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Cash-in-the-Market Pricing in a Model with Money and Over-the-Counter Financial Markets

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Abstract

Entrepreneurs need cash to finance their real investments. Since cash is costly to hold, entrepreneurs will underinvest. If entrepreneurs can access financial markets prior to learning about an investment opportunity, they can sell some of their less liquid assets for cash and, as a result, invest at a higher level. When financial markets are over-the-counter, the price that the entrepreneur receives for the assets that he sells depends on the amount of liquidity (cash) that is in the OTC market: Greater levels of liquidity lead to higher asset prices. Since asset prices are linked to liquidity, they can fluctuate over time even though asset fundamentals are fixed. Bid and ask prices naturally arise in an OTC market and the bid-ask spread is negatively correlated with asset returns when changes in asset prices are not related to changes in the OTC market structure. An increase in inflation widens bid-ask spreads and *decreases* asset prices.

1 Introduction

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In the world of Modigliani and Miller, how an entrepreneur finances his investments is largely irrelevant, whether it be by cash, debt or equity. When there are frictions, however, a pecking order among the financing alternatives may emerge. For example, if an entrepreneur is better informed about his opportunities than is the market, the cheapest way to finance is by cash (or money) followed by debt and then equity, (Myers and Majluf 1984). In this paper, we appeal to other frictions—lack of commitment and lack of record keeping—that imply the only feasible finance instrument is money (Kocherlakota 1998 and Kiyotaki and

Moore 2001).[1] As a result, entrepreneurs' investments will be inefficiently low. This follows because entrepreneurs must accumulate money prior to investing, but money is costly to hold and investment opportunities are uncertain. The existence of financial markets may improve matters. In particular, if entrepreneurs can access financial markets after receiving an encouraging signal regarding a potential imminent investment opportunity, then they can sell some of their non-monetary assets for money and undertake larger—and more efficient—investments. Once again, owing to frictions, the financial markets that entrepreneurs access are not "perfectly competitive." If financial markets are over-the-counter (along the lines of Duffie, Garleanu and Pederson 2005), then the price that the entrepreneur receives for his assets may depend on the amount of liquidity that is available in the market. A more liquid financial market may give rise to higher asset prices and, as a result, more efficient investments by the entrepreneur. In this paper, we present and analyze a dynamic general equilibrium model that seeks to understand the basic interactions and relationships between real investments, assets prices and money.

The basic model is a standard one in monetary economics (Lagos and Wright 2005). Money is essential and the framework is designed to address policy issues, e.g., the impact that a change in inflation has on economic activity. To this model, we add an over-the-counter financial market. Following Duffie, Garleanu and Pederson 2005 and Lagos and Rocheteau 2009, the hallmarks of our OTC financial market are (1) a middleman—the dealer—who intermediates asset trade between 'buyers' and 'sellers' and (2) bargaining determines asset prices. Since the dealer has bargaining power, bid and ask prices will naturally arise. The sellers of assets are the fraction of entrepreneurs, σ, that have investment opportunities (and need more money) and the buyers are the fraction $1-\sigma$ that don't. In addition to bargaining powers of the various agents, asset prices will depend on the amount of liquidity that is available in the OTC financial market—i.e., money of the $1-\sigma$ entrepreneurs that do not have an investment opportunity. Like Allen and Gale 2004 and 2007, there is cash-in-the-market" pricing of assets; higher levels of liquidity are associated with higher asset prices. (Unlike Allen and Gale, there actually is "cash" in the market as opposed to short term real assets.) Each period σ is drawn from a probability distribution which implies that the amount of liquidity that is available in the OTC market varies over time. Hence, asset prices will fluctuate over time even though asset fundamentals are unchanging. The amount of

[1] In Kiyotaki and Moore 2001, if the collateral constraint is sufficiently tight, then money emerges as a means of payment.

cash-in-the-market has implications for the bid-ask spread: Higher levels of liquidity in the OTC financial market leads to lower bid-ask spreads. Hence, changes in liquidity in the OTC market brought about by either changes in σ or changes in inflation will affect asset prices, asset returns and bid-ask spreads. The model predicts a positive relationship between asset returns and bid-ask spreads, and this relationship is well documented in the literature, (e.g., Amihud and Mendelson 1986, and Amihud, Mendelson, Pedersen 2005). The model also predicts a *positive* relationship between inflation and asset returns or, equivalently, a negative relationship between inflation and asset prices. This prediction is consistent with the observation that periods of low inflation and low nominal interest rates are usually associated with periods of high asset prices (Christiano, Ilut, Motto and Rostagno 2010).

This paper mainly contributes to the literature on asset pricing in OTC markets that starts with Duffie, Garleanu and Pederson 2005. Lagos and Rocheteau 2008 relax their indivisible asset assumption. Both papers assume that assets can be purchased by "transferable utility," or that buyers purchase the asset by producing a numeraire good that enters the seller's utility function in an additive and linear manner. Hence, liquidity—the object that buys assets—can be interpreted as being is potentially in infinite supply. This is unappealing. To limit the amount of liquidity, Geromichalos and Herrenbrueck 2012 and Lagos and Zhang 2013, like this paper, embed an OTC financial market in a monetary model. Geromichalos and Herrenbrueck 2012 have their buyers and sellers directly meeting (with some probability) in the OTC financial market—there is no dealer—which implies there is no bid-ask spread. In Lagos and Zhang 2013, buyers and sellers can either meet one another or a dealer in the OTC financial market, and dealers have access to a competitive interdealer market where they can off load their positions. Clearly, in both of these papers, like this one, asset prices deviate from their fundamental values. However, neither of these papers features a phenomenon that resembles cash-in-the-market pricing as an equilibrium outcome. As well, a novel prediction of our model is that OTC asset prices and inflation are negatively correlated. In Geromichalos and Herrenbrueck 2012 and Lagos and Zhang 2013, the effect of inflation on OTC asset prices is ambiguous. We attribute this to the differences between the OTC bargaining environments in the three papers.

The paper is organized as follows. The next section presents the model environment. In Section 3, the bargaining model is presented. Interestingly, most of the important insights regarding cash-in-the-market pricing can be understood analyzing the bargaining model, independent of general equilibrium considerations. Section 4 derives the value functions of agents and solves the general equilibrium model. The relationship between asset prices, asset return and the bid-ask spreads is characterized when inflation and agents' bargaining powers are changed in Section 5. Section 6 concludes.

2 Environment

Time is discrete and continues forever. Each time period has 3 subperiods: a financial market, FM, followed by a decentralized real investment market, DM, and finally by a competitive rebalancing market, CM. There is a unit measure of infinitely-lived agents called *entrepreneurs* that participate in all subperiods/markets; a unit measure of infinitely-lived agents called investment good producers, or simply *producers*, that participate in the DM and CM; and an infinitely-lived agent called a *dealer* that participates only in the FM. Financial services are produced in the FM; real investment goods are produced in the DM; and a numeraire consumption good is produced in the CM.

There are 2 assets, money and a real asset. The quantity of money, M_t, grows at constant gross rate μ so that $M_{t+1} = \mu M_t$. New money is injected—$\mu > 1$—or withdrawn—$\mu < 1$—by lump-sum transfers $T_t = M_t(\mu - 1)$ in the CM. Let p_t^m represent the amount of the numeraire good that one unit of money buys in the CM of period t and $z_t = p_t^m m_t$ is real cash balances (measured in terms of the date t numeraire good). Since M_t grows at a constant rate, in the steady state $p_{t+1}^m M_{t+1} = p_t^m M_t$, which implies that $p_t^m / p_{t+1}^m = \mu$. Each real asset provides a single dividend payout of δ numeraire goods and then "dies."

Entrepreneurs need money to purchase real investment goods in the DM. To this end, they accumulate money balances in the CM. At the beginning of the FM, entrepreneurs learn if they will have an investment opportunity in the subsequent DM. Those who get this opportunity would like to hold more money balances and less real assets, and those who do not, would like to hold less money balances and more real assets. A dealer operates an over-the-counter market that allows entrepreneurs to reallocate their money and real asset holdings. Entrepreneurs who have investment opportunities enter the DM and search for them. Those who are successful undertake the investment and consume the investment payoff. All entrepreneurs and producers re-enter the CM to consume and rebalance their money holdings, and so on.

More formally, in period $t - 1$, entrepreneurs exit the CM with m_t units of money and ownership of a_{t-1} units of the real asset. At the beginning of period t, entrepreneurs enter the FM, and the following sequence of events occur:

- each unit of real assets pays a dividend of δ, which the asset owner consumes;
- all entrepreneurs receive ownership of $\bar{a}$ new assets, where each asset pays a single dividend payment δ at the beginning of period $t+1$;
- entrepreneurs learn if they get investment opportunities in the subsequent DM; a fraction σ get them and a fraction $1-\sigma$ do not;
- all entrepreneurs contact the dealer;
- the dealer intermediates asset trades between entrepreneurs who have investment opportunities and those who don't, where asset ownership is exchanged for money.

