A Liquidity-based Resolution to the Dividend Puzzle

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Abstract

Contrary to the renowned irrelevance theory proposed by Modigliani and Miller in 1961, empirical evidence suggests that assets that pay dividends command a price premium, despite the fact that dividend payments are generally taxed more heavily than capital gains. In this paper, I use a monetary-search model and propose a new resolution to this puzzle, based on the idea that the price premium of dividend assets arises due to the superior liquidity role played by dividends compared to returns in the form of capital gain. As dividend is virtually identical to money in facilitating transactions, it helps stockholders avoid selling their assets at an undesirable price in financial markets with frictions and trading delays. The paper provides a number of theoretical results that find support in the data. I also study firms' optimal decision to pay dividends, and show that an increase in the interest rate can hurt the economy not only through the traditional channel, i.e., reduction in real money holdings, but also through the reduction in aggregate R&D activities.

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1 Introduction

The irrelevance theorem proposed in the renowned Miller & Modigliani (1961) paper states that, in an economy characterized by perfect capital markets, rational behavior, and perfect foresight, the current value of the firm should be independent of the dividend decision. However, empirical evidence shows that assets that pay dividends command a higher price premium compared to assets that do not pay dividends. For example, Long Jr (1978) uses a case study of Citizens Utility Company to show that claims to cash dividends have commanded a premium in the market over claims to an equal amount (before taxes) of capital gains. This phenomenon remains relevant in more recent data. For instance, Hartzmark & Solomon (2013) documents that asset pricing has a positive abnormal return during the months when firms are expected to issue dividend. Also, Karpavičius & Yu (2018) show that the price premium is constantly positive for stocks that pay regular dividends. This puzzling observation becomes even harder to reconcile when one considers that dividend payments are generally taxed more heavily than (equal amounts of) capital gains.

The goal of this paper is to offer a liquidity based resolution to the aforementioned puzzle. The underlying assumptions of the Modigliani-Miller theorem require perfect capital markets, but real world secondary (asset) markets are not perfect; they are characterized by search (and other types of) frictions, intermediation fees, and trading delays. In this, more realistic setting, assets with similar cash flows may be priced differently, because of liquidity considerations. Here, I show that assets that pay regular dividends can be priced at a premium because agents can use the dividend to satisfy random liquidity needs, and, importantly, avoid having to liquidate their assets (that do not pay dividends) in secondary markets characterized by search and bargaining (or other) frictions. After establishing the main idea of the paper, i.e., that assets that pay regular dividends are effectively more liquid, I also study the firms' decision to pay dividends or not.

To answer my research question I employ a monetary-search model, as in Lagos & Wright (2005), extended to incorporate an Over-the-Counter (OTC) secondary asset market, where agents can rebalance their portfolios. Agents are subject to random liquidity needs, and when such liquidity needs arrive agents must trade in a *quid pro quo* fashion using cash as a medium of exchange. Naturally, dividends that have already been delivered are virtually cash. Thus, developing a model that is explicit about the frictions that make a medium of exchange necessary in certain markets, is crucial for understanding that assets that pay (frequent) dividends provide *direct* liquidity to the agents and will be priced accordingly. It is important to highlight that assets that do not pay (frequent) dividends are also liquid, but only in an *indirect* way: if a liquidity shock arrives and the agent finds herself holding assets that do not pay dividends, she can still acquire liquidity by selling some assets for cash in the secondary market. However, if this secondary market is characterized by search or bargaining frictions, as is the case in my model, the agent faces the risk of not being able to sell at all or having to sell at a price that is lower than the fundamental market value. This is precisely why agents are willing to pay a premium for a dividend-paying asset: they can use the dividend to cover their current liquidity needs, thus, avoiding to sell assets in less-than-optimal conditions in the secondary market.

Whether agents can always avoid visiting the frictional secondary market to sell assets depends on the supply of dividend-paying assets (which in the first part of the paper is exogenous) and the value of the dividend. If the amount of 'direct liquidity' (provided by dividend-paying assets) is not enough to satisfy the liquidity needs of the economy, agents will visit the secondary asset market to sell bonds anyway. Thus, dividend-paying assets can carry both a direct liquidity premium (by paying dividend that the agent can use to purchase consumption) or an indirect liquidity premium (by being sold for cash in the secondary market). In contrast, non-dividend assets can carry only an indirect liquidity premium.

Besides offering a liquidity-based explanation for the dividend puzzle, the model also delivers two new and testable theoretical predictions. First, I show that asset trade exhibits a certain "pecking order". More precisely, when agents visit the secondary market to sell assets and meet their liquidity needs, non-dividend assets will be traded first before agents sell any dividend-paying assets. The intuition is simple: since dividend assets provide direct liquidity, selling them for money would imply that the seller (i.e., the agent in need of liquidity) is missing the opportunity to use the upcoming dividend to purchase goods. Thus, when liquidity is scarce, agents sell non-dividend assets first, and only when non-dividend assets are not enough to meet the liquidity needs of the agent, does the agent decide to sell some dividend-paying assets. The second testable prediction of the model is that the dividend premium increases in the degree of market frictions. Again, this is intuitive: as matching in the secondary market becomes less efficient, the chance of agents not being able to sell assets becomes larger, and this makes agents more willing to pay a premium in order to hold dividend-paying assets, which are more likely to help them avoid visiting the secondary asset market altogether.

To support both of these predictions, I use data from Compustat and CRSP of more than 7,000 firms between the year 1971-2016. The data shows a price premium of 10.75% if assets pay dividend. Furthermore, the turnover ratio of dividend-paying assets is lower, implying that non-dividend assets are traded more frequently comparing to dividend asset. This is consistent with the model prediction that non-dividend assets are traded first before dividend assets, thus having a higher trading volume. Finally, the data shows that the dividend alone does not provide much explanatory power in predicting asset prices, but only gives rise to the pricing premium in the presence of market friction. This result not only is consistent with the irrelevance theory that dividends should have no impact on firms' value (with the assumption of perfect financial market), but also provides direct support to the liquidity channel in my model, namely, the idea that dividends help agents avoid liquidating assets in frictional secondary market and, hence, command a premium.

The results described so far have been based on the assumption that the supply of dividend versus non-dividend assets are exogenously given. After carefully describing the equilibrium properties of the various asset prices, and establishing the superior liquidity of dividend-paying bonds, I endogenize the firms' decision to pay dividends or not. To make things interesting and realistic I focus on the following economic trade-off: when making the dividend decision, firms realize that paying dividend can increase the valuation of their stock (because of the higher liquidity premium established in the first part of the paper) but it can also diminish the amount of resources they can invest in R&D activities, activities which could raise their productivity.

I study a game where the typical firm takes as given the fraction of other firms who pay dividend, say Σ, and chooses optimally whether to pay dividend or not. When Σ is very low, very few firms are paying dividend, and the potential *liquidity benefit* from paying dividend is extremely high, since agents are in desperate need of liquid assets. On the other hand, when Σ is very high, the liquidity needs of agents are (likely) satiated, and agents are only willing to buy assets at their fundamental value (which is another way of saying that the stocks will not carry any liquidity premium). In this case, the obvious optimal choice for the firm is to not pay dividend but instead use their resources for investment in R&D. In all, I show that there exists a unique *interior* equilibrium Σ^*, i.e., the model predicts that a fraction of firms will choose to pay dividend while the remaining firms will engage in R&D activities. I also show that the fraction of firms who choose to pay dividends is increasing in inflation. Thus, my model suggests that higher inflation can hurt the economy not only through the traditional channel, i.e., by reduction agents' real money balances, but also through the reduction in aggregate R&D activities.

2 Literature Review

This paper is related to three strands of literatures. The first strand is the theoretical and empirical literatures on the dividend puzzle phenomenon. This is a long-standing puzzle, so there have been theories proposed in the past trying to explain it. For example, the signaling theory first proposed in Miller & Rock (1985), in which higher dividend payout is interpreted as a positive sign of a company's future earning, and hence increases investors' preference over such stocks. Despite much supporting evidence, some of the empirical studies find evidence unfavorable to the signaling theory. For example, in Bernhardt et al. (2005), the paper provides evidence that there is no positive relation between bang-for-the-buck (positive abnormal price response per dollar of dividend) and cost of signal, which contradicts with the signaling theory prediction. Another theory tries to explain the puzzle is from the behavioral finance perspective. Proposed in Shefrin & Statman (1984), the prospect theory and self-control theory state that investors with risk-averse behavior keep dividend and principal as two separate mental accounts. Being able to use only dividend for financing their consumption allows them to leave the principal untouched, hence is valued by agents. However, the questionnaire results surveyed in Dong et al. (2005) found ambiguous evidence in supporting such theory. The transaction cost theory proposed in Allen & Michaely (2003) argues that investors prefer a dividend-paying stock due to the significantly smaller transaction cost compare to selling the portfolio. However, this is not supported by the time-series evidence on transaction cost. Due to the regulation, transaction cost decreased substantially after 1975, and according to the transaction cost explanation, the demand on dividend should be lower, but empirical evidence shows that total dividend being paid out was not reduce, and the pricing premium did not respond significantly. The difference between the mechanism I propose in this paper and the transaction cost theory is that, transaction cost explanation only considers the fee charged by brokers but does not take into account the implicit cost that asset holders might not be able to sell the assets right away or might have to sell it at a price that is lower than fundamental market value. Hence despite the evidence that is unfavorable to the transaction cost theory, it does not invalidate the discussion on search and bargaining friction in the secondary asset market. There are other theories trying to solve the puzzle, such as dividend clientele theory and uncertainty resolution, however receiving conflicting empirical testing results. Moreover, besides the mixed empirical evidence, the proposed theories do not seem to pay attention to the monetary implication. Whereas in my paper, I show that monetary policy can hurt the economy not only through reducing real money holdings as traditionally believed, but also has additional negative impact by discouraging aggregate R&D activities.

The second strand of literature this paper is related to is firms' optimal dividend policy. There are many factors being proposed as determinants of firms' dividend policy. For example, Redding (1997) proposed the firm size as a key determinant of dividend policy. In DeAngelo et al. (2006), the authors argue that earned/contributed capital mix is important in determining dividend payout, more specifically firms are more likely to pay dividend if retained earning contributes to a larger share of equity. My paper complements this strand of literature by showing that firms face trade-off between paying dividend and raising future TFP, and also study the monetary implication on firms' dividend decision. The channel that firms issue dividend shares in order to benefit from the premium is also studied in Caramp & Singh (2020), that when Modigliani-Miller theorem does not hold and hence bond carries a premium, firms issue safe bonds to benefit from the bond premium. The result from my paper, that aggregate dividend increases as interest rate rises, is consistent with the prediction in Akyildirim et al. (2014)). Basse & Reddemann (2011) shows a positive relation between inflation and dividend payments, which provide empirical evidence for my model prediction as well.

This paper also relates to the literature on asset liquidity factor and liquidity premium in pricing, such as Geromichalos et al. (2007), Nosal & Rocheteau (2013), Andolfatto et al. (2014), Geromichalos et al. (2016), and Geromichalos et al. (2022). Besides the dividend puzzle I study in this paper, the liquidity service provided by assets has been used to explain some other long-standing puzzles as well, such as the on-the-run puzzle studied in Vayanos & Weill (2008), the equity premium puzzle studied in Lagos (2010), and asset home bias puzzle discussed in Geromichalos & Simonovska (2014). This paper complements this series of paper.

3 The Model

3.1 Environment

The model I employ in this paper is a monetary-search model as in Lagos & Wright (2005), with an OTC secondary market which features search and bargaining as in Duffie et al. (2005). The economy has infinite horizon and time is discrete. In each period, there are three sub-markets where different economic activities take place: a secondary asset market, a decentralized market, and a centralized market. The centralized market (henceforth CM) is the settlement market of the Lagos-Wright model. Allowing agents to visit this frictionless market at the end of every period, together with quasi-linear preferences is what makes the model tractable and prevents the state space from exploding. The decentralized market (henceforth DM) captures the idea that not all trades/transactions take place in a Walrasian and frictionless market. In cases where there is lack of record keeping or commitment, trade will require a proper means of payment. The existence of the DM allows me to model these types of transactions, and gives a special role to assets that pay dividend, which is as good as money in providing liquidity services. Finally, agents may often find themselves in need of more liquidity, and may want to sell some of their assets in exchange for money.

The existence of a secondary asset markets opening at the beginning of each period allows precisely these kinds of transactions to take place.

