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JEL Classification: D91, G21, E43

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Financial Intermediation in an Overlapping Generations Model with Transaction Costs

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We analyze an overlapping generations economy where agents interact to share liquidity risk. We show that a pure exchange economy has excessive trade in equilibrium, and that intergenerational financial intermediaries reduce the number of interactions by catering to clienteles with uncorrelated liquidity needs. In the intermediated economy equilibrium, intermediaries finance redemptions with loan income, and never sell assets. If the economy is subject to transaction costs, the intermediated economy can sustain higher stationary investment and welfare. We also find that transactions costs cause the yield curve to be downward sloping, and that the non-intermediated economy is inherently cyclical.

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1. Introduction

The main explanations for the existence of financial intermediaries are that they (i) reduce transactions costs, (ii) provide liquidity insurance, (iii) solve asymmetric information inefficiencies, and (iv) align incentives through active monitoring. There now exists a rich literature that investigates how intermediaries share liquidity risk, overcome adverse selection, and alleviate moral hazard.¹ On the other hand, research on how intermediaries reduce transactions costs is conspicuously limited.

Benston and Smith (1976) argue that “the *raison d’être* for the [financial intermediation] industry is the existence of transactions costs”. They interpret transaction costs as costs of transportation, administration, search, evaluation and monitoring, among others. Their main argument is that banks enjoy economies of scale, scope, reputation, and networks in these tasks. In this paper we disregard transaction costs due to information asymmetries or moral hazard, and only consider order processing, or *shoe leather* costs. Since Baumol (1952), Tobin (1956) and Orr and Mellon (1961), who analyze the trade-off between holding cash and financial assets in the presence of shoe leather costs, these simplest of transaction costs have been largely ignored in the micro economic theory literature, despite the fact that processing costs are estimated to account for 3% of the GDP (Humphrey *et al.*, 2000).²

In this paper, we use a three dates overlapping generations model in which agents may need to consume before a long term production technology pays a riskless dividend. To share liquidity risk, agents can trade secondary claims for consumption

¹ The seminal paper addressing the liquidity insurance argument is Diamond and Dybvig (1983). Scale economies in dealing with information asymmetries were conjectured by Leland and Pyle (1977), and modelled by Boyd and Prescott (1986) and Broecker (1990), among others. Diamond (1984) demonstrates how delegated monitoring results in economies of scale in loan supervision. Freixas and Rochet (1997) present a comprehensive review of the traditional banking literature. More recently, He *et al.* (2008) justify the existence of banks as providers of safe-keeping, and Andolfatto and Nosal (2009) shows that, in the presence of moral hazard, banks are essential in combining money creation and intermediation.

² Macro economists *do* acknowledge the importance of shoe leather costs. Lucas (2000) for instance argues that the excessive shoe leather costs brought on by inflation may account for as much as 1% of GNP when moving to the Friedman optimum.

goods in a pure exchange market or alternatively, open accounts with financial intermediaries. This representation, also known as the OLG Diamond-Dybvig model, is also studied by Qi (1994), Bhattacharya and Padilla (1996), and Fulghieri and Rovelli (1998), among others.³

The distinguishing feature of our model is the existence of transaction costs, which we model as dead weight *leaking bucket* costs that are incurred whenever agents interact. Naturally, these costs aim to capture all deadweight transaction processing costs, such as communication, search, administration, or simply paying attention. We argue that it is by netting out these tasks that financial intermediaries add value.

We find that in the pure exchange economy, a centrally located market opens up where early consumers sell secondary claims to newborns and late consumers. In equilibrium, newborns invest their endowment in a mix of long term and short term claims, and sell long term claims when they face unexpected consumption needs. Late consumers also trade on their first birthday, as they need to reinvest the dividends from their maturing assets. Hence, early consumers travel to the market twice while late consumers travel three times: once for depositing, once for rebalancing and once for withdrawing.

As an alternative to the exchange, a centrally located financial intermediary may open up. In following with the literature, we will henceforth denote this intermediary a *bank*. We emphasize however that our bank can also be interpreted as an open-end mutual fund or an insurance company, or any other institution that centralizes liquidity and reduces intragenerational transaction costs.

Agents open deposits with a bank and the bank invests in the technology. In the absence of aggregate risk, infinitely lived banks will never sell assets. As they cater to large stationary and diversified clienteles of overlapping generations, banks' total loan income plus new deposits will exactly equal depositor redemptions and investments in new securities.

³ In single generation models, the papers by Diamond Dybvig (1983), Jacklin (1987), Jacklin and Bhattacharya (1988), Hellwig (1994), Alonso (1996), Samartín (2001), Diamond (1997) and von Thadden (1998) among others, analyze the relative degrees of risk sharing provided by banks and markets. For a review of this literature, see Dwyer and Samartín (2008).

In the intermediated economy, agents only need two trips: one to deposit, and one to withdraw. Because the bank's depositor clientele is diversified and stationary, no costly rebalancing transactions are required, thus making the intermediated economy superior to the pure exchange economy.

Our finding that banks achieve higher welfare in a world with transaction costs does not depend on our assumption that only consumers incur transactions costs. In fact, when we consider transactions costs for intermediaries too, welfare is further increased. This is because transactions costs impede interbank arbitrage so that banks can accumulate larger stocks of productive assets and offer higher returns to depositors.⁴

Apart from the reduced number of transactions, our analysis uncovers an additional advantage of intermediated economies relative to exchange economies. We show that while the latter are inherently cyclical, the former achieve non-cyclical allocations.⁵

Although our main analysis is of the stationary OLG economy, we also investigate how an economy is “started up” at a hypothetical date zero. We find that for small transaction costs, the exchange economy with a starting date cannot escape from a severe cyclical pattern, and that intergenerational welfare can be increased by introducing transactions costs, as they dampen cyclicity. We also find that the starting up phase of an intermediated economy is significantly shorter than the time to stationarity in an exchange economy.

