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JEL Classifications: G21, D53, D82, D91, O12, O16.

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Having it Both Ways: A Theory of the Banking Firm with Time-Consistent and Time-Inconsistent Depositors*

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Abstract

Our equilibrium model determines the liquidity premium offered by a monopolistic bank to a pool of depositors made up of time-consistent and time-inconsistent agents. Time-consistent depositors demand compensation for illiquidity, whereas time-inconsistent ones are willing to forgo interest on illiquid savings accounts to discipline their future selves. We show that formal financial markets can reward time-inconsistent clients for illiquidity, even though these agents would agree to pay for it. The explanation combines two factors: the existence of reserve requirements making the bank keen to reward illiquid accounts more than liquid ones, and the presence of time-consistent agents who view illiquidity as a burden and therefore demand compensation for holding illiquid accounts.

1. Introduction

Time-inconsistent agents procrastinate saving, and later regret it (O'Donoghue and Rabin, 1999). Those who are aware of their condition, referred to as "sophisticated," [1] value the commitment embedded in illiquid investments (Laibson, 1997; Beshears *et al.*, 2011).[2] This paper builds an equilibrium model that explains how the presence of time-inconsistent agents affects the liquidity premium, i.e. the interest spread between illiquid and liquid deposits, offered by banks. Our model also explains why formal financial markets can reward time-inconsistent clients for illiquidity, even though these agents would agree to pay for it. The explanation combines two factors: the existence of reserve requirements making the bank keen to reward illiquid accounts more than liquid ones, and the presence of time-consistent agents who view illiquidity as a burden and therefore demand compensation for holding illiquid accounts.

The most common illiquid savings products are deposits with restrictions on before-maturity withdrawals. These restrictions materialize through financial penalties for early withdrawal, the most rigid situation corresponding to the impossibility of taking out funds before a given maturity. In contrast, holders of liquid deposits may withdraw any amount at any time provided their outstanding balance remains non-negative. Evidently, time-consistent agents demand compensation to enter into illiquid savings. In contrast, sophisticated time-inconsistent agents wish to discipline their future selves. They value the commitment device embed in illiquid savings.

[1] Time-consistency is often referred to as rationality while time-inconsistency is viewed as irrationality. One could however argue that sophisticated time-inconsistent agents rationally anticipate the behavior of their future selves. To avoid taking stance in this debate on terminology, we stick to more neutral denominations.
[2] Unsophisticated, or naïve, time-inconsistent agents are not aware of their present bias. *Ex ante*, they believe they are rational. Hence, similarly to time-consistent agents, they do not value commitment.

The presence of agents with self-control issues has long been recognized in the literature (Noor, 2007; Della Vigna, 2009; Ali, 2011; Hsiaw, 2013). Still, little is known about their influence on deposit remuneration schemes. This paper derives the equilibrium liquidity premium under the assumption that time-consistent and time-inconsistent depositors coexist. In our model, the bank supplies deposits with announced conditions. It sets the liquidity premium while knowing the composition of the pool of depositors. It can therefore exert indirect—but not direct—price discrimination.[3]

We focus on monopolistic banks because banks active in perfectly competitive markets reward deposits at their marginal benefit. Since illiquid savings act as a hedge against liquidity shortages, the liquidity premium in a competitive market is unaffected by the composition of the demand. In a monopolistic framework in contrast,[4] the bank has the possibility to exploit the savers' reservation prices, and the liquidity premium depends on the composition of the pool of depositors.

In line with the intuition, our stylized facts suggest that proportion of time-inconsistent agents in the pool of depositors has a negative impact on the liquidity premium. To reach this conclusion we rely on the literature showing that time-inconsistent agents are more frequent in poor populations than in rich populations (Banerjee and Mullainathan, 2010). Subsequently, we observe that in Bangladesh the liquidity premium proposed by regular banks is significantly higher than that offered by microfinance institutions (MFIs) to

[3] Direct (or third-degree) monopolistic price discrimination corresponds to the situation where the price depends upon observable client's heterogeneity. In contrast, indirect price discrimination means that every client is offered the same price schedule (Stole, 2007).

[4] Worldwide evidence shows that the banking sector is not perfectly competitive (Claessens and Laeven, 2004; Freixas and Rochet, 2008). Region-wise, studies include: Weill (2013) for EU Region, Anzoategui *et al.* (2010) for the Middle East and Northern Africa Region, Matousek *et al.* (2013) for Vietnam, and Yeyati and Micco (2007) for Latin America.

the poor. More surprisingly, we also observe that MFIs still offer a positive liquidity premium.

Our theoretical results help making sense out of these facts. Our model delivers both pooling and separating equilibria. When the share of time-inconsistent agents is low, indirect client segmentation is not profitable to the bank and the equilibrium is pooling. In this case, the liquidity premium is always positive. The presence of time-consistent agents prevents the bank from exploiting the time-inconsistency of their fellows. The winners are the time-inconsistent agents, who obtain a liquidity premium higher than the one they demand. In contrast, in the separating equilibrium situation, the liquidity premium coincides with the reservation price for commitment of time-inconsistent agents. The sign of the liquidity premium then depends on the probability of an adverse shock. When this probability is high, the liquidity premium is positive.

The paper is organized as follows. Section 2 presents the stylized facts from Bangladesh. Section 3 outlines our model. Section 4 derives the equilibrium liquidity premium. Section 5 concentrates on the impact of the proportion of time-inconsistent agents in the market. Section 6 concludes.

2. Stylized Facts from Bangladesh

This section explores the impact of depositors' time-inconsistency on the remuneration schemes offered on savings accounts. To circumvent the unobservability of time-inconsistency, we rely on the literature concluding that a large proportion of poor people behave like sophisticated time-inconsistent agents when making saving decisions. Our empirical strategy is thus based on the assumption that time-inconsistency is more prevalent in poor populations than in wealthier ones. To observe the interest rates paid on illiquid and liquid accounts to poor and non-poor depositors separately, we collected data from Bangladesh. In Bangladesh, regular banks serve non-poor depositors while MFIs offer financial services to the poor, including deposit taking. This country is thus ideal for tracking how the liquidity premium varies with the proportion of time-inconsistent depositors, while remaining in a single-currency jurisdiction. We contend that the lessons to be learned from Bangladesh are also relevant for banks in developed countries. Bangladeshi banks are similar to the ones active in developed economies, and the penetration of foreign banks is high (Clarke *et al.*, 2003).[5]

Sophisticated time-inconsistent agents are frequent in poor populations. The evidence underpinning this statement is twofold. First, poverty damages the ability to exercise self-control since the consequences of deviating from personal rules are more severe for poor individuals than for wealthy ones (Bernheim *et al.*, 2013). To explain time-inconsistency, Bertrand *et al.* (2004), Banerjee and Mullainathan (2010), and Spears (2011) emphasize that the poor constantly face stressful expenditure decisions involving harmful trade-offs and conflicts. Under these conditions, sticking to time-consistent decision-making is arduous

[5] Like in developed countries, banks in Bangladesh enjoy market power (Assefa *et al.*, 2013; Mujeri and Younus, 2009).

(Mullainathan and Shafir, 2009). In addition, acts of volition draw on limited resources. Self-control implies mental fatigue, which depletes a person's willpower stock (Ozdenoren *et al.*, 2012). Experimental psychology shows that people exercising self-control on a first task are more likely to fail on a second one (Baumeister *et al.*, 1998).

Second, although poverty is associated with low self-discipline, the poor desperately need secure savings opportunities, referred to as "micro-savings" (Vogel, 1984; Deaton, 1990; Rutherford, 2000; Collins *et al.*, 2009; Dupas and Robinson, 2013; Kast *et al.*, 2012). By nature, saving requires a forward-looking attitude. A host of experimental evidence suggests that poor people are not only time-inconsistent, but also aware of this condition, which validates the assumption of sophistication. Households in Bangladesh accept negative returns on illiquid savings schemes proposed by informal deposit collectors (Rutherford, 2000). Households in India invest in illiquid assets (livestock) even though the associated returns are negative (Anagol *et al.*, 2012). Women in the Philippines transfer cash from liquid to illiquid bank accounts without demanding a financial reward (Ashraf *et al.*, 2006). Lacking commitment savings products, Indian women bind themselves through microcredit contracts, which force them to save through periodic installment payments (Bauer *et al*., 2012).[6] In Chile, participants in an experiment by Kast *et al.* (2012) refused to reallocate their existing illiquid savings to liquid accounts with higher interest rates.

[6] Interestingly, these findings are gender-sensitive. The results obtained by Bauer et *al.* (2012) and Ashraf *et al.* (2006) hold for women, but not for men. Dupas and Robinson (2013) find that most women actively take up the savings account offered by a village bank in Kenya while men do not. Assuming that women and men are equally time-inconsistent (Meier and Sprenger, 2010; McLeish and Oxoby, 2007), Bauer *et al.* (2012)'s findings are consistent with women acting in a more sophisticated way than men. Possibly, conflicting savings motives within the household can generate a demand for commitment devices (Anderson and Baland, 2002). According to Schaner (2012), poorly-matched households forgo at least 58% in interest earnings. Alternatively, women could be more attracted to accessible commitment devices than men because they are poorer than men on average, enjoy less autonomy in financial decision-making (Guérin, 2006), and are sometimes discriminated against by financial institutions (Agier and Szafarz, 2013).

