsidies, and sustainable food security: A food experiment in Mozambique", which are described in more detail in Carter et al. (n.d.), where a more straightforward economic analysis of this program can be found, and shows that the agro-input subsidy resulted in a significant increase in maize production and wealth of the beneficiaries, even after the end

[7] This is true with a log utility function and otherwise depends on the relative risk aversion

of the subsidy. Similarly, the Matched Savings resulted in more farmers opening accounts, and total savings that exceeded the ones of the farmers that only benefited from the savings intervention. This paper uses the same database to test the prediction that an improvement in the economic prospect generated by the interventions generates an increase in individuals' planning horizons.

4.1 Context, intervention and identification strategy

This model predicts that among a poor population, an individual's time horizon should be increasing in her initial wealth, or more generally in the actualized value of the expected wealth[8]. Hence, the expectation of future payoffs should increase the horizon in a similar way. To test this prediction, I use data from a project where we randomly provided an agro-input subsidy and an encouragement to save money in order to help beneficiaries reach self-sufficiency in their maize production, which is the staple food in the Manica province. Participant selection was completed by the extension service, under the supervision of our partner organization, the International Fertilizer Development Center (IFDC). The sample of the baseline survey includes a total of 1,593 households in 94 localities. Table 1 provides selected summary statistics on basic economic outcomes. The population is relatively poor, but slightly less poor than the rest of the population in the region, given that the agro-input subsidy program intentionally targeted progressive small-scale farmers.

The first intervention was randomized at the individual level; within each village, half of the progressive farmers were assigned vouchers that provided a 73% subsidy for a seed and fertilizer package for a half hectare of maize production. The package consisted of 12.5 kg of improved maize seeds (either OPV or hybrid) and 100kg of fertilizer (50 kg of urea and 50 kg of NPK 12-24-12). The second intervention randomly assigned one third of the localities to a control group, one third to a savings treatment (ST) and one third to the Matched Savings treatment (MST). The ST group was encouraged to open savings accounts through easier access and financial education. The MST group received the same encouragement to save as well as a "bonus" of 50% of the savings left in the account between the harvest and the time to purchase fertilizer (from August 1st to October 31st, 2011), with a maximum match of MZN 1500 per individual (approximately USD 56). The financial reward aimed to assist farmers in developing a habit of savings in order to carry forward the benefits of the agro-input subsidy from year to year and sustainably self-finance their inputs for maize production. Here, we investigate the endogenous determination of the time horizon with two comparisons: first, by comparing the farmers assigned to the Voucher Treatment with their control group; second, by comparing the farmers in the MST group with the ST group.

[8] Both are equivalent in the absence of credit constraint

The latter comparison excludes the control group since the financial training provided to the MST and ST groups could influence the beneficiaries' time horizons.

Timing is an important element of the identification strategy. The subsidized agro-input package was made available in December 2010, and its harvest was expected from May to June 2012. The baseline survey, used to measure the impact of the voucher program on time horizon, was implemented prior to harvest, in April 2011. Hence, the first round of the survey is not a true baseline since it occurred after assignment to the first treatment, the planting, and the use of the subsidized input, but prior to the corresponding harvest. For this reason, Table 1 verifies the randomization by comparing both variables that are not expected to vary in the short term as a result of the randomization (e.g., household size, education, access to electricity) and information on maize cultivation during the 2010-2011 agricultural season, based on recall in April 2012 about the previous campaign. At the time of the "baseline" survey, both the farmers receiving the voucher and those in the control group were in similar economic conditions on average, but the economic prospects of the farmers in the voucher treatment group were higher, and, thus, a difference in time horizon at that time can be attributed to the difference in economic prospects between the two groups.

The week following the baseline survey (April to May 2011), farmers in each locality of the ST or MST group were invited to the first financial education session and were encouraged to open savings accounts. Beneficiaries of the MST group were informed of their participation to the MST program and explained how MS is calculated. The first follow-up survey (used to evaluate the impact of MS on horizon) was implemented in July-August 2011, after the beneficiaries had been informed of the MS program and had started opening accounts and saving, but two to three months before receiving the matched savings (deposited in the accounts of the beneficiaries the first week of November 2011). Therefore, the two groups had a similar economic situation, but different economic prospects at the time of the survey.

4.2 The measure of time horizon

Following the decomposition of time discounting into time preference and time horizon, as presented in section 2.4, we measured the extent to which an individual associates with her future selves by asking "How much time ahead do you plan your future expenditures?" and naming the reply to this question the "horizon" variable. No specific unit was given to the respondent, and the response was converted in number of days. When the respondent had some difficulty providing an answer to this question, the enumerator asked whether the respondent had any planned future consumption or investment and when the respondent expected to make this expenditure. The answer to this question varied greatly, with 15% planning no more than a week ahead (including no planning at all), 36% planning a year

ahead, and 5% planning more than a year ahead[9]. The question was inspired by Ameriks et al. (2003), who measured, among highly educated Americans, their propensity to plan, finding that it has a strong impact on actual savings.

I use the horizon variable, rather than typical time discounting questions (e.g., "Do you prefer receiving x today or y in a month from now?"), because the latter comprises not only time discounting but also the cost of remembering the debt and the trust that the money will be given a month later (Andreoni and Sprenger, 2010), which may be increased by the low level of income and education of the beneficiaries. This set of issues will increase the noise and affect the results in a way that is systematic across the control and treatment groups; therefore, it should still allow an unbiased comparison between the patience of the control and treatment groups. More importantly, any project that affects the wealth of the beneficiaries will affect their marginal utility of money at different points in time. Hence, because the agro-input subsidy and the matched savings affect the future wealth of the beneficiaries (but not the wealth at the time of survey), the respondents may prefer receiving the money immediately rather than later, in which case the beneficiaries of the program would erroneously appear to have become less patient than the control group. Thus, using the typical discounting questions would bias the coefficients of the impact of the program on the patience of the beneficiaries.

Because time horizon is a new variable, I first examine its correlation with key parameters. Time horizon is expected to be positively correlated with indicators of economic welfare, either because individuals with a longer time horizon accumulate more assets, or because wealth makes individuals more forward looking. Indeed, Table 2 shows a higher time horizon among respondents who have a savings account, who have already received a formal credit, who used fertilizer for maize production and who sold some of their maize production during the previous campaign, or who are more optimistic about their future. The median owner of a savings account has a planning horizon that is three times higher than the median individual without a savings account, and individuals who believe that their economic situation will be better in five years have a median planning horizon that is three times higher than that of individuals who think that their situation will be identical or worse. The latter evidence indicates a strong link between economic prospects and the planning horizon, as predicted by the model. The causality will be explored more rigorously in the following subsection.