As in Lagos and Rocheteau (2009), we assume that entrepreneurs can only buy and sell assets in the FM through a dealer.[2] In the FM and DM we must distinguish between the measure σ of entrepreneurs who get investment opportunities (and want to sell assets) and the measure $1-\sigma$ of entrepreneurs who do not (and want to buy assets). Call the former *investors* and the latter *liquidity providers.* The dealer bargains with investors and liquidity providers to determine the prices at which assets are bought and sold, as well as the quantities of assets that are bought and sold. (The bargaining environment is described in Section 3.) The dealer buys τ_t^b assets from an investor at a unit price of p_t^b, where p_t^b is the amount of assets that the dealer purchases per unit of money.[3] One can interpret $p_t^m/p_t^b \equiv P_t^b$ as the real *bid price*—the amount of real balances the dealer needs to buy one unit of the asset. The dealer sells τ_t^a assets to a liquidity provider at a unit price of p_t^a, where p_t^a is the amount of assets that a liquidity provider receives per unit of money. One can interpret $p_t^m/p_t^a \equiv P_t^a$ as the real *ask price*—the amount of real balances obtained by the dealer for one unit of the asset.

Investors enter the DM of period t and are randomly matched with producers.[4] The probability that an investor is matched with a producer is σ_D. Matched investors and producers bargain over the amount of the investment good, q_t, the producer exchanges for the

[2] Duffie, Garleanu and Pedersen (2007) assume that entrepreneurs can also directly meet one another and trade.

[3] Both Lagos and Rocheteau (2009) and Duffie, Garleanu and Pedersen (2007) are non-monetary models, where non-investors purchase assets with with transferable utility.

[4] Liquidity providers do not enter the DM since they do not have any investment opportunities available to them.

investor's real balances, τ_t^m. The cost of producing q_t units of the investment good is $c\left(q_t\right)$. For simplicity we assume that $c\left(q_t\right) = q_t$. The investor invests the good and consumes the output of the investment, $q_t R$, $R \geq 1$, which he values as $u(q_t R)$, where $u' > 0$ and $u'' < 0$. The investment output is perishable and is realized in the DM where the investment was undertaken. We assume that the investor makes a take-it-or-leave-it offer to the producer, which means that the investor can extract all of the match surplus, where the match surplus is given by $u(qR) - q$. Match surplus is maximized at q^*, where q^* solves $Ru'(q^* R) = 1$. For convenience, and without loss of generality, we assume that $R = 1$.

When investors and liquidity providers enter the CM of period t they do not know if they will get investment opportunities in the DM of period $t+1$. They do know, however, that in period $t+1$ a fraction σ of them will get investment opportunities in the subsequent DM and that the probability distribution function is $f(\sigma)$, where $\int_0^1 f(\sigma) = 1$. Conditional on σ, the probability that any particular entrepreneur gets an investment opportunity in the next DM is σ. Entrepreneurs can produce and consume in the CM. Let x_t represent the CM numeraire good CM and ℓ_t the amount of labor used to produce it. One unit of labor produces one unit of the numeraire good. An entrepreneur's utility of consuming x_t units of the numeraire good is linear and equal to x_t; his disutility of labor is linear and equal to ℓ_t. Hence, the entrepreneur's preferences over the consumption and production of the numeraire good is $x_t - \ell_t$. The numeraire good is perishable.

The producer is active only in the DM and CM. In the CM the producer can consume but cannot produce. The utility associated with consuming x_t units of the CM good is linear and equal to x_t. Hence, the producer's preferences in period t are described by $x_t - q_t$, where q_t is the amount of the investment good produced in the DM. Given the DM bargaining protocol—the investor makes a take-it-or-leave-it offer to the producer—all producers, whether they are matched or unmatched, get utility equal to zero in each period t. (A matched producer receives money in the DM which he uses to buy the numeraire good in the CM.)

The dealer is only active in the FM. The dealer's preferences are linear in dividends and, hence, his objective is to maximize real asset holdings in each period.

Real assets "reside" in the FM in the sense that entrepreneurs do not carry the real assets into the DM and CM. All agents are anonymous in the DM and CM. In the FM there exists a "book entry system" that verifies agents' identities and documents asset ownership—who owns how many assets. The book entry system can issue a physical claim regarding asset ownership to entrepreneurs, but these claims can be costlessly counterfeited. This, coupled with an absence of record keeping for agents in the DM and CM subperiods, implies that only money will be used as a medium of exchange in those subperiods. (Money cannot be counterfeited.) This is why entrepreneurs value and accumulate money balances in the CM, and why producers are willing to accept it in the DM. Since the book entry system can only record asset ownership,[5] money is also needed as a medium of exchange to buy assets in the FM.

3 Bargaining in the FM

Bargaining between the dealer, investors and liquidity providers occurs in two distinct stages. In the first stage, the dealer and σ investors are matched and bargain over the bid price and quantity, $\left(P^b, \tau^b\right)$; in the second stage, the dealer and $1-\sigma$ liquidity providers are matched and bargain over the ask price and ask quantity, (P^a, τ^a).[6] It is convenient to think of the dealer as having a "family" in $[0,1]$, where family members do all the bargaining and act to maximize the real asset holdings of the dealer. The family interpretation allows us to assume that in the first stage σ family members are matched one-on-one with the σ investors, and in the second stage the remaining family members are matched one-on-one with the $1-\sigma$ liquidity providers. When it leads to no confusion, we will refer to the family member as the dealer (since, after all, the family member represents the interests of the dealer).

The bargaining outcome in each match—$\left(P^b, \tau^b\right)$ in the first stage investor-dealer match and (P^a, τ^a) in the second stage liquidity provider-dealer match—is determined by the (Kalai) proportional bargaining solution. In the first stage, an investor receives a θ share of the investor-dealer match surplus and the dealer receives a $1-\theta$ share. Similarly, in the second stage, the liquidity provider receives a fraction θ of the liquidity provider-dealer match surplus, while the dealer gets $1-\theta$. If S represents the surplus that is generated in a representative investor-dealer match, then the dealer is able to claim $1-\theta$ of the *total* stage 1 surplus, σS. In the second stage, the dealer splits $\sigma(1-\theta)S$ with liquidity providers. In particular, the dealer receives $1-\theta$ of this surplus and *each* liquidity provider receives a $\theta/(1-\sigma)$ share. Hence, when the proportional bargaining solution is applied for each match at each stage, an investor receives θS, a liquidity provider receives $\theta(1-\theta)S\sigma/(1-\sigma)$, and the dealer receives $(1-\theta)^2 S\sigma$.

[5]It cannot not, for example, document owners and issuers of IOU's.

[6]When it does not cause confusion, we will suppress the time, t, subscript on variables.

The dealer (or its family members) cannot observe money holdings of investors or liquidity providers prior to being matched. Once a dealer family member is matched, he can observe the real balance holdings of the agent for which he is matched—either an investor in the first stage or an liquidity provider in the second stage—but cannot observe real balances of other investors or liquidity providers. Our analysis focuses on symmetric steady-state equilibria, which implies that, in equilibrium, all entrepreneurs hold the same real balances, z, in each period t. When the family member dealer bargains in the first stage with an investor, he holds the (equilibrium) beliefs that all other investors' and liquidity providers' real balances are equal to z. We assume that $z < q^*$. If $z \geq q^*$, the first stage bargaining problem is irrelevant: the investor has sufficient real balances to extract the maximum surplus in the DM if he is matched and, as a result, has no (strict) incentive to sell his assets in the FM.[7] We focus on the case where the asset endowment of the investors, $\bar{a}$, is "large" in the sense that the investor's demand for real balances are never constrained by his real asset holdings. (In an Appendix we examine the case where $\bar{a}$ is "small.")

Suppose that in a first stage investor-dealer match, the negotiated bid price and bid quantity is (P^b, τ^b). The dealer does not *pay* for the τ^b assets in the first stage as this is not feasible—the dealer does not have any real balances at that time. Instead, in the first stage the family member dealer buys the assets from the investor on consignment, as in Rubinstein and Wolinsky 1986. The "contract" (P^b, τ^b) is then financed in the second stage by the family member dealers that bargain with liquidity providers. Specifically, in the second stage the dealer will (in equilibrium) receive $P^b\tau^b$ real balances from liquidity providers in exchange for assets. Upon receiving these real balances, the dealer transfers them to the investor and thus fulfils the stage 1 contract (P^b, τ^b). We assume that dealer can commit to pay back investors and that the stage 1 bargain (P^b, τ^b) is not subject to renegotiation. If the dealer does not receive $P^b\tau^b$ real balances from liquidity providers—because, for example, liquidity providers accumulated less than the equilibrium level of real balances, z, in the previous CM—then the bid contract (P^b, τ^b) specifies that the dealer buy as many of the investors assets that he can at the unit price P^b and return those assets that cannot be financed.