Sophisticated time-inconsistency is also found in the developed world, not only among the poor. In an internet-based randomized trial by Beshears *et al.* (2011) in the U.S., subjects were asked to allocate an initial endowment between a liquid account and an illiquid account imposing a penalty for early withdrawal. A broad spectrum of penalties was investigated. Overall, the authors find that the demand for illiquid deposits is huge, and that many savers are ready to forgo interest in exchange for commitment devices.[7]

Most importantly, the reported behavioral evidence implies that depositors are *sophisticated*, and not naïve time-inconsistent agents. As stated by O'Donoghue and Rabin (1999, pp. 106-7), "The use of self-commitment devices provides evidence of sophistication. Only sophisticated people would want to commit themselves to smaller choice set." Naïve time-inconsistent agents do not worry about their future selves undertaking unwanted actions. As a consequence, they do not demand costly commitment. *Ex ante*, naïve time-inconsistency is difficult to disentangle from time-consistency (Beshears *et al.*, 2011), and goes unnoticed in most experimental trials.

In Bangladesh, banks and microfinance institutions offer a wide variety of no-maturity liquid products, known as "savings deposits." These accounts place no restrictions on withdrawals, deposits, and transfers. Their main purpose is to enable customers to save in liquid assets and earn interest. Some savings deposits make it mandatory to maintain a minimum balance for a given period of time. In MFIs, savings deposits are often called "passbook" savings.

[7] More precisely, the results obtained by Beshears *et al.* (2011) are threefold. First, 27.6% of the respondents chose the illiquid account when it was less rewarding than the liquid account and the penalty on the deposit was 10%. Second, when the liquid and illiquid accounts offer equal interest rates, fund allocation to the illiquid account increases with the penalty for early withdrawal. Third, when the illiquid account is more rewarding than the liquid one, savers are insensitive to the penalty and illiquid accounts collect around 60% of the deposits.

In contrast, illiquid savings accounts put severe restrictions on deposits and/or withdrawals. For example, pre-maturity withdrawals are heavily penalized. Illiquid accounts are classified in two groups: recurring and term deposits. Recurring deposits are made up of regular deposits, and withdrawals are forbidden prior to maturity or before a target balance has been reached. A term deposit consists of a single lump-sum payment with a fixed maturity. Term deposits are commonly proposed to wealthy savers, and recurring deposits to the poor. In MFIs, recurring deposits are often called "contractual" savings accounts. These accounts help poor people to accumulate money (Rutherford, 2000).

According to the Bangladeshi Central Bank (www.bangladesh-bank.org), the country has 47 regulated banks. We collected saving conditions for 28 of them from their websites. The market for micro-savings in Bangladesh is made of six large MFIs and a myriad of small ones. Together, the Big Six attract 83% of total domestic micro-savings (Microcredit Regulatory Authority, 2011). We found interest-rate data on the websites of five MFIs, including three of the six large ones. Surprisingly, Grameen Bank, the largest MFI in Bangladesh, gives only partial information on its website. Fortunately, other sources (Dowla and Alamgir, 2003; Rutherford *et al.*, 2004) provide information on Grameen's savings conditions. Overall, the five MFIs for which we managed to get complete data represent 64% of total micro-savings in Bangladesh.

Table 1 summarizes the information we collected. Admittedly, both samples (banks and MFIs) could be subject to a selection bias since they are restricted to institutions that widely publicize their savings conditions. For each financial institution, Table 1 gives the following information when available: total assets, interest on liquid deposits, and minimum and maximum interest rates for recurring and term deposits, respectively. For these two types of illiquid accounts, interest rates increase with maturity. Accordingly, Table 1 features intervals rather than single figures. Liquidity premiums are interest-rate spreads between illiquid and liquid accounts. Averages are computed by using interval midpoints.

In each class of savings accounts, the interest rates vary across institutions, and there is no clear-cut distinction between banks and MFIs. On average, banks pay 5.0% interest on liquid accounts, and from 10.3% to 12.2% on illiquid accounts. MFIs pay 6.0% on liquid accounts and from 8.4% to 11.8% on illiquid accounts. In contrast, the average liquidity premiums are 6.5% for banks and 3.7% for MFIs. A t-test for equal means shows that the two groups of institutions offer significantly different liquidity premiums ($p < 5\%$). Possibly, the difference stems from the pool of depositors with whom the two types of institutions work. In line with the theory linking time-inconsistency to poverty, MFIs would attract a larger share of time-inconsistent depositors than would mainstream banks. The next section builds a model explaining how the proportion of time-inconsistent agents affects the liquidity premium on deposits.

3. The Model

Section 2 highlights that the liquidity premium is lower in financial institutions where the presence of time-inconsistent depositors is expectedly high. The theoretical model proposed in this section addresses this evidence. It derives the impact of time-inconsistent agents on the pricing of fixed-interest savings products in monopolistic financial institution with a mix of depositors. The outcome of our model applies to any bank or MFI worldwide enjoying some market power.

In our equilibrium model a monopolistic bank offers both liquid and illiquid accounts to a pool of depositors made up of time-consistent and sophisticated time-inconsistent agents.[8] The model's demand side borrows from the model set up by Beshears *et al.* (2011) to rationalize their experimental findings on the prevalence of time-inconsistent savers in the U.S. The supply side is inspired by the monopolistic banking model known as the Klein-Monti model (Klein, 1971; Monti, 1972). We present our model in four steps. First, we introduce the basic setting and the notations. Second, we specify the demand side of the model. Third, we present the bank's problem. Last, we draw the timeline of the game.

The model has three periods $(t = 0,1,2)$. We consider a monopolistic bank offering two savings products: a liquid—or flexible—account $(s = F)$ permitting costless withdrawal in $t = 1$, and an illiquid—or commitment—account $(s = C)$ forbidding any withdrawal before maturity $(t = 2)$. In period 0, the bank sets its interest-rate policy for both accounts and makes it public. Like Basu (2009) and Ruiz-Porras (2011), we assume for simplicity that both accounts deliver zero interest in 0 and 1, and that interest matures in period 2. Rates r_F and r_C represent the period-2 interest on the liquid account and illiquid account, respectively. For simplicity, we assume that the liquid account is a perfect substitute for cash holding, so that the liquid interest rate is zero: $r_F = 0$.[9] Hence, the illiquid interest rate, r_C, boils down to the liquidity premium.

The need for early withdrawal stems from the possible occurrence, with probability π, of an adverse shock in period 1. This shock could be a natural disaster, which increases the

[8] We assume that all time-inconsistent agents are sophisticated because naïve ones do not demand commitment. Adding naïve time-inconsistent agents to the picture is feasible, but costly in terms of expositional complexity.
[9] Actually, even if the liquid interest rate were left to be a decision variable for the bank, it would be optimally fixed to zero as soon as the depositors are left with no preferable flexible outside saving option. Thus, setting this interest rate to zero from the start is not restrictive.

marginal utility of consumption in period 1 in the same way for all agents (see Amador *et al.*, 2006). Consumption is known to be more valuable in hard times than when conditions are good. The no-shock and shock situations are referred to as the good state (G) and the bad state (B) of nature, respectively. Thus, the agents choose their savings accounts in period 0 under uncertainty. Only the holders of a liquid account will have the opportunity to smooth future consumption through early withdrawal.[10]

The demand for savings accounts emanates from a pool comprising proportion q of sophisticated time-inconsistent agents, and proportion $(1-q)$ of time-consistent agents. Each depositor has a one-dollar initial endowment and decides to allocate it to one account at most. Alternatively, the agent may reject both contracts and get reservation utility $\bar{u}$. We assume that the reservation utility is low enough to impose the participation constraint on all agents.

The sophisticated time-inconsistent agents use quasi-hyperbolic discounting for future instantaneous utility, and are referred to by index H. Quasi-hyperbolic discounting (Strotz, 1955; Phelps and Pollack, 1968; Laibson, 1997) is standard for modeling time-inconsistency in intertemporal decision-making.[11] It entails a present bias resulting in over-valuation of immediate consumption with respect to future consumption. In contrast, time-consistent agents, referred to by index R, use exponential discounting and maximize a time-consistent expected utility function.

[10] Beshears *et al.* (2011) study illiquid accounts with a wide range of penalties. Here, we consider only the most stringent commitment, which excludes withdrawals.
[11] Alternative behavioral approaches are proposed by Gul and Pesendorfer (2001), Fudenberg and Levine (2006) and Banerjee and Mullainathan (2010).