[9] One could expect cognitive ability to affect the ability to plan; however, to the extent that the randomization ensures that it is randomly distributed among households in the treatment and control group, this should not bias the results

4.3 Empirical results

4.3.1 Model specification

The baseline survey occurred before the harvest of 2011, corresponding to the campaign in which the fertilizer was subsidized for those who received a voucher. Therefore, the farmers who received a voucher experienced an exogenous increase in their economic prospect. In the same way, when comparing farmers in the MST group to those in the ST group, while they are in similar economic conditions at the time of the first follow-up survey (July-August 2011), the households in the MST group expect an exogenous increase of their wealth in November 2011, when the Matched Savings would be disbursed. Hence, the model predicts that the two treatments should extend the time horizon of the beneficiaries, who are poor. Note that when examining the Matched Savings intervention, I compare only the savings group to the matched savings group in order to isolate the impact on the planning horizon of the subsidy that encourages savings from the financial training, which was provided in both the ST and MST groups, but not the control group. Thus, the members of the control group are always excluded from these regressions.

The following regression provides an unbiased estimate of the intention to treat effect:

$$H_i = \beta_0 + \beta_1 T_i + \epsilon_i \tag{9}$$

where H_i is the horizon of individual i, and T_i indicates whether individual i has been randomly selected to be in the treatment group. In the case of the agro-input subsidy, this means being selected to receive a voucher. In the case of the financial intervention, this means being in a community assigned to the MST.

However, winning the lottery did not always translate into receiving the voucher because the farmers who were unable to complete the subsidy declined the voucher, and some farmers who lost the lottery managed to acquire a voucher. An unbiased estimator of the impact of receiving the voucher on the time horizon can be obtained by an instrumental variable approach, where the first stage regression is:

$$V_i = \alpha_0 + \alpha_1 T_i + v_i \tag{10}$$

where V_i indicates whether the individual i received a voucher according to his own reply to the survey.

$$H_i = \beta_0 + \beta_1 \hat{V}_i + \epsilon_i \tag{11}$$

with $\hat{V_i} = \alpha_0 + \alpha_1 T_i$

Only the ITT is estimated in the case of the financial intervention; the IV approach cannot be used because self-selection into the treatment is different among the ST and the MST. Because the results can be driven by extreme values, the regressions are made using both the horizon (in number of days) and the inverse hyperbolic sine (IHS) of the horizon, proposed by Johnson (1949), which is given by $IHS(x) = log(x + (x^2 + 1)^{1/2})$. As with the logarithmic transformation, the slopes' coefficients can be interpreted as elasticities, and it has been shown by Burbidge et al. (1988) to be a better way to handle outliers and non positive values than adding a constant to the log or dropping the non-positive values[10].

4.3.2 The results

Table 3 shows the impact of the two programs on the time horizon of the beneficiaries, regardless of their level of wealth. The impact appears to be potentially high, particularly for the voucher subsidy. On average, winning the lottery increased an individual's time horizon by more than a month, from about 199 days to 236 days, increasing it by about 13% on average. The third column indicates that, once instrumented (by the result of the lottery), receiving a voucher increased the recipient's time horizon by about three months. However, these results are not particularly robust to the use of the IHS, and the impact of the MST on the time horizon of the recipient is potentially sizable but not significant. This may be due to the underlying assumption of a homogenous impact of the interventions on the time horizon of the entire population, while the theoretical model predicts a distinct effect among poor and non poor beneficiaries.

The cognitive dissonance process should affect only the time horizon of individuals with a level of wealth below a certain threshold, but not the horizon of people above it. The difficulty lies in choosing the poverty line, here defined as the level of consumption below which its anticipation is a source of anxiety. Given that the program aims to help farmers reach self-sufficiency through an increase in maize production, it is natural to approximate the poverty level by the level of self-sufficiency of the household. *Xima*, a porridge made exclusively of cornflour and water, is by far the most common meal in rural Manica, and it is very common for those in poor households to eat xima almost exclusively. Eating a more diverse food is generally a goal that comes after providing a sufficient quantity of *xima* to the family[11]. Hence, in a first estimation, I calculate the quantity of maize per capita that

[10] Only 1.6% had 0 days of time horizon (no more planning than day-to-day expenditures). In the regressions of this paper, the log or the IHS lead to very similar results

[11] The choice of the variable that is used to separate poor and rich households is also constrained by the availability of data that measures variables prior to the intervention. Given that the "baseline" occurred after voucher distribution and the planting season, it would not have been appropriate to use consumption at the time of the baseline to define the groups, given that this would be affected by the intervention. The regressions use a recall of the maize production prior to the intervention. Table 1 confirms that the recall

would be required to provide caloric need for a year, finding this quantity to be 386.1 kg[12].

Table 5.A shows the impact of the two interventions on the time horizon when the population is split according to whether the household's maize production per capita in the preceding season (2009-2010) is above or below 386.1 kg. As can be seen, the beneficiaries who are not self-sufficient increased their time horizon by almost 100 days when receiving a voucher, and by 49 days when assigned to the MST group. By contrast, the programs had no significant impact on households that are self-sufficient in maize production, which confirms propositions one and two of the model.

The number of kilos based on a caloric need fully satisfied by maize production would be overstated if farmers fulfill part of their caloric need from the self-production of other products, or any other source of income in the household. It could also be understated if farmers need to sell some maize to purchase other sources of nutrients, which would come at a loss in calories, given that maize is the cheapest calorie intake available, or because in the presence of risk, farmers would need to reach an average production beyond their consumption in order to have a buffer that allows them to not worry excessively about their future consumption. Hence, I suggest two alternative approaches.

The first alternative approach consists of using Hansen (2003)'s method for threshold estimation. This method tests the null hypothesis that the impact is homogenous across the whole population against the hypothesis of a breakpoint based on the maize production per capita. For this, a heteroskedasticity consistent Lagrange Multiplier test for a large number of breakpoints at regular intervals of maize production per capita is used, and the p-values are computed using a bootstrap. Figure 2 provides the graph obtained by the procedure adapted from Hansen (2003). In the absence of a prior on the localization of the breakpoint, the evidence does not reject the null hypothesis of constant impact of winning the Matched Savings lottery (p-value is 0.656), but it rejects the null hypothesis of constant impact of the assignment to the voucher (p-value= 0.022). Interestingly, both estimations identifying a threshold at a maize production per capita that is extremely similar since the former identifies it at 224 kg of maize per capita and the latter identifies it at 225kg per capita. This marks the value that is most likely to be the threshold at which the coefficient of the impact of the intervention on the time horizon is most likely to switch. Figure 2b shows possible values

has not been affected by the intervention since the Wald test does not reject the hypothesis of equal mean of maize production (prior to the interventions) across the treatment groups. We did not record any production other than maize in the baseline survey. It is also preferable to use prior production rather than consumption, given that the consumption decision results from the initial horizon, and, thus, a household that is initially more patient would appear to be poorer for a given income because it would save more and consume less.

[12]Energy requirements, derived from an Energy and Protein Requirement Report of a joint FAO/WHO/ONU Expert consultation from the Geneva World Health Organization, Technical Report Series No 724, are those for the population of a developing country with moderate activity level. The formula used is: (2,320 kcal)*365.25 days / (0.62kg*3,540 kcal)= 386.1 kg of maize, where 2,320kcal is the Daily energy requirement per person, 0.62 is the number of kg of cornflour obtained from one kg of maize, and 3,540kcal is the number of calories in one kg of cornflour.

for the threshold that go from 210 to 290 kg of maize per capita. This threshold is smaller than the one obtained by the calculation of caloric needs provided by the maize production, which can be explained by the existence of alternative sources of food and revenue. Table 5.B presents the results once the samples have been separated using this estimated threshold of 225 kg of maize production per capita and per year, and finds, for both interventions, impacts on time horizon that are more robust among the farmers who are not self-sufficient, and again, no significant impact among the farmers who are self-sufficient.

