Adverse Selection, Uncertainty Shocks and Monetary Policy[*]

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First draft: February, 2011
This draft: August, 2011

Abstract

I expand a model developed by Ikeda (2011) and study a dynamic monetary economy in which imperfect financial markets materialize uncertainty shocks. The uncertainty shocks change the degree of asymmetric information and affect the severity of adverse selection in financial markets. I show quantitatively that nominal rigidities amplify the effect of uncertainty shocks and generate significant business fluctuations comparable to the U.S. great recession. I then use the model to evaluate the effect of monetary policy to tackle a simulated financial crisis. The results are twofolds. First, a modified Taylor rule augmented with financial variables contributes in resolving the crisis. Second, unconventional monetary policy which subsidizes the intermediaries' cost of funds also helps recover the economy. The subsidy policy can be implemented by the government purchases of intermediaries' assets.

(*JEL*) E30, E44, E52.

Key words: Adverse selection, uncertainty shocks, unconventional monetary policy

[*]I am deeply indebted to my Ph.D. advisor at Northwestern University, Larry Christiano, for his continuous help and invaluable advice. I thank Martin Eichenbaum, Giorgio Primiceri, Matthias Doepke, Mirko Wiederholt and Matthias Kehrig for their helpful comments. The views expressed in this paper are solely the responsibility of the author and should not be interpreted as reflecting views of the Bank of Japan.

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1. Introduction

The great recession starting in late 2007 has addressed the need to understand the causes of financial instability and its effect on aggregate and financial variables. In the great recession, output, investment and employment decreased dramatically while external finance premium rose sharply. The Federal Reserve (Fed) reacted forcefully to the crisis. The Fed drove federal funds rate to near zero and conducted unconventional monetary policy including the asset purchases of financial claims on financial and non-financial institutions.

What could cause a financial crisis similar to the great recession in a dynamic general equilibrium model? What type of monetary policy is effective to tackle the crisis? To answer those questions, I expand a model developed by Ikeda (2011) and study a dynamic monetary model in which imperfect financial markets materialize uncertainty shocks.

The model features adverse selection in financial markets in a framework of monetary business cycle model developed by Christiano, Eichenbaum and Evans (2005, CEE hereafter). In the model entrepreneurs borrow funds from intermediaries to finance their projects. The entrepreneurs differ in their project's probability of success, which is the private information to the entrepreneurs, as in Stiglitz and Weiss (1981). The asymmetric information results in adverse selection in financial markets: some safer entrepreneurs do not get funded and the aggregate loan becomes lower relative to a symmetric information benchmark. The uncertainty shocks I consider in the model change the degree of asymmetric information and affect the severity of adverse selection.

I show quantitatively that the uncertainty shocks not only generate business cycles but also trigger a financial crisis comparable to the great recession. The negative uncertainty shocks increase the degree of asymmetric information and aggravate adverse selection in financial markets. Intermediaries face more uncertainty about the riskiness of providing loans to entrepreneurs. To make non-negative profits, the intermediaries respond by raising loan rates and shrinking the amount of loans. An external finance premium, defined by the ratio of loan rates to risk-free rates, rises sharply and the aggregate loan decreases considerably. With lesser loans the entrepreneurs purchase less capital goods, and the demand for capital decreases. The price of capital falls and investment decreases. A fall in the price of capital decreases the value of the current net worth held by entrepreneurs, which, in turn, decreases the amount of loans, because the loan capacity is constrained by the net worth. A decrease in the amount of loans leads to a decrease in the demand for capital again, and this vicious cycle continues. As a result, both the aggregate loan and investment decrease dramatically.

The uncertainty shocks have profound effect on an economy, because of amplification mechanisms embedded in the model. Nominal price and wage rigidities serve as the amplification mechanisms. The nominal rigidities generate a counter-cyclical markup, which offsets and overturns the substitution effect between consumption and hours, overcoming a famous co-movement problem pointed out by Barro and King (1984). Making consumption and hours co-move together, the nominal rigidities not only allow the model to generate business cycles, but also amplify the effect of uncertainty shocks. In response to the negative uncertainty shocks, consumption as well as investment decreases, so does the aggregate demand. This places an additional downward pressure on the economy. Prevented from adjusting nominal price and wages, households supply labor less and consume less, and firms produce less than they would without the nominal rigidities.