No consumption takes place in period 0.[12] The state of nature is revealed in period 1. Consumption in periods 1 and 2 may thus be contingent on this state. Let $c_t^i(s,\omega)$ denote the consumption in period t $(t = 1,2)$ of agent i $(i = R,H)$ holding account s $(s = F,C)$ when the revealed state of nature is ω $(\omega = G,B)$. All agents are assumed risk-neutral and share the same linear instantaneous utility[13] in period 1, which depends on the state of nature in the following way:

$$u_1^i(s,\omega) = (1+\theta_\omega)c_1^i(s,\omega), \tag{1}$$

where $1+\theta_\omega$,the marginal utility of consumption in period 1, is given by:

$$1+\theta_\omega = \begin{cases} 1+\theta_G, & \text{if } \omega = G \\ 1+\theta_B, & \text{if } \omega = B \end{cases} \qquad 1+\theta_\omega > 0,\ \theta_G < \theta_B. \tag{2}$$

Consumption in period 2 delivers the following instantaneous utility:

$$u_2^i(s,\omega) = c_2^i(s,\omega). \tag{3}$$

The two types of agents differ in discounting instantaneous utilities: Time-consistent agents use exponential discounting while time-inconsistent ones use quasi-hyperbolic discounting. The four corresponding intertemporal utility functions in periods 0 and 1 are given by:

[12] This assumption rules out self-control problems occurring in period 0.
[13] In line with Beshears *et al.* (2011), we use a linear specification for the utility function to keep the model as simple as possible. In contrast, Heidhues and Koszegi (2009, 2010) and Basu (2014) use a non-linear specification.

$$U_0^R(u_1^R, u_2^R) = \delta(u_1^R + \delta u_2^R) \qquad \delta \in (0,1] \tag{4}$$

$$U_1^R(u_1^R, u_2^R) = u_1^R + \delta u_2^R \tag{5}$$

$$U_0^H(u_1^H, u_2^H) = \beta\delta(u_1^H + \delta u_2^H) \qquad \delta \in (0,1], \beta \in (0,1) \tag{6}$$

$$U_1^H(u_1^H, u_2^H) = u_1^H + \beta\delta u_2^H. \tag{7}$$

Eqs. (6) and (7) describe how time-inconsistent agents weigh their period-1 and period-2 instantaneous utilities. For $\beta < 1$, the intensity of the trade-off is not the same in period 0 and in period 1. This intensity is equal to δ in period 0 and to $\beta\delta$ in period 1. The discounting of period-2 consumption – relative to period-1– is stronger in period 1 than in period 0. This incites time-inconsistent agents to consume in period 1 more than they had planned to do in period 0. However, being sophisticated, these agents know from period 0 that their future selves will behave in this way in period 1, and that this may prove detrimental to their period-2 consumption. For this reason, they are inclined to use commitment devices to discipline their future selves (O'Donoghue and Rabin, 1999). Eqs. (4) and (6) also show that, in period 0, all agents trade off similarly between period-1 and period-2 instantaneous utilities. In line with Amador *et al.* (2006) and Basu (2009), we assume for simplicity that $\delta = 1$.[14]

To produce a meaningful self-control problem, we impose the following constraints on our model parameters:[15]

$$\beta < 1 + \theta_G \leq 1 \leq 1 + \theta_B. \tag{8}$$

[14] The discount factor δ is the same for all agents. Since time-inconsistent agents have two sources of discounting–β and δ–they are more impatient than time-consistent ones when trading-off current and future utilities. This assumption is commonly made in hyperbolic consumption models (Angeletos *et al.*, 2001).
[15] Similar constraints are imposed by Beshears *et al*. (2011).

First, assuming $1+\theta_G \leq 1 \leq 1+\theta_B$ implies that withdrawal from the liquid account is *ex ante* utility-maximizing in the bad state of nature, but not in the good state. This holds true for all agents. Second, since $\beta < 1+\theta_\omega (\omega = G, B)$, the period-1 time-inconsistent agents withdraw all their savings from liquid accounts, regardless of the state of nature.

The expected intertemporal utilities of time-consistent and time-inconsistent agents in period 0 are written:

$$E[U_0^R(s)] = \pi[(1+\theta_B)c_1^R(s,B) + c_2^R(s,B)] + (1-\pi)[(1+\theta_G)c_1^R(s,G) + c_2^R(s,G)], \quad (9)$$

and:

$$E[U_0^H(s)] = \beta\{\pi[(1+\theta_B)c_1^H(s,B) + c_2^H(s,B)] + (1-\pi)[(1+\theta_G)c_1^H(s,G) + c_2^H(s,G)]\}, \quad (10)$$

where $(1-\beta)$ represents the bias for the present consumption of time-inconsistent agents. The intertemporal utilities in period 1 are given by:

$$U_1^R(s,\omega) = (1+\theta_\omega)c_1^R(s,\omega) + c_2^R(s,\omega), \quad (11)$$

and:

$$U_1^H(s,\omega) = (1+\theta_\omega)c_1^H(s,\omega) + \beta\, c_2^H(s,\omega). \quad (12)$$

The utilities in period 2 are:

$$U_2^i(s,\omega) = c_2^i(s,\omega), \quad i = R, H.$$

The utilities in periods 1 and 2 are deterministic because they are computed once the state of nature is revealed. In period 0, all agents maximize their expected utility in Eqs. (9) and (10) under the condition that their future utilities in Eqs. (11) and (12) is optimally fixed (Shestakova, 2008).

Let us now turn to the supply side of the model. Following the Klein-Monti model (Klein, 1971; Monti, 1972),[16] the monopolistic bank collects savings through two vehicles, namely liquid and illiquid accounts, and allocates these funds to earning assets A, consisting of loans, and reserves in cash, R. For simplicity, we assume that equity is null (Ruiz-Porras, 2011) and we leave insolvency risk aside (Dermine, 1986). The loans pay an exogenous net rate of return r_A in period 2. The net rate of return on reserves is zero.[17] Total reserves are split into two components derived from liquid and illiquid savings accounts, respectively:

$$R = \rho_F D_F + \rho_C D_C \qquad \rho_F, \rho_C \in [0,1], \qquad \rho_F \geq \rho_C, \tag{13}$$

where D_F and D_C represent the total amounts collected through liquid and illiquid accounts, respectively. The corresponding reserve ratios, ρ_F and ρ_C, are the proportions of savings balances assigned to reserves.[18]

The withdrawal option makes liquid accounts more volatile than illiquid accounts. For the bank, therefore, liquid accounts create higher liquidity risks than illiquid ones. This explains why regulatory reserve requirements are typically tougher on the former than on the latter. This translates into the following assumption: $\rho_F \geq \rho_C$ (Miller, 1975).[19] Hence, the

[16] See Freixas and Rochet (2008, pp. 78-81) for a summary presentation of this model.
[17] As stated by Klein (1971), the return on reserves is implicit because an increase in reserves reduces the likelihood of liquidity shortage, which can be costly to the bank.
[18] Alternatively, we could have assumed that the bank determines its optimal level of reserves by balancing the opportunity cost of holding reserves and the adjustment cost of incurring reserve deficiency (Baltensperger, 1980). Like ours, this approach stems from the principle that the bank needs illiquid accounts more than liquid ones.
[19] This generalizes Klein's (1971) assumption that there is a single reserve ratio ($\rho_F = \rho_C$).

level of reserves depends not only on the total volume of collected savings, but also on their allocations (Baltensperger, 1980). This argument stemming from liquidity management rationalizes the bank's preference for illiquid deposits, all else equal. As a consequence, the value of $(\rho_F - \rho_C)$ is expected to play a key role in equilibrium.

The bank is a risk-neutral monopolistic price-setter. Its decision variable is r_C, the liquidity premium. Its revenues come from loans while its costs consist of the interest paid on illiquid accounts. We neglect all other costs, such as management costs. In period 0, the bank knows with certainty the amounts of interests to be paid in period 2 on the illiquid accounts.[20] We assume that, similarly to the depositors, the bank uses a unit time-discounting factor. Its profit to be maximized in period 0 is: [21]

$$P_0 = r_A A - r_C D_C \tag{14}$$

under the balance-sheet constraint:

$$A = (1 - \rho_F)D_F + (1 - \rho_C)D_C. \tag{15}$$

Last, the timing of the game is the following. In period 0, the bank announces its liquidity premium, r_C. Subsequently, each agent chooses a single account. In period 1, the state of nature is revealed. The agents holding liquid accounts determine the amount they wish to withdraw, and allocate it to current consumption. The others are left with no choice

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[20] For the liquid accounts, interests are null regardless of the total amount withdrawn in period 1. Actually, withdrawals from liquid accounts made by savers in period 1 are contingent on the state of nature, but for time-consistent agents only. Time-inconsistent agents holding liquid accounts withdraw all their cash in period 1 regardless of the state of nature. Thus, the total amount withdrawn from all liquid accounts in period 1 depends on the proportion of time-inconsistent agents in the pool of savers.

[21] Our model applies to for-profit institutions, be they banks or MFIs. As a matter of facts, the share of for-profit MFIs has increased sharply, especially among deposit-taking MFIs (Assefa *et al.*, 2013).

but to keep their savings on illiquid accounts. In period 2, all agents recoup their remaining capital plus interest and consume it all.

4. Equilibrium Liquidity Premium

In this section, we solve the equilibrium model. First, we address the depositor's problem and determine the demand schedules for savings accounts. Second, we solve the bank's problem and derive the equilibrium liquidity premium and the distribution of savings accounts. Last, we discuss the role of the parameters and sketch lessons for regulators concerned with liquidity in financial institutions.

