Liquidity, Infinite Horizons and Macroeconomic Fluctuations*

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Abstract

This paper develops a computable dynamic general equilibrium model in which corporate demand for liquidity is endogenously determined. In the model liquidity demand is motivated by moral hazard as in Holmström and Tirole (1998). As a result of incorporating agency cost and endogenously determined liquidity demand, the model can replicate an empirical business-cycle fact, the hump-shaped dynamic response of output, which is hardly observed in standard RBC dynamics. Further, in the model the corporate demand for liquidity from a financial intermediary (credit line, for instance) is pro-cyclical, while the degree of liquidity-dependence (defined as liquidity demand divided by corporate investment) is counter-cyclical. These business cycle patterns are consistent with a stylized fact empirically verified in the *Lending View* literature.

Key Words: Liquidity, Corporate finance, Business cycle

JEL Classification: E3, G3

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1 Introduction

This paper develops a computable dynamic general equilibrium model in which the role of liquidity over the business cycle can be analyzed. My focus is especially the corporate demand for liquidity and its influence on business cycles via firms' investment decision rule. It is an empirical fact that corporations rely heavily on short-term debt for working capital expenses in the United States as well as in Japan.[1] In the virtual economy with perfect information so that nothing prevents the classic Modigliani-Miller theorem (MM theorem, hereafter) from holding, whatever short-term financing is chosen, either by privately or publicly issued liquid asset, such decision is a trivial matter from the viewpoint of efficiency. Nonetheless, even if we ignore the complicated aspects of the financing contracts, corporate finance and the role of the banking sector is still of interest to business cycle researchers. In this line of literature, the real business cycle (RBC) framework with financial intermediary developed by Fuerst (1992)[2] is a pioneering work. This framework was later intensively studied by Christiano (1991), Christiano and Eichenbaum (1993), Marquis and Einarson (2001), among others. The role of the financial intermediary in those models is to provide firms with financing for wage that must be paid to employees in advance of their sales of output. Overall, these models are well capable of explaining empirical business cycle facts, including bank loans and other financial variables. However, they are potentially flawed, because they fail to replicate the actual auto-correlation patterns of output and investment.[3] One advantage of the model introduced in this paper is its superior performance to the Fuerst-Christiano style of RBC models in mimicking the actual auto-correlation patterns.

Another stream of studies on the interaction of corporate finance and the business cycle extends *agency cost* models, which were originally developed in microeconomic contract theory, to macroeconomics. Roughly speaking, the difference between the value of the firm in what would be an ideal contracting situation and what is viable through negotiation is referred to as *agency costs.*[4] In agency cost models, the net present value (NPV) of an investment project is not maximized, simply because lenders and borrowers (entrepreneurs) have divergent incentives, so that for each agent NPV maximization could be suboptimal. The financial contract between lender and borrower

[1] See Einarson and Marquis (2001).

[2] Theoretical foundation of Fuerst-Christiano framework is based on the preceding study by Lucas(1990).

[3] This is pointed out by Cogley and Nason (1995) and Gilchrist and Williams (2000).

[4] Amaro de Matos (2001).

is characterized by the nature of the concessions necessary to achieve at least a second best solution. It should be noted that for models with this agency cost, MM theorem is by construction violated, and thus the financial contract structure plays a non-trivial role in firms' investment decisions. An early study of this type of financial contract is Townsend (1979). This Townsend's study is well-known as the *optimal contract theory* with costly state verification. When the outcome of a project is private information to the entrepreneur, this asymmetric information creates a moral hazard problem. The entrepreneur may have an incentive to misreport the true outcome. The agency cost in this case is that a certain portion of the profit is lost for costly monitoring. More general framework of financial contract with agency cost is developed by Grossman and Hart (1986) and Hart and Moore (1990). In general, suppose a situation where the financial contract is constrained by the existence of unverifiable future variables, which are usually assumed to be unobservable ex-post by outsiders. They are not enforceable, in the sense that contracts cannot be written to condition payoffs on these unverifiable variables. In this context, the financial contract is herein understood as an instrument for reducing agency costs by creating incentives for entrepreneurs to "behave." Hart and Moore's (1994) framework is an example in which agency problems do not necessarily stem from asymmetric information. Even though the information is complete, where the entrepreneur cannot be replaced by others[5] (or such replacement is highly costly) and renegotiation is difficult, some profitable projects are not financed. This is mainly because some portion of the profit must be paid to prevent entrepreneurs from threatening to repudiate.

In the 80s and 90s, these various types of financial structure were gradually taken into dynamic general equilibrium models (DGE models, hereafter) to investigate their outcome on business cycle dynamics. Williamson (1987) and Bernanke and Gertler's model (1989) reflect earlier attempts to construct DGE models with a Townsend-type financial contract based on costly state verification. Especially Bernanke and Gertler constructed an OLG model in which a financial market imperfection induces temporary shocks to firms' net worth to be amplified and to persist. This mechanism is known as the *financial accelerator*.[6] Similar modeling strategies can be found in Carlstrom and Fuerst (1997) and Kiyotaki and Moore (1997), although the former is based on Townsend's financial contract, while in the latter Hart/Moore's costly renegotiation contract is adopted as the central feature of the model. Both models consider infinitely-

[5] The notion of *human capital* can be brought in here. Unique human capital of the entrepreneur can play very similar role to that of private information in generating agency cost.

[6] Greenwald and Stiglitz (1993) and Bernanke, Gertler and Gilchrist (2000) studied similar interest.

lived agents so that business cycle dynamics are easier to analyze due to the models' tractability. These DGE models are mostly successful in replicating empirically reasonable business cycle dynamics, such as amplification, persistence, hump-shaped impulse response, and oscillations. Why are these DGE models with agency costs so successful in mimicking actual business cycle dynamics? In standard RBC models, a firm's investment is merely a mirror of consumers' savings. Recall that agency cost is only relative to a first best world *leakage* in process of transferring consumers' savings to firms' production inputs. By allowing agency cost to fluctuate endogenously, the tight link between savings and investment is softened, so that a firm's investment decision can influence output dynamics independently of the consumer's decision rule.[7] Roughly speaking, the reason those DGE models can exhibit more empirically reasonable dynamics is because the trough in agency cost (usually at the peak of firm's net worth) is delayed by one or two periods later behind the initial shock. Net worth is a state variable and thus limps behind. This is a commonly observed mechanism which drives the dynamics of most DGE models with agency cost.

This study is in the line of DGE models with agency cost. The core of my model, a unique financial contract structure, is taken from Holmstrom and Tirole (1998) (let us denote HT, hereafter) instead of other common financial contracts. The agency cost considered here arises from a standard moral hazard, which requires a certain portion of profit given to entrepreneurs in order to keep them diligent. This is simply because their effort is private information and therefore not enforceable. Although the style of moral hazard is quite standard and even traditional, HT model has an outstanding feature, such that corporate liquidity demand is motivated by the moral hazard. When a certain amount of profit is lost (must be given to the entrepreneur in my case as similarly handled in most moral hazard models) a firm's value is strictly less than its maximum NPV. This wedge between a firms's full value and its value for external investors entails the rationale on the firm's needs for advance financing, namely, corporate demand for liquidity. Without this wedge, the firm can raise sufficient funds by issuing claims or obtaining a credit line from investors in advance, and that is enough to defray all the firm's working capital expenses, even if such liquidity needs are stochastic. However, where a firm's value for external investors is less than its full value, some of its projects

[7] An interesting recent study by Gilchrist and Williams (2000) presents a DGE model which generates hump-shaped dynamics of output. The key of their model is *putty-clay* technology of firm's investment. This is another example that shows a certain device in firm's investment decision rule leading to a realistic output dynamics, even though information is complete.

may be terminated midstream, since it cannot finance working capital expenses by raising enough credit line or additional loans from the investors. To protect itself from such risks of liquidity shortage, a firm may want to hold liquidity reserves. This is the essential argument that HT makes in their paper.

This paper extends the HT model to an infinite horizon environment using a modeling strategy similar to that of Carlstrom and Fuerst (1997) and analyzes the business cycle dynamics that result from such liquidity-dependent corporate financing. The first notable result of the paper is that my model generates a hump-shaped impulse response very similar to that in Carlstrom and Fuerst, which is reported as an empirical fact in preceding business cycle studies.[8] The result of this study enhances the view that hump-shaped output dynamics or similar persistence is common and robust outcome of various types of agency cost models.

Further, my DGE model in this paper provides several insights into other aspects of corporate liquidity demand and business cycles. The empirical fact is that corporate firms' working capital expenses are pro-cyclical, while the degree to which firms rely on bank loans to finance their working capital expenses, measured as the volume in commercial and industrial loans relative to output, is counter-cyclical.[9] My DGE model has an advantage over others in replicating this corporate financing structure over business cycles, in the sense that it successfully generates pro-cyclical demand for liquidity, while the *degree of liquidity-dependence* (measured as liquidity demand divided by investment expenditure) is counter-cyclical. Moreover, interestingly, this outcome exhibits clear similarity to existing empirical studies in the line of *lending view* literatures, such that corporate firms become highly dependent on bank loans in recessions.

This paper is organized as follows. Section 2 introduces a version of the moral hazard model of corporate liquidity demand presented in Holmström and Tirole (1998). Section 3 develops the DGE model in which the infinite horizon version of the HT-type corporate liquidity demand is embedded. Section 4 presents calibration and simulation results. Section 5 discusses some interpretations of empirical facts and how they are related to the *lending view* studies. I will conclude the paper in section 6.

[8] Empirics of hump-shaped dynamics of output is studied by Cogley and Nason (1995).

[9] See Kashhap, Stein, and Wilcox (1996) and Marquis and Einarson (2001) on this issue.

2 Corporate Demand for Liquidity and Firms' Investment: Holmström and Tirole (1998)

In this section I introduce the model of corporate liquidity demand presented by Holmström and Tirole (1998) in a slightly modified fashion. The HT model generates a unique investment function and corporate liquidity demand function. Later in section 3 they will be embedded in an otherwise standard dynamic general equilibrium model to analyze their influence on business cycle dynamics. Since the financial contract is only one period in length, I can consider the financial contract and investment behavior separately from the rest of the dynamic general equilibrium. In the following subsections, capital price q and firms' net worth n are regarded as constant parameters which will be determined outside of the financial contract.