The economy has two types of agent, buyers and sellers, characterized by their role in DM, which will be permanent. The measure of buyers is normalized to 1. At the beginning of each period, a consumption shock is realized. ℓ fraction of the buyers will have consumption need in the upcoming DM and consume a special goods q, which will be produced by sellers. I will refer to them as active buyers (or A-buyers). The remaining $1-\ell$ fraction of buyers do not have such consumption need, hence I call them the inactive buyers (or I-buyers). This special goods consumption in DM can be thought of as an unusual purchase of goods, for example, an urgent buying of a house or an urgent medical bill needs to be paid quickly. Since matching friction in the DM is not the main focus of this paper, for simplicity I assume that all A-buyers will meet a seller in DM, and thus I normalize the measure of sellers to ℓ. Since all DM transactions need to be facilitated by proper medium of exchange, the idiosyncratic DM consumption opportunity realization makes buyers value their assets differently, hence gives rise to an incentive for assets trading between A-buyers and I-buyers in the secondary asset market (which opens right before the DM). A-buyers, who have liquidity need for DM consumption, will want to sell assets in exchange for money, thus they enter the secondary asset market as asset sellers. I-buyers do not have a consumption need in the DM, hence they participate in the secondary market as asset buyers.

The economy also has two types of assets. The first one is money, which has no intrinsic value, but is storable and recognizable in any type of transaction, hence it helps avoid the friction in DM created by the lack of record keeping. The market price of money in terms of general goods in the CM is φ. Its supply is controlled by a monetary authority, and it evolved according to the rule $M_{t+1} = (1+\mu)M_t$ with $\mu > \beta - 1$. The second type of assets is two sets of infinitely-lived Lucas trees, which agents can buy in the CM at market price ψ_1 and ψ_2. Both trees pay dividend d in time $t+1$ and have resale value in the CM. But the probability that they pay dividend in different sub-markets is different. The first tree (type-1 asset), with aggregate supply A_1, pays d in the DM with probability θ_1, and hence pays in the CM with probability $1-\theta_1$. Similarly, the second tree (type-2 asset) with aggregate supply A_2, pays d in the DM with probability θ_2. Without loss of generality, $\theta_1 > \theta_2$. Since

DM is the market which agents need liquidity, assuming that type-1 assets have a higher probability to pay dividend in the DM represents its superior ability to facilitate trade in that market. In a more realistic setting, type-1 assets would represent assets that pay dividends more frequently. The difference in probability of paying dividend reflects the fact that if the dividend is paid more frequently, the chance that the dividend paid at the 'right time' (i.e., when the agent needs it for liquidity) is higher. Hence type-1 asset serves the random consumption opportunities in the DM better than the type-2 asset. Later in the section, for simplicity, I take the probabilities to the extreme case in which $\theta_1 = 1$ and $\theta_2 = 0$, so that type-1 asset always pays d in the DM, while type-2 asset always pays d in the CM. This simplifying assumption does not affect the underlying mechanism of the model; it is just a stark way to capture type-1 assets' superior liquidity role in facilitating consumption compared to type-2 assets.

Next, I will describe the details of the economic activities in each sub-markets. Figure 1 summarizes the timing of the various economic activities in the model.

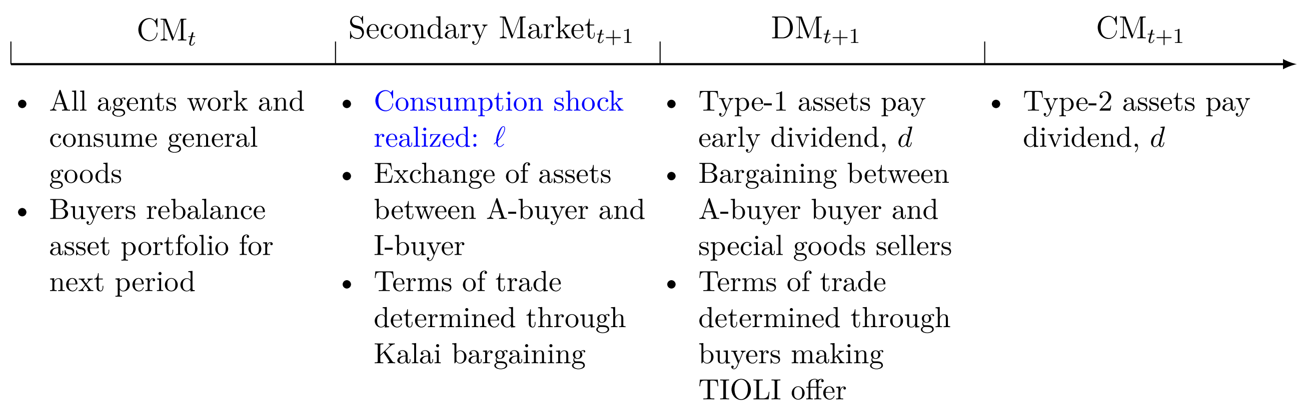

Figure 1: Timeline of economic activities.

In the CM_t, all agents work H hours and consume general goods X. I assume that one hour of work generates 1 unit of the general good, which is also the numeraire. Buyers will choose the amount of assets (i.e. money, type-1 assets, and type-2 assets) to bring into next period $t + 1$, without knowing if they will have consumption needs in the upcoming DM or not. Upon entering $t + 1$, the idiosyncratic consumption shock is realized, such that ℓ fraction of the buyers becomes A-buyers, while the remaining $1 - \ell$ will become I-buyers. Because buyers have different consumption opportunities and, hence, value assets differently, A-buyers (who need liquidity) and I-buyers (who can provide it) will participate in the secondary asset markets to re-balance their portfolio. The terms of trade in the secondary market are determined through Kalai bargaining, with λ being A-buyers' bargaining power. More specifically, A-buyers will be the assets sellers, and sell y_1 and y_2 amount of the two types of assets, in exchange for y_m amount of money from I-buyers. The measure of meeting between A-buyers and I-buyers will be determined by a matching technology $f(\ell, 1-\ell) \leq \min\{\ell, 1-\ell\}$.

After A-buyers boost their liquidity position, they enter the DM and meet with a seller for special goods consumption. Type-1 assets pay dividend d at the beginning of this sub-markets, and agents who hold type-1 assets can use the dividend for DM consumption. Even though the dividend here is modeled as fruit of the Lucas tree, in reality it is as good as cash, and that is the idea I am aiming to capture in a simple and tractable way. The trade between an A-buyer and a seller is also determined through bargaining; more precisely, A-buyers make take-it-or leave- it (TIOLI) offer to the seller of special good. The seller produces q amount of special goods using a linear production technology that can transfer 1 hour of labor into 1 unit of special goods, and in return, A-buyers will pay an amount π of real balances, which can be either money or dividend (or a combination of both). Finally, after trade in the DM has concluded, all agents move to the CM, where type-2 assets pay dividend d. (Notice that this payment comes 'too late' to be serve the liquidity needs of agents.)

The discount rate between periods is $\beta \in (0,1)$, and there is no discounting between sub-periods. Buyers consume in CM and potentially DM, and supply labor in CM, while sellers consume only in CM but supply labor in both DM and CM. Hence buyers derive utility from consuming special goods q in DM and general goods X in CM, and disutility from working H hours in the CM. The buyers' preference is given by: $U(X,H,q) = u(q) + U(X) - H$. Sellers derive utility from consuming X in CM, and distuility from working h hours in DM and working H hours in CM. The sellers' preference is given by $V(X,H,h) = -h + U(X) - H$. Several standard properties of the utility functions are imposed here: (1) both u and U are twice continuously differentiable. (2) $u(0) = 0, u'(q) > 0, u'(\infty) = 0, u'(0) = \infty, u''(q) < 0$; $U'(X) > 0$, $U''(X) < 0$. (3) There exists an optimal level of DM consumption q^*, such that $q^* \equiv \{q : u'(q^*) = 1\}$. (4)There exists a $X^* \in (0,\infty)$ such that $U'(X^*) = 1$, $U(X^*) > X^*$.

The discussion of the model will focus on steady-state equilibrium, with focus on the asset prices ψ_1 and ψ_2 as the question this paper addresses is the pricing premium of dividend assets. In Section 3 of the discussion, the asset supplies A_1 and A_2 are given exogenously, in order to focus on the liquidity channel of dividend, and how type-1 assets can include a liquidity premium. Later in Section 6 of the paper, I also study the firms' dividend decision, that is, I determine endogenously the measure of firms who decide to pay early dividend. Thus, the asset supplies of the various types of assets are also endogeneously determined in the equilibrium.

3.2 Value Functions

After a detailed description of the environment and the types of activities take place in each of the sub-markets, in this section I describe the value functions in each periods, starting with CM value functions and work backwards.

3.2.1 CM

Upon entering CM, a typical buyer's state variables are as followings. The first is remaining real balance after DM consumption z, which could be leftover real money balance or dividend. The second is shares of type 1 asset a_1 carried from last period, and has resale value in the CM. The last one is the shares of type 2 asset a_2 carried from last period, which will pay dividend and have reslae value in the CM. The Bellman equation is the following:

$$W(z, a_1, a_2) = \max_{X,H,\hat{a_1},\hat{a_2},\hat{m}} U(X) - H + \beta\mathbb{E}\{\Omega^i(\hat{m}, \hat{a_1}, \hat{a_2})\}$$

$$\text{subject to } X + \varphi\hat{m} + \psi_1\hat{a_1} + \psi_2\hat{a_2} = H + z + \psi_1 a_1 + (\psi_2 + d)a_2 + \varphi\mu M$$

where $\mathbb{E}$ is the expectation operator and Ω^i represents buyer-i's value function of the secondary asset market, with $i \in \{A, I\}$. By assuming that H is large enough, so that agents can always work enough hours to consume optimal level of general good, and substituting in $H = X + \psi_1 \hat{a}_1 + \psi_2 \hat{a}_2 + \varphi \hat{m} - z - \psi_1 a_1 - (\psi_2 + d)a_2$, buyer's CM value function becomes:

$$W(z, a_1, a_2) = \Lambda^B + z + \psi_1 a_1 + (\psi_2 + d)a_2$$
$$\text{where } \Lambda^B = U(X^*) - X^* + \max_{\hat{m}, \hat{a_1}, \hat{a_2}} \{-\varphi \hat{m} - \psi_1 \hat{a}_1 - \psi_2 \hat{a}_2 + \beta \mathbb{E}\Omega^i(\hat{m}, \hat{a}_1, \hat{a}_2)\}$$

As a standard feature of this class of model, CM value function is quasi-linear in state variables, and the optimal choice variables are not state-dependent.

Now consider a typical seller entering CM, the only state variable is z, which is the real balance that she collects in DM by producing and selling special goods q. Sellers do not carry any assets since sellers will never have liquidity need in the DM and also carrying assets across periods is costly. Hence a seller's CM value function is given by:

$$W^S(z) = \Lambda^S + z$$
$$\text{with } \Lambda^S = U(X^*) - X^* + \beta V^S$$

where V^S is seller's value function in DM. Seller does not carry any assets and she does not need any liquidity in DM, so sellers do not participate in secondary asset market, but directly proceed to DM_{t+1}.

3.2.2 DM

Next, consider the value functions in the DM. Let q be the quantity of special good produced, and π be the real balance A-buyers pay in exchange. For an A-buyer entering DM with the amount of money m, type 1 asset a_1, and type 2 asset a_2, the total amount of liquidity that can be used in DM consumption is $z = \varphi m + da_1$. Thus A-buyer's value function is

$$V(\varphi m + a_1, a_1, a_2) = u(q) + W(\varphi m + da_1 - \pi, a_1, a_2)$$

Similarly, for a seller entering DM without any assets, her value function is

$$V^S = -q + W^S(\pi)$$

3.2.3 OTC

Finally, consider the secondary asset market. At the beginning of period, the consumption shock is realized, and buyers become aware if they are A-buyers, with probability ℓ, or I-buyers in the upcoming DM, with probability $1-\ell$. Hence a typical buyer's expected value function is

$$\mathbb{E}\{\Omega^i(m, a_1, a_2)\} = \ell\Omega^A(m, a_1, a_2) + (1-\ell)\Omega^I(m, a_1, a_2)$$

After buyers become aware of their consumption type, i.e. if they are the A-buyer or I-buyer in the upcoming DM, they will exchange assets in the secondary market, where A-buyers are asset sellers and I-buyers become asset buyers. Given matching efficiency parameter, γ, and the matching function $f(\ell, 1-\ell)$, the probability that A-buyers get matched with a trading counterpart in secondary market is $\alpha_A \equiv \gamma f(\ell, 1-\ell)/\ell$, and similarly the probability of I-buyers get a match in secondary market is $\alpha_I \equiv \gamma f(\ell, 1-\ell)/(1-\ell)$. Hence the probability of A-buyers not get a match is $1-\alpha_A$, while that probability for I-buyers is $1-\alpha_I$. Denote y_m as the amount of money, y_1 as the amount of type 1 asset, and y_2 as the amount of type 2 asset changed hands in secondary market bargaining, which will be specified in later sections, the expected secondary market value function for A-buyer and I-buyer are given as

$$\mathbb{E}\{\Omega^A(m, a_1, a_2)\} = \alpha_A V\Big(\varphi(m+y_m)+d(a_1-y_1), a_1-y_1, a_2-y_2\Big)+(1-\alpha_A)V\Big(\varphi m+da_1, a_1, a_2\Big)$$

$$\mathbb{E}\{\Omega^I(m, a_1, a_2)\} = \alpha_I W\Big(\varphi(m-y_m)+d(a_1+y_1), a_1+y_1, a_2+y_2\Big)+(1-\alpha_I)W\Big(\varphi m+da_1, a_1, a_2\Big)$$

Since A-buyers consume in the DM, while I-buyers do not have consumption opportunity in the DM, A-buyers secondary market value function is the weighted average of the DM value function, while that of I-buyers is the weighted average of CM value function since I-buyers proceed directly to CM.