The Second alternative is to consider that the households may have revealed that they are self-sufficient when they sold part of their maize production in the previous agricultural campaign, which is a sign that they have enough maize to feed their family. Transforming subsistence farmers into commercial farmers (who sell part of their maize production) is a major objective that was initially stated in the voucher program. Also this method is not affected by the fact that the threshold can be different for each household, because of different its need per capita or different other sources of revenue. The median maize production per capita is 129kg among the households that did not sell their maize production after the harvest of 2010 and it is 310 kg among the households that sold some of their maize production, which clearly shows that the commercial farmers tend to be the ones who have a sufficient production to feed their family. Table 5.C shows that receiving the voucher increased the horizon of non-self-sufficient beneficiaries by 116 days, and the assignment to the MST group increased their planning horizon by 47 days (although this result is not significant the IHS transformation tells us that it increased the time horizon of the beneficiaries by a significant 20%). This provides further evidence of the robustness of the results.

4.4 Interpretation of the results

This section explores the competing explanations of the empirical evidence in this paper. Are there other ways in which the randomized interventions could have affected the planning horizon of the beneficiaries? It is sometimes argued that one can be "too poor to save". Despite an absence of theoretical foundation, this recurring argument is intuitively appealing and thus deserves some discussion. Does a scarcity of money explain the lack of planning of the poor? In fact, these elements are included in the theoretical model presented in this paper. In the model, for a poor individual, the cost of being forward looking is the disutility generated by the distress of projecting oneself into a gloomy future. It can be shown that with a log utility function, when this cost is replaced by a fixed cost of extending the time horizon, then the optimal time horizon is independent of the individual's initial wealth. In other words, while more wealth increases the benefits of planning by having more money to allocate properly across time, wealth also reduces the marginal utility of consumption, and thus the marginal cost of a misallocation across time. With a log utility function,

the two effects compensate each other exactly. In fact, which effect prevails depends on the relative risk aversion. With a relative risk aversion below one, wealth increases the optimal planning, but with a relative risk aversion higher than one, the poor individual will have a higher planning horizon and a higher savings rate than the rich. Intuitively, no matter how little money a household has, it still needs planning and saving as much as a wealthier household (in relative proportions) because poverty sharpens the cost of neglecting the future. Hence, without the reluctance to project oneself into a gloomy future (analytically represented by inclusion of the utility from anticipation), poverty in itself does not explain a reduction of the planning horizon. By contrast, the theoretical model of this paper has a clear prediction on how an increase in economic prospects affects the time horizon through the cost of anticipation, before the current consumption of the beneficiary is affected.

It can be argued that poor people can be "too hungry to think", meaning that lack of nutrition may limit one's ability to think and make the right decision, or that since hunger is a visceral need, it can be more difficult for the individual to apply self-control with this type of good. While this effect can reinforce the one that has been observed, it cannot explain the results. The identification strategy for both interventions consists of examining an improvement in the economic prospects of the individual. At the time of the survey, the farmer had not yet benefited from the harvest or Matched Savings resulting from the interventions, meaning their economic conditions had not yet been affected.

Banerjee and Mullainathan (2010) incorporate this last argument into a dynamic optimization framework, where poorer individuals have a consumption basket that includes a higher proportion of visceral goods, for which it is more difficult to behave rationally. The authors separate regular goods from temptation goods (such as fatty or sugary goods), which are assumed to provide an immediate gratification, but are not valued by the long run self, and act as a temptation tax. They find that if this temptation tax rate is higher among the poor, then poor individuals may react to the prospect of future income growth by saving more, generating a behavioral poverty trap similar to the one discussed in this paper, though for very different reasons. Yet the implications of their model on an individual's time horizon are not straightforward. In the absence of utility from anticipation, the tax may reduce savings, but not necessarily the optimal time horizon. Without a combination of the two models, which goes beyond the scope of this paper, it is not clear how the temptation goods would provide an alternative explanation for the empirical findings of this paper. It is possible that the two factors reinforce each other in the creation of a behavioral poverty trap.

One can hypothesize that the beneficiaries may have been waiting for the future resources coming from harvest or the Matched Savings. Although not in complete contradiction with the argument that the improvement in economic prospects increases peoples' planning horizon, it would cast doubt on the occurrence of a cognitive dissonance and behavioral change described in the theoretical model. The first survey (used to analyze the impact of the

voucher) was implemented two to three months before the harvest, and the second survey (used to analyze the impact of the Matched Savings) preceded the payment of Matched Savings by three months. If farmers were simply waiting for the harvest or the Matched Savings payment, then it would result in a concentration of planning horizons around the three month period. However, Figure 1a and 1b show the distribution of the planning horizon for the control and the two treatment groups, and no particular concentration of planning horizon around the three month period for the treatment group is noticeable; rather, there is an increase in time horizon spread among the different initial levels of planning horizon. Hence, the results are not driven by individuals waiting for their payments.

It could also be argued that the impact on time horizon could have been a result of the change in activity caused by the interventions (i.e., farming with more inputs or the use of savings accounts) more than the improvement of future economic prospects. Figure 2.B shows strikingly similar distributions of the planning horizon among the control group and the ST group, despite the fact that the ST increased the proportion of beneficiaries with a savings account by 13 percentage points (versus 21 for the MST), and that considerable time and effort was invested in the financial training for those in the ST and the MST groups. Hence, the data suggests that the financial training and opening of savings accounts had no impact on the time horizon of the beneficiaries, but the money (and potentially the incentive to save) provided by the Matched Savings had a considerable impact. The argument that our project does not allow us to confirm that a pure cash transfer would have had a similar impact cannot be fully rejected given that these programs include additional changes (e.g. the incentive to save or to invest) and are implicitly designed with the intention to generate a change in behavior. In fact, improving our understanding of how the design of the transfer may enhance the impact of transfer on the time horizon appears to be a very promising area for future research.

A recent paper from Bernheim et al. (2013)[13] describes an interpersonal game played by the time-inconsistent decision maker, for intermediate degrees of time inconsistencies. They find a behavioral poverty trap that results from the fact that self-control is more difficult when initial assets are low which results in similar economic consequences: the authors also conclude that a temporary increase in assets can have long term consequences and examine the theoretical implications of different interventions. The empirical results of this paper support both the conclusions of our model and those of Bernheim et al., and future work can attempt to better disentangle the causes of the behavioral poverty trap.

[13] A previous version circulated in 1999 had only numerical results, while the 2013 paper includes the theoretical results.