In the HT model, corporate liquidity demand is motivated by moral hazard. Holmström and Tirole's (1998) arguments are summarized as follows. In a moral hazard model, the entrepreneur must be given a minimum share of profit in order to be motivated. Because of this, the value of external claims on the firm is strictly less than the full value of the firm. The wedge between the full value of the firm and the external value of the firm prevents it from financing all projects that have positive net present value. This implies that liquidity shocks could force the firm to terminate a project midstream, even though the project has a positive continuation value. To avoid such risks, the firm wants to hold liquid reserves in the form of marketable assets that can be readily sold or credit lines provided by the financial intermediaries.

The HT model also demonstrates that in the absence of aggregate uncertainty, the financial intermediary can achieve production efficiency in the sense that private-issued liquid assets (including credit lines) are sufficient for insurance.[10] I will rely on this result later in extending the model to an infinite horizon environment.

2.1 Financial contract with liquidity demand

The model shown here is essentially identical to that of HT, except for two minor modifications. One is that everything is going on within a period, while the original HT model is a three-period model. I can reconcile the difference by implicitly regarding

[10] See proposition 2 in HT. Interestingly, the proposition reveals that full insurance cannot be achieved by financial market trading. Only financial intermediation can provide risk sharing by pooling idiosyncratic risks. Therefore, it is important to incorporate the financial intermediary as the *third* agent in my DGE model later.

each period is segmented into three sub-periods.[11] The other is that capital goods are distinguished from consumption goods. The end-of-period capital price is q in terms of consumption goods. Consideration of the financial contract can be separated from the rest of the general equilibrium, since the contract is only one-period in length. The financial contract is negotiated in the beginning of each period and is resolved by the end of that same period. General equilibrium issues affect the contract through the level of firms' net worth, $n > 0$ and price of capital, $q > 0$.

Here is a two-goods economy, with consumption goods and capital goods. There are two types of agents, firms (entrepreneurs) and investors (consumers). Both are assumed to be risk neutral.[12] A firm has access to a stochastic constant-returns-to-scale technology to convert an amount i of consumption goods into Ri of capital. In the midst of a period, an additional uncertain amount ωi of funds (as measured by capital goods) is necessary to cover working capital expenses and other cash needs. The liquidity shock ω is distributed according to the cumulative distribution function $\Phi(\omega)$ with a density $\phi(\omega)$. If ωi is paid, the project continues and a final pay-off is realized in sub-period 2. If ωi is not paid, the project terminates and yields nothing. Timing of events is described in Figure 1.

Investment is subject to moral hazard in that a firm (entrepreneur) privately chooses the probability π that the project succeeds. The firm can either "behave" or "shirk." If the firm behaves, the probability of success is π_H (high) if it shirks, the probability of success is π_L (low), where $\pi_H - \pi_L \equiv \Delta\pi > 0$. If the firm shirks, it enjoys a private benefit, $Bi > 0$, proportional to the level of initial investment i. The firm makes the decision on π_H or π_L after the continuation decision.

The net present value of the investment is maximized by continuing the project if and only if $\omega \leq \omega_1 \equiv \pi_H R$, that is, whenever the expected return $\pi_H R$ from continuation

[11] This three sub-periods segmentation is purely for convenience. Sequence of events is described in Figure 1.

[12] In the next section, risk averse consumers will be brought in as the source of outside fund supplier. However, in terms of the financial contract, they will be effectively risk neutral. Carlstrom and Fuerst (1997) denote two conditions which are sufficient for the risk neutrality as follows. Namely, (1) threre is no aggregate uncertainty over the duration of the contract, and (2) the financial intermediary can take advantage of the law of large numbers to eliminate idiosyncratic risks. These two properties allow the financial intermediary to assure deterministic return to consumers. I will refer to this issue again later.

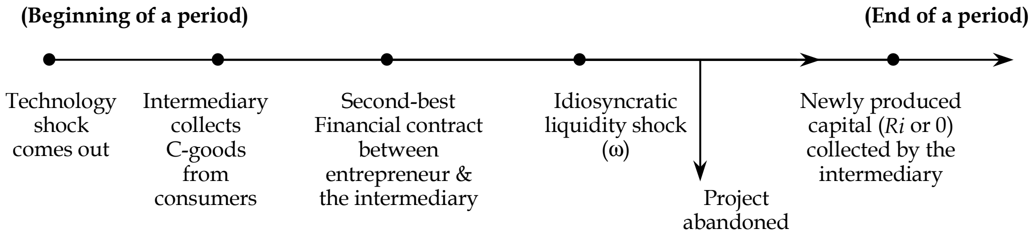

Figure 1: Timing of events

exceeds the cost ω. HT refers to this ω_1 as the *first-best cutoff.*[13] The firm has an endowment of net worth, n (> 0) in the beginning of the period and can raise additional funds from outside investors. A contract with outside investors specifies the amount that the investors will contribute $i-n$, the initial scale of the project i, the contingencies in which the project is continued at the emergence of the liquidity shock (the cut-off level of the liquidity shock $\bar{\omega}$), and the distribution of the profit from the investment Let $R_f i$ be the amount which the firm is paid when the project succeed. Generally R_f can be contingent on ω, but the second best contract is achieved by a contract such that the incentive compatible constraint, $\pi_H R_f \geq \pi_L R_f + B$, is binding. Namely, the entrepreneur's share of profit is bounded by the minimum level which prevents it from shirking. With the binding incentive compatibility constraint, $R_f = B/\Delta\pi$, outside investors' expected cash flow excluding the liquidity shock, is $\pi_H (R - R_f) \equiv \omega_0$. ω_0 is called *pledgeable unit return* from investment. The structure of moral hazard is illustrated in Figure 2.

Now I am ready to set up the optimal financial contract problem to choose $\{i, \bar{\omega}, R_f(\omega)\}$.

[13] They assume

$$\begin{aligned} & \int \max\{\pi_H R - \omega, 0\}\, \phi(\omega)\, d\omega - 1 \\ > \; & 0 \\ > \; & \int \max\{\pi_L R + B - \omega, 0\}\, \phi(\omega)\, d\omega - 1 \end{aligned}$$

so that they could concentrate on contracts that implement the effort π_H.

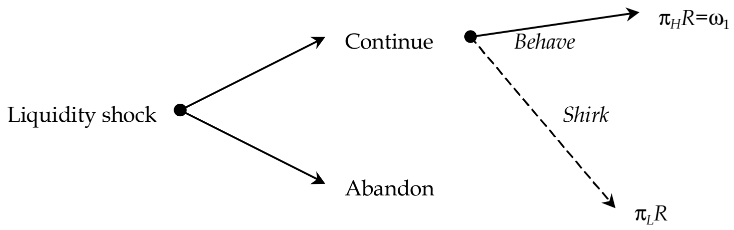

Figure 2: Structure of moral hazard

$$
\begin{aligned}
\max \quad &: \quad qi\pi_H R_f \int_0^{\bar{\omega}} \phi(\omega)\, d\omega \\
&= \quad qi\pi_H R_f \Phi(\bar{\omega})
\end{aligned}
$$

$$
\begin{aligned}
\text{s.t.} \qquad i - n \quad &\leq \quad q\left[i\int_0^{\bar{\omega}} \left(\pi_H (R - R_f) - \omega\right)\phi(\omega)\, d\omega\right] \\
&= \quad qi\left[\omega_0 \Phi(\bar{\omega}) - \int_0^{\bar{\omega}} \omega\phi(\omega)\, d\omega\right] \\
&\equiv \quad qih(\bar{\omega}) \qquad (1)
\end{aligned}
$$

$$
R_f \quad \geq \quad R_f^{low} = \frac{B}{\pi_H - \pi_L} \qquad (2)
$$

This problem is to maximize a firm's share of profit subject to investors' break-even constraint eqn (1) and the firm's incentive compatible constraint eqn (2). With the incentive compatible constraint binding, the remaining choice is i and $\bar{\omega}$. Since everything is linear in the problem, the break-even condition must hold with equality. This yields the following relation.

$$
i = \left(\frac{1}{1 - qh(\bar{\omega})}\right) n \qquad (3)
$$

Substituting this into the objective function leaves an unconstrained problem with respect to $\bar{\omega}$.

$$
\max_{\bar{\omega}} : \left(\frac{q\Phi(\bar{\omega})}{1 - qh(\bar{\omega})}\right) \pi_H R_f n \qquad (4)
$$

Here let us rewrite $h(\bar{\omega})$,

$$h(\bar{\omega}) = \omega_0 \Phi(\bar{\omega}) - \int_0^{\bar{\omega}} \omega \phi(\omega) \, d\omega \quad (5)$$

$$= (\omega_0 - \bar{\omega}) \Phi(\bar{\omega}) + \int_0^{\bar{\omega}} \Phi(\omega) \, d\omega \quad (6)$$

Paying attention to the derivative $h'(\bar{\omega}) = (\omega_0 - \bar{\omega}) \phi(\bar{\omega})$, the first order condition of eqn (4) is

$$q \int_0^{\bar{\omega}} \Phi(\omega) \, d\omega = 1. \quad (7)$$

Based on the closed form, I can define an implicit function of the optimal cutoff level of liquidity shock, $\bar{\omega} = \psi(q)$. Let us call this optimal cutoff induced by the second best financial contract "the degree of liquidity dependence" hereafter. Plugging this into eqn(3),

$$i = \left(\frac{1}{1 - qh(\psi(q))} \right) n$$
$$\equiv k(q) n \quad (8)$$

Thus investment is linear in n with a factor of proportionality of $k(q)$, which exceeds one. HT calls this $k(\cdot)$ *equity multiplier*. Let me point out that very similar multipliers to this $k(\cdot)$ can be found in many other models with agency cost.[14] In fact, it is a peculiar and common feature for those imperfect information models that investment requires a *down payment*. It can be shown that the investment function, eqn(8) is upward sloping in the capital price q just as the investment function of the adjustment cost model is increasing in the shadow price of capital. A significant difference is that eqn(8) is not only a function of q, but also of the firm's net worth n, which will be the key feature in generating unique dynamics in infinite horizon extension.