If each first stage investor-dealer match negotiates a bid price and bid quantity (P^b, τ^b), then the *total* amount of assets that the dealer purchases from investors is $\sigma\tau^b$ and for which he agrees to pay $P^b\tau^b\sigma$. At the beginning of the second stage, before matching occurs,

[7] If the growth rate of money is greater than that given by the Friedman Rule, i.e., $\mu > \beta$, then, in fact, $z < q^*$.

these assets are equally divided among the $1-\sigma$ family members who will bargain with the liquidity providers. Therefore, in the second stage, each the dealer family member brings $\tau^b\sigma/(1-\sigma)$ assets to his liquidity provider-dealer match. This implies that the surplus to be split in a typical liquidity provider-dealer match is

$$(\beta\delta - P^b)\tau^b\sigma/(1-\sigma).$$

Since the dealer must pay P^b for each asset that he buys from the investor and the value of the asset is $\beta\delta$, the surplus per asset purchased by the dealer is $\beta\delta - P^b$. (Recall that an asset pays a dividend δ at the beginning of the next FM.) The (equilibrium) match surplus that an investor and dealer receive can be expressed as, respectively,

$$\theta\left(\beta\delta - P^b\right)\tau^b\sigma/(1-\sigma) = \left(\beta\delta - P^a\right)\tau^a \tag{1}$$

and

$$(1-\theta)\left(\beta\delta - P^b\right)\tau^b\sigma/(1-\sigma) = \beta\delta\left(1 - \frac{P^b}{P^a}\right)\tau^b\sigma/(1-\sigma). \tag{2}$$

The left side of (1) is a liquidity provider's share of the match surplus and the right side expresses this surplus in terms of an ask price and ask quantity. The left side of (2) is the dealer's share of the match surplus. The dealer keeps $\tau^b\sigma/(1-\sigma) - \tau^a$ of the assets that an investor sells (per liquidity provider), resulting in a payoff of $\beta\delta[\tau^b\sigma/(1-\sigma) - \tau^a]$ to the dealer. Since, in equilibrium, the real balances received by investors equals the real balances given up by liquidity providers, i.e., $\sigma P^b\tau^b = (1-\sigma)P^a\tau^a$, the dealer's payoff can also be expressed as the right side of (2).

For a given bid price and bid quantity, (P^b, τ^b), the *equilibrium* ask price is obtained by rearranging (2),

$$P^a = \frac{P^b\beta\delta}{\theta\beta\delta + (1-\theta)P^b}, \tag{3}$$

and the equilibrium ask quantity is obtained by rearranging (1) so that we get

$$\tau^a = \frac{\theta\left(\beta\delta - P^b\right)}{\beta\delta - P^a}\tau^b\sigma/(1-\sigma)$$

or

$$\tau^a = \frac{\theta\beta\delta + (1-\theta)P^b}{\beta\delta}\tau^b\sigma/(1-\sigma). \tag{4}$$

Let's now move to stage 1 bargaining. Since we assume that the investor's asset holdings are "large," in any equilibrium, the amount of real balances that an investor receives in the

FM from selling assets, $P^b\tau^b$, equals $\min\{\tilde{z}, q^* - z\}$, where $\tilde{z} = z(1-\sigma)/\sigma$ represents the total amount of liquidity providers' real balances per investor. (Alternatively, $\tilde{z}$ represents the maximum amount of real balances that an investor can receive from the dealer.) If $\tilde{z}$ is sufficiently large so that $z+\tilde{z} \geq q^*$, then q^*-z real balances will be transferred to the investor from asset sales; if $z+\tilde{z} < q^*$, then the maximum available real balances $\tilde{z}$ will be transferred to the investor from asset sales. It should be clear that if $P^b\tau^b < \min\{\tilde{z}, q^* - z\}$ agents are leaving surplus on the table. So, one should *not* think that the first stage bargaining is over the total amount of real balances that the investor will receive as this is predetermined, i.e., it equals $\min\{\tilde{z}, q^* - z\}$. Instead, one should interpret bargaining in the first stage as being over amount of assets that the investor has to give up to in order to receive $\min\{\tilde{z}, q^* - z\}$ real balances.

The surplus that the investor receives from selling τ^b assets at price P^b, where $P^b\tau^b = \min\{\tilde{z}, q^* - z\}$, is

$$\sigma_D u\left(z + \min\{\tilde{z}, q^* - z\}\right) + (1-\sigma_D)\left(z + \min\{\tilde{z}, q^* - z\}\right) - \beta\delta\tau^b \\ - \left[\sigma_D u(z) + (1-\sigma_D) z\right]. \quad (5)$$

The second line is (minus) the expected DM payoff that the investor receives if he does not sell any assets in the FM; the first line is the expected DM payoff if he sells assets in the FM minus the loss in the value of dividends associated with selling τ^b in the FM. The investor's surplus (5) by construction is equal to θ times the match surplus. Recall that the surplus that the dealer obtains from this match is equal to $\left(\beta\delta - P^b\right)\tau^b$, which represent $1-\theta$ times the match surplus. Therefore, we have

$$\sigma_D[u\left(z + \min\{\tilde{z}, q^* - z\}\right) - u(z)] + (1-\sigma_D)\min\{\tilde{z}, q^* - z\} - \beta\delta\tau^b \\ = \frac{\theta}{1-\theta}\left(\beta\delta - P^b\right)\tau^b, \quad (6)$$

which is one equation in one unknown, τ^b. Hence, the stage 1 bargaining solution (P^b, τ^b) is given by

$$P^b = \left(\tau^b\right)^{-1}\min\{q^* - z, \tilde{z}\}, \quad (7)$$

and

$$\tau^b = \begin{cases} \{\theta(q^* - z) + (1-\theta)[\sigma_D[u(q^*) - u(z)] + \\ (1-\sigma_D)(q^* - z)]\}/\beta\delta & \text{if } \min\{q^* - z, \tilde{z}\} = q^* - z \\ \{\theta\tilde{z} + (1-\theta)[\sigma_D[u(z+\tilde{z}) - u(z)] + \\ (1-\sigma_D)\tilde{z}]\}/\beta\delta & \text{if } \min\{q^* - z, \tilde{z}\} = \tilde{z} \end{cases}. \quad (8)$$

The $\tilde{z}$ in (7) and (8) represents the *equilibrium* real money holdings of liquidity providers per investor.[8]

In summary, the first stage bargaining solution (P^b, τ^b) is given by (7) and (8), and the second stage bargaining solution (P^b, τ^b) is given by (3) and (4).

4 Returns, Spreads and Cash-in-the-Market Pricing of Assets

We are interested in understanding how supply and demand for "liquidity" affects asset prices, returns and bid-ask spreads. Although liquidity is a nebulous concept, there are a number of ways one can attempt to measure or characterize it. One measure of liquidity is the fraction of entrepreneurs that turn out to be liquidity providers in the FM, $1 - \sigma$. Once entrepreneurs exit the CM and enter the FM, their liquidity needs may be revised: An entrepreneur who turns out to be an investor in the subsequent DM may desire additional real balances, and a entrepreneur who turns out to be a liquidity provider is willing to supply them. Assuming that all entrepreneurs hold the same amount of real balances, the total amount of real balances that liquidity providers can supply to investors in the FM is $(1-\sigma)z$. When σ is "large," there may be a shortage of FM liquidity since the measure of liquidity providers in the FM is "small." And, when σ is "small," liquidity may be plentiful in the FM.

Another, rather obvious, measure of the supply of liquidity is the amount of real balances, z, that entrepreneurs accumulate in the CM. A change in various model parameters may cause investors to change their real balance holdings. For example, a change in the money growth rate changes the cost of holding real balances and, thus the amount of real balances that entrepreneurs accumulate in the CM. Since liquidity measure z involves general equi-

[8]Note that the ask price, P^a, is independent of the liquidity provider's *actual* real balances holdings. This is because the ask price, which is determined in the second bargaining stage, is a function of the bid price—see (3)—and the bid price is determined in the first bargaining stage. Hence, the bid price is "predetermined" in the second stage, and by (3), so is the ask price. Of course, the bid price is not independent of (some measure of) the real balances of liquidity providers; it depends on the liquidity providers' *equilibrium* real balance holdings per consumer, $\tilde{z}$. If a liquidity provider accumulates more than the equilibrium real balances, then in the stage 2 liquidity provider-dealer bargaining match, the liquidity provider will purchase τ^a assets, given by (4), at the price P^a. That is, the trader does not purchase any additional assets with his "extra" real balances because the ask price is essentially predetermined and the dealer who bargains with the liquidity provider brings $\tau^b\sigma/(1-\sigma)$ real assets to the match. If the trader accumulates less than the equilibrium real balances, say $\bar{z} < z$, then in the stage 2 dealer-trader match the trader will purchase $\bar{z}/P^a$ assets, which is less than the equilibrium amount.

librium considerations, we discuss and analyze this and other potential measures in Section 5, after the steady-state equilibrium to the model is characterized.

The equilibrium ask and bid prices are given by (3) and (7), respectively. There are a couple of ways to measure asset returns, e.g., a gross bid return, r^b, and a gross ask return, r^a. These returns can be measured as

$$r^b = \delta / P^b \tag{9}$$

and $r^a = \delta / P^a$. Using (3), we can define the (equilibrium) bid-ask spread as

$$\frac{P^a}{P^b} = \frac{\beta\delta}{\theta\beta\delta + (1-\theta) P^b}. \tag{10}$$

Notice that the wedge between the bid and ask price is created by the bargaining friction. When the bargaining friction disappears, i.e., $\theta = 1$, the dealer receives no surplus and $P^a = P^b$.