Finally, our model shows that, in the market economy transaction costs lead to a downward sloping yield curve in the market economy. The reason for this is that equilibrium investments in long term securities come with lower *per period* transaction costs. Constandinides (1986) describes this effect for an economy with

⁴ Bhattacharya and Padilla (1996) show that if banks offer too high demandable debt returns, they will attract other banks to open deposits, which causes the equilibrium to unravel.

⁵ The finding that overlapping generations models can have cyclical equilibria goes back to Azariadis (1981). Bhattacharya, Fulghieri and Rovelli (1998) first mention the cyclicity in the OLG Diamond Dybvig economy.

transaction costs and aggregate risk. He shows that high transaction cost securities are traded less frequently, which may offset any illiquidity premium.⁶

Related to our study are the papers of Diamond (1997) and Qian *et al.* (2004), who also investigate the effect of transactions costs on Diamond-Dybvig banks, in a one-period, and in an OLG setting respectively. However, instead of modelling shoe-leather costs for all agents, they assume that agents face a prohibitive transaction costs with some probability, making them unable to interact on their first birthday. This naturally gives them a disadvantage in the market economy so that they *ex ante* prefer to open accounts with banks. In our model all agents are able to interact on all dates but face a small transaction cost. Also related is the one-period model of Townsend (1978), who shows that if bilateral exchange is costly, a schedule where one agent acts as intermediary to all others, is an equilibrium as it avoids costly networks with superfluous bilateral relations.⁷

Papers that study the effect of transaction costs on mutual funds include Cherkes *et al.* (2008), which examines how closed end funds economize on transaction costs. Their analysis shows that retail investors find funds attractive, even at prices above net asset value, because they offer them lower round trip transaction costs than home made portfolios of illiquid stocks. Chordia (1996) investigates the case for open end funds, and shows that, apart from achieving economies of scale in transaction costs and improving on diversification, mutual funds provide transaction cost risk sharing.⁸ Neither of these papers shows that fund intermediaries avoid transactions altogether but merely rely on economies of scale or transaction costs risk.

⁶ Other papers that study the effect of transaction costs on asset prices include Aiyagari and Gertler (1991), Heaton and Lucas (1996), Vayanos (1998), Vayanos and Vila (1999), and Huang (2003), among others.

⁷ E.g. in a world with three agents and gains from trade, a fully competitive economy would have a triangle of three bilateral relations. If one agent acts as an intermediary, only two bilateral exchanges are required. In a recent paper Zhu (2008) investigates an OLG economy with search costs to show that a market equilibrium with an increasing supply of fiat money may exist. In his model asymmetry of bargaining power in the bilateral exchanges causes the transaction frictions.

⁸ Funds can effectively enforce an *ex-ante* desirable allocation of transaction costs: early consumers end up paying less and late consumers paying more. Van Bommel (2008) makes a similar argument for a Diamond Dybvig bank.

The rest of the paper is organized as follows: the basic model is presented in the next section. Section 3 analyzes the equilibrium in a pure exchange economy, while section 4 investigates how banks can improve on the above allocation. Section 5 juxtaposes the exchange and bank equilibriums in an economy with a starting date and a first generation. We discuss several possible extensions to our model in section 6, and summarize our findings in section 7. The appendix contains the proofs, an analysis of the model with variable transaction costs, and an analysis of the bank's start up phase.

2. The model

We analyze an infinite horizon, single consumption good economy, where time is represented by the unbounded set of integers $\mathbb{Z}$, representing the dates t on which agents interact. Henceforth we refer to periods between two dates as years.⁹ On every date, a continuum of size one of agents is born with an endowment of one unit of consumption good and live either one year, with probability λ , or two years, and consume only on the date they die. All agents have expected utility preferences, modelled by an instantaneous utility function with constant relative risk aversion γ : $U(C) = \frac{1}{1-\gamma} C^{1-\gamma}$. Agents born at date t learn their type after t but before $t+1$. Types are not verifiable. We will call agents with less than one year to live impatient. Agents who will live more than a year are called patient. We assume that the population is large enough so that there is no uncertainty on the aggregate distribution of early and late-diers in the economy, or within a bank's clientele.^{10,11}

The economy is endowed with two productive technologies. The first technology, *storage*, allows agents to costlessly transfer consumption goods from one period to the next. The second, *long term* or *productive* technology allows agents to convert one

⁹ This is the simplest possible set up. Letting agents maximum lifespan be $N > 2$ periods, produces the same basic insights, but with considerably more calculus.

¹⁰ That is, on ever date there will be λ impatient one-year olds, $(1-\lambda)$ patient one-year olds, and $(1-\lambda)$ two-year olds interacting. The certain aggregate distribution of types is usually justified in terms of the law of large numbers. Duffie and Sun (2007) provide a model of independent random matching that makes the law of large numbers hold exactly.

¹¹ We allow for zero-profit competition among banks, and potential interbank arbitrage as in Bhattacharya and Padilla (1996) and Fulghieri and Rovelli (1998), among others.

unit of consumption at date t into $R > 1$ units of consumption at $t + 2$. This technology, which cannot be interrupted at $t + 1$, is operated by a firm which issues, inelastically, two-year bonds with face value R .

Naturally, agents can buy 2-year bonds and share liquidity risk by trading secondary claims. To do this, agents can interact in a *market*, where they exchange one-year bonds for consumption goods. The price for such bonds, denoted p_t , is set by a Walrasian auctioneer to whom buyers and sellers submit their demand and supply curves.

Agents may also form financial intermediaries. In this case, agents set up *banks* where they deposit their endowments and receive a demandable debt security that entitles the holder to withdraw r_1 after one year or r_2 after two years. We allow for free entry banks, so that Bertrand competition assures that banks make zero profit.

The cost of transacting is the distinguishing feature of our model. To model transaction processing costs we envision that the agents are born on a circle around the production technology, and need to incur shoe leather costs to interact. For tractability we assume that all interaction takes place in the midpoint of the circle and that the cost to travel to this venue is independent of the value of claims or goods transported. In particular, each trip will cost agents c units of the consumption good.

The assumption that the travel cost is independent of the amount carried is for tractability only. We show that the fixed cost assumption produces an exchange equilibrium in which newborns employ mixed strategies and hold portfolios that consist either of only two-year bonds, or of only one-year bonds. In the appendix we show that a variable transaction cost leads to qualitatively the same insights as the fixed cost model. We further assume, also without loss of generality, that the transaction cost is levied on the way back home.