3.3 Bargaining in Secondary Asst Market and DM

Now the value functions in each sub-markets are described, in this section, I characterize the bargaining solutions in each sub-markets, more specifically in secondary asset market and DM.

3.3.1 DM

In meeting with a seller, A-buyer faces liquidity constraint, in the sense that the total payment they make for consumption cannot exceeds the amount of liquidity they have, $\varphi m + da_1$. A-buyer will make a TIOLI offer, and the two parties bargain over quantity q that seller will produce, and real balance π that A-buyer will pay. The bargaining problem maximizes A-buyer's trading surplus, subject to the TIOLI bargaining constraint that seller's bargaining surplus is 0, and A-buyer's liquidity constraint.

A-buyer's bargaining surplus is given by $u(q)+W(z-\pi, a_1, a_2)-W(z, a_1, a_2)$, in which $u(q)$ is the utility derived from consuming the special goods, and $W(z-\pi, a_1, a_2)-W(z, a_1, a_2)$ is the reduction in CM continuation value because of the payment made to sellers. Similarly, for a seller, the bargaining surplus is $-q + W^S(\pi) - W^S(0)$, in which $-q$ is the disutility from providing labor hours to produce q amount of special goods, and $W^S(\pi) - W^S(0)$ is the increase in CM continuation value because of the payment they receive from A-buyers. Hence the bargaining problem is given by

$$\begin{aligned}
&\max_{q,\pi} \; u(q) + W(\varphi m + da_1 - \pi, a_1, a, 2) - W(\varphi m + da_1, a_1, a_2) \\
&\text{subject to } \; -q + W^S(\pi) = W^S(0) \\
&\qquad \pi \leq \varphi m + da_1
\end{aligned}$$

Because of CM value function's linearity in state variables derived in previous section, DM bargaining problem can be simplified as

$$\max_{q,\pi} \; u(q) - \pi$$
$$\text{subject to } \pi = q \leq \varphi m + da_1$$

Lemma 1. *The DM bargaining solution is given by* $q = \pi = \min\{q^*, \varphi m + da_1\}$.

The bargaining solution is straightforward and standard in the literature, hence the proof is omitted. The bargaining solution states that, if A-buyers brought enough liquidity into DM, then they will consume the first-best quantity q^*, and pays the same amount of liquidity in exchange. However, in the case where the liquidity is constrained, i.e. $\varphi m + da_1 < q^*$, then A-buyers will give entire amount of liquidity and in exchange consume the same amount of special goods.

3.3.2 Secondary Asset Market

In OTC, bargaining is between an A-buyer with asset portfolio (m, a_1, a_2), and I-buyer with portfolio ($\tilde{m}$, $\tilde{a_1}$,$\tilde{a_2}$), henceforth terms with tilde are variables of I-buyers. They bargain over quantity of money,y_m and the quantity of two types of assets, y_1 and y_2, to exchange. During OTC trade, A-buyer's and I-buyer's bargaining surplus are given by

$$\begin{aligned}
S^C &= V\Big(\varphi(m + y_m) + d(a_1 - y_1), a_1 - y_1, a_2 - y_2\Big) - V\Big(\varphi m + da_1, a_1, a_2\Big) \\
&= u\Big(\varphi(m + y_m) + d(a_1 - y_1)\Big) - u\Big(\varphi m + da_1\Big) - \psi_1 y_1 - (\psi_2 + d)y_2 \\
S^N &= W\Big(\varphi(\tilde{m} - y_m) + d(\tilde{a_1} + y_1), \tilde{a_1} + y_1, \tilde{a_2} + y_2\Big) - W\Big(\varphi\tilde{m} + \tilde{a_1}, d\tilde{a_1}, \tilde{a_2}\Big) \\
&= -\varphi y_m + (\psi_1 + d)y_1 + (\psi_2 + d)y_2
\end{aligned}$$

where the second equality follows by plugging in W and V value functions derived from previous section. Since in this bargaining, A-buyers are the asset sellers, the total quantity of assets exchanged hands cannot exceeds the amount of assets A-buyer has, i.e. $y_1 \leq a_1$ and $y_2 \leq a_2$. I-buyers are the asset buyers and money provider, so the total money exchanged cannot exceeds I-buyers' money balance, i.e. $y_m \leq \tilde{m}$. With A-buyer making TIOLI offer, the bargaining problem in secondary asset market is to maximize A-buyer's bargaining surplus, subject to TIOLI constraint that I-buyer's bargaining surplus equals 0, A-buyer's assets constraints, and I-buyer's money constraint

$$\begin{aligned}
&\max_{y_m, y_1, y_2} \Big\{ u\Big(\varphi(m+y_m) + d(a_1 - y_1)\Big) - u(\varphi m + d a_1) - \psi_1 y_1 - (\psi_2 + d) y_2 \Big\} \\
&\text{s.t. } \varphi y_m = (\psi_1 + d) y_1 + (\psi_2 + d) y_2 \\
&\qquad 0 \leq y_m \leq \tilde{m} \\
&\qquad 0 \leq y_1 \leq a_1 \\
&\qquad 0 \leq y_2 \leq a_2
\end{aligned}$$

Lemma 2. *Consider a secondary market meeting between an A-buyer and an I-buyer, with portfolios (m, a_1, a_2) and $(\tilde{m}, \tilde{a}_1), \tilde{a}_2$ respectively. Define the real money balance cutoff level as*

$$\bar{z} \equiv \min \Big\{ (\psi_1 + d) a_1 + (\psi_2 + d) a_2, q^* - \varphi m - d a_1 + \frac{d}{d + \psi_1} \max \Big\{ 0, \min\{ q^* - \varphi m - d a_1, \varphi \tilde{m} \} - (\psi_2 + d) a_2 \Big\} \Big\}$$

The bargaining solution, denoted with *, is discussed in 4 regions. The description of the region division and the corresponding bargaining solution is given as following

- *Region 1: If $\varphi \tilde{m} \geq \bar{z}$ and $(\psi_1 + d) a_1 + (\psi_2 + d) a_2 \geq q^* - \varphi m$, then*

$$\begin{aligned}
(y_1^*, y_2^*) &= \{(y_1, y_2) : \psi_1 y_1 + (\psi_2 + d) y_2 = q^* - \varphi m - d a_1\} \\
\varphi y_m^* &= (\psi_1 + d) y_1^* + (\psi_2 + d) y_2^*
\end{aligned}$$

- *Region 2: If $\varphi \tilde{m} \geq \bar{z}$ and $(\psi_1 + d) a_1 + (\psi_2 + d) a_2 < q^* - \varphi m$, then*

$$\begin{aligned}
(y_1^*, y_2^*) &= (a_1, a_2) \\
y_m^* &= \frac{1}{\varphi} [(\psi_1 + d) a_1 + (\psi_2 + d) a_2]
\end{aligned}$$

- *Region 3: If $\varphi\tilde{m} < \bar{z}$ and $(\psi_2 + d)a_2 \geq \varphi\tilde{m}$, then*

$$y_1^* = 0, y_2^* = \frac{\varphi\tilde{m}}{\psi_2 + d}$$
$$y_m^* = \tilde{m}$$

- *Region 4: If $\varphi\tilde{m} < \bar{z}$ and $(\psi_2 + d)a_2 < \varphi\tilde{m}$, then*

$$y_1^* = \frac{1}{\psi_1 + d}[\varphi\tilde{m} - (\psi_2 + d)a_2], y_2^* = a_2$$
$$y_m^* = \tilde{m}$$

Proof. See Appendix A.

Depending on the abundance of real balance and relative abundance/scarcity of asset balance, there are 4 sets of bargaining solutions, depending on whether the asset constraints and money constraint bind. How are these regions divided depends on the answers of the following question. In the case where the total liquidity in the economy is enough to allow for optimal consumption q^*, the question remains whether the total assets (including both type-1 and type-2 assets) are enough for exchanging the desired amount of money. The answer to this question divides the abundant-liquidity case into regions 1 and region 2. And in the case where the total liquidity is not enough for q^*, A-buyers would like to have all the available liquidity for consumption, i.e. total real money balance together from I-buyers $\varphi\tilde{m}$ and herself φm, as well as her own dividend payment da_1. Since A-buyers would like to keep all dividend payment (hence dividend assets she has) for DM consumption, the question now is if she only sells type-2 assets, would that be enough to exchange for all of the money balance from I-buyers. And the answer to this question divides the scarce-liquidity case into region 3 and region 4.

When both real balance and assets are enough as in region 1, A-buyer is willing to give any combination of type 1 and type 2 assets in exchanged for the amount of money that allows for optimal consumption q^*. If real balance is enough for q^*, but A-buyers do not have enough assets to exchange for optimal amount of money, then A-buyers will give up all assets they have (including both asset 1 and asset 2), in exchange for equal value of money.

However, in the case where real balance is not enough to allow for consuming q^*, i.e. in region 3 and region 4, it matters which type of asset A-buyer sells first for the reason discussed above. By selling type 1 asset, even though A-buyer gets more money, she loses the dividend payment at the same time, which can serve as direct liquidity for DM consumption. Hence in such scenario, A-buyer will sell type22 asset first. If selling type-2 assets alone is enough to get all I-buyers' money balance, then A-buyers will not sell any of type-1 asset. But if type-2 asset alone is not enough to exchange for all of I-buyer's money balance, A-buyer will then sell some of the type 1 assets. So trading of assets in this case will exhibit pecking order, i.e. non-dividend assets are traded first before agents trade dividend assets.

3.4 Objective Functions and Optimal Behavior

After describing the value functions and bargaining solutions in each sub-markets, in this section I derive a representative buyer's optimal asset holdings. By leading the secondary market value function one period, the representative buyer's objective function, the objective function is given by

$$\begin{aligned}\mathbb{E}\{\Omega^i(\hat{m},\hat{a_1},\hat{a_2})\} = \gamma f V\Big(\hat{\varphi}(\hat{m}+y_m)+d(\hat{a_1}-y_1),\hat{a_1}-y_1,\hat{a_2}-y_2\Big)+(l-\gamma f)V\Big(\hat{\varphi}\hat{m}+d\hat{a_1},\hat{a_1},\hat{a_2}\Big)\\ +\gamma f W\Big(\hat{\varphi}(\hat{m}-\tilde{y_m})+d(\hat{a_1}+\tilde{y_1}),\hat{a_1}+\tilde{y_1},\hat{a_2}+\tilde{y_2}\Big)+(1-l-\gamma f)W\Big(\hat{\varphi}\hat{m}+d\hat{a_1},\hat{a_1},\hat{a_2}\Big)\end{aligned}$$

where the four items of expression in order represent a typical buyer's benefit by holding asset portfolio. ($\hat{m}$,$\hat{a}_1$,$\hat{a}_2$) when turns out to be a matched A-buyer, unmatched A-buyer, matched I-buyer, and unmatched I-buyer, respectively, with y_m, y_1, and y_2 being the bargaining solutions described in previous section. Terms with tilde represent the terms of trade in secondary market when the typical buyer turns out to be an I-buyer and thus participate in secondary market as an asset buyer and money provider. By plugging in expressions for V and W from previous sections, and inserting the obtained expression into the CM value function, we can group together all the terms that contains choice variables $\hat{m}$, $\hat{a_1}$, and $\hat{a_2}$, and call such expression J:

$$\begin{aligned}\beta^{-1}J(\hat{m},\hat{a}_1,\hat{a}_2)\equiv &-\frac{\varphi}{\beta}\hat{m}-\frac{\psi_1}{\beta}\hat{a}_1-\frac{\psi_2}{\beta}\hat{a}_2\\ &+\alpha f\Big[u\Big(\hat{\varphi}(\hat{m}+y_m)+d(\hat{a}_1-y_1)\Big)+\hat{\psi}_1(\hat{a}_1-y_1)+(\hat{\psi}_2+d)(\hat{a}_2-y_2)\Big]\\ &+(l-\alpha f)\Big[u(\hat{\varphi}\hat{m}+d\hat{a}_1)+\hat{\psi}_1\hat{a}_1+(\hat{\psi}_2+d)\hat{a}_2\Big]\\ &+(1-l)[\hat{\varphi}\hat{m}+(\hat{\psi}_1+d)\hat{a}_1+(\hat{\psi}_2+d)\hat{a}_2]\end{aligned}$$