The effect that a change in the liquidity measure σ has on the bid price is simply $\partial P^b / \partial \sigma$, and on the (bid) asset return is,

$$\frac{\partial r^b}{\partial \sigma} = -\frac{\delta}{\left(P^b\right)^2} \frac{\partial P^b}{\partial \sigma}. \tag{11}$$

Note that, not surprisingly, that bid prices and asset returns are negatively correlated.[9] The effect that a change in the liquidity measure σ has on the bid-ask spread is

$$\frac{\partial \left(P^a / P^b\right)}{\partial \sigma} = -\frac{\beta\delta (1-\theta)}{\left[\theta\beta\delta + (1-\theta) P^b\right]^2} \frac{\partial P^b}{\partial \sigma}. \tag{12}$$

The finance literature has consistently documented a positive correlation between changes in asset returns and bid-ask spreads. Our bargaining environment predicts that such a relationship will prevail (at least for the liquidity measure σ),[10] i.e., simply compare (11) and (12),

$$\frac{\partial \left(P^a / P^b\right)}{\partial \sigma} = \frac{\beta (1-\theta) \left(P^b\right)^2}{\left[\theta\beta\delta + (1-\theta) P^b\right]^2} \frac{\partial r_t^b}{\partial \sigma}.$$

[9] If one is interested in the "ask return," then, using (10), we have

$$r^a = \theta r^b + (1-\theta),$$

and

$$\frac{\partial r_t^a}{\partial \sigma} = \theta \frac{d r^b}{d \sigma}.$$

[10] In fact, as long as the change in asset prices are brought about by a change in a varilable or parameter that is *not* equal to β, δ, or θ, we can conclude there is a positive correlation between changes in asset returns and the bid-ask spread.

Let's examine the effect that a change in the composition of investors and liquidity providers in the FM has on assets prices. In particular, what is $\partial P^b/\partial\sigma$? Recall that the value of σ is drawn from the probability distribution $f(\sigma)$, where $\sigma \in [0,1]$. Hence, in a steady-state equilibrium, σ will take on different values over time. If investors are not liquidity constrained, i.e., $P^b\tau^b = q^* - z$, it is obvious from equilibrium conditions (7) and (8) that $\partial P^b/\partial\sigma = 0$. Since the amount of assets that investors sell in the FM is unaffected by an increase FM liquidity when they are not liquidity constrained, see (8), then so too is the (bid) price.

Now suppose that the investor is liquidity constrained in the FM, i.e., $P^b\tau^b = \tilde{z} < q^* - z$. When $P^b\tau^b = \tilde{z}$, (7) and (8) imply that

$$\frac{\partial P^b}{\partial \tilde{z}}\frac{\partial \tilde{z}}{\partial \sigma} = -\frac{P^{b^2}(1-\theta)\,\sigma_D}{\beta\delta\tilde{z}^2}\left[u(z+\tilde{z}) - u(z) - \tilde{z}u'(z+\tilde{z})\right]\frac{z}{\sigma^2} < 0, \tag{13}$$

where $\tilde{z} = z(1-\sigma)/\sigma$. If the fraction of liquidity providers in the FM decreases, then the amount of real balances available in a bargaining match also falls. As a result, the marginal value of the DM expected surplus increases, which makes real balances more valuable to the investor. Hence, the investor is willing to sell the real asset at a lower bid price, i.e., $\partial P^b/\partial\sigma > 0$. This result is reminiscent of cash-in-the-market pricing, see Allen and Gale (2008). Cash-in-the-market pricing has the basic flavor that asset prices fall below their fundamental values because, relative to the amount of assets that are liquidated, cash is in scarce supply. If, however, cash is "plentiful," then asset prices will be at their fundamental values. In our environment, asset prices in the FM are always below their fundamental values because asset markets are not competitive. But, the amount of cash (real balances) available in the (FM) market, $(1-\sigma)z$, can directly influence asset prices: Higher cash holdings can lead to higher asset prices. This result may seem anomalous from a classic asset pricing theory perspective, where the value of an asset is equal to the discounted stream of its dividends.

Over time, asset prices will "fluctuate" in the steady state equilibrium. More specifically, there exists a $\sigma^* \in (0,1)$ such that for all $\sigma \in (\sigma^*, 1)$ investors are liquidity constrained and for all $\sigma \in (0, \sigma^*)$ they are not.[11] Asset prices are "constant" over $\sigma \in (0,\sigma^*)$ and will be a declining function of σ for all $\sigma \in (\sigma^*, 1)$. Therefore, overtime, asset prices will "move around" since the asset price will reflect, among other things, the amount of liquidity available in the FM, $(1-\sigma)z$, and the amount of liquidity varies over time because σ is a random

[11] In the subsequent section we demonstrate the existence of such an (interior) σ^*.

variable. Once again, from classic asset pricing theory perspective, this result appears to be anomalous because asset price changes are not accompanied by new information regarding asset fundamentals.

5 Inflation, Returns and Spreads

The analysis in the previous sections takes the real balance holdings of entrepreneurs, z, as exogenous. Real balance holdings are a choice variable for entrepreneurs and the entrepreneurs' demand for money balances must equal the (exogenous) supply. We now address this issue and characterize the symmetric steady-state equilibrium for the economy. Then, we examine the effect that changes in liquidity measure z has on asset prices, asset returns and bid-ask spreads.

The value function for a entrepreneur in CM, W, of period t is:

$$W\left(z_t, a_t\right) = \max_{z_{t+1}}\{x_t - \ell_t + \beta \int_\sigma \left[\sigma Z_1\left(z_{t+1}, a_t\right) + \left(1-\sigma\right) Z_0\left(z_{t+1}, a_t\right)\right] f(\sigma) d\sigma\}$$
$$\text{s.t. } x_t + \mu z_{t+1} = \ell_t + z_t + T_t$$

or

$$\begin{aligned} W\left(z_t, a_t\right) &= z_t + T_t + \max_{z_{t+1}}\{-\mu z_{t+1} + \beta \int_\sigma [\sigma Z_1\left(z_{t+1}, a_t\right) + \\ & \quad \left(1-\sigma\right) Z_0\left(z_{t+1}, a_t\right)] f(\sigma) d\sigma\}, \end{aligned} \tag{14}$$

where Z_1 is the value function of a entrepreneur that becomes an investor in the DM and Z_0 is FM value function of a entrepreneur that becomes a liquidity provider.

The value functions in the FM for a given period, $t+1$, and realization, σ, are:

$$Z_1\left(z_{t+1}, a_t\right) = \delta a_t + V_1(z_{t+1} + P_{t+1}^{b,\sigma}\tau_{t+1}^{b,\sigma}, \bar{a} - \tau_{t+1}^{b,\sigma}) \tag{15}$$

and

$$Z_0\left(z_{t+1}, a_t\right) = \delta a_t + V_0\left(z_{t+1} - P_{t+1}^{a,\sigma}\tau_{t+1}^{a,\sigma}, \bar{a} + \tau_{t+1}^{a,\sigma}\right), \tag{16}$$

where V_1 is the value function of the investor in the DM and V_0 is the liquidity provider's DM value function. In the FM, the investor sells $\tau_{t+1}^{b,\sigma}$ assets and receives $P_{t+1}^{b,\sigma}\tau_{t+1}^{b,\sigma}$ real balances; the liquidity provider buys $\tau_{t+1}^{a,\sigma}$ assets in exchange for $P_{t+1}^{a,\sigma}\tau_{t+1}^{a,\sigma}$ real balances. Plugging (15) and (16) into (14) we get,

$$
\begin{aligned}
W_t\left(z_t, a_t\right) &= z_t+\beta \delta a_t+T_t \\
&\max_{z_{t+1}}\{-\mu z_{t+1}+\beta \int_\sigma[\sigma V_1(z_{t+1}+P_{t+1}^{b, \sigma} \tau_{t+1}^{b, \sigma}, \bar{a}-\tau_{t+1}^{b, \sigma})+ \\
&(1-\sigma) V_0(z_{t+1}-P_{t+1}^{a, \sigma} \tau_{t+1}^{a, \sigma}, \bar{a}+\tau_{t+1}^{a, \sigma})] f(\sigma) d \sigma\}.
\end{aligned} \tag{17}
$$