In the following we will characterize the equilibrium allocations, denoted $\{C_1, C_2\}$, in the exchange and bank economies. To compare social welfare, we shall compare agents' *ex-ante* expected utility in both economies.

3. The exchange economy

In a pure exchange economy, newborns and patient one-year olds can store their endowment or invest it in one- or two-year bonds. To save space we shall limit our

attention to the case where transaction costs are low enough for storage to be always dominated by investing. Because there is no uncertainty, and transaction costs are fixed, newborns choose between two strategies: they either spend their entire endowment on buying two-year bonds, which they will sell if they become impatient, or they buy only one-year bonds in the secondary market and *roll over* these bonds if they remain patient. We denote these strategies LT and ST respectively. Notice that in the LT strategy all agents travel twice, while in the ST strategy, patient agents travel three times.

Clearly, in equilibrium we need both types of agents. This implies that agents employ mixed strategies. In equilibrium, agents must be indifferent between both strategies.

Hence, we need that:

$$\begin{aligned} E[U]_{LT} &\equiv \lambda U((1-c)p_{t+1} - c) + (1-\lambda)U((1-c)R - c) \\ &= E[U]_{ST} \equiv \lambda U\left(\frac{(1-c)R}{p_t} - c\right) + (1-\lambda)U\left(\left(\frac{(1-c)R}{p_t} - c\right)\frac{R}{p_{t+1}} - c\right) \quad \forall t \end{aligned} \quad (1)$$

The first bracketed term denotes the consumption of an agent who employs the LT strategy and becomes impatient: when born she buys $1-c$ two-year bonds and sells them at her first birthday for p_{t+1} . The fourth bracketed term is the consumption of an agent who plays ST and turns out patient: he buys $\frac{1-c}{p_t}$ one-year bonds when born, and hence on his first birthday receives $\frac{(1-c)R}{p_t}$. Because he is patient, he reinvests the proceeds (net of transaction costs) in one-year bonds. One year later he travels again and consumes $\left(\frac{(1-c)R}{p_t} - c\right)\frac{R}{p_{t+1}} - c$.

Notice that we do not consider the case where newborns buy one-year bonds, and then roll them over into two-year bonds when they stay patient. We will show that this strategy is strictly dominated by playing LT or ST .

It can be easily verified that there is a unique stationary price process, $p_t^* = p^*$ that solves (1) for all t . With this p^* , we can derive the equilibrium probability, denoted θ^* , with which newborns play LT from the following market clearing condition:

$$p^* = \frac{(1 - \theta^*)(1 - c) + (1 - \theta^*)(1 - \lambda) \left(\frac{R(1 - c)}{p^*} - c \right)}{\theta^*(1 - c)\lambda} \quad (2)$$

In equation (2) the numerator is the equilibrium supply of goods, and the denominator the equilibrium supply of bonds. The following proposition gives the solution for the unique full investment equilibrium in the unbounded market economy.

Proposition 1 (*market equilibrium*)

For low enough c , there exists a unique stationary market equilibrium with fully invested agents (no storage). For the equilibrium price we have:

$$p^* \in \left(\frac{\sqrt{c^2 + 4R(1 - c)^2} - c}{2(1 - c)}, \sqrt{R} \right) \quad (3)$$

Newborn agents invest their endowment in two year bonds with probability θ^ , and invest all in one-year bonds otherwise. The equilibrium periodic investment in primary (two-year) bonds is given by:*

$$\theta^* = \frac{(1 - c)p^* + (1 - \lambda)(R - c(R + p^*))}{(1 - c)(\lambda p^* + 1)p^* + (1 - \lambda)(R - c(R + p^*))} \quad (4)$$

A closed form solution for p^* can only be found for certain values for γ . For brevity and relevance we focus on the interval in which p^* lies. This interval, given by (3), follows from equation (1). The upper bound for p^* , $\sqrt{R}$, makes the LT strategy dominant: with $p^* = \sqrt{R}$ impatient consumption is independent of the strategy played, while patient consumption is higher under the LT strategy (see (1)). Similarly, if $p^* = \frac{\sqrt{c^2 + 4R(1 - c)^2} - c}{2(1 - c)}$, the ST strategy would dominate. The expression for θ^* follows from rearranging equation (2).

The key point is that $p^* < \sqrt{R}$, which implies that the return on a one-year bond is higher than the one year return on a two-year bond. This also is the reason why one-year old patient agents do not buy two-year bonds. Since their holding period is one year with certainty, patient one-year olds will opt for one-year bonds.

Notice that proposition 1 limits itself to the full investment case. We shall later see that if c is zero or is higher than a threshold, multiple cyclical equilibria exist. Moreover, if the economy has a starting date (and hence a unique equilibrium), the economy may be by stuck in severe cyclical. In such an economy, severe cyclical will obtain if $c = 0$. In section 5 we show that for a wide range of parameter values, the presence of transaction costs in a pure exchange economy with a starting date may enable convergence to the non-cyclical equilibrium characterized in proposition 1 and hence *improve* overall welfare vis-à-vis the transaction cost free economy. But before considering the truncated economy, we shall first investigate how a financial intermediary can improve on the market allocation.

4. The intermediated economy

Following the literature, we consider the simplest of intermediaries: infinitely lived deposit institutions, henceforth called *banks*, whose only source of capital are deposits. We first assume zero transaction costs for the banks. It seems natural that, in our spatial model, banks establish themselves next to technology. We show that by doing so banks can increase welfare by reducing the number of transactions (trips) that obtain in the market economy.

In section 4.2. we will relax this assumption and consider transactions costs for banks too. Interestingly, we find that bank transaction costs *increases* welfare in the competitive bank economy even further. This is due to the fact that bank transaction costs relax the interbank arbitrage constraint.