One observation is that, the objective function depends on the outcome of secondary asset market bargaining solution y_m, y_1, and y_2, which further depends on which region the economy is in. Thus depending on whether the two assets constraints bind, as well as the typical buyer's expectation about her asset trading counterpart's asset holding, $\tilde{m}$, the typical buyer's optimal portfolio choice should be discussed for different regions. Here I focus on symmetric equilibrium, and asset demand functions under optimal behavior of the representative buyer is summarized as following

Lemma 3. *Taking prices (φ,ψ_1,ψ_2), and beliefs $(\tilde{m},\tilde{a}_1,\tilde{a}_2)$ as given, the optimal portfolio choice of a representative buyer satisfies the following condition*

Region 1:

$$\begin{aligned}\{\hat{m}\}:&\frac{1+\mu}{\beta}=1+(\ell-\gamma f)[u'(z+da_1)-1]\\ \{\hat{a}_1\}:&\psi_1=\frac{\beta}{1-\beta}\Big\{1+(\ell-\gamma f)[u'(z+da_1)-1]\Big\}=\frac{1+\mu}{1-\beta}d\\ \{\hat{a}_2\}:&\psi_2=\frac{\beta}{1-\beta}d\end{aligned}$$

Region 2:

$$\begin{aligned}\{\hat{m}\}:&\frac{1+\mu}{\beta}=1+(\ell-\gamma f)[u'(z+da_1)-1]+\gamma f[u'\Big(z+(\psi_1+d)a_1+(\psi_2+d)a_2\Big)-1]\\ \{\hat{a}_1\}:&\frac{\psi_1}{\beta}=\psi_1\{1+\gamma f\Big[u'\Big(z+(\psi_1+d)a_1+(\psi_2+d)a_2\Big)-1\Big]\}+\frac{1+\mu}{\beta}d\\ \{\hat{a}_2\}:&\frac{\psi_2}{\beta}=(\psi_2+d)\{1+\gamma f\Big[u'\Big(z+(\psi_1+d)a_1+(\psi_2+d)a_2\Big)-1\Big]\}\end{aligned}$$

Region 3:

$$
\begin{aligned}
\{\hat{m}\} :& \frac{1+\mu}{\beta} = 1 + (\ell - \gamma f)[u'(z + da_1) - 1] + \gamma f[u'(2z + da_1) - 1] \\
\{\hat{a_1}\} :& \psi_1 = \frac{\beta}{1-\beta}\Big\{1 + (\ell - \gamma f)[u'(z + da_1) - 1] + \gamma f[u'(2z + da_1) - 1]\Big\} = \frac{1+\mu}{1-\beta}d \\
\{\hat{a_2}\} :& \psi_2 = \frac{\beta}{1-\beta}d
\end{aligned}
$$

Region 4:

$$
\begin{aligned}
\{\hat{m}\} :& \frac{1+\mu}{\beta} = 1 + (\ell - \gamma f)[u'(z + da_1) - 1] + \gamma f\Big[u'\Big(z + da_1 + \frac{\psi_1}{\psi_1 + d}z + \frac{\psi_2 + d}{\psi_1 + d}a_2\Big) - 1\Big] \\
\{\hat{a_1}\} :& \psi_1 = \frac{\beta}{1-\beta}\Big\{1 + (\ell - \gamma f)[u'(z + da_1) - 1] + \gamma f\Big[u'\Big(z + da_1 + \frac{\psi_1}{\psi_1 + d}z + \frac{\psi_2 + d}{\psi_1 + d}a_2\Big) - 1\Big]\Big\} = \frac{1+\mu}{1-\beta}d \\
\{\hat{a_2}\} :& \psi_2 = (\psi_2 + d)\Big\{1 + \frac{\gamma f d}{\psi_1 + d}\Big[u'\Big(z + da_1 + \frac{\psi_1}{\psi_1 + d}z + \frac{\psi_2 + d}{\psi_1 + d}a_2\Big) - 1\Big]\Big\}
\end{aligned}
$$

Proof. See Appendix A.

4 Equilibrium

4.1 Definition of Equilibrium

I here focus on the symmetric steady state equilibrium. Since A-buyer and I-buyer are ex-ante the same, so they will choose the same portfolio, i.e. $\hat{m} = \tilde{m}$, $\hat{a}_1 = \tilde{a}_1$, and $\hat{a}_2 = \tilde{a}_2$. Also, I focus on the more interesting case where the total liquidity is not too abundant, i.e. $z + dA_1 \leq q^*$. This is because if total liquidity supply is large enough, i.e. $Z + dA_1 > q^*$, A-buyers can rely entirely on her own liquidity to consume the first-best q^* in the DM and hence no trade will happen in the secondary asset market. Next, in describing the equilibrium, let q_1 be the DM consumption quantity if A-buyer didn't meet an I-buyer in secondary market and thus didn't have the opportunity to boost her liquidity position, and q_2 be the quantity of DM consumption if A-buyer matched with an I-buyer in secondary market, and $z = \varphi M$ represents the real money balances.

Definition 1. *The symmetric steady-state equilibrium is a list of* $\{Z, \psi_1, \psi_2, y_m, y_1, y_2, q_1, q_2\}$*, which satisfy:*

1. *The representative buyer behaves optimally under the equilibrium prices* φ*,* ψ_1*, and* ψ_2*.*

2. *The equilibrium quantity* q_1 *satisfies* $q_1 = Z + dA_1$*. For quantity* q_2*,* $q_2 = q^*$ *if in case 1,* $q_2 = Z + (\psi_1 + d)A_1 + (\psi_2 + d)A_2$ *if in case 2,* $q_2 = 2Z + dA_1$ *if in case 3, and* $q_2 = Z + dA_1 + \frac{\psi_1}{\psi_1+d}A_1 + \frac{\psi_2+d}{\psi_1+d}A_2$ *if in case 4.*

3. *Secondary asset market terms of trade (*y_m*,* y_1*,* y_2*) satisfies the bargaining solution when evaluated with aggregate asset supply* M*,* A_1 *and* A_2

4. *Market clears and expectations are rational:* $\hat{a}_1 = \tilde{a}_1 = A_1$*,* $\hat{a}_2 = \tilde{a}_2 = A_2$*, and* $\hat{m} = \tilde{m} = (1 + \mu)M$*.*

Given the definition of equilibrium, the aggregate regions description is the region division equation described in Lemma 2, while the pricing functions are asset demand functions described in Lemma 3, both evaluated at the aggregate asset supplies.

4.2 Properties of Equilibrium

4.2.1 Dividend Premium in Equilibrium

The first implication of the model under equilibrium is that, dividend assets price carries a premium when comparing to non-dividend assets. This result is summarized in the following proposition.

Proposition 1: Dividend premium. *The equilibrium asset prices depend on aggregate asset supplies* M*,* A_1 *and* A_2*. Given the aggregate supplies, the equilibrium could be in one of the four cases. In each of the equilibria, dividend asset price* ψ_1 *is greater than non-dividend asset price* ψ_2*. Define the liquidity relative abundance/scarcity cutoff level as*

$$\bar{Z} \equiv \min\left\{(\psi_1+d)A_1+(\psi_2+d)A_2, q^*-Z-dA_1+\frac{d}{d+\psi_1}\max\left\{0, \min\{q^*-Z-dA_1, Z\}-(\psi_2+d)A_2\right\}\right\}$$

Region 1: If $Z \geq \bar{Z}$, and $(\psi_1 + d)A_1 + (\psi_2 + d)A_2 \geq q^* - Z$, equilibrium is in Region 1 and

$$\psi_1 = \frac{\beta d}{1-\beta}\Big\{1 + \Big[u'(Z + dA_1) - 1\Big]\Big\} = \frac{1+\mu}{1-\beta}d$$
$$\psi_2 = \frac{\beta d}{1-\beta}$$

Region 2: If $Z \geq \bar{Z}$, and $(\psi_1 + d)A_1 + (\psi_2 + d)A_2 < q^* - Z$, equilibrium is in Region 2 and

$$\psi_1 = \beta\psi_1\Big\{1 + \alpha f\Big[u'\Big(Z + (\psi_1 + d)A_1 + (\psi_2 + d)A_2) - 1\Big]\Big\} + (1+\mu)d$$
$$\psi_2 = \beta(\psi_2 + d)\Bigg\{1 + \alpha f\Big[u'\Big(Z + (\psi_1 + d)A_1 + (\psi_2 + d)A_2\Big) - 1\Big]\Bigg\}$$

Region 3: If $Z < \bar{Z}$, and $(\psi_2 + d)A_2 \geq Z$, equilibrium is in Region 3 and

$$\psi_1 = \frac{\beta}{1-\beta}\Big\{1 + (\ell - \alpha f)[u'(Z + dA_1) - 1] + \alpha f[u'(2Z + dA_1) - 1]\Big\} = \frac{1+\mu}{1-\beta}d$$
$$\psi_2 = \frac{\beta d}{1-\beta}$$

Region 4: If $Z < \bar{Z}$, and $(\psi_2 + d)A_2 < Z$, equilibrium is in Region 4 and

$$\psi_1 = \frac{\beta}{1-\beta}\Big\{1 + (\ell - \alpha f)[u'(Z + dA_1) - 1] + \alpha f\Big[u'\Big(Z + dA_1 + \frac{\psi_1}{\psi_1 + d}Z + \frac{\psi_2 + d}{\psi_1 + d}A_2\Big) - 1\Big]\Big\} = \frac{1+\mu}{1-\beta}d$$
$$\psi_2 = \beta(\psi_2 + d)\Big\{1 + \frac{\alpha f}{\psi_1 + d}\Big[u'\Big(Z + dA_1 + \frac{\psi_1}{\psi_1 + d}Z + \frac{\psi_2 + d}{\psi_1 + d}A_2\Big) - 1\Big]\Big\}$$

The pricing functions might look a bit complicated, but they're quite intuitive. In the cases where the assets constraints are not binding, type-2 assets will always be priced at the fundamental value, where type-1 assets will carry direct liquidity premium in the scenarios whenever the DM consumption is less than first-best q^*. To help understand this idea, take Region 2 (liquidity abundant but asset scarce) and Region 3 (liquidity scarce but asset abundant) as examples, and pricing functions in region 1 and region 4 adopts the same logic.

In Region 2, where total liquidity is enough however total assets are not enough to exchange for optimal money balance, A-buyers do not get to consume optimal q^* even when they get the chance to rebalance their portfolio. Since dividend payment is a perfect substitute for money, the value of dividend payment is always determined the same way as real money balance, by μ. In addition to the direct liquidity provided by dividend payment, the resale value of type-1 assets also allows A-buyers to exchange for more money, hence provide liquidity indirectly with probability $\ell - \gamma f$ through secondary market. Hence the resale value component of type-1 asset, ψ_1, carries a indirect liquidity premium. For type-2 assets, they do not provide liquidity directly, but provide indirect liquidity with probability γf by allowing for exchanging more money balance in the secondary market. Hence both dividend component and resale value component carry indirect liquidity premium.

In Region 3, total liquidity is scarce, thus even after pulling together all A-buyers' and I-buyers' money balance it still does not allow for optimal consumption q^*. And since type-2 asset alone is enough to exchange for all I-buyers real money balance, A-buyers will not sell any of the type-1 asset in order to keep the dividend for extra liquidity. Type-1 asset in this region only provide direct liquidity, same as money, and does not provide liquidity indirectly since agents do not sell any of the type-1 asset in secondary market. Hence the price is determined by μ, with no indirect liquidity premium. For type-2 assets, since type-2 assets is abundant in this region, additional unit of type-2 asset does not help provide liquidity either directly or indirectly, hence will always be priced at the fundamental value.