The important feature of the model lies in the role of imperfect financial markets which materialize the uncertainty shocks. Without asymmetric information, the uncertainty shocks would have no real effect on the economy. In an economy with symmetric information, a risk associated with entrepreneurial projects is perfectly diversified in financial markets. A change in the distribution of the riskiness of the projects does not have any effect on an economy. This observation suggests that there may exist a room for (monetary) policy to improve welfare in an economy with imperfect financial markets and the uncertainty shocks.

I consider two types of monetary policy to tackle a simulated financial crisis. First, I consider a modified Taylor rule augmented with financial variables. Specifically, I consider a modified Taylor rule augmented with external finance premiums, as suggested by Taylor (2008), and a modified Taylor rule augmented with credit growth, as suggested by Christiano, Ilut, Motto and Rostagno (2010). I find that the two modified Taylor rules help resolve the crisis. In response to the negative uncertainty shocks the modified Taylor rules allow the nominal interest rate to fall more than suggested by the standard Taylor rule. This generates expectations that the monetary policy stimulates an aggregate demand in response to the negative uncertainty shocks. The stimulus mitigates the effect of the uncertainty shocks in the future, which, in turn, weakens the amplification of the shocks and their ultimate effect today. As a result, the modified Taylor rules have a powerful effect to combat the crisis.

Second, I consider unconventional monetary policy which subsidizes the intermediaries' cost of funds, as analyzed by Christiano and Ikeda (2010) in two-period general equilibrium models. The subsidy policy shares similar features to those implemented by Fed during the great recession. Actually, the subsidy policy can be implemented by the government's purchases of intermediaries' assets. The subsidy policy gets to the core of the problem. The negative uncertainty shocks make adverse selection in financial markets more severe and decrease the amount of intermediation or the amount of aggregate loans. By lowering the cost of intermediaries' funds adequately, the intermediaries can lend more and lower the loan rates offered to entrepreneurs. This offsets the negative effect of the uncertainty shocks, curing adverse selection in financial markets. Because the subsidy policy directly cures the problem, the policy is more welfare improving than a modified Taylor rule.

The model presented in this paper is an extension of my former paper (Ikeda, 2011) which develops a dynamic real economy with imperfect financial markets. In the former paper I analyze uncertainty shocks in a real business cycle framework and show that a counter-cyclical markup in wages and variable capital utilization rates serve as important amplification mechanisms of the uncertainty shocks. Because my focus lies in the role of uncertainty shocks I model a counter-cyclical markup in wages in an exogenous manner. In this paper I endogenize the counter-cyclical markup by introducing nominal rigidities. The nominal rigidities not only generate a counter-cyclical markup but also make responses to uncertainty shocks more persistent. More importantly, the introduction of nominal rigidities allows me to study the role of monetary policy.

The model of financial markets in this paper builds upon an asymmetric information model developed by Stiglitz and Weiss (1981), and further analyzed by Mankiw (1986) and Bernanke and Gertler (1990) in the context of macro economy. Unlike Stiglitz and Weiss (1981) and the others who fix the scale of investment made by entrepreneurs, I extend their model allowing for variable scale of investment. In so doing I introduce an agency problem, similar to Gertler and Karadi (2010), in which entrepreneurs can pledge at most a fraction of their returns. This agency problem limits the amount of loans provided by intermediaries, and determines the amount of investment made by entrepreneurs endogenously. In this sense the financial markets studied in this paper feature both adverse selection and an agency problem (moral hazard).

I embed the asymmetric information model into a monetary business cycle model in line with Bernanke, Gertler and Gilchrist (1999, BGG hereafter) and Gertler and Karadi (2010). BGG (1999) embeds Townsend's (1979) costly state verification (CSV) model into a dynamic monetary model in a way that entrepreneurs own, trade and rent out capital, whose activity ultimately defines the aggregate demand for capital. Gertler and Karadi (2010) features a household consisting of large number of family members who are either workers or bankers (entrepreneurs). Combined with perfect consumption insurance among family members, this setting allows me to model entrepreneurs in a meaningful way within an otherwise representative agent framework.

Uncertainty shocks have got a lot of attention as a source of business cycles. Uncertainty, measured by various second moments, appears to increase after major economic and political incidents (Bloom, 2009) and during recessions in the U.S. including the great recession (Bloom, Floetotto and Jaimovich, 2010). Bloom (2009) and Bloom, et al (2010) focus on firms' non-convex adjustment costs as mechanisms to materialize uncertainty shocks. This paper provides another mechanisms through which the uncertainty shocks drive business cycles and generate a crisis comparable to the great recession.