5 Conclusion and policy implications

Effective development interventions require structural changes that will outlive the interventions. Poverty dynamics show that patience is a fundamental factor for an individual to be willing to make the sacrifices required to transit toward a higher equilibrium. This paper looks at the psychological causes behind myopic economic behaviors, offers a new theoretical approach, building on the psychology literature, according to which the anticipation of future poverty generates a disutility makes it costly for the poor to have a long term planning horizon. It shows the possible existence of a behavioral poverty trap, even in the absence of non-convex production technologies or any other external cause of poverty trap that would. The paper also provides some primary empirical evidence of the endogeneity of one's planning horizon, . Using a field experiment among Mozambican maize producers, I test the predictions using two different interventions. I find that, among the households who were initially not self-sufficient in maize production, benefiting from an agro-input subsidy of a value equivalent to USD 65 increased their planning horizon by about 100 days, and being offered Matched Savings with an average transfer of USD 34 increased the time horizon of small producers by about 48 days. These are very substantial increases from an average of 200 days in the control group of the baseline survey. As predicted by the theoretical model, both interventions have a large and significant impact for households that are not self-sufficient, but no significant impact for households that are self-sufficient in maize production, and the results are robust to multiple definitions of self-sufficiency.

The long term implications depend on whether the change of attitude towards the future is permanent or temporary and how the planning horizon translates into economic decisions such as consumption, savings and investment. On this question, the results of Ameriks et al., 2003 indicate that planning is essential for savings and capital accumulation, but further research is certainly necessary to better understand this dynamic, particularly in the context of rural developing countries. In the case of the projects described in this paper, Carter et al. (n.d.) show an impact of the intervention on maize production, asset accumulations and welfare indicators, that outlives the duration of the project, which is in line with the results of this paper (although it is not the only type of model that can lead to a long term impact of the interventions).

To the best of my knowledge, this paper provides the first bounded rationality model that explains how disutility from anticipation can dissuade the poor from being forward looking. It also provides new evidence of the endogeneity of one's attitude toward her future, especially among households that are not self-sufficient. The two interventions were designed to leverage the amounts transferred by requiring contributions from the farmers, and to orient farmers towards productive and forward looking activities. Hence, simple cash transfer of the same amount may or may not have a lower impact on the beneficiaries' planning horizon. Future

research could try to answer this question, but more interestingly for policy implications, scholars should investigate what type of intervention best stimulates the beneficiary's time horizon. Variants to be compared can include help in kind or cash, individual or group intervention and requiring the beneficiary's contribution or not. This article contributes to a better knowledge of the mechanisms that affect economic aspirations, which will inform the design of projects that enhance this effect. The Individual Development Accounts, which offer a match at a fixed rate on savings towards the acquisition of assets, were praised by Schreiner and Sherraden (2007) for generating "less fear and more hope". This change of attitude toward the future is confirmed by this empirical analysis and acts as a multiplier of the impact of the program on asset accumulation.

An economic intervention can affect the beneficiaries' asset accumulation not only through its direct economic impact, but also through a behavioral impact, which embraces all changes in preference, as well as aspirations or attitudes that will, in turn, affect economic decisions. Depending on the intervention, the behavioral impact may be positive (e.g., increase in patience or aspirations) or negative (e.g., increase in passivity or moral hazard). Improving the design of future projects requires a deep understanding of both the economic and behavioral impact of the interventions. While most of the literature has evaluated the economic impact, fewer theoretical and empirical studies have analyzed the behavioral effects and their interaction with the economic effects. This paper shows that it is possible for randomized control trials to include an evaluation of the behavioral changes that are expected to be affected by economic interventions. This area has an important untapped potential for future research, at the junction between economics and psychology.

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Figure 1.A:

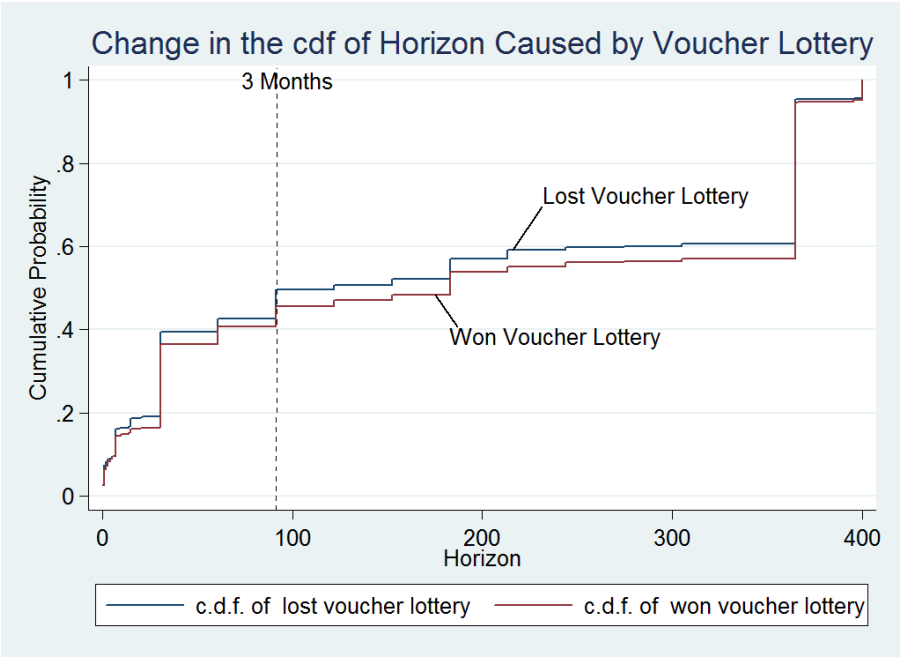


Figure 1.B:

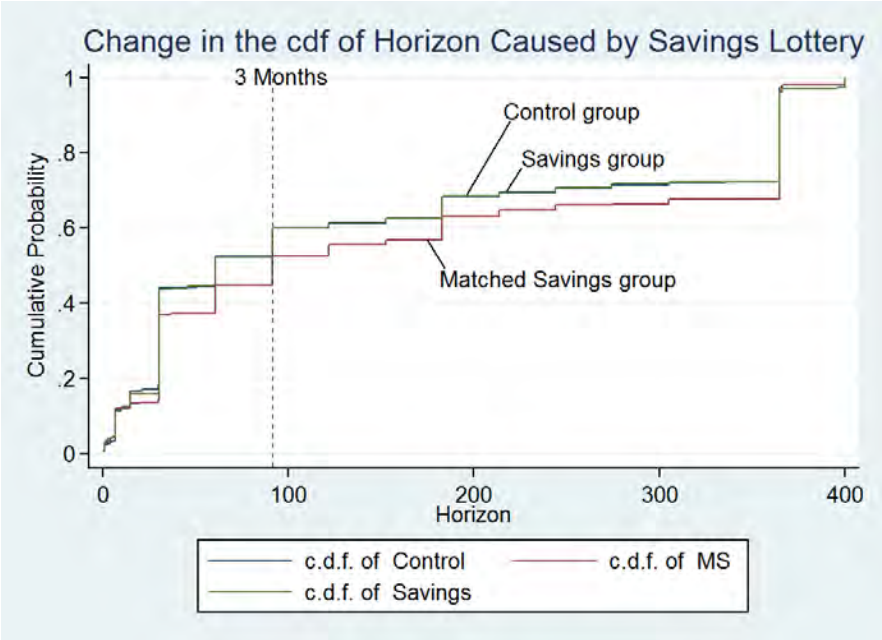
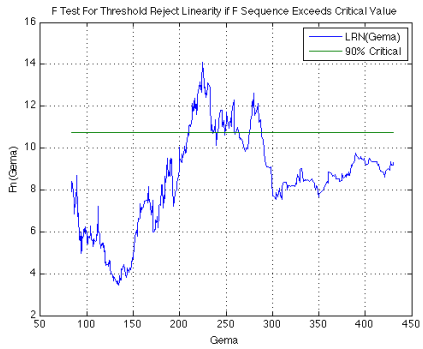
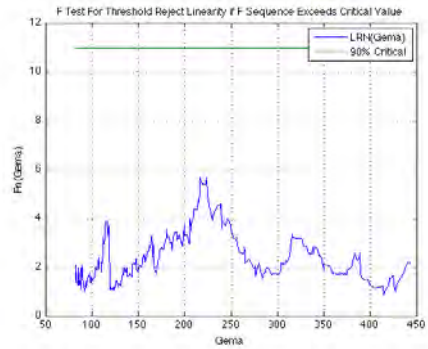