Proposition 2. *Non-dividend assets (type-2 assets) have higher turnover ratio than dividend assets (type-1 asset).*

This results follow directly from the pecking order behavior of selling assets when liquidity is relatively scarce, i.e. case 3 and case 4. Since in these 2 cases, type-2 assets will be offloaded first before agents begin to sell type-1 assets, type-2 assets are traded more frequently and hence have a higher turnover ratio. Intuitively, this is due to the fact that type-2 assets only serve the role as store of value, while type-1 assets serve the role of both store of value and providing direct liquidity. So agents will hold onto type-1 assets longer, and turnover type-2 assets faster.

Proposition 3. *The dividend premium decreases in market matching efficiency, α.*

Here, I define the dividend preimium as the difference between the two asset prices $\psi_1 - \psi_2$. And it can be shown that, for any given region, $\frac{\partial(\psi_1 - \psi_2)}{\partial \alpha} < 0$. Intuitively, as secondary market matching becomes more efficient, agents can sell their assets to boost liquidity position right away when having liquidity needs. With such efficient market, agents' demand for dividend in facilitating urgent consumption is lower, and hence are not willing to pay a high premium for the liquidity service.

5 Empirical Analysis

In this section, I provide empirical evidence to support the model predictions. The data I use are from Compustat and CRSP, which covers over 7,000 firms, excluding financial firms and public utlity firms, over the period 1971-2016. To test Proposition 1 on dividend premium, I replicate the empirical strategy from Karpavičius & Yu (2018). The specification used is given as following

$$\textit{Market-to-Book Ratio} = a_0 + \alpha_1 DVD_{it} + \Omega'(L) Z_{it} + \lambda_t + \mu_i + \varepsilon_{it}$$

ME/E is the market-to-book ratio of equity as a measure of price premium. For completeness, besides market-to-book ratio of equity, market-to-book ratio of asset is also used as measure of price premium. For the explanatory variable, dividend status is the variable of main interest. In the regression, DVD is the dividend dummy variable that equals 1 if the stock pays dividend in that year and equals 0 otherwise. In addition to the dividend dummy variable, the test is performed also on dividend as a continuous variable $DIV(Continuous)$.

Z_{it} is the set of control variables which include asset size, net income, total debt, total cash, PPE, capital expenditure, R&D, and volatility which is measured as the standard deviation of monthly stock return. All control variables are normalized either by total equity size or total asset size, depending on if the price premium on the left hand side of the regression is measure by market-to-book ratio of equity or asset. And to control for unobserved firm characteristics and year-related factors, the least-squares model also includes year fixed effects λ_t and firm fixed effects μ_i.

With the model prediction, the expectation of the empirical result is that the coefficient estimates for dividend variable (dummy or continuous) should be positive, implying that dividend assets are valued more by the market comparing to non-dividend assets, hence carry a price premium. The results show in the Table 1 following the empirical strategy confirm the model prediction.

Variables	ME/E	ME/E	MA/A	MA/A
DVD	0.361**		0.131***	
	(0.156)		(0.0288)	
DIV (Continuous)		4.589***		0.0212
		(0.110)		(0.0314)
R-squared	0.760	0.766	0.521	0.521
Control Variables	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

Standard errors in parentheses

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

Table 1: Dividend as a determinant for asset market value.

The results show that dividend assets on average have a higher market-to-book ratio using both type of measure of price premium. The average market-to-book ratio of equity for the entire data set is 3.357, hence a coefficient estimate of 0.361 represents a price premium of 10.75%; market-book-ratio of asset of the data set is 1.893, hence the coefficient estimate of 0.131 represents a price premium of 6.92%. These results confirm that dividend assets are priced higher than non-dividend assets.

Next to test Proposition 2, that turnover ratio for non-dividend assets is higher than that of dividend assets, I use the same set of data and control variables, with normalization of control variables using either total asset or total equity. I define turnover ratio as: Turnover ratio = Trade Volume/Total Shares Outstanding. The specification is given by

$$TurnoverRatio = \alpha_0 + \alpha_1 DVD_{it} + \Omega'(L)Z_{it} + \lambda_t + \mu_i + \varepsilon_{it}$$

With Proposition 2, it is expected that the coefficient estimates for the dividend dummy variable should be negative, implying that the turnover ratio for a dividend asset should be lower. And this prediction is confirmed in the data.

VARIABLES	Turnover Ratio (Equity)	Turnover Ratio (Asset)
DVD	-1.935***	-1.599***
	(0.544)	(0.542)
Control Variables	Yes	Yes
Firm FE	Yes	Yes
Year FE	Yes	Yes

Standard errors in parentheses

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

Table 2: Dividend as a determinant for turnover ratio.

From the results presented in Table 2, dividend assets have lower turnover ratio comparing to non-dividend assets, regardless of whether the explanatory variables are normalized by asset size or equity size.

Finally, to test Proposition 3 that dividend premium decreases in market matching efficiency, I add a new dummy variable 'Illiquid', which equals to 1 if the turnover ratio of the stock is below the median. With the same matching function $f(\ell, 1-\ell)$ for all assets, the ones that are less liquid would have additional matching friction which is represented by a smaller value of γ. So here I use 'Illiquid' as a measure of individual stock's matching efficiency. And to see that dividend plays an more important role when market is less liquid as suggested by Proposition 3, I add an interaction term of dividend dummy variable and illiquid dummy variable. The specification is as the following

$$\textit{Market-to-Book Ratio} = \alpha_0 + \alpha_1 DVD_{it} + \alpha_2 Illiquid + \alpha_3 DVD \times Illiquid + \Omega'(L) Z_{it} + \lambda_t + \mu_i + \epsilon_{it}$$

According to proposition 3, the coefficient estimate for the interaction term should be positive, implying that when stocks are less liquid, there is additional premium that dividend provides. This prediction is confirmed in the data, and is summarized in Table 3.

Variables	ME/E	MA/A
DVD	0.0548	-0.0376
	(0.175)	(.032739)
Illiquid	-0.971***	-0.536***
	(0.118)	(.0222)
DVD×*Illiquid*	0.802***	0.399***
	(0.184)	(0.034)
Firm FE	Yes	Yes
Year FE	Yes	Yes
R-squared	0.769	0.5260

Standard errors in parentheses

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

Table 3: Matching efficiency and dividend premium.

This empirical exercise provides some interesting results. First of all, dividend dummy variable alone does not produce positive and significant prediction for price premium anymore. The coefficient estimates of 0.0548 and -0.0376 using equity and asset measures respectively have contradicting signs but are both insignificant. This result is consistent with the irrelevance theory that dividend alone should have no impact on explaining firm's value or asset prices. However the most important observation is that, the coefficient estimates for the interaction term is positive and significant, meaning that if an asset is illiquid, paying dividend now would raise the market valuation comparing to a non-dividend asset that is equally illiquid. This result provides direct evidence to support the liquidity channel of the model that, because the asset market is not always perfect as assumed in the irrelevance theory, the friction in selling assets is what gives rise the the pricing premium for the dividend assets.

6 Engogenizing Asset Supply

Until this point, I studied the dividend premium through asset liquidity channel, taking asset supply A_1 and A_2 as given. The question remains to be addressed is, if paying dividend is always better (or worse) than not paying dividend, then why not all firms behave in the same way, i.e. all firms pay dividend or none of the firms pay dividend? To answer this question, I study firms' choice in paying dividend and endogenize aggregate supply for both types of assets in this section.

To better understand firms' behavior, especially what activities do dividend firms and non-dividend firms do differently, I look into the balance sheets of firms in the sample. Because in order for the balance sheet to balance, i.e. Asset = Liability + Equity, the action of paying dividend (which affects the equity category) must be accompanied by a change in other balance sheet account(s). I use the balance sheet data with the same 7,000 firms, and normalize all balance sheet items with asset size. Then in order to control for the impact of firm size on firms' strategic planning, i.e. small firms might have different priorities than big firms in allocating the limited funding resource, I further divide the data set into three groups based on firm size. One balance sheet item that is significantly different between dividend firms and non-dividend firms is the R&D expenditures. More specifically, R&D expenditures are significantly higher for non-dividend firms than for dividend firms, and this is true across all three size groups, which the result is summarized in Table 4.

	R&D Expenditures		
Firm size	Dividend	Non-dividend	Difference
Small	0.023	0.345	0.322***
Medium	0.014	0.092	0.078***
Large	0.013	0.035	0.022***

Table 4: Normalized R&D expenditure from balance sheet

This observation provides a direction about the trade-off that firms are facing when making dividend decisions, hence in modeling firms' optimal dividend choice, I study the trade-off between paying dividend and investing in R&D activities. By paying dividend, firms benefit from having a higher share price because of the dividend premium. And by not paying dividend but invest into R&D instead, firms can make use of the resource in a more productive way by having higher TFP in production.

6.1 Model Environment

In this section, I will describe the environment. The structure of this general equilibrium model is the same as in the partial equilibrium model in previous section, with several differences to accommodate a more non-trivial optimal behavior from the supply side of the economy. And since this section focuses on firms' optimal decision, I first impose a few simplifying assumptions, without loss of generality. First of all, there will be no secondary asset market. This assumption should not affect firms' decision because participants of the secondary asset market are A-buyers and I-buyers, but not the firms. Second, to simplify the math expression, assets in this environment will have no resale value. And this again should have no impact on firms making optimal decision, since with or without resale value, dividend assets carry a price premium hence firms still benefit from the dividend premium and facing the same trade-off between higher share price and higher TFP.

There are firms with measure of 1, which will replace the sellers' DM role in the partial equilibrium model. In the CM, all firms are endowed with k amount of capital to work with for $t+1$ production, which for simplicity I assume k is large enough to produce optimal quantity q^*. This assumption is not necessary for the results to go through, but simplifies the discussion. A more generalized version that does not impose assumption on k is discussed in the appendix. In addition to the endowed capital, firms issue stock shares to raise additional resource to maximize firms' value, either by paying dividend or by taking advantage of R&D opportunities. Among the measure of 1 firms, Σ fraction of the firms are the dividend firms, while the remaining $1-\Sigma$ firms are the non-dividend firms. This fraction Σ will be uniquely determined in equilibrium.

In the CM, firms need to make decision on whether to enter next period as a dividend firm or a non-dividend firm. And when making such entry decision, all firms take asset prices ψ_1, ψ_2 and all other firms' entry decision, Σ, as given. If firms decide to enter as the dividend type, they will issue type-1 stocks, pay early dividend d in DM_{t+1}, and distribute the remaining firm's value, Δ_1^{CM}, back to shareholders in CM_{t+1}. If the firms decide to enter as the non-dividend type, they issue type-2 stocks, and invest e amount in R&D activities, which will translate into higher TFP factor, $A(e)$, for producing intermediate goods for DM production. Since type-2 firms do not pay dividend, they distribute back the entire firm's value back to shareholders in CM_{t+1}.

The objective of the firms is to maximize the total amount of 'value' they can give to the shareholders. For type-1 (dividend) firms, this 'value' includes the early dividend d paid in the DM, and the remaining firms value shareholders are entitled to at CM, i.e. $d + \Delta_1^{CM}$. And for type-2 (non-dividend) firms, this 'value' is only the firm's value shareholders entitled to at CM, i.e. Δ_2^{CM}. Given this, if paying dividend produces a higher value, then firms will choose to enter the market as a dividend type, and vice versa. The model predicts that, in equilibrium, there exist a unique and interior fraction, $\Sigma^* \in (0,1)$, such that firms are indifferent between entering the market as a dividend type or as a non-dividend type.

6.2 Value Functions

In this section, I will describe the value functions in each sub-markets. The main differences comparing to the exogenous asset supply model is that, the objective of a firm (replacing the seller's role in exogenous supply model) is to maximize the value of the firm, instead of utility. In addition, since now firms' role is non-trivial hence needs to be modeled more carefully, I allow a more general bargaining protocol in DM such that the bargaining surplus is shared between A-buyers and firms, instead of a TIOLI bargaining as in exogenous model such that firm's DM surplus is 0.

6.2.1 CM

Upon entering the CM, firms' state variables are: remaining capital after DM production z_k, and profit p from DM production. Firms maximize the remaining value to distribute to the shareholders:

$$W^F(z_i^k, p_i) = \max_{\Delta_i^{CM}} \Delta_i^{CM}$$
$$\text{s.t. } \Delta_i^{CM} = z_i^k + p_i$$

Hence firms' CM value function is given by $W^F(z_i^k, p_i) = z_i^k + p_i$, where $i \in \{1, 2\}$ denotes the type-i firms.

Buyers' CM value functions adopts the same form as in the previous section but simpler because of the simplifying assumptions of no resale value and no secondary asset market: $W^B(z, a_1, a_2) = \Lambda^B + z + da_2$.