Finally, I introduce aggregate corporate liquidity demand D and the "degree of liquidity dependence" x which is defined as aggregate liquidity demand divided by aggregate investment I for a later purpose in the empirical discussion.

$$D = qi \int_0^{\bar{\omega}} \omega \phi(\omega) \, d\omega \quad (9)$$

$$x = \frac{D}{qI} = \frac{\int_0^{\bar{\omega}} \omega \phi(\omega) \, d\omega}{\Phi(\bar{\omega}) \, \omega_1} \quad (10)$$

[14] See Bernanke and Gertler (1989), Bernanke, Gertler and Gilchrist (2001), Carlstrom and Fuerst (1997) and Kiyotaki and Moore (1997), for examples.

where aggregate investment $I = i\omega_1 \Phi(\bar{\omega})$[15] instead of $\omega_1 i$, since the fraction of investment projects whose liquidity shocks are larger than $\bar{\omega}$ are abandoned.

2.2 The role of the financial intermediary

One of HT's fundamental questions is whether a privately issued liquid asset would be sufficient for achieving the (second) best outcome described above. In the absence of aggregate uncertainty (idiosyncratic risk for each entrepreneur is independent), the answer is yes. I assume there is a continuum of entrepreneurs with unit mass. Thanks to the constant-returns-to-scale technology, there is no loss in assuming that entrepreneurs have identical net worth; the representative entrepreneur is endowed with n units of net worth at the beginning of the period. Then additional liquidity needs, D demanded by whole productive sector is defined as in eqn (9), $D = qi \int_0^{\bar{\omega}} \omega\phi(\omega)\, d\omega$, where i is the representative firm's investment. Note that by taking advantage of the law of large numbers, this amount D is a deterministic number. On the other hand, the maximum amount of the claims for the existing firms is equal to $qi\omega_0\Phi(\bar{\omega}) \equiv V$. Since $qi\omega_0\Phi(\bar{\omega}) - D = i - n > 0$, in this economy without aggregate uncertainty, there can be sufficient amount of private-issued claims to meet firms' additional liquidity demands. Now I herein incorporate the third agent, the financial intermediary.[16] The financial intermediary collects all of the consumption goods and offers credit lines up to $q\bar{\omega}i$ for each entrepreneur so that the second best financial contract described above can be implemented. The law of large numbers allows the intermediary to grant D of funds to entrepreneurs in total. As a result of each entrepreneur's production with the credit line up to the second best cut-off, the entrepreneurial sector as a whole can produce V of capital at the end of the period. Note that again, the law of large number makes V deterministic.

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[15] I am slightly abusing notations here. In the next section for dynamic general equilibrium analysis, I assume that fraction η of the population of the economy is entrepreneurs. Hence to define the *aggregate* firm's liquidity demand, D and investment, I they should be muptiplied by the population weight η, that is, $D = \eta qi \int_0^{\bar{\omega}} \omega\phi(\omega)\, d\omega$ and $I = \eta q\omega_1\Phi(\bar{\omega})$ instead of those without η shown here.

[16] Carlstrom and Fuerst (1997) refer to this financial intermediary as a "capital mutual fund" (CMF). This nortion was first incorporated by Williamson (1986). It should be emphasized that the notion of "mutual fund" referred to in the HT model is a different concept. The HT's "mutual fund" has no risk pooling function. Actually, HT admits that their "mutual fund" cannot achieve production efficiency, and thus it is not classified as a kind of intermediary. Essentially, what distinguishes *the* intermediary here from other financial institutions is whether they have the ability to offer credit lines to entrepreneurs. Note that the value of marketable claims held by a firm cannot be made contingent on that firm's idiosyncratic shock. Risk pooling can be implemented only via credit lines.

Essentially, the role of financial intermediary in this economy is *risk pooling* to achieve insurance. HT demonstrates that there can be many variants of this kind of financial intermediaries in the real world. Any variants that can offer credit lines to entrepreneurs are sufficient for the purpose.

3 The Dynamic General Equilibrium Model

In this section the investment function and liquidity demand function derived in the previous section are embedded into an otherwise standard DGE model.

Again there are two types of agents, firms (entrepreneurs) and consumers (investors) in the economy. The fraction η of the population is entrepreneurs and the rest is consumers. Capital is produced from consumption goods using constant-return-to-scale technology which is specific to the entrepreneurs. This capital producing process takes place under moral hazard as described in the previous section. At the beginning of each period, entrepreneurs receive $i-n$ consumption goods from the financial intermediary as a part of the financial contract, and use them as inputs to produce capital. At the end of the period, newly produced capital is ready for use, if the entrepreneur's project is not abandoned due to a liquidity shock. It is a substantial modification from the standard RBC in which there is an *ex-post* one-to-one technology for transforming consumption goods into capital. In the standard RBC model, a unit input of consumption goods is transformed into one unit of capital at the end of the period. In this environment, it does not make sense to distinguish capital from consumption goods, and the price of capital is always equal to one. Hence, it is virtually regarded as a one-good economy.

In the economy assumed here, entrepreneurs receive external funds and credit lines via the financial intermediary. As shown in the previous section, the role of the intermediary here is to assure a certain return to consumers by providing entrepreneurs with collected consumption goods and necessary credit lines. Consumers who sold q units of consumption goods at the beginning of the period will receive one unit of capital from the intermediary in the end of the period. Because of this deterministic return over the duration of financial contract, consumers are regarded as effectively risk neutral in terms of the financial contract.

The economy is also populated with many firms producing a single consumption good. (I call them *retailers* to distinguish them from entrepreneurs.) Retailers are assumed to be free from moral hazard, and so I do not have to specify their financing contract. Instead, they are mechanically producing consumption goods at the level at which price equals marginal cost.

3.1 Optimization set-ups

- **Consumers' optimization**

Consumers' problem is standard. They are maximizing an infinite sum of discounted utility from consumption.(c_t) and labor supply (l_t).

$$\max : U^c = E_0 \sum_{t=0}^{\infty} \beta^t u(c_t, l_t) \tag{11}$$

where β is a discount rate. At the beginning of each period, they rent previously accumulated capital at a rental rate r_t, and purchase consumption goods at a price of unity. (The consumption good is numeraire.) At the end of each period they purchase newly produced capital with the help of the financial intermediary. Also they supply their labor force at a wage rate w_t. Consumers' optimal conditions are summarized as follows.

$$\begin{aligned} \frac{u_{L,t}}{u_{c,t}} &= w_t \\ E_t \beta \left(\frac{q_{t+1}(1-\delta) + r_{t+1}}{q_t} \right) \frac{u_{c,t+1}}{u_{c,t}} &= 1 \end{aligned}$$

where δ is the depreciation rate of capital.

- **Entrepreneurs' optimization**

Entrepreneurs are risk neutral. They are maximizing an infinite sum of discounted consumption c_t^e. Because of the moral hazard discussed before, the return on internal funds is higher than that on external funds. This higher return on internal funds induces entrepreneurs to postpone their consumption forever and thus the economy never reaches a steady state. To avoid oversavings of entrepreneurs, their discount factor $\gamma\beta$ is assumed to be smaller than that of consumers: $\gamma\beta < \beta$.[17] Entrepreneurs' optimization is written as follows.

[17] Another technique to avoid negative consumption of entrepreneurs is to assume simply that they consume a certain amount of wealth in each period. I can interpret this as that certain fraction of entrepreneur is dying in each period. This type of assumption is taken in Kiyotaki and Moore (1997) for example.

$$\begin{aligned} \max \quad &: \quad U^e = E_0 \sum_{t=0}^{\infty} (\gamma\beta)^t c_t^e \\ \text{s.t.} \quad q_t K_{t+1}^e &= (1+\rho_t) n_t - c_t^e \\ \text{where,} \quad n_t &= (1-\delta) q_t K_t^e + r_t K_t^e + w_t^e \\ 1+\rho_t &= \frac{q_t \pi_H R_f \Phi(\bar{\omega}_t)}{1 - q_t h(\bar{\omega}_t)} \end{aligned} \tag{12}$$

where K_t^e, n_t, and ρ_t denote an entrepreneur's capital, net worth and net return rate respectively. w_t^e is a wage rate for entrepreneurs' labor supply, which is fixed at one. This labor income assures positive net worth of entrepreneurs. Entrepreneurs invest whole n_t at the beginning of a period to receive its return $q_t \pi_H R_f \Phi(\bar{\omega}_t)$ at the end of the period. Since $i_t = n_t / \{1 - q_t h(\bar{\omega}_t)\}$ as shown in eqn(3), the return rate ρ_t is defined as in eqn(12). Using this notation, entrepreneurs' Euler equation can be written as

$$q_t = E_t \beta\gamma \left(q_{t+1}(1-\delta) + r_{t+1}\right)\left(1+\rho_{t+1}\right).$$

It should be noted that net worth does not appear in this equation, so that this condition holds for any level of net worth.

- **Retailers' optimization**

Retailers' problem is again standard. Their production function is constant return to scale, such that $Y_t = v_t F(K_t, L_t, H_t)$, where K_t, L_t and H_t denote aggregate capital, labor input from consumers and labor input from entrepreneurs, respectively. v_t is a random productivity shock which is normalized at one in steady state. Since retailers are free from moral hazard, their production always takes place at the efficient level of input, so that $r_t = v_t F_K(K_t, L_t, H_t)$, $w_t = v_t F_L(K_t, L_t, H_t)$ and $w_t^e = v_t F_H(K_t, L_t, H_t)$.

3.2 Recursive competitive equilibrium

The equilibrium of the economy is defined as the set of K_{t+1}, K_{t+1}^e, H_t, L_t, n_t, i_t, c_t^e, c_t, q_t, x_t, D_t, w_t, r_t, and $\bar{\omega}_t$ which satisfies the following consumer's decision rule (eqn(13)-(14)), entrepreneur's decision rule and optimal financial contract (eqn(15)-(16)), retailer's decision rule (eqn(18)-(19)), resource constraints (eqn(20)-(22)) and exogenous state transition (eqn(23)).