The depositor's maximization problem is solved backward in time. In period 2, the depositor consumes the remaining capital plus interest. In period 1, agent *i* observes state of nature ω. Subsequently, she fixes consumption plan $\{c_1^i(s,\omega), c_2^i(s,\omega)\}$ by maximizing utility in Eqs. (11) and (12):

$$\max_{c_1^i(s,\omega),c_2^i(s,\omega)} U_1^i(s,\omega) = (1+\theta_\omega)c_1^i(s,\omega) + \beta_i c_2^i(s,\omega), \;\; i = R,H; \; s = F,C; \;\; \omega = G,B; \quad (16)$$

$$\text{s.t.} \quad c_1^i(s,\omega) + \frac{c_2^i(s,\omega)}{1+r_s} \leq 1.$$

Let $U_1^{i,*}(s,\omega)$ be the maximum for $U_1^i(s,\omega)$ corresponding to consumption plan $\{c_1^{i,*}(s,\omega), c_2^{i,*}(s,\omega)\}$:

$$\{c_1^{i,*}(s,\omega), c_2^{i,*}(s,\omega)\} = ArgMax\; U_1^i(s,\omega) \qquad i = R,H; \quad s = F,C; \quad \omega = G,B. \quad (17)$$

Since the instantaneous utility functions in Eqs. (1) and (3) are linear, the optimal consumption plans in Eq. (17) are corner solutions. This implies that, in equilibrium, the holders of a liquid account withdraw and consume their total wealth in a single period, which is contingent on the state of nature. More precisely, the optimal consumption plan for agents holding a liquid account is given by:

$$c_t^{R,*}(F,\omega) = \begin{cases} 1 & if\ 1+\theta_\omega > 1 \\ 0 & if\ 1+\theta_\omega \leq 1 \end{cases} \qquad t = 1,2;\ \omega = G, B \tag{18}$$

$$c_t^{H,*}(F,\omega) = \begin{cases} 0 & if\ \ 1+\theta_\omega > \beta \\ 1 & if\ \ 1+\theta_\omega \leq \beta \end{cases} \qquad t = 1,2;\ \omega = G, B. \tag{19}$$

In contrast, all holders of an illiquid account are bound to consume their total wealth in period 2, regardless of the state of nature in period 1:

$$c_1^{i,*}(C,\omega) = 0 \qquad i = R, H; \omega = G, B \tag{20}$$

$$c_2^{i,*}(C,\omega) = 1 + r_C \qquad i = R, H; \omega = G, B. \tag{21}$$

Table 2 summarizes the results. In the no-shock situation (i.e. *G* state of nature), time-consistent agents holding liquid accounts consume their unit endowment in period 2. If a shock occurs (i.e. *B* state of nature), they consume their unit endowment in period 1. The shock has thus a dramatic impact on their optimal savings plans. In contrast, time-inconsistent agents holding a liquid account consume their unit endowment in period 1, regardless of the state of nature. The situation is different for holders of an illiquid account, who keep their savings until maturity, and therefore consume $(1 + r_C)$ in period 2.

In period 0, the agents contemplate the possibilities offered in Table 2. They make their decision under uncertainty knowing that the probability of an adverse shock is π. The presence of uncertainty makes flexibility valuable to both types of agents. In the bad state of nature, i.e., when a shock is observed in period 1, all agents are better-off withdrawing the cash from their savings accounts. The agents are aware of this in period 0. As a consequence, the time-inconsistent agents' need for commitment is mitigated by their expectations regarding the consumption needs associated with the possible occurrence of a shock.

All agents choose the savings account that maximizes their expected utility in Eqs. (9) and (10). To do so, they compare the maximal utilities driven by each type of savings account:

$$EU_0^{i,*} = \max_{s=F,C}\left\{\max EU_0^i(F), \max EU_0^i(C)\right\} \qquad i = R, H, \tag{22}$$

where $EU_0^{i,*}$ is the maximal expected utility agent *i* can get, and $s^{i,*}$ is the optimal account for agent *i*:

$$s^{i,*} = \text{argmax}\left\{\max EU_0^i(F), \max EU_0^i(C)\right\}. \tag{23}$$

From Eqs. (9) and (10), we derive the optimal utilities for time-consistent and time-inconsistent agents, respectively:

$$EU_0^{R,*} = \max_{s=F,C}\{\pi(1+\theta_B) + (1-\pi); (1+r_C)\} \tag{24}$$

$$EU_0^{H,*} = \max_{s=F,C}\{\beta(1+E\theta); \beta(1+r_C)\}, \tag{25}$$

where $E\theta = \pi\theta_B + (1-\pi)\theta_G$ is the expected value of θ.

Solving the optimization problems in Eqs. (24) and (25) yields the minimal liquidity premiums[22] demanded by time-consistent and time-inconsistent agents, respectively, to hold an illiquid account. Let us denote $r_C^{i,min}$ the minimal premium required by agent i. We get:

$$r_C^{R,min} = \pi\theta_B \quad (26)$$

$$r_C^{H,min} = E\theta = \pi\theta_B + (1-\pi)\theta_G \quad (27)$$

Eq. (27) shows that the minimal liquidity premium required by time-inconsistent agents does not depend on their present-bias parameter, β. This outcome results from the combination of quasi-hyperbolic discounting and absence of consumption in time 0. The only role of parameter β is to incite time-inconsistent agents to withdraw their full endowment in period 1, regardless of the state of nature.

However, we have another parameter to gauge the present bias of time-inconsistent depositors: the absolute value of parameter θ_G (< 0), $|\theta_G|$, which represents the marginal utility that all agents get from consumption in period 1 in the good state of nature. By assumption, parameter θ_G is common to both types of savers, but in fact time-consistent agents are insensitive to it because they never consume in period 1 in the good state of nature. Either they contract an illiquid account with time-2 maturity, or they hold a liquid account, which is used as a hedge in the bad state of nature only. In any case, time-consistent agents do not capture utility from consumption in time 1 in the good state of nature. In contrast, θ_G

[22] The minimal liquidity premium is the equivalent to the consumers' reservation price in industrial organization theory (Armstrong and Porter, 2007).

matters to time-inconsistent agents, who always consume in period 1 if they hold the liquid account. Consequently, we interpret parameter $|\theta_G|$ as an indirect measure of the present bias. The closer $|\theta_G|$ from zero, the smaller the gap between the minimal liquidity premiums required by the two types of agents to hold illiquid account (see Eqs. (26) and (27)). The limit cases are: 1) when $\theta_G = 0$ the gap collapses, and 2) when $|\theta_G| = 1$ the gap is maximal.

Thanks to Eq. (8), time-consistent agents always demand a non-negative liquidity premium. They need to be compensated for holding an illiquid account, which would prevent them from hedging against the adverse shock. In contrast, time-inconsistent agents value commitment. This is however mitigated by their need for flexibility in the bad state of nature. Time-inconsistent agents thus face a trade-off between commitment and flexibility. On the one hand, commitment protects them against over-consumption in period 1 in the good state of nature. On the other, flexibility offers a hedge against the bad state. As a consequence, the minimal premium demanded by time-inconsistent agents, in Eq. (27), has no predetermined sign. It is negative when the expected marginal utility of period-1 consumption, $(1 + E\theta)$, is lower than 1, and null or positive otherwise.[23]

The minimal premium required by time-consistent agents in Eq. (26) is larger than or equal to the minimal premium demanded by their time-inconsistent counterparts. This is because time-consistent agents face no trade-off; they uniformly prefer flexibility over commitment, all things equal. Fig. 1 illustrates the situation. The position of r_C with respect to $r_C^{R,min}$and $r_C^{H,min}$ determines the demand of each type of agent for each type of account, and hence the aggregate demand function. More specifically, N being the total number of savers, and q being the proportion of time-inconsistent ones, we have:

[23] In their demand-sided model, Beshear *et al.* (2011) assume that $E\theta < r_F$, where the interest rate on liquid accounts, $r_{F,}$ is exogenous. As a consequence, the minimal liquidity premium for time-inconsistent agents is always negative.

$$D_F = \begin{cases} N & if \quad r_C < E\theta \\ N(1-q) & if \quad E\theta \leq r_C < \pi \\ 0 & if \quad r_C \geq \pi\theta_B \end{cases} \tag{31}$$

and

$$D_C = N - D_F = \begin{cases} 0 & if \quad r_C < E\theta \\ Nq & if \quad E\theta \leq r_C < \pi\theta_B \\ N & if \quad r_C \geq \pi\theta_B \end{cases} \tag{32}$$

where D_F and D_C are the demand schedules for liquid accounts and illiquid accounts, respectively. Eqs. (31) and (32) allow us to partition the possible values for $r_C \in \mathbb{R}$ into three zones, each representing a possible configuration for the demand functions:

$$Zone\ I: \quad r_C \in (-\infty, E\theta) \tag{33}$$

$$\text{Zone } II: \quad r_C \in [E\theta, \pi\theta_B) \tag{34}$$

$$\text{Zone } III: \quad r_C \in [\pi\theta_B, +\infty). \tag{35}$$

In zone *I*, all agents opt for liquid accounts. In zone *II*, there is a complete separation between time-inconsistent agents, who take illiquid accounts, and time-consistent agents, who take liquid accounts. In zone *III*, all agents opt for illiquid accounts.

Let us consider the two polar cases regarding the probability of adverse shock. First, if the shock happens with certainty ($\pi = 1$), all agents demand the same minimal liquidity premium, $\theta_B \geq 0$, and zone *II* vanishes. Second, if the shock is impossible ($\pi = 0$), flexibility loses value for everyone. The minimal liquidity premium is then zero for time-consistent agents and $\theta_G \leq 0$ for time-inconsistent agents.