6.2.2 DM

DM bargaining is between A-buyer buyers and firms. Firms produce special goods using intermediate goods they brought into DM as input. The production technology transform one unit of intermediate goods into one unit of special goods. Consumers' bargaining surplus remains unchanged from previous section $u(q) - \pi$, and firms' bargaining surplus adopts from sellers' bargaining surplus, $q - \pi$, from previous section as well. However, besides the bargaining constraint and liquidity constraint as in the exogenous model, now the production faces additional input capital constraint, i.e. the amount of special goods being produced, q, cannot exceeds the amount of intermediate goods that firms bring into the DM. Hence the bargaining problem is given by

$$\begin{aligned}
&\max_{q,\pi} u(q) - \pi \\
\text{s.t. } & u(q) - \pi = \frac{\theta}{1-\theta}(\pi - q) \\
&\pi \leq da_1 \\
&q \leq z_i^k
\end{aligned}$$

Now, since there are two types of firms, with potentially different amount of input capital, the bargaining solution would depend on which type of firm A-buyer meets with.

For a type-1 firm entering time $t+1$, they carry k amount of endowed capital and ψ_1 amount of additional capital raised from issuing stocks. However, because they are the dividend type and promised to pay dividend d at the beginning of DM, the amount of working capital they have is $k + \psi_1 - d$, which can be transformed one-to-one into input capital for DM production. If the firm pays too much dividend in DM, then it's possible that the firms do not have enough input capital to produce what A-buyer demands. So the quantity of special goods being produced when meeting with a type-1 firm is limited by either the input capital amount firms have, or the amount of liquidity A-buyers carry, whichever side is more limited. The bargaining solution is hence given by

$$\begin{cases} q_1 = \min\{\psi_1 + k - d, \nu^{-1}(da_1)\} \\ \pi_1 = \nu(q_1) = (1-\theta)u(q_1) + \theta q_1 \end{cases}$$

For a type-2 firm entering time $t+1$, with e amount invested into R&D, total TFP is higher and can transform resources into input capital more efficiently. And such TFP factor, $A(e)$, has the following properties: $A(0) = 0$, $A'(0) \to \infty$, $A'(e) > 0$, and $A''(e) < 0$. If firms decide to invest $e = 0$, then the production technology is just one-to-one, which is the same technology faced by type-1 firm with no R&D investment, i.e. $e = 0$.

Upon entering $t+1$, type-2 firm has k amount of endowed capital and ψ_2 amount of additional capital raised from issuing stocks. After spending e amount in R&D activities, firm's TFP is raised to $A(e) > 1$, and the remaining working capital is hence $k + \psi_2 - e$. The

TFP factor $A(e)$ can thus transform the working capital $k + \psi_2 - e$ in to $A(e)(k + \psi_2 - e)$ amount of input capital to be used in DM production. Different from type-1 firms that dividend policy could potentially lower its capital to a sub-optimal level for production, investing in R&D can only raise the amount of input capital beyond the level of special goods production that firms is originally capable of producing, q^*. Thus the input capital constraint when meeting with a type-2 firm is never binding. The bargaining solution is given by

$$\begin{cases} q_2 = \nu^{-1}(da_1) \\ \pi_2 = \nu(q_2) = (1-\theta)u(q_2) + \theta q_2 \end{cases}$$

6.3 Objective Functions and Optimal Behavior

Now, after describing the value functions, I proceed to the objective functions of agents and firms, and analyze the optimal behavior of agents and firms.

6.3.1 Buyers

By plugging in expression for V and W into the CM value function, buyers' objective function adopts a similar form

$$\beta^{-1}J(\hat{a}_1, \hat{a}_2) = -\psi_1 a_1 - \psi_2 a_2 + \beta(1-\ell)W^C(d\hat{a}_1, \hat{a}_1, \hat{a}_2) + \beta\ell\Big\{u(\nu^{-1}(d\hat{a}_1) - d\hat{a}_1 + W^C(d\hat{a}_1, \hat{a}_1, \hat{a}_2)\Big\}$$

where the first two terms represent the cost of carrying assets, and the remaining terms represent the benefit of carrying assets. Hence by taking derivative to the objective function with respect to $\hat{a}_1$ and $\hat{a}_2$, the pricing functions are given by

$$\frac{\psi_1}{\beta} = (d + \Delta_1^{CM}) + \ell d\left\{\frac{u'[\nu^{-1}(d\hat{a}_1)]}{\nu'[\nu^{-1}(d\hat{a}_1)]} - 1\right\}$$
$$\frac{\psi_2}{\beta} = \Delta_2^{CM}$$

6.3.2 Firms

In the CM, type-1 firms will choose and announce the amount of dividend d to be paid in DM_{t+1} in order to maximize the total value to be distributed to the shareholders. Hence type-1 firms solve the following problem:

$$\max_{d} d + \Delta_1^{CM} = d + [(\psi_1 + k - d - q) + \pi] = \psi_1 + (1-\theta)[u(q) - q]$$

where the value Δ_1^{CM} consists of remaining capital after production and dividend payment $\psi_1 + k - d - q_1$, and the DM profit $(1-\theta)u(q_1) + \theta q_1$. One observation is that, dividend d does not directly show up in the expression. This is because for firms, the timing of paying dividend (either in the DM or in the CM) does not affect the total payment they make to the shareholders, hence does not affect firms' objective directly. However, dividend d could potentially affect the objective through DM bargaining surplus $(1-\theta)[u(q_1) - q_1]$. If the dividend payment is too high, such that after paying dividend, firms do not have enough input capital to produce the quantity of special goods that buyers demand, then the total profit would be lower. Given this, the dividend d would be optimal only if firms preserve enough input capital to produce the demanded quantity of special goods, and distributing the residual capital as dividend. where the terms with tilde denotes firms expectation of A-buyers' liquidity holding.

As for type-2 firms, they will choose the optimal e amount to invest into R&D and get a higher TFP. Hence the problem for type-2 firm is:

$$\max_{e} \Delta_2 = \Delta_2^{CM} = [A(e)(\psi_2 + k - e) - q] + (1-\theta)[u(q) - q]$$

With the properties of the TFP factor $A(e)$, there exists a unique $e^* \in (0, \psi_2 + k)$ such that Δ_2 is maximized.

Lemma 4. *Given firms' expectation of A-buyers liquidity position $\tilde{d\tilde{a}}_1$, a type-1 (dividend) firm's optimal dividend payment is $d^* \in [0, \psi_1 + k - \nu^{-1}(\tilde{d\tilde{a}}_1)]$; and for a type-2 (R&D) firm, there exists a unique and interior $e^* \in (0, \psi_2 + k)$ such that firm's value is maximized.*

Proof. See Appendix A.

6.4 Equilibrium and Policy Implication

In this section, I define the equilibrium of the endogenous asset supply model, and describe the policy implications in equilibrium.

Definition 2 *The symmetric steady-state equilibrium is a list of DM bargaining solution $\{q_1, q_2\}$, firms' dividend and R&D decision $\{d, e\}$, firms' entry decision Σ, and prices $\{\psi_1, \psi_2\}$ such that:*

1. *The representative buyers and firms behave optimally under the equilibrium price ψ_1, ψ_2, and equilibrium entry decision Σ*

2. *Σ satisfies $\Delta_1(\Sigma) = \Delta_2$, so that firms are indifferent between entering as a dividend firm and non-dividend firm*

3. *$\{q_1, q_2\}$ satisfies the bargaining solution evaluated at the aggregate asset supply, Σ and $1 - \Sigma$*

4. *Market clears: $\hat{a}_1 = \Sigma$, $\hat{a}_2 = 1 - \Sigma$*

In equilibrium, taking the asset prices ψ_1, ψ_2 and other firms' decision Σ as given, type-1 firms will follow the optimal dividend policy d^*, type-2 firms invest optimal e^* in R&D activities, and agents choose optimal assets to carry into next period. And the market clears with $\hat{a}_1 = \Sigma$ and $\hat{a}_2 = 1 - \Sigma$. Hence the pricing functions in equilibrium are given as:

$$\frac{\psi_1}{\beta} = (d + \Delta_1^{CM}) + \ell d \left\{ \frac{u'[\nu^{-1}(d\Sigma)]}{\nu'[\nu^{-1}(d\Sigma)]} - 1 \right\}$$
$$\frac{\psi_2}{\beta} = \Delta_2^{CM}$$

And firms' values are given by:

$$\Delta_1 = \psi_1(\Sigma) + (1 - \theta)[u(q) - q]$$
$$\Delta_2 = A(e^*)(\psi_2 + k - e^*) + (1 - \theta)[u(q) - q]$$

One direct observation is that, in equilibrium, dividend asset price and hence firms' value Δ_1 depends on aggregate dividend amount $d\Sigma$, while non-dividend firms share price and hence Δ_2 does not depend on Σ. Given this, if $\Delta_1(\Sigma) > \Delta_2$, then all firms should be entering the market as a type-1 firm, and vice versa.

Proposition 4. *In equilibrium, there exists a unique fraction of dividend firms, Σ^*, such that the values of dividend firms and non-dividend firms are the same, i.e. $\Delta_1(\Sigma^*) = \Delta_2$.*

Intuitively, Σ determines the total amount of dividend in the economy, and hence how much premium buyers are willing to pay for dividend asset. When all other firms decide to pay dividend, i.e. $\Sigma = 1$, aggregate liquidity is too high and buyers will not be willing to pay premium on additional dividend anymore. This is the case where the dividend premium, which is also the benefit of firms entering as a dividend firm, is completely exploited, and hence the optimal entry decision would be to enter as a non-dividend firm and invest in R&D activities to boost productivity. Oppositely, if all other firms choose to not pay dividend, i.e. $\Sigma = 0$, the aggregate dividend is scarce, and buyers would be willing to pay an extremely high premium to get dividend. The optimal entry decision now would be to enter as a dividend firm to take advantage of such high dividend premium. And since the dividend premium is monotonically decreasing in aggregate dividend $d\Sigma$, there exist a unique fraction Σ^* such that the dividend premium and the higher TFP from R&D investment contribute the same to firms' value, and hence $\Delta_1(\Sigma^*) = \Delta_2$.

From previous analysis, firms' entry decision is uniquely determined by aggregate liquidity and hence dividend premium. But besides dividend, real money balance plays the same role in determining the aggregate liquidity and hence dividend premium. Hence I next analyze how monetary policy and aggregate dividend jointly determine the dividend premium, and then further affect aggregate R&D decision.

Notice that real money balance Z enters the pricing function through DM utility the same way as dividend. Hence the to make firms indifferent between entering as a dividend firm and a non-dividend firm, we must have $\Delta_1 = \Delta_2$. And when real money balance and aggregate dividend jointly determine the total liquidity, using the equilibrium firms' value defined in previous discussion, this indifference condition in equilibrium becomes

$$(d+\Delta_1^{CM})+\ell d\left\{\frac{u'[\nu^{-1}(z+d\Sigma^*)]}{\nu'[\nu^{-1}(z+d\Sigma^*)]}-1\right\}+\pi=A(e^*)(\psi_2+k-e^*)+\pi$$

where $\pi=(1-\theta)[u(q)-q]$ is the DM bargaining surplus and is the same for both types of firms since DM production for both firms are pinned down by A-buyers' liquidity holding.

By taking total differentiation on both side with respect to interest rate i, it can be shown that $\frac{\partial\Sigma^*}{\partial i}=-d\frac{\partial z}{\partial i}>0$. This implies that, if interest rate increases, there will be more firms start to pay dividend, hence less firms invest in R&D. Proposition 5 summarizes this result.

Proposition 5. *A contractionary monetary policy raises aggregate dividend payment, and lowers aggregate R&D activities, i.e.* $\frac{\partial\Sigma^*}{\partial i}>0$.

The intuition for this result is simple as the following. An increase in interest rate depresses real money balance, which makes buyers rely more on dividend payment for DM consumption. The higher demand for dividend raises the premium for dividend assets, which makes the option of paying dividend more attractive for firms when comparing to investing in R&D. Thus more firms will pay dividend and take advantage of the high share price, while at the same time discourage firms to invest in R&D activities. This prediction shows that, besides the common belief that a contractionary monetary policy hurts the economy through reducing real money balance and hence consumption, it can have additional negative impact on the economy through discouraging R&D activities.

7 Conclusion

Selling assets in the frictional secondary market could be costly. Because of this, dividend assets which provide direct liquidity when agents have consumption needs would help avoid such friction, and hence command a price premium for its superior liquidity role. In this paper, I explore this mechanism and provide a theoretical framework to understand it. I show that through the liquidity channel, dividend assets are priced higher comparing to the non-dividend assets, with equal price only when carrying liquidity is not costly, i.e. at the Friedman Rule.