- **Efficiency conditions and optimal financial contract**

$$c_t^{-\theta} = E_t\beta\left(\frac{q_{t+1}(1-\delta)+r_{t+1}}{q_t}\right)c_{t+1}^{-\theta} \tag{13}$$

$$w_t = \frac{U_{L,t}}{U_{c,t}} \tag{14}$$

$$q_t = E_t\beta\gamma\left(q_{t+1}(1-\delta)+r_{t+1}\right)\left(1+\rho_{t+1}\right) \tag{15}$$

$$x_t = \frac{D_t}{q_t I_t} \tag{16}$$

$$\text{where, } 1+\rho_t = \frac{q_t\pi_H R_f \Phi(\bar{\omega}_t)}{1-q_t h(\bar{\omega}_t)}$$

$$i_t = \left(\frac{1}{1-q_t h(\bar{\omega}_t)}\right)n_t$$

$$D_t = \eta q_t i_t \int_0^{\bar{\omega}_t}\omega\phi(\omega)\,d\omega$$

$$I_t = \eta\Phi(\bar{\omega}_t)\,\omega_1 i_t \tag{17}$$

$$\bar{\omega}_t = \psi(q_t)$$

$$r_t = v_t F_K(K_t, L_t, H_t) \tag{18}$$

$$w_t = v_t F_L(K_t, L_t, H_t) \tag{19}$$

- **Resource constraint and exogenous state transition**

$$Y_t = (1-\eta)c_t + \eta i_t + \eta c_t^e \tag{20}$$

$$\text{where, } Y_t = v_t F(K_t, L_t, H_t)$$

$$K_{t+1} = (1-\delta)K_t + I_t \tag{21}$$

$$K_{t+1}^e = \frac{1}{q_t}\left\{(1+\rho_t)n_t - c_t^e\right\} \tag{22}$$

$$\text{where, } n_t = w_t^e + \frac{1}{\eta}K_t^e\left(q_t(1-\delta)+r_t\right)$$

$$v_{t+1} = \sigma v_t + (1-\sigma)v^* \tag{23}$$

Some remarks are in order. Eqn(20) denotes consumption goods market clear condition. Eqn(22) describes entrepreneur's capital accumulation. Since investment projects with a liquidity shock larger than $\bar{\omega}_t$ are abandoned as discussed in the previous section, newly produced capital I_t in eqn(17) is not equal to $\omega_1 i_t$, but to $\Phi(\bar{\omega}_t)\,\omega_1 i_t$ multiplied by the population weight η. Productivity shock is specified as AR(1) as shown in eqn(23), where v^* denotes the normalized steady state level of productivity.

4 Simulation

4.1 Calibration

Let us start with the entrepreneurs' technology. I assume a uniform distribution $[0, 2]$ for liquidity shocks as a benchmark. This distribution implies that the initial unit of investment requires the same amount of working capital expenses as the mean.[18] Following a standard RBC environment, consumption goods are converted into capital via one-to-one transformation technology. That is, total expected return from unit investment ($= \omega_1 \Phi(\omega_1)$) is set at unity so that the technology of the entrepreneurial sector as a whole is one-to-one transformation in the presence of perfect information Note that even in the case with symmetric information, fraction $(1 - \Phi(\omega_1))$ of investment is abandoned, because of liquidity shocks. Given the uniform distribution, this one-to-one technology gives us ω_1 set equal to 1.414. With the imperfect information in the economy, this technology does not assure the full return, since a certain portion of the return disappears due to the agency cost. In this sense, the unpledgeable part of the profit, which is given to the entrepreneur as the minimum share by incentive compatible constraint, is the most important parameter to calibrate. As Holmström and Tirole (1998) argue in their paper, where there is no moral hazard in the capital production process ($B = 0$ or $\omega_1 = \omega_0$, equivalently), entrepreneurs do not demand any liquidity, since the moral hazard is the essential motivation for advance financing. It should be emphasized that in a special case of my DGE model, where ω_1 is set equal to ω_0 (the entrepreneur's share of the profit is zero), my DGE model collapses to the standard RBC model.[19] Here, as a tentative value, I set $\omega_0/\omega_1 = 0.75$, which implies 25% of the profit is given to the entrepreneur on average. This value of 25% is purely ad-hoc, so I will examine how the model is sensitive to this value later. Given these parameter settings, the ex-post capital production out of unit input ($= \omega_1 \Phi(\bar{\omega})$) is 0.987 in the steady state, which implies about 1.2% of resource is lost during the capital production process as the result of agency cost.

For most of the other parameters and functional forms, I followed Carlstrom and Fuerst (1997). The consumers' utility is additively separable in consumption and labor, such that $U(c_t, l_t) = \left(c_t^{1-\theta}/1 - \theta\right) + \mu(1 - l_t)$, where θ is set at 1.5. As for μ, it is chosen so that steady state labor supply is 0.3. Consumption goods production is

[18] As for this mean (or the upper bound) of the uniform distribution, I will examine alternative values in the following subsection for sensitivity analysis.

[19] This is another similar point to Carlstrom and Fuerst (1997). In their model, if monitoring cost is set at zero, which implies no agency cost, their model also collapses to the standard RBC model.

Cobb-Douglas, such that $F(K_t, L_t, H_t) = v_t K_t^{\alpha} L_t^{1-\alpha-\alpha'} H_t^{\alpha'}$, where α is 0.3 and α' is 0.01. Discount rates are $\beta = 0.99$ and $\gamma = 0.95$.

I am left with only two parameters: η which represents the proportion of entrepreneurs population; and σ, the AR(1) coefficient for productivity shock. η as a tentative value is set at 0.3, which implies that 30% of the population is entrepreneurs. Finally, σ is chosen at 0.9.

4.2 Simulation results

4.2.1 Impulse response to a productivity shock

The solution technique that I utilize here is the standard undetermined coefficient method. (the eigen decomposition method) Simulations are based on the log-linearized model around the steady state of the non-stochastic part of the system.

I report simulation results in Figure 3-5. The figures show the response of my "liquidity model" (denoted "LI" model hereafter) to a positive productivity shock. For comparative purposes, the impulse response of the standard RBC model[20] is presented in each panel. The notable feature of the LI model is a hump-shaped response of output as shown in the upper panel in Figure 3. This is a sharp contrast to the familiar RBC dynamics, that is, investment and output jump up on impact and begin to decrease immediately. Cogley and Nason (1993, 1995) demonstrate the dynamics of output (also labor hours and investment) of the RBC model inherited from the autocorrelation structure of the productivity shock. Since the productivity shock is assumed to be AR(1), the output dynamics of the RBC model appears with sharp rise followed by monotone decline accordingly. The key variable which is generating this contrast between two models is the behavior of the entrepreneur's net worth. Recall that the entrepreneur's net worth is a combination of the entrepreneur's capital and wage/rental income. Although her income can jump to its stable path, her capital cannot, since it is a state variable. Because of this, the initial response of net worth is limited. Similarly, the entrepreneur's investment is a function of capital price and net worth, which directly means that investment is driven to jump by initial increase in capital price, while such jump is limited, since net worth is nearly fixed on impact. Cogley and Nason (1995) and Carlstrom and Fuerst (1997) report that output dynamics observed in actual U.S. time series data is consistent with this hump-shaped behavior. Economic intuition behind

[20] Recall that the RBC model is a special case of the LI model where parameters are chosen such that $\omega_1 = \omega_0$. This is a perfect information environment.

this hump-shape is as follows. At an initial shock of increased productivity, the firm finds that her investment is now more profitable, but actual investment expenditure does not rise much until she can accumulate a certain amount of cash-flow. Without sufficient internal funds the required return rate on externally raised funds still remains high, which limits the increased profitability of investment. Essentially this is because investment needs a down payment as shown in section 2 due to the imperfect information that is given. Especially, let us compare the initial responses of investment and the capital price. The lower two panels in Figure 3 show that from periods 0 to 2, investment starts to boom gradually according to the increase in her net worth (or accumulated profit), while capital price has already started to fall. Since capital price is the proxy of profitability, my simulation results suggest that profitability and investment can move in opposite directions. This implication is consistent with many empirical studies reporting the poor explanatory power of Tobin's Q in estimating investment function, since naive Q theory predicts a one-to-one relationship between profitability and investment.[21] Among many empirical studies on firms' investment, a recent work by Lamont (2000) provides an insightful empirical fact on the relationship between actual investment and profitability. According to the paper, U.S. data shows weakly *negative contemporaneous* correlation between investment and current stock return, mainly because of investment *lag*. Lamont (2000) presents the empirical evidence that while actual investment expenditure responds to stock return with lags, their investment *plan* (based on survey data) reveals its *positive contemporaneous* correlation with stock return. I cannot specify the reason behind this lagged actual investment. However, potentially, the empirical evidence presented by Lamont (2000) seems to support my simulation results.

Another interest is the dynamic behavior of corporate demand for liquidity. The lower two panels in Figure 4 present the impulse response of corporate liquidity demand and the degree of liquidity-dependence. On impact of positive productivity shock, the capital price sharply rises as similarly observed in Tobin's Q theory. Higher capital price implies that the entrepreneur's investment is more profitable. This profitable environment reduces marginal benefit for holding liquidity, and thus the degree of liquidity-dependence (liquidity demand divided by investment) falls. The reason here should be emphasized. Firms tend to find more profitable investment projects in booms, and thus they do not need to rely on credit lines from a financial intermediary to withstand liquidity shocks. The lowest panel in Figure 4 reflects this lower marginal benefit for

[21] Among them, see Fazzari, Hubbard, and Petersen (1988) or Hoshi, Kasyhap, and Sharfstein (1991) for example.

holding liquidity. On the other hand, liquidity demand (degree of liquidity-dependence multiplied by investment volume) itself shows the net effect of the fall in degree of liquidity dependence and increase in investment. Under my calibrated parameter settings, corporate liquidity demand stays almost still on impact, since these two opposite effects approximately cancel each other out. One quarter later, it starts to go up, since the latter effect, increase in investment, dominates the former effect.

4.2.2 Impulse response to a wealth shock

Wealth shock introduced here is a one time transfer of unit wealth from consumers to entrepreneurs. This experiment is insightful in understanding the nature of agency cost models. Recall that in standard RBC models, where information is complete and thus corporate finance is a trivial matter for business cycles, a transfer of wealth from one agent to another does not cause any real change in the economy. On the other hand, in agency cost models, transfer of wealth among different agents induces a non-trivial real effect on a firm's investment. This is because quantity of the internal funds of entrepreneurs (note that this is the firm's net worth in my model here) plays a significant role in agency cost models. Figure 6-7 shows the result of this wealth shock simulation.

As can be seen in the figure, one time transfer of wealth from entrepreneurs to consumers causes a downturn of output, investment, and aggregate consumption in spite of the temporary increase in the household's consumption. This implies that even if the aggregate net worth endowed in the economy as a whole stays constant, a re-distribution of wealth from firms to households can cause a recession, where agency cost is a non-trivial issue in that economy. In fact, this outcome is neither new nor surprising in the literature. Similar results of this wealth re-distribution are observed in other agency cost models such as Carlstrom and Fuerst (1997) and Kiyotaki and Moore (1997).