As this point, we have derived the demand functions. Let us now turn to the maximization problem to be solved by the bank. We denote $P_j(r_C)$ the bank's profit in zone $j \;\; (j = I, II, III)$. We have:

$$P_j(r_C) = \begin{cases} r_A(1-\rho_F)N & if\ j = I \\ [r_A(1-\rho_C) - r_C]qN + r_A(1-\rho_F)(1-q)N & if\ j = II. \\ [r_A(1-\rho_C) - r_C]N & if\ j = III \end{cases} \quad (36)$$

Maximizing profits in Eq. (36) yields the following zone-specific optimal liquidity premium:[24]

$$r_{C,j}^* = \begin{cases} -\infty & if \quad j = I \\ E\theta & if \quad j = II. \\ \pi\theta_B & if \quad j = III \end{cases} \quad (38)$$

Accordingly, the zone-specific optimal profits for the bank are:

$$P_j^* = \begin{cases} r_A(1-\rho_F)N & if\ j = I \\ [r_A(1-\rho_C) - E\theta]qN + r_A(1-\rho_F)(1-q)N & if\ j = II. \\ [r_A(1-\rho_C) - \pi\theta_B]N & if\ j = III \end{cases} \quad (41)$$

Table 3 summarizes the three possible configurations. Once the zone-specific solutions are obtained, the bank determines its overall optimum by comparing the zone-specific maximal profits. Its optimization problem becomes:

$$Max\{r_A(1-\rho_F)N, [r_A(1-\rho_C) - E\theta]qN + r_A(1-\rho_F)(1-q)N, [r_A(1-\rho_C) - \pi\theta_B]N\}. \quad (42)$$

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[24] For expositional facility, we conventionally fix the optimal liquidity premium of inexistent accounts as $r_{C,I}^* = -\infty$.

From Eq. (42), we have:

$$P_{II}^{*} \geq P_{I}^{*}, \qquad \text{if} \quad E\theta \leq r_A(\rho_F - \rho_C) \tag{43}$$

$$\mathrm{P}_{\mathrm{III}}^{*} \geq \mathrm{P}_{\mathrm{II}}^{*}, \qquad \text{if} \quad \frac{\pi\theta_B - qE\theta}{1-q} \leq r_A(\rho_F - \rho_C) \tag{44}$$

$$\mathrm{P}_{\mathrm{III}}^{*} \geq \mathrm{P}_{\mathrm{I}}^{*}, \qquad \text{if} \quad \pi\theta_B \leq r_A(\rho_F - \rho_C) \tag{45}$$

These inequalities determine the bank's optimal liquidity premium for each parameter configuration. Consequently, we describe the equilibrium quantities and prices in Theorems 1 and 2, respectively.

Theorem 1: Equilibrium quantities

If the pool of savers is made up of proportion q of time-inconsistent agents and proportion $(1-q)$ of time-consistent agents, then the equilibrium quantities of savings accounts, D_F^* and D_C^*, are given by:[25]

(i) $r_A(\rho_F - \rho_C) < E\theta \quad \Rightarrow \quad D_F^* = N$ and $D_C^* = 0$

(ii) $E\theta \leq r_A(\rho_F - \rho_C) < \frac{\pi\theta_B - qE\theta}{1-q} \quad \Rightarrow \quad D_F^* = (1-q)N$ and $D_C^* = qN$

(iii) $r_A(\rho_F - \rho_C) \geq \frac{\pi\theta_B - qE\theta}{1-q} \quad \Rightarrow \quad D_F^* = 0$ and $D_C^* = N$

Theorem 2: Equilibrium prices

If the pool of savers is made up of proportion q of time-inconsistent agents and proportion $(1-q)$ of time-consistent agents, then the equilibrium liquidity premium, r_C^*, is given by:[26]

[25] For $q = 1$, there is not upper bound to $\frac{\pi\theta_B - qE\theta}{1-q}$, and case (iii) does not occur.

(i) $r_A(\rho_F - \rho_C) < E\theta \quad \Rightarrow \quad r_C^* = -\infty$

(ii) $E\theta \leq r_A(\rho_F - \rho_C) < \frac{\pi\theta_B - qE\theta}{1-q} \quad \Rightarrow \quad r_C^* = E\theta$

(iii) $r_A(\rho_F - \rho_C) \geq \frac{\pi\theta_B - qE\theta}{1-q} \quad \Rightarrow \quad r_C^* = \pi\theta_B \ (\geq 0)$

The three cases are identical in both theorems. In our setting, the bank cannot directly observe clients' heterogeneity. Therefore, our model delivers both pooling equilibria (cases (i) and (iii)) and separating equilibria (case (ii)).

In the pooling equilibrium case (i), the differential in reserve requirements is too low to motivate the bank to offer a liquidity premium that savers would accept. As a consequence, all savers opt for liquid accounts. In equilibrium, the composition of the pool of savers is irrelevant to the bank.[27]

In the separating equilibrium case (ii), the differential in reserve requirements is high enough to motivate the bank to offer a liquidity premium equal to $E\theta$. This premium induces only time-inconsistent agents to opt for illiquid accounts. In contrast, time-consistent agents prefer liquid accounts because the liquidity premium is unattractive: it does not compensate for forgoing the protection that flexibility offers against the occurrence of the adverse shock. In this case, the bank indirectly segments its clientele by offering a menu of prices and products that allow clients to self-select. Interestingly, the impact of each type of agent on the other is not symmetric. On the one hand, time-inconsistent agents are insensitive to the

[26]For $q = 1$, there is not upper bound to $\frac{\pi\theta_B - qE\theta}{1-q}$, and case (iii) does not occur.

[27] In a repeated-game perspective, one could argue that the bank progressively learns about the time-consistency of its clients from their reactions to past shocks. As a result, the prevalence of the pooling equilibrium would decrease. In this sense, relationship banking favors market segmentation and separating equilibria.

presence of time-consistent agents because they get the minimal premium they demand for holding illiquid accounts. On the other, the time-consistent agents are barred from illiquid accounts because they are bound to share savings conditions with time-inconsistent agents. Without time-inconsistent agents in the market, the bank would have been forced to offer a higher equilibrium liquidity premium.

Parameter $E\theta = \pi\theta_B + (1-\pi)\theta_G$ measures the intensity of the trade-off between flexibility and commitment faced by time-inconsistent agents. Importantly, this parameter has no predetermined sign since $\pi \in [0,1]$, $\theta_B \geq 0$ and $\theta_G \leq 0$. The lower $E\theta$, the lower the equilibrium liquidity premium. In particular, when $E\theta \leq 0$, time-inconsistent agents end up paying for commitment. This corresponds to the standard situation found in the literature on commitment devices (see Della Vigna and Malmendier, 2004).

Lastly in the pooling equilibrium case (iii), the differential in reserve requirements is high enough to motivate the bank to offer a non-negative liquidity premium equal to $\pi\theta_B$. This is precisely the threshold needed for both types of agent to opt for illiquid accounts. Since $\pi\theta_B \geq E\theta$, the presence of time-consistent savers permits time-inconsistent savers to obtain a liquidity premium higher than the one they would be offered otherwise. There is no indirect clientele segmentation. The presence of time-consistent agents prevents the bank from exploiting the time-inconsistency of their fellows.

The economic climate, depicted by probability π of an adverse shock, plays a key role through its impact on $E\theta$. Let us assume that, in the bad economic situation, π is high enough to drive $E\theta > 0$. As a result, time-inconsistent agents value flexibility, i.e., the opportunity of early withdrawal, more than commitment. Hence, they demand a positive premium for binding themselves by means of illiquid accounts. Still, the minimal premium they require is equal to or lower than the one required by time-consistent agents, $\pi\theta_B$. When $E\theta > 0$, all three situations depicted in Theorems 1 and 2 are possible. The final decision belongs to the bank, depending on both its reserve requirements and the profitability of its lending activity.

In contrast, in a good economic situation, π is low and $E\theta \leq 0$. Then, flexibility is less valuable and time-inconsistent agents consent to pay for commitment. Logically, the bank is keen to seize this opportunity. As a result, in equilibrium all time-inconsistent agents end up with illiquid accounts, and case (i) disappears. Still, two cases are possible. In the first, the bank reaches its optimum by supplying illiquid accounts to time-inconsistent agents only. Accordingly, the monopolistic bank captures the profit surplus associated with the (positive) price that time-inconsistent agents pay for commitment. In the second case, this surplus is low and the bank prefers to supply costlier illiquid accounts to all agents. In this situation, the additional stable funds the bank receives from time-consistent agents are worth giving up in return for the surplus associated with time-inconsistent savers. The winners are thus time-inconsistent agents, who end up being rewarded for holding illiquid savings accounts they would have agreed to pay for.

The supply-side parameters, r_A and $(\rho_F - \rho_C)$ influence the bank's earning potential associated with a clientele shift from liquid to illiquid accounts. While r_A is bank-specific, parameters ρ_F and ρ_C relate to reserve requirements and are fixed by banking regulations. The assumption according to which $\rho_F - \rho_C$ is positive is key to our argument. If the bank is indifferent between liquid accounts and the illiquid ones (i. e. $\rho_F = \rho_C$), the model admits two possible equilibria only. In the first, all the agents opt for liquid accounts (case (i)). In the second, the liquidity premium is negative and the market is fully segmented (case (ii)). Consequently, case (iii) collapses.