Besides offering a liquidity-based explanation for the dividend puzzle, the model delivers two additional testable predictions. First of all, asset trade exhibits a certain "pecking order". More specifically, to meet an urgent liquidity needs, agents will visit the secondary asset market and sell non-dividend assets before selling any dividend assets. The intuition is that, dividend provides direct liquidity for transaction, and by selling dividend assets, agents miss the opportunity of using the upcoming dividend for consumption. Hence in the economy where liquidity is scarce, agents first sell non-dividend assets, and only when non-dividend assets alone cannot exchange for enough liquidity should agents decide to sell dividend assets. The second prediction is that, dividend premium is more pronounced when market is less liquid. This is due to the fact that, less liquid secondary market means more friction and the chance of agents not being about to sell assets becomes larger. This makes agents more willing to pay a premium on dividend assets to help avoid the need of visiting the frictional secondary market. I then provide empirical evidence in supporting these testable predictions.

I further study firms' dividend decision by endognenizing the aggregate asset supplies. I show that when firms face trade-off between higher share price and higher production TFP, in equilibrium, there exists a unique fraction of firms, Σ^* that will engage in R&D activities, while the remaining firms will pay dividend. Furthermore, I show that the fraction of firms who decide to pay dividend (the fraction of R&D firms) increases (decreases) in inflation. Thus my model suggests that higher inflation hurts the economy not only the traditional channel of depressing real money balance, but also through discouraging aggregate R&D activities.

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A Appendix

Proof of Lemma 2.

For the secondary market bargaining between an A-buyer and an I-buyer, the Lagrangian function becomes:

$$\begin{aligned}\mathcal{L} =& u\Big(\varphi(m+y_m)+d(a_1-y_1)\Big)-u(\varphi m+da_1)-\psi_1 y_1-(\psi_2+d)y_2\\ &+\tau_B\Big[(\psi_1+d)y_1+(\psi_2+d)y_2-\varphi y_m\Big]+\tau_m(\tilde{m}-y_m)+\lambda_m y_m\\ &+\tau_1(a_1-y_1)+\lambda_1 y_1+\tau_2(a_2-y_2)+\lambda_2 y_2\end{aligned}$$

where τ_b is the Lagrangian multiplier on the bargaining constraint, τ_m, τ_1, τ_2 are the Lagrangian multipliers on the feasibility constraints, and λ_m, λ_1, λ_2 are the Lagrangian multipliers on the non-negativity constraints. The corresponding first order conditions are given by

$$u'\Big(\varphi(m+y_m)+d(a_1-y_1)\Big)\varphi-\tau_B\varphi-\tau_m+\lambda_m=0 \tag{a.1}$$

$$-u'\Big(\varphi(m+y_m)+d(a_1-y_1)\Big)d-\psi_1+\tau_B(\psi_1+d)-\tau_1+\lambda_1=0 \tag{a.2}$$

$$-(\psi_2+d)+\tau_B(\psi_2+d)-\tau_2+\lambda_2=0 \tag{a.3}$$

$$\varphi y_m=(\psi_1+d)y_1+(\psi_2+d)y_2 \tag{a.4}$$

I describe the cases that yield the bargaining solutions, and omitted the cases which reach a contradiction.

<u>Case 1:</u> $\tau_m=0,\lambda_m=0;\tau_1=0,\lambda_1=0;\tau_2=0,\lambda_2=0\Rightarrow 0<y_m<\tilde{m},0<y_1<a_1,0<y_2<a_2$.

Equation (a.3) implies that $\tau_B=1$, which further implies from equation (a.1) and (a.2) that $\varphi(m+y_m)+d(a_1-y_1)=q^*$. Equation (a.4) implies that $\varphi y_m=(d+\psi_1)a_1+(d+\psi_2)a_2$. Hence with these two conditions, it is implied that the $\varphi y_m-dy_1=q^*-\varphi m-da_1\leq\psi_1 a_1+(d+\psi_2)a_2$. And also, $\varphi\tilde{m}\geq\varphi y_m=q^*-\varphi m-da_1+\frac{d}{d+\psi_1}[q^*-\varphi m-da_1-(d+\psi_2)a_2]$ as the liquidity constraint.

<u>Case 2:</u> $\tau_m=0,\lambda_m=0;\tau_1>0,\lambda_1=0;\tau_2>0,\lambda_2=0\Rightarrow 0<y_m<\tilde{m},y_1=a_1,y_2=a_2$.

Equation (a.4) implies that $\varphi\tilde{m}>\varphi\bar{y}_m=(d+\psi_1)a_1+(d+\psi_2)a_2$. Equation (a.3) implies that $\tau_B > 1$, which further implies from equation (a.1) and (a.2) that $\varphi(m + \bar{y}_m) < q^*$.

<u>Case 3:</u> $\tau_m > 0$, $\lambda_m = 0$; $\tau_1 > 0, \lambda_1 = 0$; $\tau_2 > 0, \lambda_2 = 0 \Rightarrow y_m = \tilde{m}, y_1 = a_1, y_2 = a_2$.

In this case, equation (a.3) implies that $\tau_2 = (\tau_B - 1)(d + \psi_2) > 0$, or $\tau_B > 1$. And using this in equation (a.1) shows that $u'\Big(\varphi(m+\tilde{m})\Big) - \tau_B = \frac{\tau_m}{\varphi} > 0$, hence $u'\Big(\varphi(m+\tilde{m})\Big) > \tau_B > 1$. By plugging $\tau_B > 1$ into (a.2), there exists positive τ_1. The corresponding total liquidity then must satisfy $\varphi(m + \tilde{m}) < q^*$. The corresponding asset constraint is given by equation (a.4): $\varphi m = (\psi_1 + d)a_1 + (\psi_2 + d)a_2$.

<u>Case 4:</u> $\tau_m > 0, \lambda = 0; \tau_1 = 0, \lambda_1 = 0; \tau_2 > 0, \lambda_2 = 0 \Rightarrow y_m = \tilde{m}, 0 < y_1 < a_1, y_2 = a_2$.

Equation (a.4) implies that $(d + \psi_1)y_1^* = \varphi\tilde{m} - (d + \psi_2)a_2$. And similar to case 1, equation (a.3) implies $\tau_B > 1$, which satisfies equation (a.2) as well. This further implies that $\varphi(m+\tilde{m}+d(a_1-y_1^*)) < q^*$. Hence for this case, the asset constraint satisfies $(d+\psi_1)a_1+(d+\psi_2)a_2 > \varphi\tilde{m}$, and the liquidity constraint satisfies $\varphi\tilde{m} < q^* - \varphi m - da_1 + \frac{d}{d+\psi_1}[\varphi\tilde{m} - (d+\psi_2)a_2]$.

<u>Case 5:</u> $\tau_m > 0, \lambda_m = 0; \tau_1 = 0, \lambda_1 > 0; \tau_2 = 0, \lambda_2 = 0 \Rightarrow y_m = \tilde{m}, y_1 = 0, 0 < y_2 < a_2$.

Equation (a.4) implies that $\varphi\tilde{m} = (d+\psi_2)y_2 < (d+\psi_2)a_2$ as the asset constraint. Equation (a.3) shows that $\tau_B = 1$, which further implies from equation (a.1) that $\varphi(m+\tilde{m}+da_1) < q^*$ as the liquidity constraint, which is also confirmed from equation (a.2).

<u>Case 6:</u> $\tau_m > 0, \lambda_m = 0; \tau_1 = 0, \lambda_1 > 0; \tau_2 > 0, \lambda_2 = 0 \Rightarrow y_m = \tilde{m}, y_1 = 0, y_2 = a_2$.

Equation (a.4) implies that $\varphi\tilde{m} = (d + \psi_2)a_2$ as the asset constraint. Equation (a.3) shows that $\tau_B > 1$, which further implies from equation (a.1) that $\varphi(m + \tilde{m} + da_1) < q^*$ as the liquidity constraint, which is also confirmed from equation (a.2).

The other combinations of Lagrangian multipliers yield contradicting results among equation (a.1)-(a.4), and hence cannot be the solution to the bargaining problem. Case 1 corresponds to the bargaining outcome for region 1, while case 2 is the bargaining solution for region 2. Case 3 4 jointly determine the bargaining solution for region 3, and case 5 6 jointly determine the bargaining solution for region 4.

Proof of Lemma 3.

Since the bargaining solution depends on which region the economy is in, hence different sets of bargaining solution will yield different objective functions for each region.

<u>Region 1:</u> The bargaining solution (y_m^*, y_1^*, y_2^*) satisfy the asset condition derived in Lemma

2, $(d+\hat{\psi}_1)y_1^* + (d+\hat{\psi}_2)y_2 = q^* - \hat{\varphi}\hat{m} - d\hat{a}_1$. Hence the objective function for region 1 adopts the following form

$$\beta^{-1}J^1(\hat{m},\hat{a_1},\hat{a_2}) = -\frac{\varphi}{\beta}\hat{m} - \frac{\psi_1}{\beta}\hat{a_1} - \frac{\psi_2}{\beta}\hat{a_2} + \gamma f u(q^*) - \gamma f(q^* - \hat{\varphi}\hat{m} - d\hat{a}_1)$$
$$+(\ell-\gamma f)u\Big(\hat{\varphi}\hat{m} + d\hat{a}_1\Big) - \ell(\hat{\varphi}\hat{m} + d\hat{a}_1) + \Big[\hat{\varphi}\hat{m} + (d+\hat{\psi}_1)\hat{a}_1 + (d+\hat{\psi}_2)a\hat{a}_2\Big]$$

The superscript 1 denotes it is the objective function in region 1, and $\in (1,2,3,4)$ for the 4 regions. The FOCs with respect to the three variables are given as following, with the subscript denotes which variable the derivative is taken with respect to, e.g. $j=1$ means FOC with respect to the first variable $\hat{m}$.

$$\begin{aligned}
\{\hat{m}\} : \beta^{-1}J_1^1(\hat{m},\hat{a}_1,\hat{a}_2) =& -\frac{\varphi}{\beta} + \hat{\varphi}\Big\{1 + (\ell-\gamma f)\Big[u'\Big(\hat{\varphi}\hat{m} + d\hat{a}_1\Big) - 1\Big]\Big\} \\
\{\hat{a}_1\} : \beta^{-1}J_2^1(\hat{m},\hat{a}_1,\hat{a}_2) =& -\frac{\psi_1}{\beta} + d\Big\{1 + (\ell-\gamma f)\Big[u'\Big(\hat{\varphi}\hat{m} + d\hat{a}_1\Big) - 1\Big]\Big\} + \hat{\psi}_1 \\
\{\hat{a}_2\} : \beta^{-1}J_3^1(\hat{m},\hat{a}_1,\hat{a}_2) =& -\frac{\psi_2}{\beta} + (d+\hat{\psi}_2)
\end{aligned}$$

By setting the FOCs = 0, the results imply the following pricing functions.

$$\begin{aligned}
\frac{1+\mu}{\beta} =& 1 + (\ell-\gamma f)\Big[u'(\hat{\varphi}\hat{m} + d\hat{a}_1) - 1\Big] \\
\frac{\psi_1}{\beta} =& d\Big\{1 + (\ell-\gamma f)\big[u'(\hat{\varphi}\hat{m} + d\hat{a}_1)\big]\Big\} + \hat{\psi}_1 \Rightarrow \psi_1 = \frac{1+\mu}{1-\beta}d \\
\frac{\psi_2}{\beta} =& d + \hat{\psi}_2 \Rightarrow \psi_2 = \frac{\beta d}{1-\beta}
\end{aligned}$$