4.2.3 Sensitivity analysis

The most controversial parameters here would be the mean of the distribution of liquidity shock in terms of investment volume and the entrepreneur's share of profit. As for the mean of the liquidity shock, the amount of working capital expenses that are demanded on average for a unit of investment project should be empirically investigated. However, as shown in the upper panel in Figure 8, the output dynamics is pretty robust for various means of liquidity shocks. Essentially, this is because whatever distribution is expected, the optimal cut-off level of liquidity shock is mainly determined by the entrepreneur's technology itself. In this sense, the profit share of the entrepreneur ($= 1 - \omega_0/\omega_1$) dramatically changes output dynamics. For instance, as mentioned in the previous subsection, with $\omega_0/\omega_1 = 1$ (or $B = 0$, equivalently), the dynamics of my model is the same as that of standard RBC model, namely, the hump-shaped response of output and investment totally disappears. As can be seen in the lower panel of Figure 8, the hump-shaped dynamics requires a certain magnitude of agency cost to be generated. It seems that 10% for the entrepreneur's share of profit ($\omega_0/\omega_1 = 0.9$) is sufficient for significant hump-shaped dynamics.

5 Discussions

5.1 Some empirical facts

As I have discussed in the previous section, the hump-shaped dynamics of output and investment are empirically verified by preceding studies. Here in this section, let us consider the empirical validity of the cyclical pattern of corporate demand for liquidity and the degree of liquidity dependence predicted by my model.

Figure 9 shows the Japanese data. In the upper panel of Figure 9, the solid line depicts bank loans for working capital expenses.[22] The data can be a reasonable proxy for the liquidity provided via the financial intermediary. The dashed line is aggregate output. My model's prediction on the relationship of these two variables is moderate positive correlation. This is because bank loan volume is the result of the net effect of the counter-cyclical degree of liquidity dependence and pro-cyclical investment expenditure. Actual correlation calculated by the data turns out to be 0.2. The lower panel reveals more clear cyclical patterns. As can be seen on the panel, the degree of liquidity dependence, which is measured as bank loans for working capital expenses divided by investment here, is apparently negatively correlated with output. Actual correlation within the sample period is -0.6.

Let us take a look at the U.S. data. The upper panel on Figure 10 shows commercial bank loans[23] (the solid line) and output. (the dashed line) Actual correlation of these

[22] All the data series (except for bank loans for working capital expenses/investment for Japanese data) are detrended by using the HP filter with smoothing parameter =1600. As for bank loans for working capital divided by investment (for Japanese data), it is not detrended, since it is stationary.

[23] As for the U.S. data, I could not find the exact data for bank loans for working capital expenses. Instead, I show here total bank loans, which contain both loans for fixed business investment and other

two variables are 0.41 during the sample period. Similarly, in the lower panel of the same figure, the solid line depicts a proxy for the degree of liquidity dependence, measured as commercial bank loans divided by investment. Again, the panel reveals a clear counter-cyclical pattern of the degree of liquidity dependence. Actual correlation for U.S. data turns out to be -0.5. It should be noted that I am not claiming that most of the business cycle dynamics is driven by productivity shocks. Nonetheless, these casual observations on actual correlations seem to support my simulation results presented in the previous section.

5.2 Relation to the *Lending View* and other studies

One of the major predictions of *Lending View* theory is that firms will be more bank loan-dependent in recessions. According to the lending view, this cyclical pattern of firms' financing structure can be explained as follows. During recessions, investment projects are not so profitable on average as in booms; firms cut some of their projects whose returns do not exceed their financing cost. Since direct financing, such as equity finance, are usually more costly than loans from an intermediary, the result of cutting those unprofitable investment projects is to increase the ratio of bank loan financing in total financing. The mechanism which governs the cyclical fluctuations of financial structure in my model is slightly different from the standard lending view, but as I have already seen in the previous subsection, both the lending view and our model yield very similar predictions. The similarity is that in my model, firms become more liquidity-dependent in recessions, because lower profitability of their investment projects raises the marginal benefit of holding liquidity, while firms in the lending view demand more bank loan financing, because the marginal cost of obtaining it is lower. The difference is that the lending view considers *asset substitution* such as from bank loan to equity financing. This is in contrast to my model where the firm's choice is whether to demand credit lines from banks or not. Let us see this point more precisely. Differentiating the first order condition (eqn(7)) in the financial contract to obtain,

$$\frac{\partial \bar{\omega}}{\partial q} = \frac{-\int_0^{\bar{\omega}} \Phi(\omega)\, d\omega}{q\Phi(\bar{\omega})} \leq 0 \tag{24}$$

which directly implies that the optimal credit line offered by the financial intermediary will decrease when investment projects become more profitable. This relation in eqn(24) is the source of the negative correlation between capital price (investment profitability)

kinds of long-term financing.

and the firm's degree of liquidity-dependence x in eqn(10) as discussed so far. This can be verified by the following relation,

$$\begin{aligned}
\frac{\partial x}{\partial q} &= \frac{\partial \bar{\omega}}{\partial q}\frac{\partial x}{\partial \bar{\omega}} \\
&= \frac{\partial \bar{\omega}}{\partial q}\frac{\partial}{\partial \bar{\omega}}\left(\frac{\int_0^{\bar{\omega}} \omega\phi(\omega)\,d\omega}{\Phi(\bar{\omega})\,\omega_1}\right) \\
&= \underbrace{\frac{\partial \bar{\omega}}{\partial q}}_{\leq 0}\underbrace{\frac{\omega_1\phi(\bar{\omega})\int_0^{\bar{\omega}}(\bar{\omega}-\omega)\,\phi(\omega)\,d\omega}{(\Phi(\bar{\omega})\,\omega_1)^2}}_{\geq 0} \\
&\leq 0.
\end{aligned}$$

Basically, raising credit lines from the intermediary has a trade-off. A higher credit line is beneficial in withstanding larger liquidity shocks, while it reduces the investment profitability and thus the volume of investment. When investment projects are highly profitable on average, both firms and consumers are willing to cut credit lines, since they have larger investment volumes. Because of this mechanism, I find that the degree of liquidity dependence tends to be counter-cyclical in the simulation results, which is consistent with the actual data observation as shown in Figure 9 and 10.

Note that it is this point that my DGE model has an advantage over others with a different financial structure such as costly state verification. It is well known that some DGE models with agency costs tend to show anomalies regarding the cyclical pattern of financial aspects of the economy in spite of their superior performance in replicating the dynamics of the real variables such as investment and output.[24] By adapting HT type financial contract instead of the costly state verification, my DGE model yields both a theoretically and empirically reasonable cyclical pattern of a firm's financing structure, maintaining the auto-correlation dynamics of the real variables.

Another prediction of the lending view is that smaller firms, which are usually considered to be confronted with higher financing costs, are more bank loan-dependent. Another similarity can be derived from the variant of the HT model regarding this prediction. Eqn(7) implies that the credit line given to a firm does not depend on either ω_0 or ω_1, but solely on q. Consequently, the optimal credit line in terms of the firm's NPV, $\bar{\omega}/\omega_1$ (or in terms of pledgeable value, $\bar{\omega}/\omega_0$) is higher for a firm with lower ω_1 (or ω_0). In other words, a firm with larger NPV tends to demand less liquidity than

[24] For exapmle, one anomaly observed in Carlstrom and Fuerst (1997) model is pro-cyclical risk premium, which does not appear in my model.

smaller firms in terms of their NPVs. This is a direct result from insurance provided by the financial intermediary. In addition, changes in $\bar{\omega}$ with respect to profitability, that is, $\partial\bar{\omega}/\partial q$ (≤ 0) is again constant over ω_1, which can be interpreted as that a firm's (maximum) liquidity demand, $\bar{\omega}i$ divided by her NPV, $\omega_1 i$ tends to be more sensitive to the profitability for smaller firms. Namely,

$$\frac{d\left(\bar{\omega}/\omega_1^B\right)}{dq} > \frac{d\left(\bar{\omega}/\omega_1^A\right)}{dq}, \qquad \text{for} \quad \omega_1^A > \omega_1^B. \tag{25}$$

This relation is consistent with a common observation that smaller firms tend to fall in liquidity shortage during recessions (interpreted as periods when q is lower), in the sense that credit lines should be intensively allocated to smaller firms when the economy is in a recession.[25]

6 Concluding Remarks

Although the HT model is highly stylized, it requires a much less specific environment than it appears. Recall the calibration in section 4. I need to specify only two parameters and one distribution for entrepreneurial technology, namely ω_1, ω_0 and Φ. Actually, as long as we are sticking to one-to-one transformation technology in capital production, $\omega_1\Phi(\omega_1)$ must be set at one, and therefore only one parameter and one distribution need to be calibrated. This implies that the hump-shaped dynamics of output is robust to a broad class of models in which the investment process is characterized by a *leakage* due to moral hazard or imperfect information. My guess is that any reasonable theory which yields eqn(8), $i = k(q)n$ type investment function is consistent with hump-shaped dynamics of output. However, of course, this must await further research on this issue to be verified.

Another robust result of the model is that corporate demand for liquidity is procyclical, while the degree of liquidity-dependence is counter-cyclical. These predictions are consistent with empirical evidence presented in *lending view* literatures.

A potential flaw of my model in this paper is that it is lacking in the ability to analyze the role of public-supplied liquidity. A version of the HT model that provides a rationale for government-supplied liquidity has aggregate uncertainty present in the economy. Intuitively, the role of the government is to eliminate the aggregate uncertainty to achieve

[25] However, general consequence of heterogeneity in firms' NPV is not examined in my DGE model. My DGE model allows heterogeneity only for levels of net worth.

at least the second best outcome on the production side of the economy. However, my model is constructed on the assumption of no aggregate uncertainty in the capital production process.[26] I need this assumption to maintain modeling consistency. Especially in the presence of aggregate uncertainty, I cannot separate intra-period financial contract and the rest of the general equilibrium any more. Nonetheless, incorporating aggregate uncertainty and hence the role of government-supplied liquidity are potentially interesting, because of the following two advantages. One is that such a model can provide much richer implications on economic welfare. The other is that it allows us to analyze the business cycle patterns of liquidity premia on government-supplied securities, such as T-bills. For these purposes, we must await further research with this extension.