If an investor is matched in the DM, then he purchases the DM good from a producer. The investor transfers τ_{t+1}^m units of real balances for q_{t+1} units of the investor good in the DM of period t. The value functions in the DM of period $t+1$ are

$$
\begin{aligned}
V_1\left(z_{t+1}, a_{t+1}\right) &= \sigma_D\left[u\left(q_{t+1}\right)+W\left(z_{t+1}-\tau_{t+1}^m, a_{t+1}\right)\right]+ \\
&\left(1-\sigma_D\right) W\left(z_{t+1}, a_{t+1}\right) \\
&= \sigma_D\left[u\left(q_{t+1}\right)-q_{t+1}\right]+W\left(z_{t+1}, a_{t+1}\right)
\end{aligned} \tag{18}
$$

and

$$
V_0\left(z_{t+1}, a_{t+1}\right)=W\left(z_{t+1}, a_{t+1}\right). \tag{19}
$$

Recall that $\tau_{t+1}^m=q_{t+1}$ since the investor makes a take-it-or-leave-it offer to the producer. Plugging (18) and (19) into (17), we get

$$
\begin{aligned}
W_t\left(z_t, a_t\right) &= z_t+\beta \delta a_t+T_t+\max_{z_{t+1}}\{-\mu z_{t+1}+\beta \int_\sigma[\sigma \sigma_D(u(q_{t+1}^\sigma)-q_{t+1}^\sigma)+ \\
&\sigma W(z_{t+1}+P_{t+1}^{b, \sigma} \tau_{t+1}^{b, \sigma}, \bar{a}-\tau_{t+1}^{b, \sigma})+ \\
&(1-\sigma) W(z_{t+1}-P_{t+1}^{a, \sigma} \tau_{t+1}^{a, \sigma}, \bar{a}+\tau_{t+1}^{a, \sigma})] f(\sigma) d \sigma\},
\end{aligned} \tag{20}
$$

where,

$$
q_{t+1}^\sigma=\min\{z_{t+1}+P_t^{b, \sigma} \tau_{t+1}^{b, \sigma}, q^*\},
$$

and q^* solves $u^{\prime}\left(q^*\right)=1$. Linearity of $W(z, a)$ implies that (20) can be simplified to,

$$
\begin{aligned}
W_t\left(z_t, a_t\right) &= z_t+T+\beta \delta a_t+\beta^2 \delta \bar{a}+\beta W(0,0)+ \\
&\max_{z_{t+1}}\{-\mu z_{t+1}+\beta z_{t+1}+\beta \int_\sigma\{(\sigma P_{t+1}^{b, \sigma} \tau_{t1}^{b, \sigma}-(1-\sigma) P_{t+1}^{a, \sigma} \tau_{t+1}^{a, \sigma}) \\
&+\beta \delta[(1-\sigma) \tau_{t+1}^{a, \sigma}-\sigma \tau_{t+1}^{b, \sigma}]+\sigma \sigma_D[u\left(q_{t+1}^\sigma\right)-q_{t+1}^\sigma] f(\sigma) d \sigma\}\},
\end{aligned} \tag{21}
$$

Notice that the entrepreneur's CM period t decision problem—the max term in (21)—does not depend on the amount of real balances, z_t, he brings into the CM. Hence, all entrepreneurs, independent of their history, face the identical CM decision problem. We focus our analysis on a symmetric steady-state equilibrium. When a entrepreneur chooses z_{t+1}, he assumes that all other investors have chosen the equilibrium level of real balances.

The entrepreneur's CM real balance decision is given by the solution to

$$\begin{aligned}&\max_{z_{t+1}}\{-\mu z_{t+1}+\beta z_{t+1}+\beta\int_{\sigma}[(\sigma P_{t+1}^{b,\sigma}\tau_{t+1}^{b,\sigma}-(1-\sigma)\,P_{t+1}^{a,\sigma}\tau_{t+1}^{a,\sigma}]\\&+\beta\delta[(1-\sigma)\,\tau_{t+1}^{a,\sigma}-\sigma\tau_{t+1}^{b,\sigma}]+\sigma\sigma_{D}[u\left(q_{t+1}^{\sigma}\right)-q_{t+1}^{\sigma}]f\left(\sigma\right)d\sigma\},\end{aligned}\tag{22}$$

The first two terms are standard and represent the date t cost and the date $t+1$ benefit of accumulating z_{t+1} real balances in the CM of period t. The first term of the integral expression of (22),

$$\int_{\sigma}[\sigma P_{t+1}^{b,\sigma}\tau_{t+1}^{b,\sigma}-(1-\sigma)\,P_{t+1}^{a,\sigma}\tau_{t+1}^{a,\sigma}]f\left(\sigma\right)d\sigma\tag{23}$$

represents the expected transfer of real balances to the entrepreneur (when he is an investor) from the entrepreneur (when he is a liquidity provider) in the FM. The entrepreneur is interested in knowing how a change in his real balances affects the amount of real balances he can obtain in the FM, $P_t^b\tau_t^b$, at the margin when he is an investor and the amount of that he pays for assets in the FM, $P_t^a\tau_t^a$, at the margin when he is a liquidity provider. Although, in equilibrium, $\sigma P_t^b\tau_t^b=(1-\sigma)P_t^a\tau_t^a$, a change in the right side, brought about by a change in real balance holdings, need not equal the change in the left side.

In the analysis, we must distinguish the real balances of the entrepreneur when he is an investor in the FM and when he is a liquidity provider. Call z_{t+1} the real balances of an entrepreneur when he is an investor and $\hat{z}_{t+1}$ the real balances when he is a liquidity provider. Suppose the entrepreneur marginally increases his holdings of real balances in the CM of period t from the equilibrium level. If the entrepreneur turns out to be a investor, then he has more real balances of his own to spend in the DM. The higher real balances changes the solution to the bargaining problem since the bargaining surplus at the margin decreases and this will affect the cash, $P_{t+1}^b\tau_{t+1}^b$, that he receives and assets that he sells, τ^b, at the margin. Similarly, if the entrepreneur turns out to be a liquidity provider, a change in real balances may affect the amount of assets he buys, τ^a, and what he pays for them, $P^a\tau^a$, at the margin.

The second term on the second line of (22), i.e.,

$$\beta\delta\int_{\sigma}[(1-\sigma)\,\tau_{t+1}^{a,\sigma}-\sigma\tau_{t+1}^{b,\sigma}]f(\sigma)d\sigma$$

represents the expected value future dividends transferred to the dealer. Finally, the third line of (22), i.e.,

$$\int_{\sigma} \sigma\sigma_M[u\left(q^{\sigma}_{t+1}\right) - q^{\sigma}_{t+1}]f(\sigma)d\sigma$$

represents the investor's surplus in the DM. The quantity q^{σ}_{t+1} is a function of τ^b_{t+1} and P^b_{t+1}, i.e., $q^{\sigma}_{t+1} = z_{t+1} + \min\{q^* - \hat{z}_{t+1}(1-\sigma)/\sigma, P^{b,\sigma}_{t+1}\tau^{b,\sigma}_{t+1}\}$.

In the entrepreneur's money demand problem (22), the bargaining variables present themselves as τ^a_{t+1}, $P^a_{t+1}\tau^a_{t+1}$, τ^b_{t+1}, and $P^b_{t+1}\tau^b_{t+1}$ We first examine how these variables are affected by a change in real balance accumulation in the CM; then we characterize the solution to entrepreneur's money demand problem (22).

The effect that a change in real balances has on bid and ask variables depends on whether or not investors are liquidity constrained. Suppose first that investors are not liquidity constrained for the σ realization, i.e., $P^b_{t+1}\tau^b_{t+1} = q^* - z_{t+1}$. Clearly,

$$\partial\left(P^b_{t+1}\tau^b_{t+1}\right)/\partial z_{t+1} = -1.$$

The effect that an increase in the investor's real balances, z_{t+1}, have on the bid quantity can be determined by using the upper expression in (8); that is,

$$\frac{\partial \tau^b_{t+1}}{\partial z_{t+1}} = -\frac{\theta + (1-\theta)[\sigma_D u'\left(q^*\right) + 1 - \sigma_D]}{\beta\delta} < 0. \tag{24}$$

Now suppose that investors are liquidity constrained, which implies that

$$P^b_{t+1}\tau^b_{t+1} = \tilde{z}_{t+1}, \tag{25}$$

where $\tilde{z}_{t+1} = \hat{z}_{t+1}(1-\sigma)/\sigma$. Equation (25) immediately implies that

$$\partial\left(P^b_{t+1}\tau^b_{t+1}\right)/\partial z_{t+1} = 0;$$

an increase in the investor's real balances has no effect on the total value of asset that he sells. The effect that an increase in the investor's real balances has on the bid quantity can be determined by using the lower expression in (8), that is

$$\frac{\partial \tau^b_{t+1}}{\partial z_{t+1}} = (1-\theta)\sigma_D\frac{u'(z_{t+1} + \tilde{z}) - u'\left(z_{t+1}\right)}{\beta\delta} < 0. \tag{26}$$

This result is somewhat interesting: if the investor brings in more real balances, he will sell less assets in the FM but at a higher price.

Whether or not the investor is liquidity constrained, a marginal increase in a liquidity provider's real money holdings, $\hat{z}_{t+1}$, does not affect τ^b_{t+1} and $P^b_{t+1}\tau^b_{t+1}$ since these are determined in the first stage, when the dealer and investor bargain under the belief that liquidity providers are holding the equilibrium level of real balances, (see discussion in footnote 13). Therefore, an increase in $\hat{z}_{t+1}$ from its equilibrium value will does not affect τ^a_{t+1} and $P^a_{t+1}\tau^a_{t+1}$, i.e., $\partial(P^a_{t+1}\tau^a_{t+1})/\partial\hat{z}_{t+1} = 0$ and $\partial\tau^a_{t+1}/\partial\hat{z}_{t+1} = 0$.