Figure 2:

2a: Threshold of impact of winning Voucher



2b: Threshold of impact of assignment to Matched Savings



The procedure designed by Hansen (2003) estimates a threshold regression by least squares, and provides tests of the null of the homogenous impact of the treatment conditional on the level of maize production per capita against the alternative of a significant change of impact at a threshold. It rejects the null hypothesis of constant impact of the assignment to receiving the voucher at the 95% level (p-value= 0.022), identifying a threshold at a maize production per capita of 225 kg of maize per capita, (used for the regressions in Table 5.B), but It does not reject the null of constant impact of winning the voucher lottery (p-value is 0.656), with a place where the threshold is most likely to occur at 224 kg of maize per capita.

Table 1: Descriptive Statistics and Verification of Randomization

	Control		Savings		Matched Savings		All treatment groups	p-value of Wald test
	No voucher	Voucher	No voucher	Voucher	No voucher	Voucher		
Hh size (nb)	7.43	7.64	7.87	7.63	7.82	7.46	7.65	0.6234
	[2.87]	[3.41]	[3.86]	[3.34]	[3.60]	[3.26]	[3.41]	
Hh head educ (yrs)	4.78	4.67	4.83	4.75	4.71	4.42	4.70	0.9267
	[3.35]	[3.14]	[3.42]	[3.41]	[3.00]	[3.24]	[3.27]	
Hh head male (%)	0.85	0.85	0.82	0.87	0.85	0.82	0.84	0.6854
	[0.36]	[0.35]	[0.38]	[0.34]	[0.36]	[0.38]	[0.36]	
Hh head age	45.9	46.4	46.2	46.6	46.3	46.0	46.2	0.9728
	[14.06]	[13.68]	[13.90]	[14.19]	[13.74]	[13.94]	[13.90]	
Hh head literacy (%)	0.79	0.76	0.77	0.74	0.77	0.73	0.76	0.6359
	[0.41]	[0.43]	[0.42]	[0.44]	[0.42]	[0.45]	[0.43]	
Electricity (%)	0.10	0.10	0.15	0.13	0.11	0.08	0.11	0.7712
	[0.31]	[0.30]	[0.35]	[0.34]	[0.31]	[0.27]	[0.32]	
Banking account (%)	0.14	0.23	0.20	0.21	0.19	0.22	0.20	0.147
	[0.34]	[0.42]	[0.40]	[0.41]	[0.39]	[0.41]	[0.40]	
Livestock value (MZN) 1	30 762	37 100	36 071	35 977	34 113	35 791	34 969	0.8487
	[41432.06]	[49496.01]	[50208.39]	[47453.06]	[47785.69]	[48045.72]	[47480.25]	
Total area owned (ha)	9.2	9.3	9.9	17.1	7.9	7.6	10.3	0.4876
	[20.04]	[18.14]	[26.57]	[126.82]	[9.43]	[10.48]	[55.69]	
Area for maize (ha) t-1	3.4	3.8	3.8	3.7	3.3	3.5	3.6	0.8932
	[3.09]	[3.74]	[4.72]	[3.96]	[3.93]	[3.20]	[3.84]	
Fertilizer for maize (kg) t-1	29.1	28.6	26.0	22.3	23.3	19.1	24.8	0.7662
	[83.83]	[167.25]	[66.77]	[95.69]	[59.12]	[64.90]	[95.72]	
Maize Production (kg)$_{t-1}$ 1	2 202	2 375	2 260	2 301	2 120	1 949	2 207	0.2532
	[2369.00]	[2522.20]	[2788.08]	[2782.31]	[2648.35]	[2310.13]	[2586.90]	
Maize Yield (kg/ha)$_{t-1}$ 1	988	839	925	889	911	806	896	0.7327
	[1121.00]	[795.75]	[1052.86]	[1017.27]	[1009.91]	[839.01]	[985.76]	
Number of observations	267	247	278	303	248	246	**1 593**	

Standard deviations in brackets

1: the top 1% of the values have been replaced by the 99th percentile, to limit the influence of extreme values.

All statistics are from baseline survey, prior to assignment to savings and Matched Savings treatments; after the distribution of input vouchers, but before harvest. Information on maize cultivation are based on recalls about the prior agricultural campaign (before assignment to voucher treatment).

Table 2: Horizon mean and median conditional on economic variables (nb of days):

		Nb of hh	Horizon mean	Horizon median
Has a savings account	No	1237	207	122
	Yes	304	257***	365**
Has already received a credit from a formal bank	No	1355	210	152
	Yes	188	263**	244
Cultivated more than 2ha of maize in 2009-2010 campaign	No	709	206	122
	Yes	814	230	183**
Used Fertilizer in 2009-2010 campaign	No	1251	214	152
	Yes	284	235	183
Sold some of its maize production of 2009-2010 campaign	No	840	206	91
	Yes	706	231*	183***
Believes that the hh's economic situation will be better in 5 years	No	163	159	61
	Yes	1368	225***	183**
All households		**1546 hh**	**217 days**	**152 days**

The stars indicate the p-value of the equality of means and medians *** p<0.01, ** p<0.05, * p<0.1

Table 3: Impact of the voucher subsidy and Matched Savings program on Horizon

	(1)	(2)	(3)	(4)	(5)	(6)
	Impact of the voucher subsidy				**Impact of Matched Savings**	
	ITT - OLS		ATE - IV		ITT - OLS	
	Horizon	IHS horizon	Horizon	IHS horizon	Horizon	IHS horizon
Won lottery	37.55**	0.13				
	[15.94]	[0.09]				
Voucher(s) received			92.99**	0.33		
			[41.26]	[0.23]		
Matched Savings					24.48	0.12
					[18.16]	[0.08]
Constant	198.52***	4.46***			160.27***	4.39***
	[7.94]	[0.06]			[8.60]	[0.05]
Observations	1,546	1,546	1,533	1,533	960	960

Regressions (1) to (4) include village fixed effects (the stratification level for the voucher randomization)

In regressions (5) and (6), standard errors are clustered by locality (the level of randomization)

They include fixed effects at stratification level (groups of 3 localities by proximity)

Robust standard errors in brackets
*** p<0.01, ** p<0.05, * p<0.1
The explained variable of columns (3), (4) and (6) is the inverse hyperbolic sine transformation of the horizon, given by IHS(x)=log(x + (x^2 + 1)^0.5), which can be interpreted like a log transformation but allows for non positive horizon values.