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[26] Note that productivity shock is not an aggregate uncertainty in this sense here. Since productivity shock is realized *before* the financial contract is implemented, and thus the current level of productivity shock is in everyone's information set when the financial contract is about to be implemented.

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Figure 3 : The Response to a Productivity Shock of Liquidity Model and RBC model

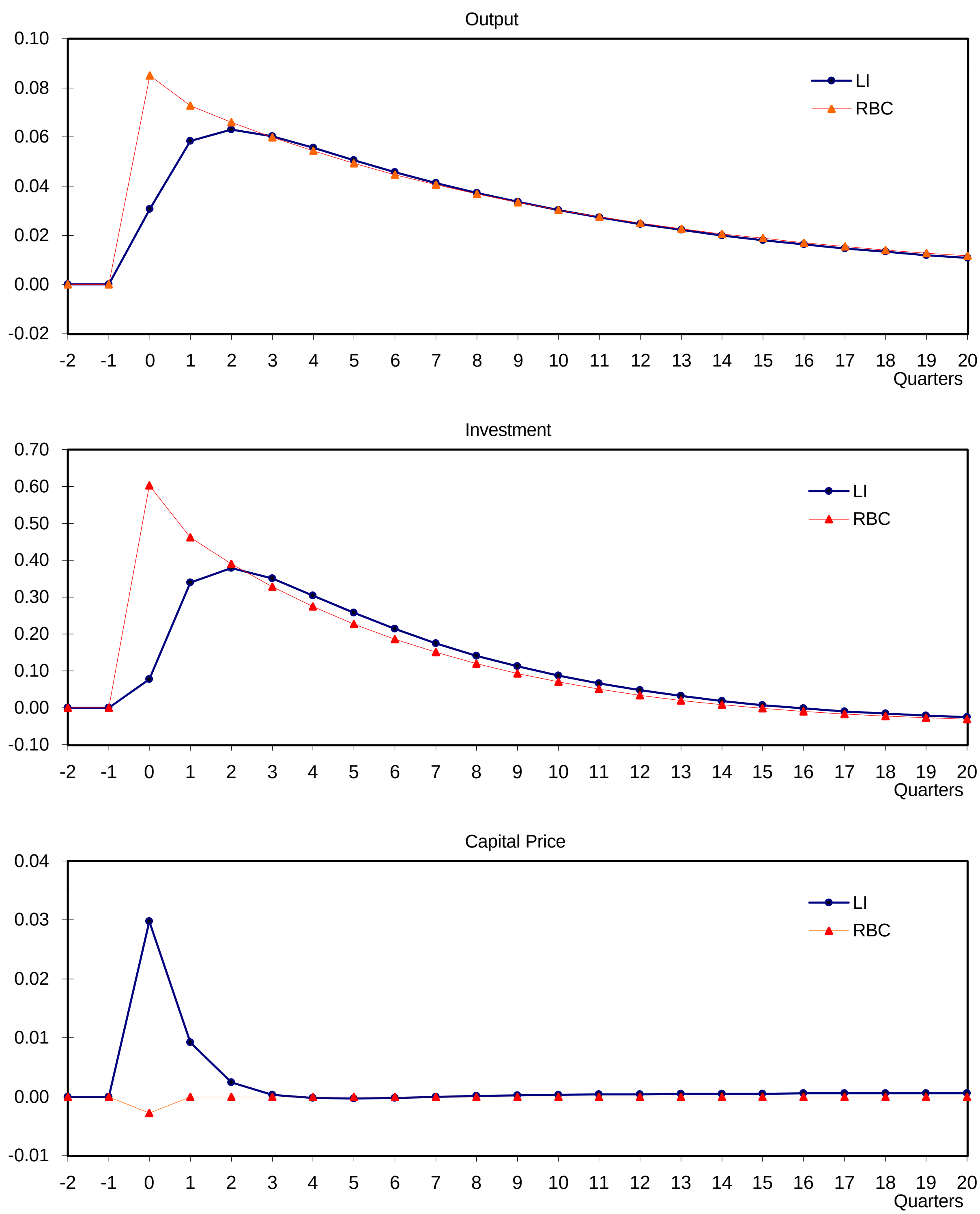


Figure 4 : The Response to a Productivity Shock of Liquidity Model and RBC model

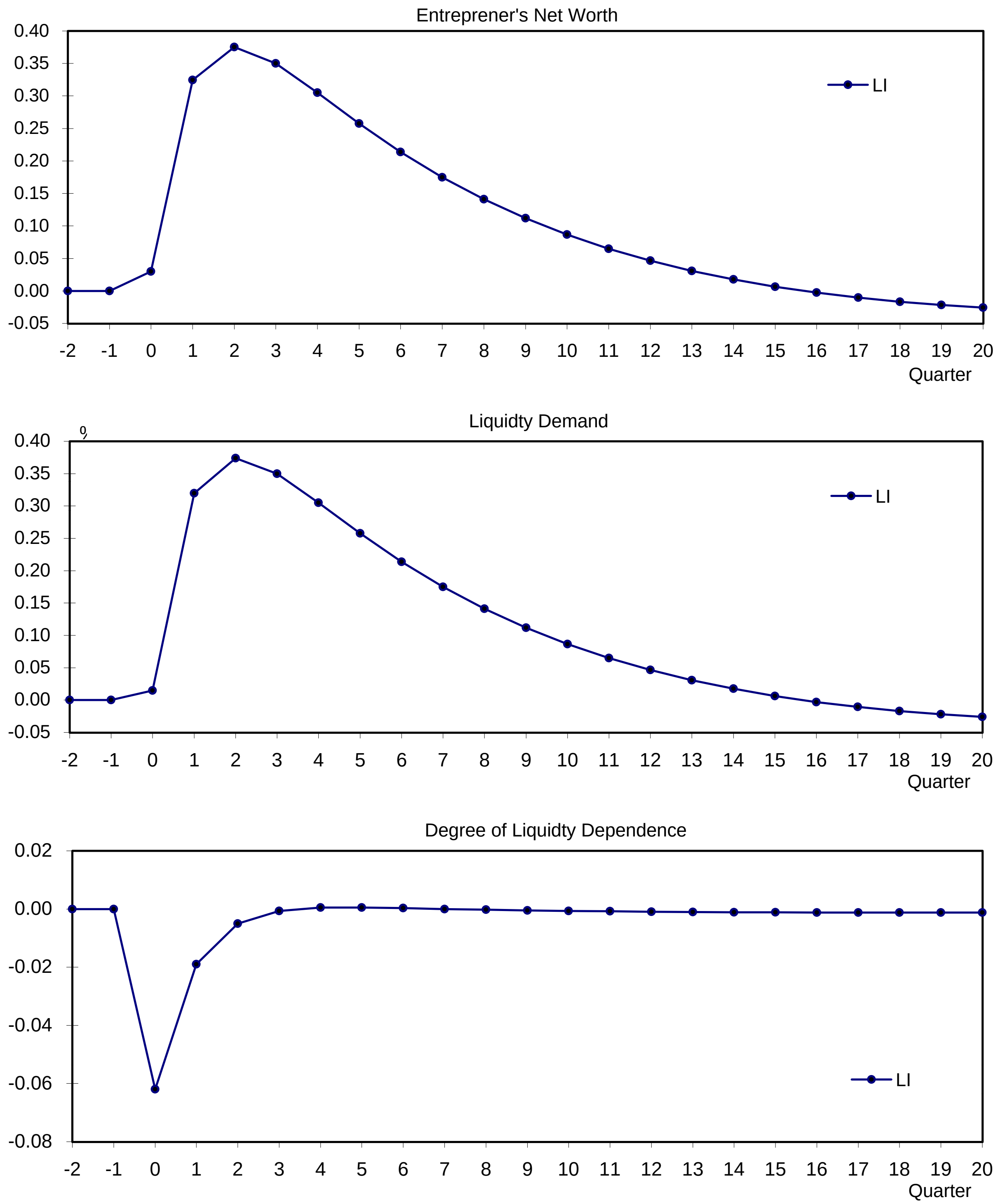
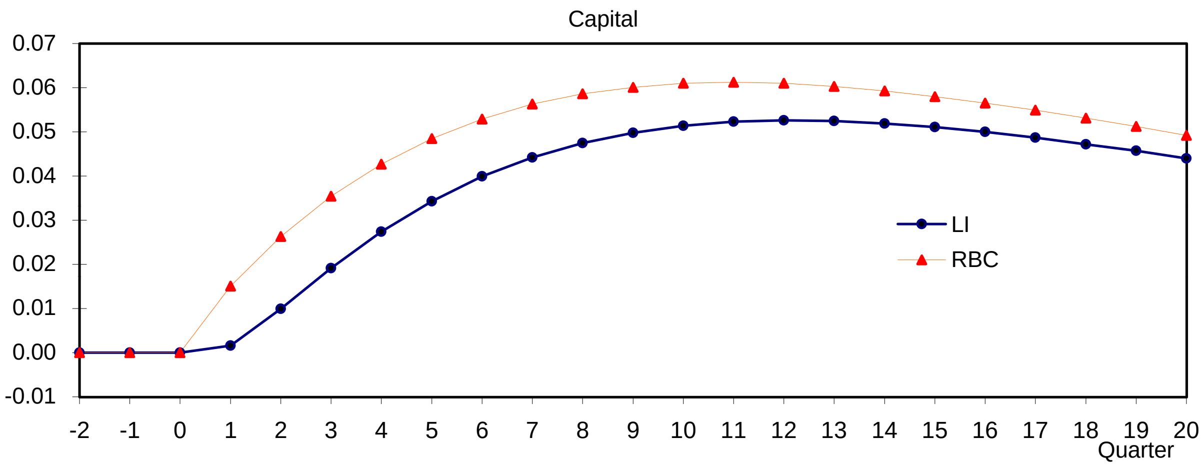
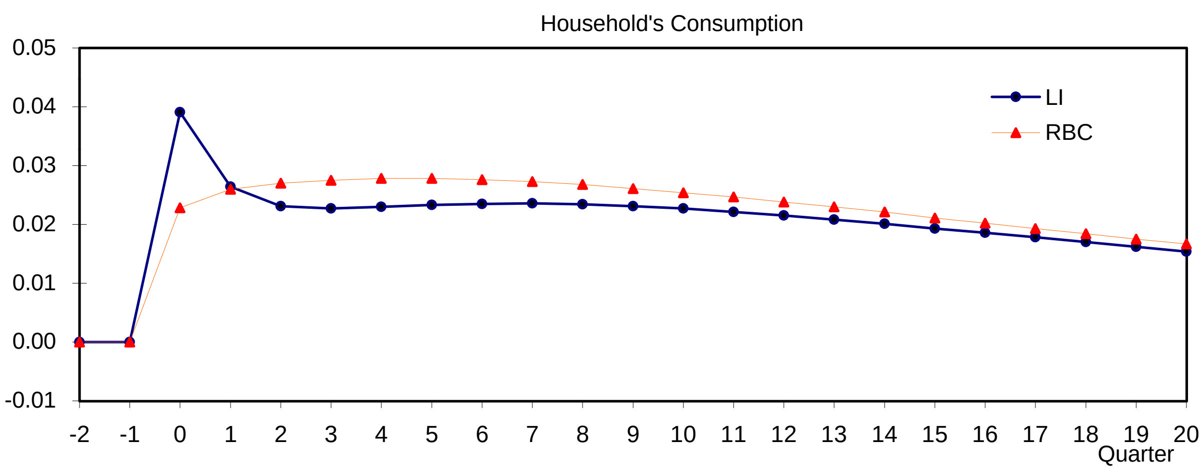