We can now solve the entrepreneur's CM maximization problem (22). The first-order condition to this problem is

$$\begin{aligned}\frac{\mu}{\beta} - 1 = \int_0^{\sigma^*(z_{t+1})} &\{-1\cdot\sigma - 0\cdot(1-\sigma) + 0\cdot\beta\delta(1-\sigma) \\ &\quad - \beta\delta\frac{\partial\tau^{b,\sigma}_{t+1}}{\partial z_{t+1}}\sigma + \sigma\sigma_D[u'(q^*) - 1]\}f(\sigma)d\sigma \\ &+ \int_{\sigma^*(z_{t+1})}^1 \{0\cdot\sigma - 0\cdot(1-\sigma) + 0\cdot\beta\delta(1-\sigma) \\ &\quad - \beta\delta\frac{\partial\tau^{b,\sigma}_{t+1}}{\partial z_{t+1}}\sigma + \sigma\sigma_D[u'(z_{t+1} + \tilde{z}_{t+1}) - 1]\}f(\sigma)d\sigma,\end{aligned}$$

where integration limit $\sigma^*(z_{t+1})$ is equal to $\hat{z}_{t+1}/(q^* + \hat{z}_{t+1} - z_{t+1})$. Using $(1+i) = \mu(1+r)$ and $\beta = 1/(1+r)$, the nominal interest rate, i, can be expressed as

$$i = \frac{\mu}{\beta} - 1. \tag{27}$$

The above first-order condition can be simplified to,

$$\begin{aligned} i \;=\; & \int_0^{\sigma^*(z_{t+1})} \sigma\left\{-1 + \theta + (1-\theta)\left[\sigma_D u'(q^*) + 1 - \sigma_D\right]\right\} f(\sigma)d\sigma \\ & + \int_{\sigma^*(z_{t+1})}^1 \sigma\{-(1-\theta)\,\sigma_D\left[u'(z_{t+1} + \tilde{z}_{t+1}) - u'(z_{t+1})\right]\}f(\sigma)d\sigma \\ & + \int_{\sigma^*(z_{t+1})}^1 \sigma\sigma_D[u'(z_{t+1} + \tilde{z}_{t+1}) - 1]f(\sigma)d\sigma \end{aligned}$$

or

$$i = \sigma_D \int_{\sigma^*(z_{t+1})}^1 \sigma\{(1-\theta)[u'(z_{t+1}) - 1] + \theta[u'(z_{t+1} + \hat{z}_{t+1}(1-\sigma)/\sigma) - 1]\}f(\sigma)d\sigma \tag{28}$$

In the steady state equilibrium: (i) $z_{t+1} = \hat{z}_{t+1}$; and (ii) the real money supply is constant over time, $M_{t+1}p_{t+1} = M_t p_t$, which implies that

$$\frac{M_{t+1}}{M_t} = \frac{p_t}{p_{t+1}} = \mu. \tag{29}$$

and that $z_{t+1} = z_{s+1} = \hat{z}_{t+1} = \hat{z}_{s+1} = z$ for all s, t. Given the money growth rate μ and, hence, nominal interest rate $i = \mu/\beta - 1$, in the CM of period t entrepreneurs' choose real balances evaluated in period $t+1$ prices, z_{t+1}, so as to satisfy condition (28). In period t, the aggregate demand for real balances *evaluated in period t prices* is μz_{t+1}; the total supply of real balances is $p_t M_t$. Since $z_{t+1} = z_{s+1} = z$ for all s and t, the market clearing price of money is

$$p_t = \frac{\mu z}{M_t}.$$

5.1 Inflation and Liquidity Measure z

An increase in the money growth rate increases inflation by the same amount, (29) and increases the nominal interest rate by a factor of $1 + r$, (27). From the equilibrium condition (28) and the steady-state condition, $z_{t+1} = z_t = \hat{z}_{t+1} = z$, the relationship between equilibrium real balance holdings and the (gross) inflation rate is given by

$$\begin{aligned}\frac{dz}{d\mu} = \{\beta\sigma_D \int_{z/q^*}^{1} \sigma[(1-\theta)u''(z) + \theta u''(z/\sigma)]f(\sigma)d\sigma \\ - \beta(\sigma^*/q^*)[(1-\theta)[u'(z)-1] + \theta[u'(z/\sigma)-1]]\}^{-1} < 0,\end{aligned} \tag{30}$$

which means that an increase in inflation, decreases entrepreneurs' real balance holdings. To determine the effect that a change in inflation has on asset prices, asset real returns and the bid-ask spread, we must examine the effect that a change in real balances has on asset prices, asset real returns and the bid-ask spread. The effect that a change in real balances (for *all* entrepreneurs) has on the bid asset price depends on whether the investor is liquidity constrained or not in the FM. If investors are not liquidity constrained in their bargaining matches, i.e., $P^b\tau^b = q^* - z$, then using (8), (7) can be written as

$$\beta\delta\frac{q^* - z}{P^b} = \theta\left(q^* - z\right) + (1-\theta)\left\{\sigma_D\left[u\left(q^*\right) - u\left(z\right)\right] + (1-\sigma_D)\left(q^* - z\right)\right\}$$

or

$$\frac{\beta\delta}{P^b} = \theta + (1-\theta)\,\sigma_D\frac{u\left(q^*\right) - u\left(z\right)}{q^* - z} + (1-\theta)\left(1-\sigma_D\right). \tag{31}$$

Therefore,

$$\frac{dP^b}{dz} = \frac{P^{b^2}\left(1-\theta\right)\sigma_D}{\beta\delta\left(q^*-z\right)^2}\left[u'\left(z\right)\left(q^*-z\right)-u\left(q^*\right)+u\left(z\right)\right] > 0.$$

If investors are liquidity constrained, i.e., $P^b\tau^b = \tilde{z}$, where $\tilde{z} = z(1-\sigma)/\sigma$, then using (8), (7) can be written as

$$\beta\delta\frac{\tilde{z}}{P^b} = \theta\tilde{z} + \left(1-\theta\right)\left[\sigma_D\left[u\left(z+\tilde{z}\right)-u\left(z\right)\right]+\left(1-\sigma_D\right)\tilde{z}\right.$$

or

$$\frac{\beta\delta}{P^b} = \theta + \left(1-\theta\right)\sigma_D\frac{u(z/\sigma)-u\left(z\right)}{z(1-\sigma)/\sigma} + \left(1-\theta\right)\left(1-\sigma_D\right). \tag{32}$$

Therefore,

$$\frac{dP^b}{dz} = \frac{P^{b^2}\left(1-\theta\right)\sigma_D}{\beta\delta z^2(1-\sigma)/\sigma}\left\{u'(z/\sigma)z/\sigma - u'\left(z\right)z - u(z/\sigma) + u\left(z\right)\right\} > 0.$$

An increase in the real balance holdings of all entrepreneurs—and hence, an increase in the total real money supply—increases asset prices, and this is independent of whether or not the investor is liquidity constrained. The intuition behind this result is straightforward. There are two effects associated with an increase in real balance holdings that work in the same direction. If a *investor's* real balances increase (holding the liquidity provider's balances constant), then the marginal value of the bargaining match surplus falls. If a *liquidity provider's* real balances increase (holding the investor's balances constant), then although the match surplus increases, the marginal value of the surplus falls. (This latter effect is not operative if the investor is not liquidity constrained.) In both cases, the investor's value for an additional unit of real balances falls, which implies that bid asset price increases, i.e., the investor gives up a smaller quantity of the asset for an additional unit of real balances. Interestingly, higher levels of liquidity, as measured by z, are associated with higher asset prices: this is the cash-in-the-market effect at work. Since an increase in inflation decreases real balance holdings, an increase in inflation actually *decreases* asset prices. This is in contrast to the standard so-called Mundell-Tobin effect, which is present in many models of money, that posits a positive relationship between inflation and asset prices.

The effect that a change in real balances has on asset returns and the bid-ask spread is similar to the effect of a change in σ, (11) and (12); in particular,

$$\frac{dr^b}{dz} = -\frac{\delta}{\left(P^b\right)^2}\frac{dP^b}{dz}.$$

and

$$\frac{d\left(P^a/P^b\right)}{dz} = -\frac{\beta\delta\left(1-\theta\right)}{\left[\theta\beta\delta+\left(1-\theta\right)P^b\right]^2}\frac{dP^b}{dz}.$$

Hence, asset returns and the bid-ask spreads are positively correlated. An increase in inflation *increases* asset returns, as well as the bid-ask spread. The latter result reinforces a standard view of liquidity and bid-ask spreads: An increase in inflation reduces real balances (liquidity) in the economy which results in higher bid-ask spreads.

Before we move on, we should point out that there is a subtle but important difference in interpreting the results for liquidity measure z and liquidity measure σ. In the steady-state equilibrium, entrepreneurs accumulate μz real balances in the CM, and then enter the FM. The amount of liquidity available to investors, $z(1-\sigma)$, will fluctuate over time, as will asset prices, asset returns and bid-ask spreads. So we can sensibly ask, *in the equilibrium*, how does an increase or decrease in liquidity affect asset prices, asset returns and bid-ask spreads? In contrast, in the equilibrium, there is a unique value of real balances, z, given by (28). We can compare differences in asset prices, asset returns and bid-ask spreads associated with different values of real balances—that result from, say, different money growth rates—but this is a comparison *across equilibria* associated with different economies.