Table 4: First stage for IV regressions (receiving a voucher is the explained variable)

VARIABLES	(1) **All hh**	(2) **Prod < 386kg**	(3) **Prod >= 386kg**	(4) **Prod < 225kg**	(5) **Prod >=225kg**	(6) **Did not sell Maize**	(7) **Sold Maize**
Won lottery	0.38***	0.38***	0.44***	0.40***	0.36***	0.40***	0.36***
	[0.023]	[0.026]	[0.061]	[0.029]	[0.042]	[0.029]	[0.039]
Constant	0.13***	0.11***	0.19***	0.08***	0.20***	0.10***	0.17***
	[0.013]	[0.015]	[0.033]	[0.015]	[0.025]	[0.017]	[0.022]
Observations	1,539	1,138	354	852	640	836	703
R-squared	0.262	0.255	0.417	0.286	0.316	0.307	0.288

Regressions include village fixed effects
Robust standard errors in brackets. *** p<0.01, ** p<0.05, * p<0.1

Column 1 includes all households and in the following columns households are divided simiilarly to table 5.

Table 5: Impact of the voucher subsidy and Matched Savings program on Horizon, by food security level

5.A Households are separated based on whether the household is self-sufficient in maize production, based on caloric need per capita (maize production/capita/year = 386kg)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Model	Impact of the voucher subsidy				Impact of the Matched Savings			
	Not self-sufficient	Self-sufficient	Not self-sufficient	Self-sufficient	Not self-sufficient	Self-sufficient	Not self-sufficient	Self-sufficient
	Horizon	Horizon	IHS Horizon	IHS Horizon	Horizon	Horizon	IHS Horizon	IHS Horizon
ITT - OLS	40.86***	14.86	0.19*	-0.11	48.70*	-20.35	0.22**	-0.03
	[15.80]	[52.85]	[0.10]	[0.21]	[24.40]	[23.62]	[0.09]	[0.19]
LATE - IV	99.55**	36.01	0.48*	-0.22				
	[41.17]	[118.32]	[0.27]	[0.46]				
Nb of obs.	854	645	854	645	617	308	617	308

5.B Households are separated endogenously, using Hansen(2003)'s method for threshold estimation (resulting theshold is at maize production/capita/year = 225kg)

	Impact of the voucher subsidy				Impact of the Matched Savings			
	Not self-sufficient	Self-sufficient	Not self-sufficient	Self-sufficient	Not self-sufficient	Self-sufficient	Not self-sufficient	Self-sufficient
	Horizon	Horizon	IHS Horizon	IHS Horizon	Horizon	Horizon	IHS Horizon	IHS Horizon
ITT - OLS	36.13**	42.37	0.16	0.16	76.52**	-26.65	0.41***	-0.13
	[16.77]	[29.71]	[0.12]	[0.14]	[35.71]	[16.05]	[0.10]	[0.11]
LATE - IV	88.59**	104.39	0.38	0.45				
	[41.86]	[79.77]	[0.29]	[0.38]				
Nb of obs.	854	645	854	645	528	400	528	400

5.C Households are separated based on whether they sold a part of their maize production during previous season.

	Impact of the voucher subsidy				Impact of the Matched Savings			
	Did not sell maize	Sold Maize	Did not sell maize	Sold Maize	Did not sell maize	Sold Maize	Did not sell maize	Sold Maize
	Horizon	Horizon	IHS Horizon	IHS Horizon	Horizon	Horizon	IHS Horizon	IHS Horizon
ITT - OLS	47.43**	24.34	0.12	0.16	47.01	0.36	0.20**	0.06
	[21.90]	[21.79]	[0.12]	[0.13]	[30.99]	[21.23]	[0.10]	[0.13]
LATE - IV	116.44**	56.78	0.27	0.45				
	[54.03]	[58.36]	[0.30]	[0.36]				
Nb of obs.	839	707	839	707	530	430	530	430

Columns (1) to (4) include village fixed effects

In columns (5) to (8), standard errors are clustered by locality (the level of randomization)

They include fixed effects at stratification level (groups of 3 localities by proximity)

Robust standard errors in brackets,

*** p<0.01, ** p<0.05, * p<0.1

The explained variable of columns (3), (4), (7) and (8) is the inverse hyperbolic sine transformation of the horizon, given by IHS(x)=log(x + (x^2 + 1)^0.5), which can be interpreted like a log transformation but allows for non positive horizon values.

APPENDIX

Proof of existence of an optimum

Prior to the demonstration of the three propositions, I show that assumption 1 implies the existence of a maximum (or maxima) of $U(H, w_0)$ reached for $H \in (0, \bar{H}]$. Since the utility function and horizon function are both continuous and differentiable, and $c_t^i(w_0, H)$ is continuous and differentiable for $H \in (0, \bar{H}]$, then $U(H, w_0)$ is also continuous and differentiable on $H \in (0, \bar{H}]$. Since by assumption $\lim_{c \longmapsto 0} u(c) = -\infty$, then $\lim_{H \longmapsto 0} U(H, w_0) = -\infty$. Hence, $\exists e > 0$ such that $U(H, w_0) < U(e, w_0)$ $\forall$ $H < e$. Since for any w_0, $U(H, w_0)$ is continuous on the closed and bounded interval $H \in [e, \bar{H}]$, then by the extreme value theorem, $U(H, w_0)$ must attain its maximum(a) in $(0, \bar{H}]$.

Proof of proposition 1

From the outer self's maximization, the following equation is equivalent to equation 4 (under the same constraints):

$$\max_{\{c_t^i\}} U_i\left(\{c_t^i\}, h_i\right) = \int_i^T e^{-\rho(t-i)} u(c_t^i) \left[h(t-i, H) \; + \gamma \int_{\tau=i}^{t} h(\tau - i, H) h(t-\tau, H) \, d\tau \right] dt \tag{12}$$

Equation 4 is the sum of the utility (from instantaneous consumption and anticipation of future consumption) at every point in time between i and T while equation 12 is the sum of the utility derived from every consumption c_t^i, from instantaneous consumption and its anticipation at time τ between i and t. The two are equivalent.

Let $k_t^i(H)$ be the weight that the outer self i puts on her consumption at time t:

$$k_t^i(H) = e^{-\rho(t-i)} \left[h(t-i, H) \; + \gamma \int_{\tau=i}^{t} h(\tau - i, H) h(t-\tau, H) \, d\tau \right] \tag{13}$$

This weight combines the motivation provided by utility directly derived from consumption at time t and by the utility of its anticipation between time i and time t. k_t^i is increasing in H for any $i < t \leq T$, and note that $k_i^i = 1$, which is obtained by substituting t into i in equation 13.