4.1. Competitive bank economy without transaction costs for the bank

In a stationary economy the intermediaries issue demandable debt securities that give depositors the right to withdraw, per unit of consumption good deposited, either r_1 after one year, or r_2 after two years. Naturally, the former payout is earmarked for the impatient agents, and the latter for the patient types. If we denote y the bank's periodic investment in the productive technology, we can write its objective function as follows:

$$\max_{r_1, r_2, y} \lambda U((1-c)r_1 - c) + (1-\lambda)U((1-c)r_2 - c) \quad (5)$$

$$\text{subject to: } (1-c)(\lambda r_1 + (1-\lambda)r_2) + y \leq 1-c + yR \quad (6)$$

$$((1-c)r_1 - c)r_1 - c \leq (1-c)r_2 - c \quad (7)$$

$$\left\{ ((1-c)r_1 - c)\frac{R}{r_2} - c, (1-c)R - c \right\} \prec \left\{ (1-c)r_1 - c, (1-c)r_2 - c \right\} \quad (8)$$

$$r_1 \leq \sqrt{R} \quad (9)$$

$$r_2 \leq R \quad (10)$$

Equation (6) gives the bank's budget constraint. The left hand side gives the periodic outflows, the right hand side the inflows. Equation (7) gives the roll over arbitrage constraint, which requires that patient depositors do not withdraw and redeposit. Equation (8) is the side trade constraint due to Jacklin (1987). It requires that agents do not buy bonds in the primary market, and sell them to patient bank depositors in case they become impatient. Notice that a bond offered to patient depositors fetches at most $\frac{(1-c)r_1 - c}{(1-c)r_2} R$, as it needs to make patient depositors indifferent between withdrawing and buying bonds, and sticking to their deposit.¹² Hence, side traders consume at most $((1-c)r_1 - c)\frac{R}{r_2} - c$ when they are patient, and $(1-c)R - c$ if they remain patient.

Equations (9) and (10) are the *interbank arbitrage* conditions, which need to hold to avoid that competing banks open up immediately next to the incumbent bank and invest with their neighbors instead of the production technology.¹³ It can be verified

¹² The consumption of a depositor who withdraws and buys bonds at a price p is $\frac{(1-c)r_1 - c}{p} R - c$, while his reservation consumption is $(1-c)r_2 - c$. Equation both expressions gives $p = \frac{(1-c)r_1 - c}{(1-c)r_2} R$.

¹³ The possibility of interbank arbitrage was first discussed by Bhattacharya and Padilla (1998). Notice if we assume away interbank arbitrage, we need an assumption regarding the technology's production function to obtain a finite equilibrium. Qi (1994) makes such an assumption: He assumes that the maximum periodic investment in the technology is unity, and shows that (in the absence of interbank arbitrage) banks can improve on the market allocation by carrying an asset buffer over time.

that only (9) and (10) will bind in every period, so that we have a unique stationary bank economy equilibrium given by the following proposition:

Proposition 2 (*the intermediated economy without bank transaction costs*)

If c is sufficiently small, there exists a bank equilibrium in which banks offer, per unit of good deposited, $r_1 = \sqrt{R}$ one year after deposit, or $r_2 = R$ after two years, at the option of the depositor. The periodic investment is given by:

$$y^* = (1-c) \frac{\lambda \sqrt{R} + (1-\lambda)R - 1}{R-1} \quad (11)$$

and all agents consume $\{(1-c)\sqrt{R}-c, (1-c)R-c\}$.

We have essentially the same bank as suggested by Bhattacharya and Padilla (1996), who show that in an economy without transaction costs, the threat of arbitrage destroys the bank's superior risk allocation potential and that the best schedule it can offer its clients is the market allocation. However, because in our model the payouts are offered at the central location, and agents incur shoe-leather costs, the bank offers the agents a strictly better allocation than the exchange mechanism:

Corollary (*banks versus markets*)

For positive transaction cost c , the bank allocation is Pareto superior to the one-periodic exchange allocation.

Proof: Agents who choose the LT strategy in the market economy receive an consumption schedule $\{(1-c)p^* - c, (1-c)R - c\}$, whereas bank depositors consume $\{(1-c)\sqrt{R} - c, (1-c)R - c\}$. The bank allocation is superior because $p^* < \sqrt{R}$. *Q.E.D.*

The reason for the superiority of banks lies in the difference in total travel. In the market economy, the total number of trips to the midpoint of the circle is $2+\theta(1-\lambda)$ per generation, while in the bank equilibrium only two trips are made.

4.2. Competitive bank economy with transaction costs for the bank

In this section we analyze what happens if banks are subject to transaction cost too. We first observe that if the bank has transactions costs in both the primary and the

interbank market, the equilibrium described is the same as described by proposition 2. This is because in the analysis of the bank's problem only the budget constraint changes. It becomes:

$$(1-c)(\lambda r_1 + (1-\lambda)r_2) + y' + c \leq 1 + y'R - 2c \quad (12)$$

Equation (12) incorporates the transaction cost of the intermediary on both investments and payoffs. However, the budget constraint does not affect the stationary payouts r_1 and r_2 , nor welfare. This is because the binding interbank arbitrage constraints (9) and (10) are unchanged, because both primary investment as interbank deposits come with transaction costs. The new budget constraint only implies that the periodic investment in the intermediated economy is higher. In particular, solving for the equilibrium allocation now gives:

$$y' = \frac{(1-c)(\lambda\sqrt{R} + (1-\lambda)R - 1) + 2c}{R-1} \quad (13)$$

In the next section we show how also this increased stationary level can be attained if the economy has a starting date.

We now consider a transaction cost for the bank only in the interbank market. In this variation of the model, the banks' problem continues to be given by (5) subject to (6), (7) and (8), but now the interbank arbitrage constraints become:

$$((1-c)r_1 - c)r_1 - c \leq R \quad (13)$$

$$(1-c)r_2 - c \leq R \quad (14)$$

It can be shown that also in the bank economy with transaction costs these arbitrage constraints are binding. We find:

Proposition 3 (*the intermediated economy with interbank transaction costs*)

If c is sufficiently small, there exists a bank equilibrium in which banks offer a payout

schedule with $r'_1 = \frac{c + \sqrt{c^2 + 4((1-c)(c+R))}}{2(1-c)} > \sqrt{R}$ and $r'_2 = \frac{R+c}{1-c} > R$.