Our model emphasizes two effects. First, the banking authorities can modify the supply of loans in the economy by managing the differential in reserve requirements imposed on banks. For example, by increasing reserve requirements on liquid accounts, regulators push banks to offer higher interest on illiquid accounts, thus attracting more stable deposits. The shift releases funds that the bank then invests in earning assets. This confirms the findings by Weiss (1958) and Smith (1962) about the positive effect of time deposit rates on credit-expansion. Second, stable deposits, where withdrawal is costly or impossible, are instrumental for avoiding bank runs, especially in the presence of adverse shocks (Freixas and Rochet, 2008). By increasing reserve requirements on liquid accounts, regulators increase the share of stable deposits and reduce overall liquidity risk in the banking system.[28]

However, lowering liquidity risks through tougher regulations on reserves has limitations. For instance, widening spreads between lending and deposit rates increase the cost of credit and tend to reduce the level of financial intermediation (Montoro and Moreno, 2011). Interestingly, our model shows that those regulations need not be as tough as they look in the first place on one of two conditions: either the banks manage to attract a significant proportion of sophisticated time-inconsistent savers–i.e. when q is high–or the economic climate is good–i.e. when π is low.

[28] Bankers are not necessarily spontaneously willing to do so, because they could expect to be bailed out in distress situations, as the recent banking crisis in Europe has shown (see Freixas and Rochet, 2008, Chapter 7, pp. 217-264).

The literature amply documents that time-inconsistent savers are frequent in poor populations (Banerjee and Mullainathan, 2010; Spears, 2011; Bernheim *et al.*, 2013). Consequently, regulations on institutions serving the poor, such as MFIs, may be milder than those imposed on mainstream banks. This point is timely since the issue of what regulations to impose on MFIs offering savings has been hotly debated for several years in developing countries such as Nigeria, Uganda, the Philippines, India, and Bangladesh (Christen *et al.*, 2003; Porteous *et al.*, 2010).

Theorems 1 and 2 show that the inequalities differentiating between the cases of pooling and separating equilibrium $\left(r_A(\rho_F - \rho_C) \lesseqgtr \frac{\pi\theta_B - qE\theta}{1-q}\right)$ are sensitive to proportion q of time-inconsistent agents in the market. The next section describes the impact of q on equilibrium outcomes.

5. Impact of the Proportion of Time-inconsistent Agents

The stylized facts in Section 2 show that MFIs offer lower liquidity premiums than do mainstream banks. Possibly, the evidence indicates that the financial institutions serving a larger market share of time-inconsistent agents find it optimal to offer a lower liquidity premium. This section explores how our model rationalizes the facts. More precisely, we analyze the consequences of variations of parameter q representing the proportion of time-inconsistent savers in the market. The next proposition gives the cut-off value $\tilde{q}$ between the pooling and the separating equilibriums.

Proposition 3:

If $r_C^* \in \mathbb{R}$,[29] *and* $\tilde{q} = \frac{r_A(\rho_F - \rho_C) - \pi\theta_B}{r_A(\rho_F - \rho_C) - E\theta}$, then r_C^* is given by:

(i) $q > \tilde{q}$ $\Rightarrow$ the equilibrium is separating and: $r_C^* = E\theta = \pi\theta_B + (1-\pi)\theta_G$

(ii) $q \leq \tilde{q}$ $\Rightarrow$ the equilibrium is pooling and: $r_C^* = \pi\theta_B$.

Proof: see Appendix A.

Proposition 3 highlights that the equilibrium liquidity premium depends on the composition of the pool of depositors. The bank is more reluctant to attract time-consistent agents to illiquid accounts when the share of time-inconsistent agents in the market is high ($q > \tilde{q}$). This could explain why MFIs offer lower liquidity premiums than mainstream banks, as illustrated in Section 2.

The cut-off value $\tilde{q}$ introduced in Proposition 3 is a key parameter. It summarizes the influence of all structural parameters except for proportion q on the equilibrium liquidity premium. The nature of the equilibrium follows from the direction of the inequality between q and $\tilde{q}$. The next proposition examines the impact on $\tilde{q}$ of the structural parameters of the model.

Proposition 4

(i) Impact of bank's productivity:

$$\frac{\partial \tilde{q}}{\partial r_A} = (\rho_F - \rho_C)\ \frac{\pi\theta_B - E\theta}{[r_A(\rho_F - \rho_C) - E\theta]^2}\ \geq 0,$$

[29] This condition simply rules out the situation where the bank fails to supply illiquid accounts, so that the liquidity premium r_C^* is a real number. Expressed in terms of model parameters, this condition writes: $E\theta \leq r_A(\rho_F - \rho_C)$.

(ii) Impact of banking regulation:

$$\frac{\partial \tilde{q}}{\partial(\rho_F - \rho_C)} = r_A \frac{\pi\theta_B - E\theta}{[r_A(\rho_F - \rho_C) - E\theta]^2} \geq 0,$$

(iii) Impact of present bias of time-inconsistent agents:

$$\frac{\partial \tilde{q}}{\partial|\theta_G|} = -\frac{(1-\pi)[r_A(\rho_F - \rho_C) - \pi\theta_B]}{[r_A(\rho_F - \rho_C) - E\theta]^2} \begin{cases} < 0 & if\ r_A(\rho_F - \rho_C) > \pi\theta_B \\ \geq 0 & if\ r_A(\rho_F - \rho_C) \leq \pi\theta_B \end{cases}$$

(iv) Impact of the environment:

$$\frac{\partial \tilde{q}}{\partial \pi} = \frac{-\theta_G[r_A(\rho_F - \rho_C) - \theta_B]}{[r_A(\rho_F - \rho_C) - E\theta]^2} \begin{cases} > 0 & if\ r_A(\rho_F - \rho_C) > \theta_B \\ \leq 0 & if\ r_A(\rho_F - \rho_C) \leq \theta_B \end{cases}$$

First, Proposition 4 (i and ii) highlights that the critical value $\tilde{q}$ is an increasing function of the supply-side parameters: the net rate of return on loans, r_A, and the spread of reserve ratios between liquid and illiquid accounts, $(\rho_F - \rho_C)$. All else equal, the higher r_A and/or $(\rho_F - \rho_C)$, the higher the probability that time-consistent agents hold illiquid accounts. Higher r_A and/or $(\rho_F - \rho_C)$ imply that illiquid accounts are more profitable to the bank, pushing it towards paying a higher liquidity premium and attracting time-consistent depositors. When r_A $(\rho_F - \rho_C)$ is high enough, the bank is not motivated to exploit the presence of time-inconsistent agents. This can happen even when the proportion of those agents is high.

Next, Proposition 4 (iii) states that if $r_A(\rho_F - \rho_C) > \pi\theta_B$—i.e. when $\tilde{q}$ is positive—the cut-off value $\tilde{q}$ is a decreasing function of $|\theta_G|$, which measures the present bias of time-inconsistent agents. A high $|\theta_G|$ translates into a small chance that time-consistent agents will end up with illiquid accounts. This is because the bank is more willing to segment the market and sell the illiquid account to time-inconsistent agents only. In contrast, when $r_A(\rho_F -$

$\rho_C) \leq \pi\theta_B$, collecting illiquid deposits from time-consistent agents is not profitable for the bank. As a consequence, the inequality $q > \tilde{q}$ is not binding ($\tilde{q}$ is non-positive while q is a non-negative proportion) and the equilibrium is separating irrespective of the proportion of time-inconsistent agents in the market. Hence, the equilibrium outcomes are insensitive to the (positive) impact of $|\theta_G|$ on $\tilde{q}$.

Proposition 4 (iv) provides the impact of the environment, captured by the shock of probability π on the cut-off value $\tilde{q}$. The impact of π on $\tilde{q}$ depends on the net benefit the bank makes by collecting illiquid deposits from time-consistent agents, $r_A(\rho_F - \rho_C) - \theta_B$. Uncertainty pushes the minimal required liquidity premium of time-consistent agents upwards proportionally to θ_B. As a consequence, when $r_A(\rho_F - \rho_C) > \theta_B$ providing illiquid accounts to time-consistent depositors is profitable and π impacts $\tilde{q}$ positively, which increases the likelihood of reaching a pooling equilibrium. In contrast, when $r_A(\rho_F - \rho_C) \leq \theta_B$, higher uncertainty yields a smaller $\tilde{q}$.

Lastly, we examine in more detail the two polar cases associated with homogenous pools of savers. Propositions 5 and 6 give the sub-cases of the theorems corresponding to the pool of savers being exclusively composed of time-consistent and of time-inconsistent agents, respectively. Regarding quantities, both cases logically lead to all-or-nothing situations.

Proposition 5:

If the pool of savers is made up of time-consistent agents only ($q = 0$)*, the equilibrium quantities of savings accounts,* $D_F^{R,*}$ *and* $D_C^{R,*}$*, and the equilibrium liquidity premium* $r_C^{R,*}$*, are given by:*

(i) $r_A(\rho_F - \rho_C) < \pi\theta_B \quad \Rightarrow \quad D_F^{R,*} = N,\ D_C^{R,*} = 0$, and $r_C^{R,*} = -\infty$

(ii) $r_A(\rho_F - \rho_C) \geq \pi\theta_B \quad \Rightarrow \quad D_F^{R,*} = 0,\ D_C^{R,*} = N$, and $r_C^{R,*} = \pi\theta_B$.