<u>Region 2:</u> The bargaining solution in region 2 is $y_1^* = a_1, y_2^* = a_2, y_m^* = (d+\hat{\psi}_1)\hat{a}_1 + (d+\hat{\psi}_2)\hat{a}_2$. Hence the objective function adopts the form

$$\begin{aligned}
\beta^{-1}J^2(\hat{m},\hat{a_1},\hat{a_2}) =& -\frac{\varphi}{\beta}\hat{m} - \frac{\psi_1}{\beta}\hat{a_1} - \frac{\psi_2}{\beta}\hat{a_2} + \gamma f u\Big[\hat{\varphi}\hat{m} + (d+\hat{\psi}_1)\hat{a}_1 + (d+\hat{\psi}_2)\hat{a}_2\Big] \\
&-\gamma f[\hat{\psi}_1\hat{a}_1 + (\hat{\psi}_2 + d)\hat{a}_2] + (\ell-\gamma f)u\Big(\hat{\varphi}\hat{m} + d\hat{a}_1\Big) - \ell(\hat{\varphi}\hat{m} + d\hat{a}_1) \\
&+\Big[\hat{\varphi}\hat{m} + (d+\hat{\psi}_1)\hat{a}_1 + (d+\hat{\psi}_2)\hat{a}_2\Big]
\end{aligned}$$

$$\{\hat{m}\}: \beta^{-1}J_1^2(\hat{m},\hat{a}_1,\hat{a}_2) = -\frac{\varphi}{\beta} + \hat{\varphi}\Big\{1+(\ell-\gamma f)\Big[u'\Big(\hat{\varphi}\hat{m}+d\hat{a}_1\Big)-1\Big]$$
$$+\gamma f u'\Big[\hat{\varphi}\hat{m}+(d+\hat{\psi}_1)\hat{a}_1+(d+\hat{\psi}_2)\hat{a}_2\Big]\Big\}$$
$$\{\hat{a}_1\}: \beta^{-1}J_2^2(\hat{m},\hat{a}_1,\hat{a}_2) = -\frac{\psi_1}{\beta} + d\Big\{1+(\ell-\gamma f)\Big[u'\Big(\hat{\varphi}\hat{m}+d\hat{a}_1\Big)-1\Big]$$
$$+\gamma f u'\Big[\hat{\varphi}\hat{m}+(d+\hat{\psi}_1)\hat{a}_1+(d+\hat{\psi}_2)\hat{a}_2\Big]\Big\}$$
$$+\hat{\psi}_1\Big\{1+\gamma f\Big[u'\Big[\hat{\varphi}\hat{m}+(d+\hat{\psi}_1)\hat{a}_1+(d+\hat{\psi}_2)\hat{a}_2\Big]-1\Big]\Big\}$$
$$\{\hat{a}_2\}: \beta^{-1}J_3^2(\hat{m},\hat{a}_1,\hat{a}_2) = -\frac{\psi_2}{\beta} + (d+\hat{\psi}_2)\Big\{1+\gamma f\Big[u'\Big[\hat{\varphi}\hat{m}+(d+\hat{\psi}_1)\hat{a}_1+(d+\hat{\psi}_2)\hat{a}_2\Big]-1\Big]\Big\}$$

By setting the FOCs = 0, the results imply that pricing functions in region 2 are

$$\frac{1+\mu}{\beta} = 1+(\ell-\gamma f)\Big[u'\Big(\hat{\varphi}\hat{m}+d\hat{a}_1\Big)-1\Big]+\gamma f\Big[u'\Big(\hat{\varphi}\hat{m}+(d+\hat{\psi}_1)\hat{a}_1+(d+\hat{\psi}_2)\hat{a}_2\Big)-1\Big]$$
$$\frac{\psi_1}{\beta} = d\frac{1+\mu}{\beta}+\hat{\psi}_1\Big\{1+\gamma f\Big[u'\Big[\hat{\varphi}\hat{m}+(d+\hat{\psi}_1)\hat{a}_1+(d+\hat{\psi}_2)\hat{a}_2\Big]-1\Big]\Big\}$$
$$\frac{\psi_2}{\beta} = (d+\hat{\psi}_2)\Big\{1+\gamma f\Big[u'\Big[\hat{\varphi}\hat{m}+(d+\hat{\psi}_1)\hat{a}_1+(d+\hat{\psi}_2)\hat{a}_2\Big]-1\Big]\Big\}$$

Region 3: The bargaining solution in this region is $y_m^* = \tilde{m}, y_1^* = 0, y_2^* = \frac{\hat{\varphi}\hat{m}}{\hat{\psi}_2+d}$. Hence the objective function is

$$\beta^{-1}J^3(\hat{m},\hat{a}_1,\hat{a}_2) = -\frac{\varphi}{\beta}\hat{m}-\frac{\psi_1}{\beta}\hat{a}_1-\frac{\psi_2}{\beta}\hat{a}_2+\gamma f u\Big[\hat{\varphi}(\hat{m}+\tilde{m})+d\hat{a}_1\Big]-\gamma f\hat{\varphi}\tilde{m}$$
$$+(\ell-\gamma f)u\Big(\hat{\varphi}\hat{m}+d\hat{a}_1\Big)-\ell(\hat{\varphi}\hat{m}+d\hat{a}_1)$$
$$+\Big[\hat{\varphi}\hat{m}+(d+\hat{\psi}_1)\hat{a}_1+(d+\hat{\psi}_2)\hat{a}_2\Big]$$

$$\{\hat{m}\}: \beta^{-1}J_1^3(\hat{m},\hat{a}_1,\hat{a}_2) = -\frac{\varphi}{\beta}+\hat{\varphi}\Big\{1+(\ell-\gamma f)u'(\hat{\varphi}\hat{m}+d\hat{a}_1)+\gamma f\Big[u'\Big(\hat{\varphi}(\hat{m}+\tilde{m})+d\hat{a}_1\Big)-1\Big]\Big\}$$
$$\{\hat{a}_1\}: \beta^{-1}J_2^3(\hat{m},\hat{a}_1,\hat{a}_2) = -\frac{\psi_1}{\beta}+d\Big\{1+(\ell-\gamma f)u'(\hat{\varphi}\hat{m}+d\hat{a}_1)+\gamma f\Big[u'\Big(\hat{\varphi}(\hat{m}+\tilde{m})+d\hat{a}_1\Big)-1\Big]\Big\}+\hat{\psi}_1$$
$$\{\hat{a}_2\}: \beta^{-1}J_3^3(\hat{m},\hat{a}_1,\hat{a}_2) = -\frac{\psi_2}{\beta}+(d+\hat{\psi}_2)$$

By setting FOCs = 0, the pricing functions in region 3 are

$$
\begin{aligned}
\frac{1+\mu}{\beta} =&1+(\ell-\gamma f)\Big[u'\Big(\hat{\varphi}\hat{m}+d\hat{a}_1\Big)-1\Big]+\gamma f u'\Big[\hat{\varphi}(\hat{m}+\tilde{m})+d\hat{a}_1)-1\Big] \\
\frac{\psi_1}{\beta} =&d\Bigg\{1+(\ell-\gamma f)u'(\hat{\varphi}\hat{m}+d\hat{a}_1)+\gamma f\Big[u'\Big(\hat{\varphi}(\hat{m}+\tilde{m})+d\hat{a}_1\Big)-1\Big]\Bigg\}+\hat{\psi}_1 \Rightarrow \psi_1=\frac{1+\mu}{1-\beta}d \\
\frac{\psi_2}{\beta} =&d+\hat{\psi}_2 \Rightarrow \psi_2=\frac{\beta}{1-\beta}d
\end{aligned}
$$

Region 4: The bargaining solution in region 4 is $y_m^*=\tilde{m}, y_1^*=\frac{\hat{\varphi}\tilde{m}-(d+\hat{\psi}_2)a_2}{d+\hat{\psi}_2}, y_2^*=a_2$. To save on math expression, I define $q_2=\hat{\varphi}(\hat{m}+\tilde{m})+d\hat{a}_1-\frac{d}{d+\hat{\psi}_1}\hat{\varphi}\tilde{m}+\frac{d}{d+\hat{\psi}_1}(d+\hat{\psi}_2)\hat{a}_2$ as the DM consumption quantity when A-buyers matched with an I-buyer and was able to boost their liquidity position. So the objective function in region 4 adopts the following form

$$
\begin{aligned}
\beta^{-1}J^4(\hat{m},\hat{a}_1,\hat{a}_2)=&-\frac{\varphi}{\beta}\hat{m}-\frac{\psi_1}{\beta}\hat{a}_1-\frac{\psi_2}{\beta}\hat{a}_2 \\
&+\gamma f u(q_2)-\gamma f\Big[\frac{\hat{\psi}_1}{d+\hat{\psi}_1}\hat{\varphi}\tilde{m}+\frac{d}{d+\hat{\psi}_1}(d+\hat{\psi}_2)\hat{a}_2\Big] \\
&+(\ell-\gamma f)u\Big(\hat{\varphi}\hat{m}+d\hat{a}_1\Big)-\ell(\hat{\varphi}\hat{m}+d\hat{a}_1) \\
&+\Big[\hat{\varphi}\hat{m}+(d+\hat{\psi}_1)\hat{a}_1+(d+\hat{\psi}_2)\hat{a}_2\Big]
\end{aligned}
$$

$$
\begin{aligned}
\{\hat{m}\}:\beta^{-1}J_1^4(\hat{m},\hat{a}_1,\hat{a}_2)=&-\frac{\varphi}{\beta}+\hat{\varphi}\Bigg\{1+(\ell-\gamma f)u'(\hat{\varphi}\hat{m}+d\hat{a}_1)+\gamma f\Big[u'(q_2)-1\Big]\Bigg\} \\
\{\hat{a}_1\}:\beta^{-1}J_2^4(\hat{m},\hat{a}_1,\hat{a}_2)=&-\frac{\psi_1}{\beta}+d\Bigg\{1+(\ell-\gamma f)u'(\hat{\varphi}\hat{m}+d\hat{a}_1)+\gamma f\Big[u'(q_2)-1\Big]\Bigg\}+\hat{\psi}_1 \\
\{\hat{a}_2\}:\beta^{-1}J_3^4(\hat{m},\hat{a}_1,\hat{a}_2)=&-\frac{\psi_2}{\beta}+\gamma f\frac{d+\hat{\psi}_2}{d+\hat{\psi}_1}[u'(q_2)-1]d+\hat{\psi}_2
\end{aligned}
$$

By setting FOCs = 0, the pricing functions in region 4 are

$$
\begin{aligned}
\frac{1+\mu}{\beta} =&1+(\ell-\gamma f)\Big[u'\Big(\hat{\varphi}\hat{m}+d\hat{a}_1\Big)-1\Big]+\gamma f\Big[u'(q_2)-1\Big] \\
\frac{\psi_1}{\beta} =&d\Bigg\{1+(\ell-\gamma f)\Big[u'\Big(\hat{\varphi}\hat{m}+d\hat{a}_1\Big)-1\Big]+\gamma f\Big[u'(q_2)-1\Big]\Bigg\}+\hat{\psi}_1 \Rightarrow \psi_1=\frac{1+\mu}{1-\beta}d \\
\frac{\psi_2}{\beta} =&(d+\hat{\psi}_2)\Bigg\{1+\gamma f\frac{d}{d+\hat{\psi}_1}[u'(q_2)-1]\Bigg\}
\end{aligned}
$$

Proof of Lemma 4.

For a dividend firm facing objective function $\psi_1 + (1-\theta)[u(q_1) - q_1]$, notice that $(1-\theta)[u(q_1) - q_1]$ increases in q_1 before reaching $q_1 = q^*$. The bargaining solution between an A-buyer with a type-1 firm is $q_1 = \min\{\psi_1 + k - d, \nu^{-1}(da_1)\}$ derived in the main text. So given the expectation of A-buyers' liquidity position, if firms pay out too much dividend, i.e. $\psi_1 + k - d < \nu^{-1}(da_1)$, then total value of the firm is $\psi_1 + (1-\theta)[u(\psi_1 + k - d) - (\psi_1 + k - d)]$, which is less than the firm's value $\psi_1 + (1-\theta)[u(\nu^{-1}(\tilde{d}\tilde{a}_1)) - (\tilde{d}\tilde{a}_1]$ when paying slightly less dividend so that the input capital is enough to produce the demanded quantity. Since endowed capital k alone is enough to produce q^*, so as long as d is not too high, firms are always able to satisfy A-buyer's DM demand. Hence the optimal dividend policy is to reserve enough input capital, $\nu^{-1}(\tilde{d}\tilde{a}_1)$, to meet A-buyers' DM demand, and distribute the residual capital $\psi_1 + k - \nu^{-1}(\tilde{d}\tilde{a}_1)$ as dividend.

For a non-dividend R&D firm facing objective $[A(e)(\psi_2 + k - e) - q_2] + (1-\theta)[u(q_2) - q_2]$, first notice that with the properties of $A(e)$, $A(e)(\psi_2 + k - e) \geq \psi_2 + k > q^*$ regardless of the value of e. Hence q_2 is determined by A-buyer's liquidity position that $q_2 = \nu^{-1}(\tilde{d}\tilde{a}_1)$. So now the objective is to maximize $K = A(e)(\psi_2 + k - e)$. When $e \to 0$, $\frac{\partial K}{\partial e} \to \infty$; when $e \to \psi_2 + k$, $\frac{\partial K}{\partial e} \to -\infty$. And $\frac{\partial^2 K}{\partial e^2} < 0$, so there exists a unique and interior solution of e^* such that $\frac{\partial K}{\partial e} = 0$, and firm's value is maximized.