The periodic investment is given by:

$$y' = \frac{(1-c)(\lambda r'_1 + (1-\lambda)r'_2 - 1)}{R-1} \quad (15)$$

Proof: Solving (5)-(8), (13), (14) shows that r'_2 follows from (14) being binding and r'_1 from (13) and (7) binding. As before, y' follows from the budget constraint (6). Since $r'_1 > \sqrt{R}$ and $r'_2 > R$, the side trade constraint (8) is always met. *Q.E.D.*

The most interesting observation of proposition 3 is of course that the stationary payoffs to consumers are higher than in the banking economy without bank transaction costs. The key to the paradox that a transaction costs for banks enables the bank economy to sustain higher welfare, is that transaction costs relaxes the interbank arbitrage constraint, so that higher levels of stationary investment are attainable. If interbank arbitrage can be prohibited altogether, the stationary welfare is only limited by the maximum amount that can be periodically invested in the technology.

5. Starting up the economy

Now that we have shown that in the unbounded OLG economy banks offer agents a higher expected utility than exchanges, a natural question to ask is how the economy develops when there is a starting date and a first generation.

5.1. The exchange economy

Because in a hypothetical first year, there are no one-year bonds for sale, agents of the first generation will either store their entire endowment or play LT . In equilibrium they need to be indifferent so that we have:

$$\begin{aligned} E[U]_{LT,0} &\equiv \lambda U((1-c)p_1 - c) + (1-\lambda)U((1-c)R - c) \\ &= E[U]_{Store,0} \equiv \lambda U(1) + (1-\lambda)U\left((1-c)\frac{R}{p_1} - c\right) \end{aligned} \quad (16)$$

Clearly there exists a unique p_1 which solves this equality. We shall denote it p_1^* .

Similarly, the second and consecutive generations need to be indifferent between playing LT and either storing or playing ST :

$$E[U]_{LT} = \max(E[U]_{ST}, E[U]_{Store}) \quad (17)$$

Where $E[U]_{LT}$ and $E[U]_{ST}$ are defined by (1) and $E[U]_{Store}$ is the same as in the second line of (16) but with p_t instead of p_1 . Clearly, also to (17) a unique solution exists. Since we have p_1^* , we can find $\mathbf{p}^* \equiv \{p_1^*, p_2^*, p_3^*, \dots\}$ by recursively solving (17).

It can be easily seen from (16) that the first market price is smaller than the stationary price: $p_1^* < p^*$. Because on the second date of a bounded economy one-year bonds are relatively cheap, the second generation prefers playing ST over storing. The equation which solves (17) for the second generation then gives $p_2^* > p^*$, which implies that the third generation may prefer storing over buying one-year bonds. If it does, the relevant equation to find p_3^* is equal to (16), with p_3 instead of p_1 . This means that if the third generation stores, all consecutive odd generations will, and we have a two-periodic equilibrium without full investment. If, however, the third generation does not store, and divides itself ST and LT players, then all consecutive odd generations will have ST players and the price will two-periodically converge to the stationary level, p^* .

We therefore have that in a bounded economy, one of three types of equilibrium obtains: (i) autarky, in which case the first generation, and hence consecutive generations, do not find it worthwhile to invest, (ii) a perpetually cyclical equilibrium in which the first and consecutive odd generations store, and (iii) a cyclical start-up that converges to the steady state equilibrium characterized in proposition 1.

To gain insight into the different types of equilibrium, we compute the equilibria for different parameter values. Figure 1 shows how, for $\lambda = \frac{1}{2}$ and $\gamma = 2\frac{1}{2}$, the equilibrium type depends on parameters c and R . Not surprisingly, for low values of R and high transaction costs c , it is more difficult to start up the economy.

We also see that there exists a wedge-shaped region where a full investment exchange equilibrium exists in the unbounded economy, but the economy with a starting date is stuck in autarky. This is due to the fact that the first generation that invests faces more payoff risk than a stationary generation. It is not surprising then that the size of the wedge increases in γ .

There is also a region where a bounded exchange economy gets stuck in cyclicity. We find that the size of this triangular region sharply decreases in γ . For $\lambda = \frac{1}{2}$, convergence always obtains for $\gamma > 3$, while for $\gamma < 2$ convergence only obtains for

very high values of R . Risk aversion thus helps an economy to converge to stationarity. The reason is that the risk averse agents of the first generation store more, which helps to increase p_1^* , (and decrease p_2^* , etc.).

Finally, there is a parameter region where the bounded economy is better off with transaction costs than without. Above the dashed line in figure 1, the presence of a transaction costs enables the exchange economy to converge to a one-periodic price p^* , while in the absence of transaction costs, the price process would be two-periodic $\{..., 1, R, 1, R, \dots\}$. Although total intergenerational consumption in the economy with transaction costs is lower, and the second and consecutive even start-up generations enjoy lower utility than in the transaction cost free economy, the reduced cyclicity causes long run welfare to be higher. Naturally, the region where the economy is better off with transaction costs increases in risk aversion parameter γ .

Figure 2 illustrates the convergence process for an economy with $\lambda = \frac{1}{2}$, $R = 2$, $c = 0.10$, and $\gamma = 4$. Not surprisingly, the speed to convergence increases in γ . To illustrate convergence we chose $\gamma = 4$ because for lower values of γ , convergence is significantly slower, so that either the convergence shape, or the zigzag pattern would be difficult to appreciate in a graph.

5.2. The intermediated economy

In section 4 we saw that in the stationary bank equilibrium, impatient one-year olds are paid partly from the proceeds of investments made one year before they were born. In the bounded economy, the first generation's impatient agents can only be paid from the deposits made by the second generation, which limits the amount of risk sharing. To reach the stationary level, the bank needs to build up a buffer during a start up phase. Qi (1994) and Bhattacharya *et al.* (1998) show that this can be achieved by 'holding out' early generations. A bank in the start up phase will invest as much as possible in the technology while offering early agents the utility they would obtain if they would be ostracized. To minimize the payouts in early periods, the bank sets r_1 as high as possible, and is constrained only by the rollover constraint $r_1^2 \geq r_2$. To meet its r_1 obligation on early dates, the bank may need to store. Appendix C gives the precise maximization problem of the bank in an economy with a starting date.