5.2 Bargaining parameter θ as a liquidity measure

One could consider the bargaining parameter, θ, as a measure of liquidity. The dealer is essential in matching suppliers (liquidity providers) and demanders (investors) of liquidity and, because of this, is able to extract some of the surplus generated by trade in the FM. The dealer, however, is taking away resources from investors and liquidity providers; resources that could have provided additional liquidity to investors. For example, if θ increases, the dealer is able to extract less surplus, leaving more resources for investors and liquidity providers. In addition, a change in θ may affect the entrepreneur's real balance decision in the CM. An entrepreneur may reason that an increase in θ implies that he will be able to obtain more real balances per asset sold if he turns out to be a investor in the FM. He may respond by changing the amount of real balances he accumulates in the CM.

The effect that a change in the entrepreneur's bargaining power, θ, has on prices, asset returns rates and bid-ask spreads can be decomposed into a direct effect and an indirect effect. The direct effect assumes that real balances are constant and asks how does a change in θ affects the solution to the bargaining game. The indirect effects asks how a change in θ affects the entrepreneurs' accumulation of real balances and, as a result, how the change in real balances affects the solution to the bargaining game.

We examine the indirect effect first. The equilibrium real balance equation for entrepreneurs, (28), indicates that a change in the bargaining power of investors, θ, will affect the entrepreneur's real balance accumulation decision. In particular, from (28) we get,

$$\frac{dz}{d\theta} = -\int_{z/q^*}^{1} \sigma\{-[u'(z) + u'(z/\sigma)]\}f(\sigma)d\sigma\frac{dz}{d\mu} < 0,$$

where $dz/d\mu$ is given by (30).

We now examine the direct effect. First we determine how a change in the bargaining parameter θ affects the bid price in the bargaining game (holding real balances constant) if investors are not liquidity constrained, i.e., if $P^b\tau^b = q^* - z$. Using (31), we get

$$\frac{\partial P^b}{\partial\theta} = \frac{(P^b)^2\sigma_D}{\beta\delta}[u(q^*) - q^* - u(z) + z] > 0.$$

If investors are liquidity constrained, $P^b\tau^b = \tilde{z}$, then using (32) we get

$$\frac{\partial dP^b}{\partial\theta} = \frac{(P^b)^2\sigma_D}{\beta\delta}\{u(z/\sigma) - z/\sigma - u(z) + z] > 0.$$

Therefore, independent of whether the investor is liquidity constrained or not, an increase in the investor's bargaining power, θ, increases asset prices. Since

$$\frac{\partial r^b}{\partial\theta} = -\frac{\delta}{(P^b)^2}\frac{dP^b}{d\theta} < 0$$

and, from (10),

$$\frac{\partial\left(P^a/P^b\right)}{\partial\theta} = -\frac{\beta\delta\left(1-\theta\right)}{\left[\theta\beta\delta + \left(1-\theta\right)P^b\right]^2}\frac{\partial P_t^b}{\partial\theta} - \frac{\beta\delta\left(\beta\delta - P^b\right)}{\left[\theta\beta\delta + \left(1-\theta\right)P^b\right]^2} < 0, \tag{33}$$

there is a positive correction between asset returns and the bid-ask spread when asset prices move as a result of a change in bargaining power (and z is constant).

The *total* effect of a change in θ on asset prices, asset returns and bid-ask spreads simply "aggregates" the indirect and direct effects, that is,

$$
\begin{aligned}
\frac{dP^b}{d\theta} &= \frac{dP^b}{dz}\frac{dz}{d\theta} + \frac{\partial P_t^b}{\partial\theta}, \\
\frac{dr^b}{d\theta} &= \frac{dr^b}{dz}\frac{dz}{d\theta} + \frac{\partial r_t^b}{\partial\theta}, \\
\frac{d(P^b/P^a)}{d\theta} &= \frac{d(P^b/P^a)}{dz}\frac{dz}{d\theta} + \frac{\partial(P^b/P^a)}{\partial\theta},
\end{aligned}
$$

respectively. Since $dz/d\theta < 0$, the total effect of a change in θ on these objects is ambiguous, as is the correlation between asset returns and bid-ask spreads, e.g., for each of the above expressions, the first term on the right side is of the opposite sign of the second term on the right side. The intuition that underlies this ambiguity is straightforward. An increase in the entrepreneurs' bargaining power decreases real balances and a decrease in real balances decreases the bid price, (this is the indirect effect). In terms of the direct (bargaining) effect, an increase in the entrepreneurs' bargaining power increases the bid price. The indirect and direct effects work in opposite directions.

As in the case with the liquidity measure z (Section 5.1), when we compare differences in asset prices, asset returns and bid-ask spreads associated with different θ's, we are making across equilibria comparisons.

6 Conclusions

We have examined a world where money is needed to facilitate investments. Since money is costly to hold, entrepreneurs tend to underinvest. A financial market that allows investors to trade their less liquid assets for more liquid ones can improve matters. When financial markets are over-the-counter, we find that asset prices depend on the amount of liquidity that is available in the market. Interestingly, the amount of liquidity that is available depends on the ex post distribution of investment opportunities: individuals who do not find opportunities are willing to provide liquidity to those that do. If few investment opportunities are available, then the supply of liquidity will be high and so will asset prices. If money becomes more costly to hold because inflation increases, agents will hold less real balances. This implies higher inflation is associated with in lower levels of liquidity available in the OTC financial market, and will result in *lower* asset prices. This is in contrast to the standard Mundell-Tobin effect, where an increase in inflation implies that asset prices will *increase.* Since our financial markets are over-the-counter, a bid-ask spread emerge as long as the agent who operates the market, the dealer, has some bargaining power. If liquidity in financial market changes because of changes in inflation or entrepreneurs' investment opportunities, bid-ask spreads are negatively correlated with asset returns. A change in bargaining power has a direct liquidity effect—entrepreneurs will accumulate lower real balances—and an indirect effect—for a given z, investors are able to extract more liquidity per asset sold. Since these effects work in opposite directions, a change in bargaining power has ambiguous effects on asset prices, returns and bid-ask spreads. Nevertheless, there will be a positive correlation between asset returns and the bid-ask spread.

7 Appendix

This Appendix examines the case where the asset endowment is "small," in the sense that $z + P^b\bar{a} < q^*$, i.e. if the investor is able to sell all of his real assets, he will have insufficient real balances the purchase q^* in the subsequent DM. We will say that an investor is asset constrained if $P^b\bar{a} < \tilde{z}$ and liquidity constrained if $P^b\bar{a} > \tilde{z}$.

7.1 Bid and ask prices and quantities

First note that the equilibrium ask price and ask quantity (P^a, τ^a), which is determined in the second stage of bargaining, are identical to the "large" asset endowment case, and are equal to (3) and (4), respectively. The stage 1 bargain determines the bid price and bid quantity. Since the asset endowment is small, we now have $P^b\tau^b = \min\{\tilde{z}, P^b\bar{a}\}$. If $P^b\tau^b = \tilde{z}$, then the analysis is identical to the large asset endowment case analyzed in the body of the paper. If, instead, $\min\{\tilde{z}, P^b\bar{a}\} = P^b\bar{a}$, then $\tau^b = \bar{a}$. In this case the surplus the investor receives (in the first stage bargain with the dealer) is

$$\sigma_D u\left(z + P^b\bar{a}\right) + (1 - \sigma_D)\left(z + P^b\bar{a}\right) - \beta\delta\bar{a} \\ - \left[\sigma_D u\left(z\right) + (1 - \sigma_D) z\right].$$

The equilibrium bid price, denoted as $\tilde{P}^b$, solves

$$\sigma_D u(z + \tilde{P}^b\bar{a}) + (1 - \sigma_D)\left(z + \tilde{P}^b\bar{a}\right) - \beta\delta\bar{a} \\ - \left[\sigma_D u\left(z\right) + (1 - \sigma_D) z\right] = \frac{\theta}{1-\theta}(\beta\delta - \tilde{P}^b)\bar{a}, \tag{34}$$

The left side is the investor's surplus and the right side is the investor's share of the match surplus. From (7) and (8)—when the investor is liquidity constrained—and above, the bargaining solution to the first stage bargaining problem, (P^b, τ^b), is given by

$$P^b = (\tau^b)^{-1} \min\{\tilde{P}^b \bar{a}, \tilde{z}\} \tag{35}$$

and

$$\tau^b = \begin{cases} \bar{a} & \text{if } \min\{\tilde{P}^b \bar{a}, \tilde{z}\} = \tilde{P}^b \bar{a} \\ \{\theta \tilde{z} + (1-\theta)\left[\sigma_D \left[u(z+\tilde{z}) - u(z)\right] + \right. & \text{if } \min\{\tilde{P}^b \bar{a}, \tilde{z}\} = \tilde{z} \\ \left.(1-\sigma_D)\,\tilde{z}\right]\}/\beta\delta & \end{cases}, \tag{36}$$

where $\tilde{P}^b$ is given (implicitly) by (34).

7.2 Cash-in-the-market pricing

When the investor is asset constrained, $P^b = \tilde{P}^b$. In this case, $\partial P^b/\partial\sigma = 0$. When the investor is liquidity constrained, then, from (13), $\partial P^b/\partial\sigma < 0$. Therefore, as in Section 4, when the asset endowment is small, the equilibrium is characterized by cash-in-the market pricing (for σ sufficiently high). As well, asset prices will fluctuate in the steady state equilibrium. Qualitatively speaking, all of the results contained in Section 4 apply to the case when the asset endowment is small.