The marginal change in utility of increasingc_t^i is thus given by $k_t^i \, u'(c_t^i)$.

Given the interest rate r, the actualized unitary cost at time i of consumption at time t is equal to $e^{-r(t-i)}$.

At the optimum, the marginal utility derived from one monetary unit dedicated to consumption must be the same for every period:

$$e^{-r(s-i)}k_t^i(H)u'(c_s^{i*}) = e^{-r(t-i)}k_t^i(H)u'(c_t^{i*}) \ \forall \ s,t \in [i,T] \tag{14}$$

Using the fact that $e^{-r(i-i)}k_i^i(H) = 1$, then when $t = i$, equation 14 gives:

$$u'(c_i^{i*}) = e^{-r(t-i)}k_t^i(H)u'(c_t^{i*}) \ \forall \ t \in [i,T] \tag{15}$$

From which an implicit differentiation with respect to w_0 leads to:

$$\frac{dc_i^{i*}}{dw_0} = \underbrace{e^{-r(t-i)}k_t^i(H)\frac{u''(c_t^{i*})}{u''(c_i^{i*})}}_{>0}\frac{dc_t^{i*}}{dw_0} \ \forall \ t \in [i,T]$$

which shows that at the optimum, all c_t^{i*} must vary in the same direction as a reaction to an increase in w_0. Hence, $\frac{dc_t^{i*}}{dw_0} > 0 \ \forall \ t \in [i,T]$.

I now turn to the maximization of the inner self. For conciseness, I will use c_t^i as an abbreviation for $c_t^i(w_0, H)$, referring to the consumption that results from the decisions of the succession of outer selves once w_0 and H are set. Aware of this, the inner self selects the horizon parameter $H \in (0, \bar{H}]$, which maximizes the agent's intertemporal utility given by equation (12). :

$$\max_H U(w_0, H) = \int_0^T e^{-\rho(i)}\left[u\left(c_i^i\right) + \gamma\int_i^T e^{-\rho(\tau-i)}h(\tau-i,H)\,u\left(c_i^i(w_0,H)\right)d\tau\right]di \tag{16}$$

Similar to equations 12, this can be re-written in the following way:

$$\max_H U(w_0, H) = \int_0^T e^{-\rho i}u\left(c_i^i\right)\left(1 + \gamma\int_0^i h(i-\tau,H)\right)d\tau di \tag{17}$$

If the time horizon H, which maximizes the objective function of the inner self, is an interior solution, then it must satisfy the first order condition:

The solution $H(w_0)$ to the inner self's problem can be either a corner solution at $H(w_0) = \bar{H}$ if it satisfies $\frac{dU(\bar{H},w_0)}{dH} \geq 0$, or an interior solution satisfying the first order condition:

$$\frac{dU(w_0,H)}{dH} = \int_0^T e^{-\rho i} u'\left(c_i^i\right) \frac{dc_i^i}{dH} \left(1 + \gamma \int_0^i h(i-\tau,H)d\tau\right) + e^{-\rho i} u\left(c_\tau^i\right) \gamma \int_0^i \frac{dh(\tau - i, H)}{dH} d\tau di = 0 \tag{18}$$

For a more intuitive interpretation, equation 27 can be presented as follows:

$$\underbrace{\int_0^T e^{-\rho i} u'\left(c_i^i\right) \frac{dc_i^i}{dH} \left(1 + \gamma \int_0^i h(i-\tau,H)d\tau\right) di}_{Marginal\, benefit\, of\, correcting\, the\, misallocation} = \underbrace{-\int_0^T e^{-\rho i} u\left(c_\tau^i\right) \gamma \int_0^i \frac{dh(\tau - i, H)}{dH} d\tau di}_{Marginal\, benefit\, of\, closing\, the\, eyes} \tag{19}$$

As a reminder, by definition, $h(\theta, \bar{H}) = 1 \; \forall \theta$. Hence, when $H(w_0) = \bar{H}$, then the objective function of every outer self is the same as the objective function of the inner self, thus the consumption is not updated at each period ($c_t^{i*} = c_t^{j*} \; \forall 0 \leq i \leq j \leq t \leq T$) because the individual is time consistent, and the objective function of every outer self is the same as that of the inner self, resulting in an optimal allocation of consumption between periods. As a result, the marginal utility derived from one monetary unit dedicated to consumption $c_t^i(H, w_0)$ must be the same for every period t. When $H = \bar{H}$, equation 14 holds not only for a given outer self i, but also across all outer selves.

Therefore, by the envelope theorem, any marginal reallocation of consumption $\{c_t^i(H, w_0)\}$ leads to no change in $U(H, w_0)$, implying that the LHS of equation 19 is null. To show this formally, with LHS being the left hand side of equation 19 :

$$\begin{aligned} LHS &= \int_0^T e^{-\rho i} u'\left(c_i^i(\bar{H}, w_0)\right) \frac{dc_i^i(\bar{H},w_0)}{dH} \left(1 + \gamma \int_0^i h(i-\tau,\bar{H})d\tau\right) di \\ &= \int_0^T e^{-\rho i} u'\left(c_i^i(H, w_0)\right) \frac{dc_i^i(H,w_0)}{dH} \left(1 + \gamma i\right) di \end{aligned}$$

Using the fact that $c_i^0 = c_i^i$, since the consumption plan is common to all outer selves when $H(w_0) = \bar{H}$, equation 15 shows that $u'(c_i^0) = \frac{u'(c_0^0)}{e^{-(r+\rho)i}(1+\gamma i)}$, which can be replaced to obtain:

$$\begin{aligned} LHS &= \int_0^T e^{-\rho i} \frac{u'\left(c_0^0\right)(1+\gamma i)}{e^{-(r+\rho)i}(1+\gamma i)} \frac{dc_i^i(H,w_0)}{dH} di \\ &= u'\left(c_0^0\right) \int_0^T e^{ri} \frac{dc_i^i(H,w_0)}{dH} di \end{aligned}$$

The last line of calculation uses the fact that the budget constraint is always binding, which implies that $\int_0^T e^{ri} \frac{dc_i^i(H,w_0)}{dH} di = 0$. Hence, the LHS of equation 19 is equal to 0.

As a result, when $H = \bar{H}$ then:

$$\frac{dU(w_0,\bar{H})}{dH} = \gamma \int_0^T \int_i^T e^{-\rho\tau} \frac{dh(\tau - i, H)}{dH} u\left(c_\tau^i(H, w_0)\right) d\tau di \tag{20}$$

Because we showed that $\frac{dc_\tau^i}{dw_0} > 0 \ \forall \tau$, we know that $\frac{dU(\bar{H},w_0)}{dH}$ is strictly increasing in w_0. Hence, $\exists$ a unique $\hat{w_0}$ such that $\frac{dU(\bar{H},w_0)}{dH} = 0$. When $w_0 \geq \hat{w_0}$, then $\bar{H}$ maximizes $U(H, w_0)$; it is a global maximum given the absence of tradeoff: any $H < \bar{H}$ increases the cost of misallocation and reduces the (positive) utility from anticipation.