We find that for most parameter values, the bank can be started up within a single period, which means that it can already offer the second generation the stationary schedule $\{\sqrt{R}, R\}$. Not surprisingly, the length of the start-up phase decreases in the R/c ratio.

We also find that whenever a bank equilibrium exists, it can be started up. This is because there is no cyclical in an intermediated economy, and the bank's allocation is superior to the market allocation due to transaction costs.

Figure 3 gives the number of start up periods as a function of R and c , if $\lambda = \frac{1}{2}$ and $\gamma = 2\frac{1}{2}$. For comparison, the equilibrium regions in the exchange economy (see figure 1) are displayed in gray. As can be seen from the figure, there is a narrow parameter region for which there would be no trade in the market economy, but a bank equilibrium exists (and can be started up). Appendix C gives an illustration of such a bank.

6. Discussion

In the previous sections we characterized equilibrium allocations in simple models of pure exchange and intermediated economies, and showed that intermediaries can save on transaction costs by servicing a large diversified clientele of agents who face uncorrelated liquidity shocks and fixed transaction costs. In this section we conjecture that the key insights of our model continue to hold in more realistic models.

Under our first simplifying assumption agents can only become impatient on a single intermediary date. It is easy to see that if we assume more impatience dates before the technology makes a payoff, our results will be stronger. This is because with more impatience dates, more rebalancing would take place in exchange economy. Agents would continuously rebalance, slanting their portfolio to ever more short term securities as they get older (Vayanos, 1998; Vayanos and Vila, 1999). By catering to a continuum of agents, financial intermediaries do not need to rebalance their asset portfolios and thus save on transactions, as long as they continuously renew their clientele of depositors and investors.

A second unrealistic assumption concerns the gestation period of the production technology, which we assumed to equal the maximum life span of the agents. Moreover, in real world, there are several multiple production technologies, of

different gestation lags. It can be shown that if in the pure exchange economy long term projects attract investment, and at least one productive technology has a gestation lag longer than the minimum time until potential impatience, agents will rebalance their portfolios to shorter duration securities as they get older, and hence incur unnecessary transaction costs that can be avoided in the intermediated economy.

This will also be the case if the long term assets have maturities beyond agents' lives (as is the case of consols or equity investments). In this case, surviving agents in the exchange economy will, over their life cycle, rebalance their portfolio from predominately growth securities to high income securities. Our model formalizes this conventional wisdom, and shows that, in the presence of transaction costs, agents align consumption duration with portfolio duration, because long term securities fetch lower prices on intermediary dates.¹⁴

A third simplifying assumption in our model is that of no payoff risk. A natural extension to our model is to consider a long term technology that offers a stochastic dividend. It can be shown that also in such a model newborn agents will buy a mix of long and short term securities and rebalance their portfolios over their lifecycle.¹⁵ In the intermediated economy on the other hand, mutual funds will offer their investors state dependent redemption schedules (based on *net asset values*), that *ex-ante* offer them higher expected utility than the market economy due to the avoidance of excessive dividend reinvestment and maturity rebalancing.

Finally, we assume that agents' liquidity shocks are independent, and that there is no aggregate liquidity risk. However, it can be shown that our results continue to hold with aggregate risk, as long as agents' liquidity shocks are less than perfectly correlated. In this case, intermediaries will hold cash buffers alongside a portfolio of

¹⁴ This intuition was first described in Thaler and Shefrin (1981), who attributed the observed consumption/cashflow duration matching to self-control. Notice that in our model intermediaries do not have a comparative advantage in life cycle rebalancing driven by tax reasons (Miller, 1977) or risk preferences. In any case, whether life cycle risk rebalancing is optimal is still an open question. See Merton (1969) and Samuelson (1969) and references thereof.

¹⁵ Maturity rebalancing in the face of liquidity risk is studied by Eisfeldt (2007).

long term and short term assets. The optimal cash buffer depends mostly on the covariances of depositors' liquidity shocks.¹⁶

In our model we assume away aggregate risk so as to best illustrate the main trust of this paper, which is that through intergenerational pooling of depositor clienteles, intermediaries are able to cancel rebalancing transaction that would occur in the free market. Correlated liquidity shocks and aggregate flow risk obfuscate this advantage but do not eliminate it.

7. Summary and conclusions

In this paper we formalize the widely held intuition that the comparative advantage of financial intermediaries lies in their ability to internalize transaction costs by holding buffers of assets with different durations.

In a simple model with shoe leather costs in which agents face consumption risk, excessive trade obtains in the pure exchange economy because equilibrium prescribes late dying agents to reinvest dividends and incur unnecessary transaction costs. We show that an intermediary that offers demand deposits can internalize the rebalancing trades, and improve welfare.

If intermediaries incur transaction costs too, the welfare attained in the banking economy increases further, due to the increased barrier against interbank arbitrage, which enables a higher stationary investment level.

Our model also shows that unlike the intermediated economy, the market economy is inherently cyclical. Finally our model shows that, in the absence of risk, the yield curve is downward sloping, because longer lived assets internalize less per-period transactions costs.

¹⁶ Edgeworth (1888) first discussed the bank's cash-inventory problem in the presence of stochastic net withdrawals.

Appendix A: Proofs

Proof of proposition 1

We first show that there exists a unique one-periodic equilibrium. Substituting p for p_t and p_{t+1} in equation (1) and rewriting gives:

$$\lambda \left\{ U((1-c)p-c) - U\left((1-c)\frac{R}{p}-c\right) \right\} + (1-\lambda) \left\{ U((1-c)R-c) - U\left((1-c)\frac{R^2}{p^2}-c\frac{R}{p}-c\right) \right\} = 0 \quad (A1)$$

Differentiating shows that the lhs of (A1) is continuously increasing in p for all relevant parameter values. The derivative of the first term is positive. The derivative of the second term of (A1) is:

$$(1-\lambda) \left(2\frac{(1-c)R^2}{p^3} - \frac{cR}{p^2} \right) U' \left((1-c)\frac{R^2}{p^2} - c\frac{R}{p} - c \right) \quad (A2)$$

which is positive unless $p > \frac{2(1-c)R}{c}$. The latter inequality cannot hold in equilibrium because if it would, nobody would buy one-year bonds.