Proposition 6:

If the pool of savers is made up of time-inconsistent agents only $(q = 1)$, *the equilibrium quantities of savings accounts,* $D_F^{H,*}$ *and* $D_C^{H,*}$, *and the equilibrium liquidity premium* $r_C^{H,*}$, *are given by:*

(i) $r_A(\rho_F - \rho_C) < E\theta \quad \Rightarrow \quad D_F^{H,*} = N,\ D_C^{H,*} = 0,$ and $r_C^{H,*} = -\infty;$

(ii) $r_A(\rho_F - \rho_C) \geq E\theta \quad \Rightarrow \quad D_F^{H,*} = 0,\ D_C^{H,*} = N,$ and $r_C^{H,*} = E\theta.$

According to Proposition 5, when the pool of savers is composed of time-consistent agents exclusively, the bank has two possibilities: It supplies them either with liquid accounts, or with illiquid accounts with premium $\pi\theta_B$ (≥ 0). In other words, the intermediate case–(ii) in the theorems–collapses. The cut-off value for $r_A(\rho_F - \rho_C)$ in Proposition 5 is $\pi\theta_B$, which is lower than the cut-off value applying to the general case, $\frac{\pi\theta_B - qE\theta}{1-q}$ (see Theorems 1 and 2) since:

$$\pi\theta_B - \frac{\pi\theta_B - qE\theta}{1-q} = \frac{q(1-\pi)\theta_G}{1-q} (< 0), \text{ for } q \in (0,1) \tag{46}$$

When q is close to 1, the difference can be huge. Thus, compared to banks serving a heterogeneous market, those serving time-consistent savers only are more likely to offer illiquid accounts to them. This is the consequence of the impossibility for banks to directly segment their savings market. The presence of time-inconsistent agents makes it harder for their time-consistent counterparts to get illiquid accounts.

Proposition 6 describes the situation of a bank facing time-inconsistent savers only. In a good economic situation $(E\theta \leq 0)$, the savers agree to pay for commitment and, in equilibrium, they do so. Enjoying its monopolistic situation, the bank extracts the full surplus from its savers. In a bad economic situation $(E\theta > 0)$, two cases are possible: either the differential in reserve requirements is low and the bank is better-off offering liquid accounts only, or the differential is high and the bank prefers to pay a–relatively low but positive–liquidity premium to its savers. Interestingly, when $E\theta \leq r_A(\rho_F - \rho_C) < \pi\theta_B$, the exact same bank would offer liquid accounts to a pool of time-consistent savers but illiquid accounts to a pool of time-inconsistent ones.

Evidently, the bank is always better-off with time-inconsistent clients only. When the economic situation is good, it can even earn a financial reward by offering the illiquid accounts it needs to hedge liquidity risk. Interestingly, in this situation formal financial markets are not better than informal ones from the saver's point of view (Anagol *et al.*, 2012; Rutherford, 2000). However, we are not aware of any real-life example of such situations in a formal financial market. The explanation could stem from the fact that time-inconsistent agents are never alone in savings markets. There are always time-consistent–or naïve time-inconsistent–agents around. This argument does not hold for informal savings markets, where providers can directly segment their clientele. In this respect, forcing banks to publicize their savings conditions is crucial.

Even though sophisticated time-inconsistent savers are ready to pay for commitment, the liquidity premium may be positive in equilibrium because there are time-consistent savers in the market. Time-consistent agents prevent the bank from extracting a monopoly rent from their time-inconsistent fellows. The stylized facts in Section 2 indicate that, in practice, this mechanism is highly effective.

6. Conclusion

This paper determine the equilibrium liquidity premium offered by a monopolistic bank that is facing a mix of time-consistent and sophisticated time-inconsistent savers but is unable to segment its clientele directly. Our model produces relevant predictions for the banking sector. First, the presence of time-inconsistent agents in the market tends to mitigate the size of liquidity premiums, possibly making illiquid accounts less attractive to time-consistent savers. This is especially true for banks that fail to develop a profitable lending activity and for those that poorly hedge their liquidity risk. Second, various institutional arrangements exist for preserving banking system stability. For instance, Diamond and Dybvig (1983) demonstrate that deposit insurance is most efficient when withdrawals are uncertain. Also illiquid deposits, which are costly or impossible to withdraw, are crucial for avoiding bank runs. In this respect, our model delivers a key message to banking authorities. Paying attention to the composition of the pool of savers can be useful when setting reserve requirements. This paper shows that, compared to the situation where all savers are time-consistent, a mix of savers spontaneously reduces the liquidity risk for the bank, all things equal. The presence of sophisticated time-inconsistent agents creates intrinsic demand for illiquid and stable deposits.

Admittedly, pools of savers are bank-specific while regulations are country-wide. Nevertheless, the microfinance literature shows that time-inconsistent agents are more prevalent in poor populations. Therefore, financial institutions targeting poor savers benefit from a sort of spontaneous hedge against liquidity risks. As a consequence, the regulatory framework for micro-savings does not have to be as stringent as the one applicable to mainstream banks. This point is especially relevant given that complying with regulations is shown to curtail the social and financial performance of microfinance institutions (Cull *et al*., 2011).

The financial sector provides a meaningful example to show that sophisticated time-inconsistent agents do not necessarily have to pay for commitment contracts. Our model departs from the literature on commitment pricing (Della Vigna and Malmendier, 2004, 2006; Oster and Morton, 2005; Gottlieb, 2008) by addressing a situation where the provider has an intrinsic motivation for proposing commitment contracts. Further work could investigate whether similar situations exist outside the banking sector. For instance, binding contracts should be valuable to firms facing pervasive uncertainty. Still, the contracts at stake should be renegotiation-free, which puts severe restrictions on their design (Gottlieb, 2008).

Our model suffers from several limitations. First, we consider a monopolistic bank, and so disregard the potential impact of imperfect competition, which can undeniably affect banks' pricing policies. As sophisticated time-inconsistent savers offer attractive opportunities to banks, it is likely that banks–especially those having developed a profitable loan-granting activity–would compete strongly to attract them. Other limitations stem from the simplicity of our model. We confine our investigation to a three-period situation where cash may be withdrawn from the liquid account in one period only. Likewise, we use linear objective functions. A multi-period model with non-linear utilities could deliver more nuanced results, especially if the occurrence of the adverse shock is client-specific. The same holds true had we allowed for the possibility of finite penalties for withdrawal and of combining savings accounts. Still, we contend that adding a layer of complexity would have little effect on the qualitative outcomes of our model. The purpose of our exceedingly simple model is to pinpoint the impact of time-inconsistent savers on the market price for illiquid accounts. To our knowledge, this model is the first of its kind.

Finally, the interest in time-inconsistency in financial behavior has emerged from the microfinance literature. However, the evidence that not all savers are time-consistent has long been recognized in the mainstream banking literature. Strikingly, so-called irrational agents are typically caricatured in this literature as noise traders or over-optimistic/pessimistic speculators. The lack of self-discipline is a more subtle, yet unaddressed, type of behavioral feature. The time-inconsistency factor has proven fruitful in analyzing markets for goods and services, but has so far been disregarded in the field of banking. We hope our model will convince researchers to fill this gap.

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Tables and Figures

Table 1. Interest Rates on Savings Accounts in Bangladeshi Banks and MFIs

	Assets (in USD)[a]	Interest rate on liquid accounts (%)[d]	Interest rate on illiquid accounts (%)	Liquidity premium (%) Min	Max
		Banks			
AB Bank	1,872,454,119	6.0	12.0-12.5 (t)	6.0	6.5
Agrani Bank	4,269,996,473	4.0	7.0-9.0 (r) 10.0-12.5 (t)	3.0 6.0	5.0 8.5
Bangladesh Krishi Bank[b]	2367,679,022	6.0[d]	10.0-15.0 (r) 11.0-12.5 (t)	4.0 5.0	9.0 6.5
Asia Bank	1,441,153,418	5.5	10.0-12.0 (t)	4.5	6.5
Basic Bank	955,204,814	7.0	12.5 (t)	5.5	5.5
BRAC Bank	1,630,545,414	4.0	7.0-10.0 (t)	3.0	6.0
Dhaka Bank	1,281,971,354	6.25[e]	12.5 (t)	6.25	6.25
Eastern Bank	1,004,437,337	6.0	10.5-12.5 (t)	4.5	6.5
Exim Bank	1,589,823,422	5.0	11.0-12.0 (r) 12.5 (t)	6.0 7.5	7.0 7.5
ICB Islamic Bank	220,527,855	5.0	10.5-11.5 (r) 12.0-12.5 (t)	5.5 7.0	6.5 7.5
IFIC Bank	1,120,165,333	5.0	12.0 (r) 12.5 (t)	7.0 7.5	7.0 7.5
Mercantile Bank	1,426,752,901	6.0	12.5 (t)	6.5	6.5
Mutual Trust Bank	936,501,247	6.0	12.5 (t)	6.5	6.5
National Bank	2,069,226,418	4.0	9.0-9.5 (r) 10.5-12.0 (t)	5.0 6.5	5.5 8.0
National Bank of Pakistan	n.a.	5.0	11.25-12.25 (r)	6.25	7.25
National Credit & Commerce Bank	1,267,098,856	6.0	10.0-12.5 (t)	4.0	6.5
One Bank	827,740,648	6.0	12.5 (t)	6.5	6.5
Pubali Bank	1,923,755,586	4.5	10.0-12,0 (r) 8.0-12.0 (t)	5.5 3.5	7.5 7.5
Rajshahi Krishi Unnayan Bank[b]	629,542,184	6.0[d]	9.0 (r) 8.0-9.5 (t)	3.0 2.0	3.0 3.5
Shahjalal Bank	1,312,613,757	4.0	12.05-12.3 (r) 12.0-12.5 (t)	8.05 8.0	8.3 8.5
Social Islami Bank	1,033,235,923	n.a.	13.5 (r)	n.a.	n.a.
Standard Bank	914,473,659	5.0	12.0 (t)	7.0	7.0
Standard Chartered Bank	n.a.	2.0	6.25-12.5 (t)	4.25	10.5
The City Bank	1,416,751,246	4.0	10.0-12.5 (t)	6.0	8.5
HSBC Bangladesh	1,236,331,766,	1.5	6.25-11.0 (t)	4.75	9.5
Trust Bank	932,968,477	6.0	7.78 (r) 7.0-12.5 (t)	1.78 1.0	1.78 6.5
United Commercial Bank	2,067,444,032	4.5	12.5 (t)	8.0	8.0
Uttara Bank	1,192,515,804	4.5	12.50 (t)	8.0	8.0
Average for banks		**4.99**	**10.26-11.32 (r)** **10.58-12.15 (t)**	**6.50**	