When $w_0 < \hat{w_0}$, then $\frac{dU(\bar{H},w_0)}{dH} < 0$, and, thus, a marginal deviation from $\bar{H}$ to $H < \bar{H}$ improves the utility of the agent, hence the solution is interior, $H(w_0) \in (0, \bar{H})$.

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Proof of proposition 2

Proposition 2 requires the assumption that $u(c)$ is a log utility function. As a result, at the optimum:

$$\frac{e^{-r(s-i)} k_t^i(H)}{c_s^i} = \frac{e^{-r(t-i)} k_t^i(H)}{c_t^i} \ \forall \ s, t \in [i, i + h_i] \tag{21}$$

When $s = i$, then, since $k_i^i(H) = 1$, it can be simplified to:

$$c_t^i = e^{-r(t-i)} k_t^i(H)\, c_i^i \tag{22}$$

I introduce the budget constraint: $\int_i^T e^{r(t-i)} c_t^i dt = w_i$, and substitute 22 to obtain:

$$\int_i^T k_\tau^i(H)\, c_i^i dt = w_i \tag{23}$$

The immediate consumption that is planned and happens at time i is thus:

$$c_i^i = \frac{w_i}{\int_i^T k_\tau^i(H)\, dt} \ \forall\, 0 \leq i \leq T \tag{24}$$

Re-using equation 22, the consumption planned at time i for period t is given by:

$$c_t^i = w_i \frac{e^{-r(t-i)} k_t^i(H)}{\int_i^T k_\tau^i(H)\, d\tau} \ \forall\, 0 \leq i \leq t \leq T \tag{25}$$

As a reminder, the consumption c_i^i always happens, as opposed to c_t^i for $t \neq i$, which would

happen only if the consumption plan has not changed once the outer self reaches period i (when $H = \bar{H}$).

From $\dot{w}_i = rw_i - c_i$ and equation 24, we obtain :

$$\frac{\dot{w}_i}{w_i} = r - \frac{1}{\int_i^T k_\tau^i(H)\, d\tau} \tag{26}$$

$\frac{\dot{w}_i}{w_i}$ is independent from w_0 at any i implies that $\frac{\dot{w}_i}{w_0}$ is independent of w_0. From equation 24 and 26, all w_i and c_t^i are proportional to w_0. Hence $\frac{\partial w_i(w_0,H)}{\partial w0} > 0$ and $\frac{\partial c_t^i(w_0,H)}{\partial w0} > 0$ for any $0 < i < T$. Also, since $w_i(w_0, H)$ and $c_t^i(w_0, H)$ are both proportional to w_0, then $\frac{\partial \frac{w_i(w_0,H)}{w_0}}{\partial w0} = 0$ and $\frac{\partial \frac{c_t^i(w_0,H)}{w_0}}{\partial w0} = 0$ for any $0 \leq i < T$.

Back to the maximization problem of the inner self, I take the derivative of $U(H, w_0)$ in equation 7 with respect to H to obtain the first order condition:

$$\frac{dU(w_0,H)}{dH} = \int_0^T e^{-\rho i} u'\left(c_i^i\right) \frac{dc_i^i}{dH} + \gamma \int_i^T e^{-\rho\tau} \left(h(\tau - i, H) u'\left(c_\tau^i\right) \frac{dc_\tau^i}{dH} + \frac{dh(\tau - i, H)}{dH} u\left(c_\tau^i\right) \right) d\tau di \; = 0 \tag{27}$$

I have shown that, for a given H, c_t^i is proportional to w_0 $\forall 0 \leq i \leq t \leq T$; the relative allocation of consumption at the optimum is independent from the initial wealth. Hence, with the log utility function, $u'\left(c_t^i\right) \frac{dc_t^i}{dH}$ is independent from w_0. As a result, the derivation of equation 27 with respect to w_0, simplifies to:

$$\frac{d^2U(H,w_0)}{dH\, dw_0} = \gamma \int_0^T \int_i^T e^{-\rho\tau} \frac{dh(\tau - i, H)}{dH} \frac{dc_\tau^i}{dw_0} u'\left(c_\tau^i(H, w_0)\right) d\tau di \; > 0 \tag{28}$$

H and w_0 are complementary because when the horizon increases, more weight is put on the anticipation of future utility, and a high w_0 leads to a higher level of future consumption, and thus higher benefit from the increased weight on anticipated utility.

In the case of an interior solution ($H(w_0) < \bar{H}$), an implicit differentiation of $\frac{dU(H(w_0),w_0)}{dH} = 0$ with respect to H gives the following:

$$\frac{d^2U(H,w_0)}{dH^2} \frac{dH(w_0)}{dw_0} + \frac{\partial \frac{dU(H,w_0)}{dH}}{\partial w_0} = 0 \tag{29}$$

Because the solution $H(w_0)$ must satisfy the first and second order conditions, then $\frac{dU(H,w_0)}{dH} = 0$ and $\frac{d^2U(H,w_0)}{dH^2} < 0$.

Hence:

$$\frac{dH(w_0)}{dw_0} = -\frac{\frac{d^2U(H(w_0),w_0)}{dH\,\partial w_0}}{\frac{d^2U(H,w_0)}{dH^2}} > 0 \tag{30}$$

Hence when $w_{0<}\hat{w_0}$, then equation 30 tells us that $H(w_0)$ is an increasing function.

■

Proof of propositions 3:

For a given i, equation 26 shows that:

$$\frac{\dot{w_i}}{w_i}(w_0, H(w_0)) = r - \frac{1}{\int_i^T k_\tau^i(H(w_0))\,d\tau}$$

Since $\frac{\partial \frac{\dot{w_i}}{w_i}}{\partial w_0} = 0$ and $\frac{\partial \frac{\dot{w_i}}{w_i}}{\partial H} > 0$, then:

$$\frac{d\frac{\dot{w_i}}{w_i}}{dw_0} = \frac{\partial \frac{\dot{w_i}}{w_i}}{\partial w_0} + \frac{\partial \frac{\dot{w_i}}{w_i}}{\partial H}\frac{\partial H}{\partial w_0} > 0$$

This indicates that wealthier individuals will save a higher share of their income.

When $r > \underline{r}(i) = \frac{1}{\int_i^T k_\tau^i(\overline{H})\,d\tau}$ then $\frac{\dot{w_i}}{w_i} > 0$ for some w_0.

Let $H_l = \lim_{w_0 \to 0} H(w_0)$, then when $r < \overline{r}(i) = \frac{1}{\int_i^T k_\tau^i(H_l)\,d\tau}$, then $\frac{\dot{w_i}}{w_i} < 0$ for some w_0.

Since $\frac{\dot{w_i}}{w_i}$ is continuous and increasing in w_0, when $\underline{r}(i) < r < \overline{r}(i)$ there exists a unique $\tilde{w_0}$ such that $\frac{\dot{w_i}}{w_i}(\widetilde{w_0}, H(\widetilde{w_0})) = 0$ and such that when $w_0 < \widetilde{w_0}$ then $\frac{\dot{w_i}}{w_i} < 0$ and when $w_0 > \widetilde{w_0}$ then $\frac{\dot{w_i}}{w_i} > 0$.

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