Also, the lhs of (A1) is positive if $p = \sqrt{R}$ and negative for $p = \frac{\sqrt{c^2 + 4R(1-c)^2} - c}{2(1-c)}$.

This proves that there is a unique one periodic equilibrium, and that it lies between abovementioned values.

We still need to prove that no two-periodic equilibrium exists. A potential two-periodic equilibrium solves the following system of equations:

$$\lambda \left\{ U((1-c)p_j-c) - U\left((1-c)\frac{R}{p_i}-c\right) \right\} + (1-\lambda) \left\{ U((1-c)R-c) - U\left((1-c)\frac{R^2}{p_i p_j} - c\frac{R}{p_j} - c \right) \right\} = 0 \quad (A3)$$

And

$$\lambda \left\{ U((1-c)p_i-c) - U\left((1-c)\frac{R}{p_j}-c\right) \right\} + (1-\lambda) \left\{ U((1-c)R-c) - U\left((1-c)\frac{R^2}{p_j p_i} - c\frac{R}{p_i} - c \right) \right\} = 0 \quad (A4)$$

Assume $p_i > p^*$, then clearly, from both (A3) and (A4), we must have $p_j < p^*$.

Consider the lhs's of (A3) and (A4) functions of p_j , for given $p_i > p^*$. The functions cross at p_i , and increase continuously. The derivatives are:

$$\frac{\partial \text{lhs}(A3)}{\partial p_j} = \lambda(1-c)U'((1-c)p_j-c) + (1-\lambda) \left(\frac{(1-c)R^2}{p_i p_j^2} - c\frac{R}{p_j^2} \right) U' \left((1-c)\frac{R^2}{p_i p_j} - c\frac{R}{p_j} - c \right) \quad (A5)$$

$$\frac{\partial lhs(A4)}{\partial p_j} = \lambda \frac{(1-c)R}{p_j^2} U' \left((1-c) \frac{R}{p_j} - c \right) + (1-\lambda) \frac{(1-c)R^2}{p_i p_j^2} U' \left((1-c) \frac{R^2}{p_j p_i} - c \frac{R}{p_i} - c \right) \quad (A6)$$

Clearly $\frac{\partial lhs(A4)}{\partial p_j} > \frac{\partial lhs(A3)}{\partial p_j} \forall p_j < p^*$, which proves that for any $p_i > p^*$, no p_j exists

that simultaneously satisfies equations (A3) and (A4).

The periodic investment $\theta^* = \frac{(1-c)p^* + (1-\lambda)(R - c(R + p^*))}{(1-c)(\lambda p^* + 1)p^* + (1-\lambda)(R - c(R + p^*))}$, follows from rewriting the market clearing condition (2).

Proof of Proposition 2

The optimal bank allocation follows immediately from solving (5) subject to (7) and (8). The expression for the periodic investment, $y^* = (1-c) \frac{\lambda \sqrt{R} + (1-\lambda)R - 1}{R-1}$, follows from rewriting (6).

Appendix B: Variable Transaction Costs

We now investigate the exchange economy equilibrium in the case of variable transaction costs. In this case the transaction costs are cV , where V is the value of the goods transported to the circle's midpoint, at the midpoint. This means that newborns can spend $(1-c)$ on either one-year or two year bonds, and a patient agent who sells x one year bonds for p , can spend $\frac{x}{p}(1-c)$ on buying new bonds. In such an economy, newborns will buy both types of bonds. If they become impatient they sell the two-year bonds before they mature (as one-year bonds), and if they stay patient they roll over the one-year bonds. Denote y_t the amount that newborns invest in two year bonds. Their objective function is then:

$$\max_{y_t} \lambda U \left(\left((1-c-y_t) \frac{R}{p_t} + y_t p_{t+1} \right) (1-c) \right) + (1-\lambda) U \left(\left((1-c-y_t)(1-c) \frac{R^2}{p_t p_{t+1}} + y_t R \right) (1-c) \right) \quad (B1)$$

The first order condition of this maximization problem is:

$$\left(\frac{R}{p_t} - p_{t+1} \right) \lambda U'(C_1^*) = \left(R - \frac{R^2(1-c)}{p_t p_{t+1}} \right) (1-\lambda) U'(C_2^*) \quad (B2)$$

In a one-periodic stationary equilibrium both (B2) with $p_t = p_{t+1} = p^*$ and $y_t = y^*$ must hold together with the market clearing condition:

$$p^* = \frac{(1-y^*-c) + (1-\lambda)(1-y^*-c) \frac{R}{p^*} (1-c)}{y^* \lambda} \quad (B3)$$

A unique solution exists to these two equations. This can be seen by rewriting (B3):

$$y^* = \frac{(1-c)p^* + (1-\lambda)(1-c)^2 R}{p^{*2} \lambda + p^* + (1-\lambda)R(1-c)} \quad (B4)$$

Substituting this in (B2), and rewriting gives:

$$(R - p^{*2}) \lambda U'(C_1^*) = \frac{R}{p^{*2}} (p^{*2} - R(1-c)) (1-\lambda) U'(C_2^*) \quad (B5)$$

With

$$C_1^* = p^* (1-c)^2 \frac{\lambda R + p^* + (1-\lambda)(1-c)R}{p^{*2} \lambda + p^* + (1-\lambda)(1-c)R} \quad (B6)$$

And

$$C_2^* = (1-c)^2 R \frac{p^* + (1-c)R}{p^{*2}\lambda + p^* + (1-\lambda)R(1-c)} \quad (\text{B7})$$

It can be shown that for $p^* = \sqrt{R}$, the rhs of (B5) is positive (and clearly the lhs is zero). As we let p^* decrease, the rhs decreases, while the lhs increases so that a unique p^* exists that solves (B2) and (B3). This proves that also with variable transactions costs, and pure strategies, a unique noncyclical market equilibrium exists. Because the derivation is slightly more complicated and less intuitive, we opted for modelling the transaction costs be fixed.