Table 1 (cont'd). Interest Rates on Savings Accounts in Bangladeshi Banks and MFIs

	Assets (in USD)[a]	Interest rate on liquid accounts (%)[d]	Interest rate on illiquid accounts (%)	Liquidity premium (%) Min	Max
		Microfinance Institutions (MFIs)			
GrameenBank[c]	125,396,957,972	8.5	10.0-12.0 (r)	1.5	3.5
			8.75-9.5 (t)	0.25	1.0
ASA	55,168,439,063	6.0	9.0-12.0 (r)	3.0	6.0
Buro[c]	6,321,618,792	4.5	6.0-8.0 (r)	1.5	3.5
SafeSave[b]	83,085,698	6.0	7.0-10.0 (r)	1.0	4.0
Jagorani Chakra Foundation[b]	5,848,252,608	5.0	10.0-12.0 (r)	5.0	7.0
			14.0 (t)	9.0	9.0
Average for MFIs		**6.0**	**8.40-10.80 (r)**	**3.71**	
			11.38-11.75 (t)		

Notes
[a] For most institutions, data is retrieved as of December 31, 2011. Each exception is specified. For readability, we convert the figures to USD by using the exchange rate prevailing at the date of the issuance of the financial report (www.exchange-rates.org).
[b] Data retrieved as of June 30, 2011.
[c] Data retrieved as of December 31, 2010.
[d] Average of urban and rural interest rates.
[e] Average of conventional and Islamic interest rates.
(r): Recurring deposit; (t): Term deposit.

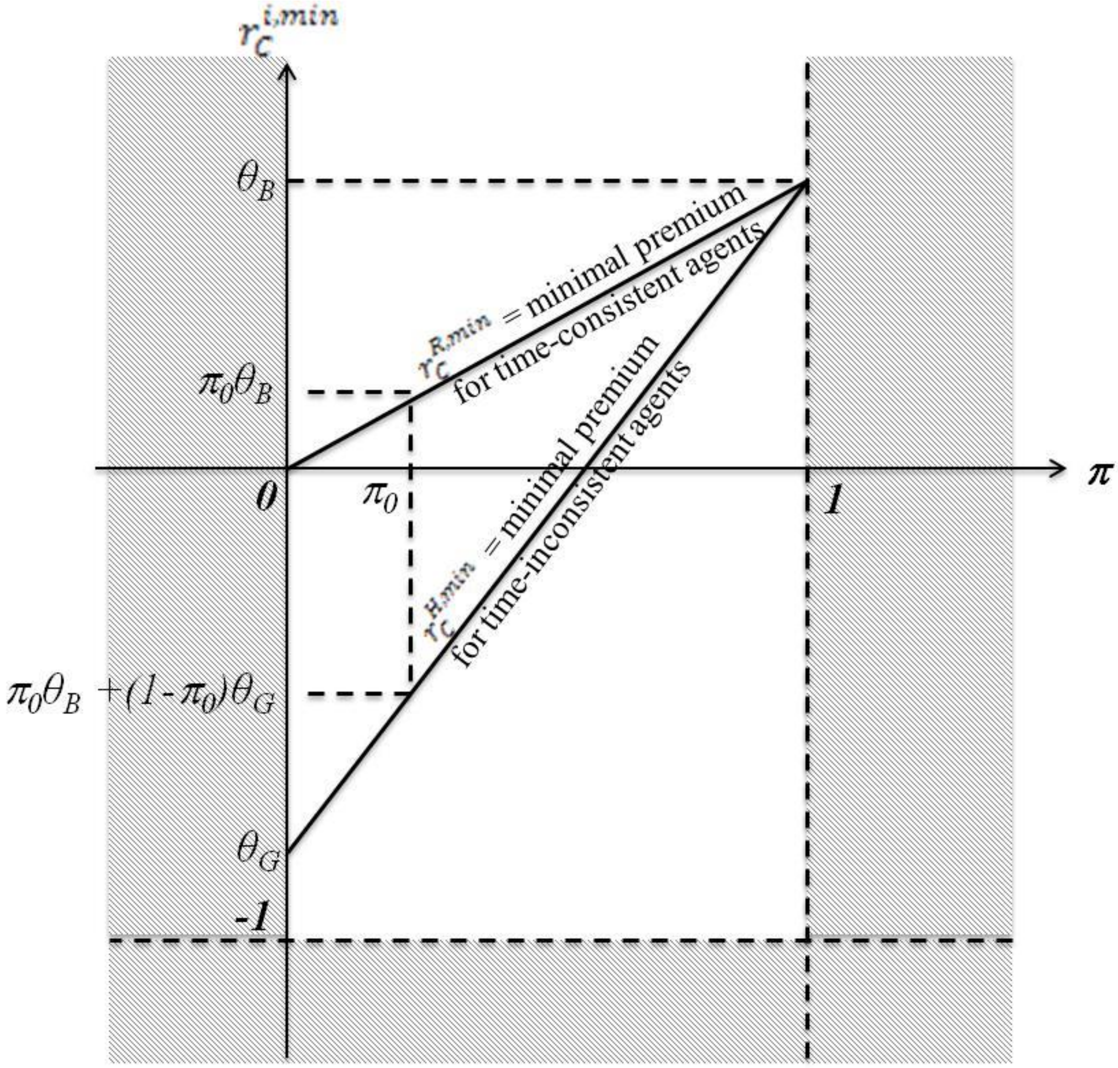
Table 2. Optimal Consumption and Intertemporal Utility with Given Accounts

	Consumption in period 1: $c_1^{i,*}(s,\omega)$		Consumption in period 2: $c_2^{i,*}(s,\omega)$		Intertemporal utility in period 1: $U_1^{i,*}(s,\omega)$	
Agent / State of nature	Time-consist. $(i = R)$	Time-inconsist. $(i = H)$	Time-consist. $(i = R)$	Time-inconsist. $(i = H)$	Time-consist. $(i = R)$	Time-inconsist. $(i = H)$
Liquid account $(s = F)$						
No shock $(\omega = G)$	0	1	1	0	1	$1+\theta_G$
Shock $(\omega = B)$	1	1	0	0	$1+\theta_B$	$1+\theta_B$
Illiquid account $(s = C)$						
No shock $(\omega = G)$	0	0	$1+r_C$	$1+r_C$	$1+r_C$	$\beta(1+r_C)$
Shock $(\omega = B)$	0	0	$1+r_C$	$1+r_C$	$1+r_C$	$\beta(1+r_C)$

Table 3. Zone-specific Optimums for the Bank

Zone	Zone-specific optimal quantities	Zone-specific optimal liquidity premium	Zone-specific optimal profit of the bank
I	$D^*_{F,I} = N$ $D^*_{C,I} = 0$	$\mathrm{r}^*_{\mathrm{C,I}} = -\infty$	$P^*_I = r_A(1 - \rho_F)N$
II	$D^*_{F,II} = (1 - q)N$ $D^*_{C,II} = qN$	$r^*_{C,II} = E\theta$	$P^*_{II} = [r_A(1 - \rho_C) - E\theta]qN + r_A(1 - \rho_F)(1 - q)N$
III	$D^*_{F,III} = 0$ $D^*_{C,III} = N$	$r^*_{C,III} = \pi\theta_B$	$P^*_{III} = [r_A(1 - \rho_C) - \pi\theta_B]N$

Figure 1. Minimal Liquidity Premiums for the two Types of Agents



Appendix A: Proof of Proposition 3

From Theorems 1 and 2, the equilibrium is separating (and only time-inconsistent agents hold illiquid deposits) if and only if:

$$r_A(\rho_F - \rho_C) < \frac{\pi\theta_B - qE\theta}{1-q}. \quad \text{(A1)}$$

Or equivalently:

$$q > \frac{r_A(\rho_F - \rho_C) - \pi\theta_B}{r_A(\rho_F - \rho_C) - E\theta} \quad \text{(A2)}$$

The right-hand side of (A2) is the critical value $\tilde{q}$ defined in Proposition 3.