Figure 5 : The Response to a Productivity Shock of Liquidity Model and RBC model





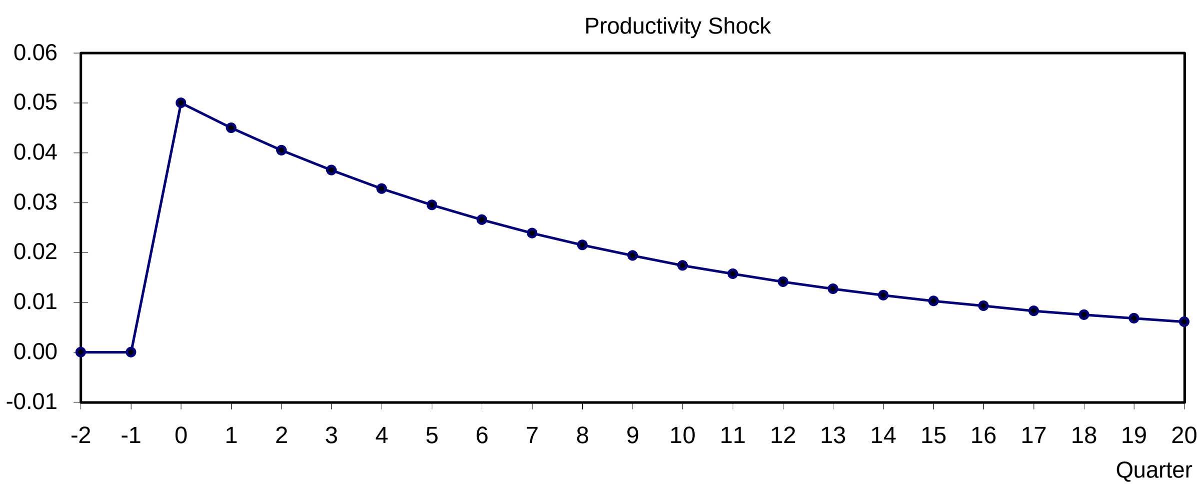


Figure 6 : The Response to a Wealth Shock of Liquidity Model

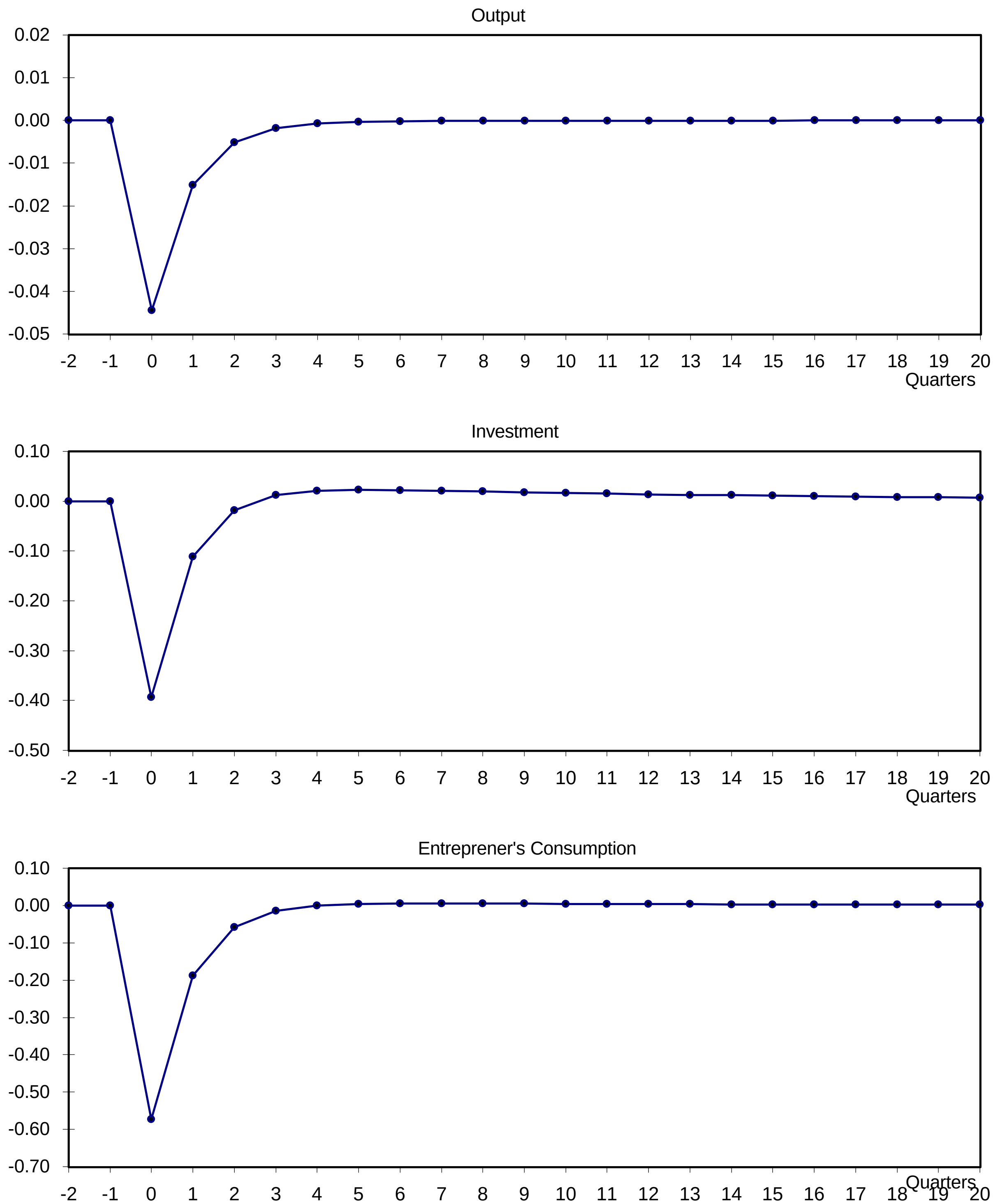


Figure 7 : The Response to a Wealth Shock of Liquidity Model

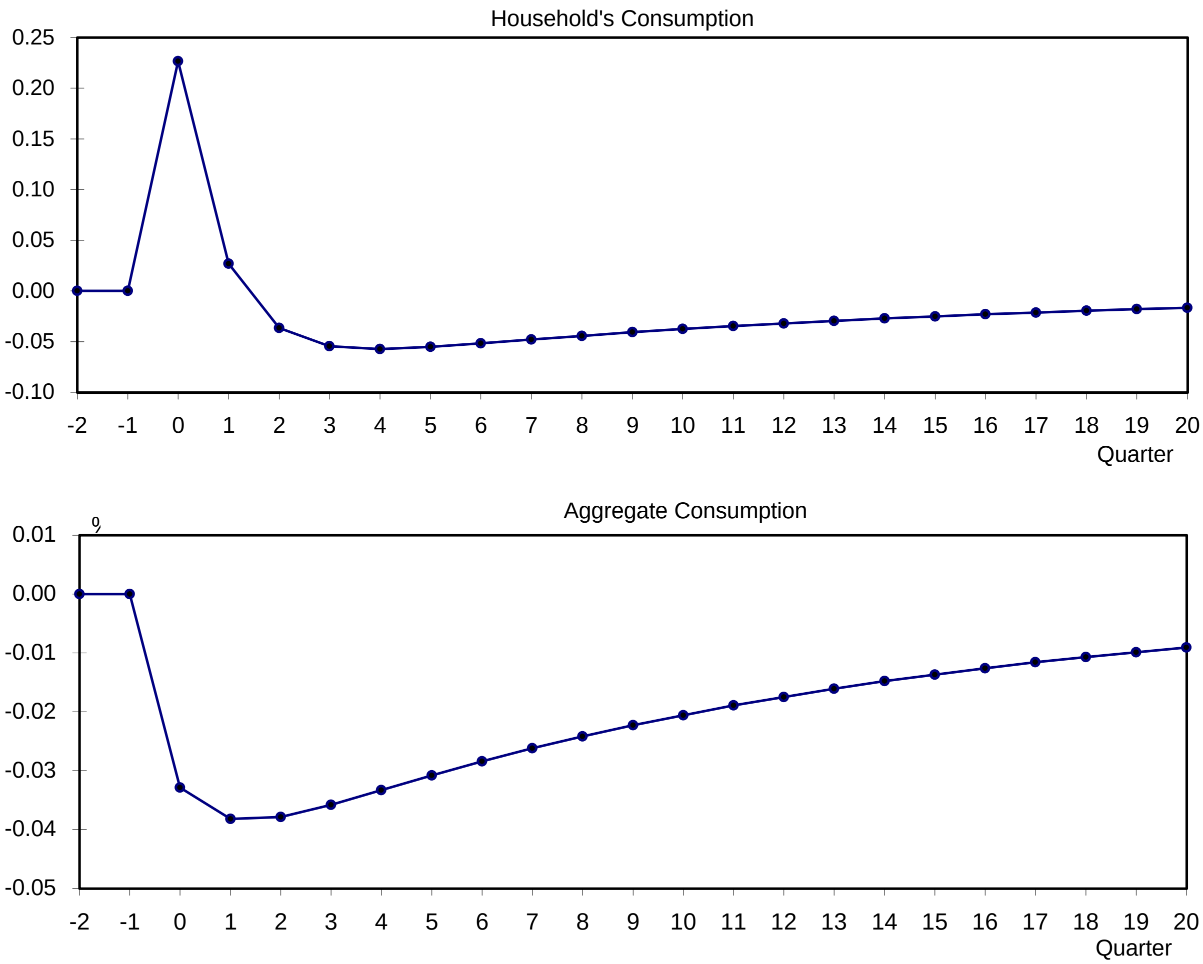
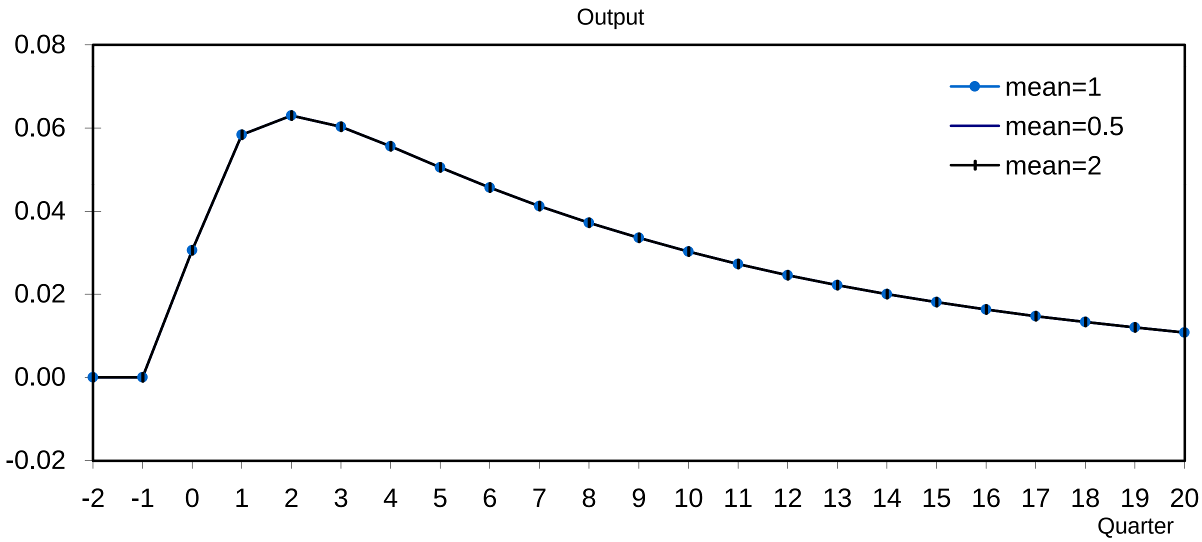