Appendix C: Starting up the bank

First we observe that to minimize the time to stationarity, banks will maximize investment in the long term asset in early years, until the stationary investment y^* is reached. In the following denote y_t the bank's investment at t , s_t the investment in the storage technology and $\{r_1^t, r_2^t\}$ the payoffs distributed on date t . Let T be the time when $y_t = y^* = (1-c) \frac{\lambda\sqrt{R} + (1-\lambda)R-1}{R-1}$. Clearly at T , the bank can offer a schedule $\{\sqrt{R}, R\}$ per deposited unit of consumption good. The maximization problem during the start-up phase is then:

$$\min_{\{r_1^t, r_2^t\}_{t=1..T}} T \quad (C1)$$

$$\text{Subject to: } y_0 = s_0 = r_2^1 = 0 \quad (C2)$$

$$(1-c)(\lambda r_1^t + (1-\lambda)r_2^t) + y_t + s_t \leq 1-c + Ry_{t-2} + s_{t-1} \quad \forall t > 0, \quad (C3)$$

$$\lambda U((1-c)r_1^t - c) + (1-\lambda)U((1-c)r_2^{t+1} - c) \geq \max(U(1), U((1-c)(\lambda + (1-\lambda)R) - c)) \quad \forall t > 0, \quad (C4)$$

$$\text{and } r_1^t r_1^{t+1} \geq r_2^{t+1} \quad \forall t > 0 \quad (C5)$$

This maximization problem can be solved by letting the budget constraint (C3), participation constraint (C4) and roll-over constraint (C5) bind until T .

Table 1 illustrates the start up phase of such a bank in an economy where an exchange will not open: If $R = 1.33$, $\gamma = 2.5$ and $c = 0.10$. To see that an exchange equilibrium does not exist, solve (1) with the above parameter values. The solution gives $p^* = 1.1348$. If we now compute the agents' expected utility in with this p^* , we find it to be less than $U(1)$, the expected utility in autarky.¹⁷ Table 1 shows that in a world with the above parameter values a bank equilibrium *does* exist, and can be started up in five years.

¹⁷ With $U(C) = -\frac{2}{3}C^{-\frac{3}{2}}$, we find $E[U]_{LT} = E[U]_{ST} = -0.6709$, while $U(1) = -0.6667$.

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Figure 1: Equilibria in a Bounded Exchange Economy

We compute the equilibrium price prices in a bounded OLG Diamond Dybvig economy with $\lambda = \frac{1}{2}$ and where agents have utility functions given by $U(C) = -\frac{2}{3}C^{-\frac{3}{2}}$ (CRRA parameter $\gamma = 2.5$), for varying fixed transaction costs c , and asset payoffs R . The areas between the black lines give the equilibrium type. Above the gray line a one-periodic stationary equilibrium exists in the unbounded economy. The dashed gray line denotes the area where overall welfare is higher in the bounded exchange economy with transaction costs than without transaction costs.

Figure 2: Market Equilibrium Start-up in a Bounded Economy

We compute the equilibrium prices in a bounded OLG Diamond Dybvig economy with transaction costs with $\lambda = \frac{1}{2}$, $R = 2$, $c = 0.10$, and agents' utility function is given by $U(C) = -\frac{1}{3}C^{-3}$ (CRRA parameter $\gamma = 4$). The graph gives the equilibrium price of one year bonds as a function of time.

Figure 3: Start-up Bank Equilibria in a Bounded Economy

We compute the bank allocations in a bounded OLG Diamond Dybvig economy with $\lambda = \frac{1}{2}$, $R = 2$, $c = 0.10$, and agents' utility function is given by $U(C) = -\frac{2}{3}C^{-\frac{3}{2}}$ (CRRA parameter $\gamma = 2.5$), for varying c and R . The areas between the black lines give the minimum number of periods it takes to start up the stationary bank equilibrium. Below the bottom black line, no bank equilibrium exists. In the region immediately above this line the bank's start up phase is at least three periods. In the background are the demarcation lines - in gray - for the exchange economy equilibria.

Table 1: Example of a Bank Start-up

For an economy with $\lambda = \frac{1}{2}$, $R = 1.33$, $\gamma = 2.5$ and $c = 0.10$, we compute the payoff schedule for a competitive bank. To build an asset buffer it offers early generations their reservation utility, obtained in Autarky. The first two columns give the promised payoffs, per unit of consumption good deposited. The third-last column equals the second column of the previous row multiplied by $\lambda(1-c)$. The inflow from investment equals the amount stored in the previous period plus the amount invested two periods earlier multiplied by R .

t	r_1	r_2	E[U]	Goods Inflow			Goods Outflow				
				From newborns	From investment	Total in	Invest	Store	Out to impatientes	Out to patients	Total out
0	1.1462	1.3139	-0.6667	0.9		0.9000	0.6256	0.2744			0.9000
1	1.1462	1.3139	-0.6667	0.9	0.2744	1.1744	0.6313	0.0273	0.5158		1.1744
2	1.1462	1.3139	-0.6667	0.9	0.8656	1.7656	0.6389	0.0197	0.5158	0.5912	1.7656
3	1.1462	1.3139	-0.6667	0.9	0.8656	1.7656	0.6490	0.0095	0.5158	0.5912	1.7656
4	1.1553	1.3400	-0.6525	0.9	0.8656	1.7656	0.6586		0.5158	0.5912	1.7656
5	1.1576	1.3400	-0.6513	0.9	0.8697	1.7697	0.6586		0.5199	0.5912	1.7697
6	1.1576	1.3400	-0.6513	0.9	0.8825	1.7825	0.6586		0.5209	0.6030	1.7825
7	1.1576	1.3400	-0.6513	0.9	0.8825	1.7825	0.6586		0.5209	0.6030	1.7825
8				0.9	0.8825	1.7825	0.6586		0.5209	0.6030	1.7825