7.3 Money demand and inflation

The entrepreneur's money demand problem is given by (22). As in the text, an increase in the entrepreneur's real balances has no effect on $P^a\tau^a$ or τ^a. If the investor is liquidity constrained, then effect of an increase in real balances on $P^b\tau^b$ and τ^b is exactly the same as in the text, i.e., $\partial(P^b\tau^b)/\partial z = 0$ and $\partial\tau^b/\partial z$ is given by (26). If the investor is asset constrained for the σ realization, then, from (34) we get

$$\frac{\partial \tilde{P}^b}{\partial z} = -\sigma_D \frac{u'(z+\tilde{P}^b\bar{a}) - u'(z)}{\sigma_D u'(z+\tilde{P}^b\bar{a})\bar{a} + (1-\sigma_D)\,\bar{a} + \theta/(1-\theta)\bar{a}} > 0, \tag{37}$$

which implies that $\partial(P^b\tau^b)/\partial z = \bar{a}\tilde{P}^b\partial/\partial z > 0$. Since $\tau^b = \bar{a}$, when the investor is asset constrained, $\partial\tau^b/\partial z = 0$.

The first order condition for the entrepreneur's CM maximization problem (22) is

$$\begin{aligned}
\frac{\mu}{\beta}-1 &= \int_{0}^{\hat{z}_{t+1}/(\tilde{P}^{b}_{t+1}\bar{a}+\hat{z}_{t+1})}\{\frac{\partial \tilde{P}^{b,\sigma}_{t+1}}{\partial z_{t+1}}\bar{a}\cdot\sigma-0\cdot(1-\sigma)+0\cdot\beta\delta(1-\sigma)-0\cdot\beta\delta\sigma \\
&\quad +\sigma\sigma_{D}[u'\left(z_{t+1}+\tilde{P}^{b}_{t+1}\bar{a}\right)-1]\}f(\sigma)d\sigma \\
&\quad +\int_{\hat{z}_{t+1}/(\tilde{P}^{b}_{t+1}\bar{a}+\hat{z}_{t+1})}^{1}\{0\cdot\sigma-0\cdot(1-\sigma)+0\cdot\beta\delta(1-\sigma) \\
&\quad -\beta\delta\frac{\partial\tau^{b,\sigma}_{t+1}}{\partial z_{t+1}}\sigma+\sigma\sigma_{D}[u'\left(z_{t+1}+\tilde{z}_{t}\right)-1]\}f(\sigma)d\sigma
\end{aligned}$$

or

$$\begin{aligned}
\frac{\mu}{\beta}-1 &= \int_{0}^{\hat{z}_{t+1}/(\tilde{P}^{b}_{t+1}\bar{a}+\hat{z}_{t+1})}\sigma\{\frac{\partial \tilde{P}^{b,\sigma}_{t+1}}{\partial z_{t+1}}\bar{a}+\sigma_{D}[u'\left(z_{t+1}+\tilde{P}^{b}_{t+1}\bar{a}\right)-1]\}f(\sigma)d\sigma \\
&\quad +\int_{\hat{z}_{t+1}/(\tilde{P}^{b}_{t+1}\bar{a}+\hat{z}_{t+1})}^{1}\sigma\{-\beta\delta\frac{\partial\tau^{b,\sigma}_{t+1}}{\partial z_{t+1}}+\sigma_{D}[u'\left(z_{t+1}+\tilde{z}_{t+1}\right)-1]\}f(\sigma)d\sigma.
\end{aligned}$$

This equation can be rewritten as

$$\begin{aligned}
\frac{\mu}{\beta}-1 &= \sigma_{D}\int_{0}^{\hat{z}/(\tilde{P}^{b}_{t+1}\bar{a}-\hat{z})}\sigma\Theta(z_{t+1})f(\sigma)d\sigma \\
&\quad +\sigma_{D}\int_{\hat{z}/(\tilde{P}^{b}_{t+1}\bar{a}-\hat{z})}^{1}\sigma\left\{(1-\theta)[u'\left(z_{t+1}\right)-1]+\theta[u'[z_{t+1}+\hat{z}_{t+1}(1-\sigma)/\sigma]-1]\right\}f(\sigma)d\sigma
\end{aligned} \tag{38}$$

where

$$\Theta(z_{t+1})=-\frac{u'(z_{t+1}+\tilde{P}^{b,\sigma}_{t+1}\bar{a})-u'(z_{t+1})}{\sigma_{D}u'(z_{t+1}+\tilde{P}^{b,\sigma}_{t+1}\bar{a})+(1-\sigma_{D})+\theta/(1-\theta)}+u'\left(z_{t+1}+\tilde{P}^{b,\sigma}_{t+1}\bar{a}\right)-1$$

7.4 Liquidity measure z

From the equilibrium condition (38), the relationship between equilibrium real balance holdings and the (gross) inflation rate in the steady state is given by

$$\begin{aligned}
\frac{dz}{d\mu} &= \sigma_{D}\{\int_{0}^{z/(\tilde{P}^{b}\bar{a}+z)}\sigma\frac{d\Theta(z)}{dz}f(\sigma)d\sigma \\
&\quad +\int_{z/(\tilde{P}^{b}\bar{a}+z)}^{1}\sigma\left\{(1-\theta)u''(z)+\theta u''\left(z/\sigma\right)\right\}f(\sigma)d\sigma\}^{-1},
\end{aligned}$$

since $d[z/(\tilde{P}^b\bar{a}+z)]/dz=0$ and

$$\begin{aligned}
\frac{\Theta(z)}{dz} &= -\frac{u''(z+\tilde{P}^b_{t+1}\bar{a})(1+\bar{a}d\tilde{P}^b/dz)[\sigma_D u'(z)+(1-\sigma_D)+\theta/(1-\theta)\}}{[\sigma_D u'(z+\tilde{P}^b\bar{a})+(1-\sigma_D)+\theta/(1-\theta)]^2} \\
&\quad +\frac{u''(z)\left[\sigma_D u'(z+\tilde{P}^b\bar{a})\bar{a}+(1-\sigma_D)+\theta/(1-\theta)\right]}{[\sigma_D u'(z+\tilde{P}^b\bar{a})+(1-\sigma_D)+\theta/(1-\theta)]^2} \\
&\quad +\frac{u''(z+\tilde{P}^b_{t+1}\bar{a})\left[1+\bar{a}d\tilde{P}^b/dz\right][\sigma_D u'(z)+(1-\sigma_D)+\theta/(1-\theta)]^2}{[\sigma_D u'(z+\tilde{P}^b\bar{a})+(1-\sigma_D)+\theta/(1-\theta)]^2} \\
&= \frac{u(z+\tilde{P}^b_{t+1}\bar{a})\left[1+\bar{a}d\tilde{P}^b/dz\right][\sigma_D u'(z)+(1-\sigma_D)+\theta/(1-\theta)]}{[\sigma_D u'(z+\tilde{P}^b\bar{a})+(1-\sigma_D)+\theta/(1-\theta)]^2}\times \\
&\quad \times[\sigma_D(u'(z)-1)+\theta/(1-\theta)] \\
&\quad +\frac{u''(z)\left[\sigma_D u'(z+\tilde{P}^b\bar{a})+(1-\sigma_D)+\theta/(1-\theta)\right]}{[\sigma_D u'(z+\tilde{P}^b\bar{a})+(1-\sigma_D)+\theta/(1-\theta)]^2}<0
\end{aligned}$$

Therefore, $dz/d\mu<0$; as in the case with large asset endowments, an increase in inflation decreases entrepreneurs' real balance holdings.

From (37), if the investor is asset constrained, then an increase in inflation has a negative effect on asset prices; if the investor is liquidity constrained, then from the text, we know that an increase in inflation has negative effect on asset prices. Finally, an increase in inflation increases the bid-ask spread.

7.5 Summary

Although the direct effect on the bid price of a change in θ is positive, i.e., using (34), we get

$$\frac{d\tilde{P}^b}{d\theta}=-\sigma_D(1-\theta)\frac{u'(z+\tilde{P}^b\bar{a})-u'(z)}{\bar{a}}>0,$$

the indirect effect is ambiguous. This implies that the total effects of a change in θ on the bid price, bid return and bid-ask spread are also ambiguous. Qualitatively speaking, the basic results when the endowment $\bar{a}$ is small mirror those of when the endowment $\bar{a}$ is large. There is an important difference between the two cases. When the endowment $\bar{a}$ is large, for $\sigma\in(0,\sigma^*)$, the investor is able to purchase the efficient level of investment goods, $q=q^*$; otherwise, $q<q^*$. When the endowment $\bar{a}$ is small, it is always the case that $q<q^*$. There

exists a $\hat{\sigma}$, $0 < \hat{\sigma} < 1$, such that for $\sigma \in (0, \hat{\sigma})$, the investor is asset constrained and for $\sigma \in (\hat{\sigma}, 1)$ the investor is liquidity constrained. When $\bar{a}$ is small the cash-in-the-market phenomenon is operative when $\sigma \in (\hat{\sigma}, 1)$.

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