Figure 8: The Response to a Productivity Shock of Liquidity Model with Alternative Parameter Values



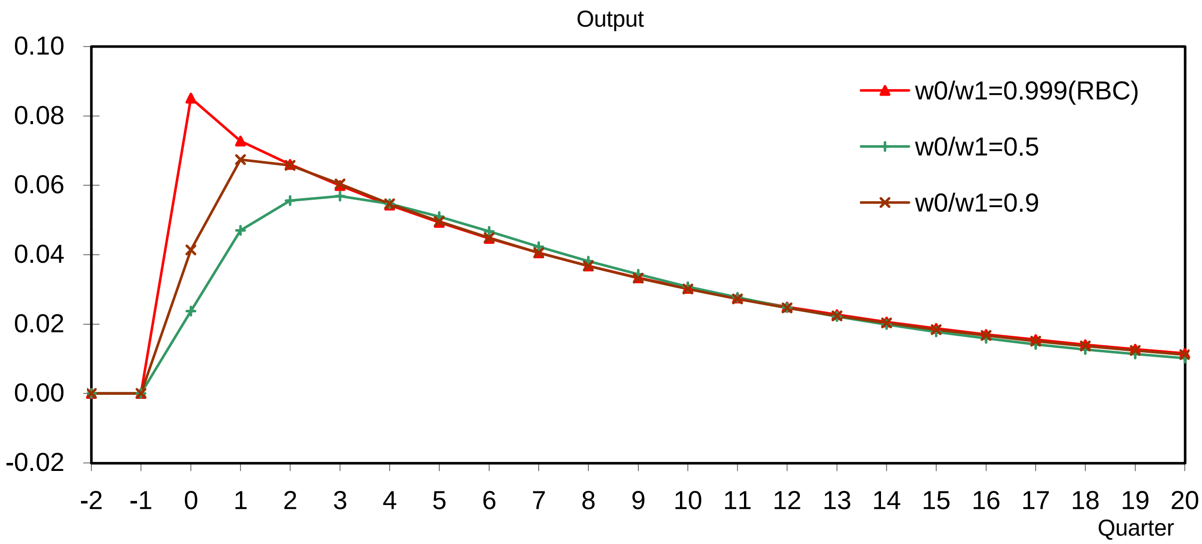
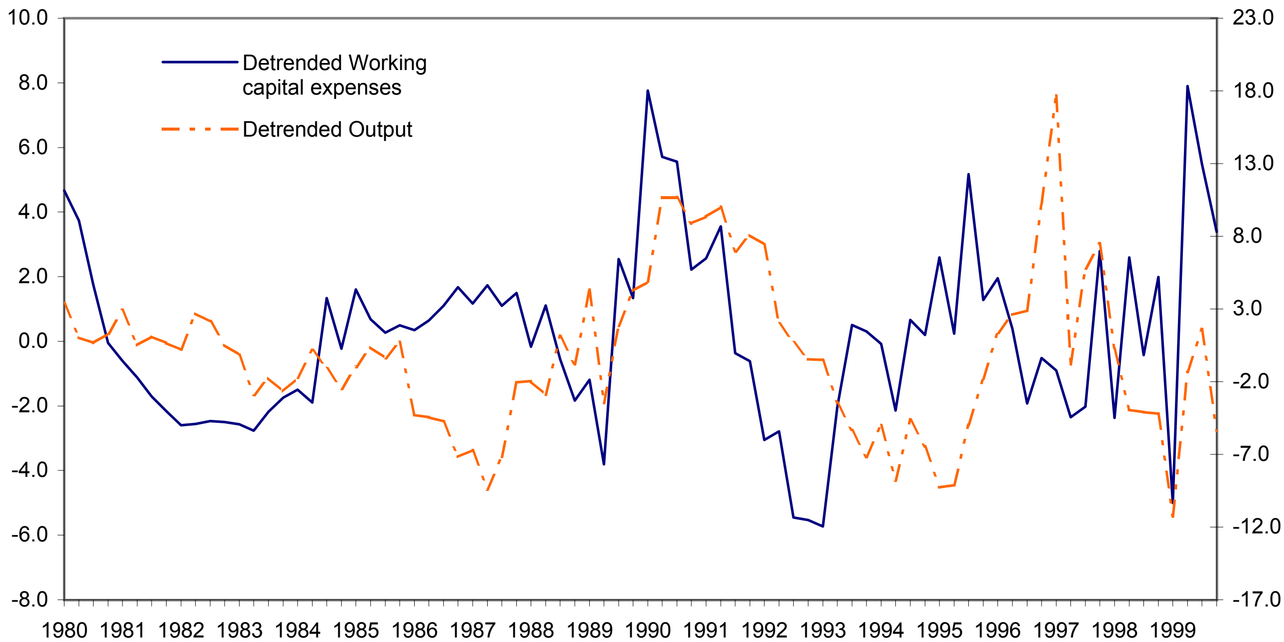


Figure 9: Liquidity Demand and Degree of Liquidity Dependence

Japanese data (80q1-99q4)



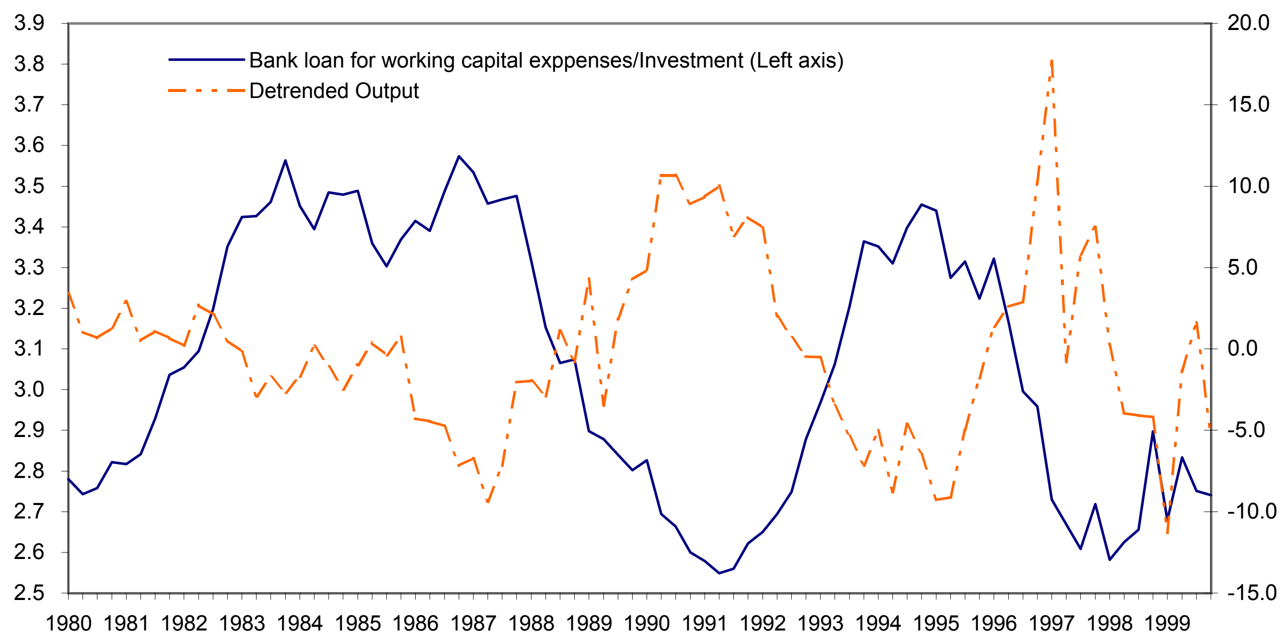


Figure 10: Liquidity Demand and Degree of Liquidity Dependence

US data (80q2-2000q1)