The uncertainty shocks I consider in my model shares the same spirits with Williamson (1987) who considers shocks to the riskiness of the entrepreneur's return in the framework of the CSV model. Christiano, Motto and Rostagno (2010) considers and estimates similar shocks named risk shocks in a dynamic stochastic general equilibrium (DSGE) model with

BGG (1999) financial frictions. Ikeda (2011) discusses conceptual difference and quantitative similarities between the uncertainty shocks in this model and the risk shocks.

The uncertainty shocks in this paper are also closely related with financial shocks analyzed by Hall (2010), Gilchrist, Yankov and Zakresjek, (2009) and Gilchrist and Zakresjek (2010) among others. They study the financial shocks which change a wedge between the return to capital and the risk-free rate exogenously. They consider the financial shocks as the trigger of the great recession. As shown by Ikeda (2011), the uncertainty shocks in this model coincide with the financial shocks after log-linearization. The uncertainty shocks in imperfect financial markets provide micro-foundations for the reduced-form financial shocks.

The analysis on the role of a modified Taylor rule in this paper is closely related with Taylor (2008), Christiano, et al (2010), Curdia and Woodford (2010) and Gilchrist and Zakresjek (2010). Curdia and Woodford (2010) considers a modified Taylor rule augmented with financial variables in a simple credit frictions model. They argue that a modified Taylor rule augmented with spreads (external finance premiums), as suggested by Taylor (2008), performs better than a modified Taylor rule augmented with credits, as suggested by Christiano, et al (2010). They also find that the optimal size of coefficient attached to spreads is unlikely to be as large as unity in contrast to the one suggested by Taylor (2008). Gilchrist and Zakresjek (2010) estimate financial shocks in the great recession and argue that a modified Taylor rule augmented with spreads would contribute in mitigating the recession. My result reinforces their findings, while both the modified Taylor rules work well in the model under baseline parameters values. I find that the optimal size of coefficient attached to spreads is smaller than unity in line with Curdia and Woodford (2010).

The analysis on unconventional monetary policy in this paper follows Gertler and Karadi (2010) and Christiano and Ikeda (2010). Gertler and Karadi (2010) analyzes government asset purchases in a moral hazard model. Christiano and Ikeda (2010) analyzes four different credit frictions model in a simple two-period general equilibrium framework and find that subsidizing intermediaries' cost of funds work well in the four models.[1]

This paper constitutes a growing literature on adverse selection in macroeconomic settings (Eisfeldt 2004, Kurlat 2010, Bigio 2010, 2011, Ikeda 2011). This paper builds upon Ikeda (2011) and differs from the other papers with respect to the source of asymmetric information. While I focus on asymmetric information on the riskiness of projects as in Stiglitz and Weiss (1981), the other papers focus on asymmetric information on the quality of assets (projects). House (2005) studies Stiglitz and Weiss (1981) model in an overlapping generations framework, keeping the fixed scale of investment. I allow the variable scale of

[1]There is also a growing literature on unconventional monetary policy. For example, Del Negro, Eggertsson, Ferrero and Kiyotaki (2010) studies the effect of non-standard open market operations in which the government exchanges liquid government liabilities for illiquid private assets.

investment and embed adverse selection into a dynamic general equilibrium model in a reasonable manner.[2]

I organize the rest of the paper as follows. In Section 2 I provide the overview of the model. In Section 3 I present a partial equilibrium model of financial markets and solve for the optimal contract between entrepreneurs and intermediaries. In Section 4 I embed the partial equilibrium model into a DSGE model. In Section 5 I conduct simulations to explore the effect of uncertainty shocks quantitatively. Then I make clear the role of amplification mechanisms of uncertainty shocks and the role of adverse selection. In Section 6 I use the model to simulate a financial crisis and study the role of monetary policy to tackle the simulated crisis. In Section 7 I provide some concluding remarks.

2. The Model: Overview

I expand a real business cycle model with both adverse selection and an agency problem in financial markets, developed by Ikeda (2011), to a monetary business cycle model in line with CEE (2005). Adverse selection occurs due to asymmetric information about the riskiness of project run by entrepreneurs who rely on external finance from intermediaries. An entrepreneurial project differs in its probability of success, which characterizes the riskiness of the project as in Stiglitz and Weiss (1981), Mankiw (1986) and Bernanke and Gertler (1990). An agency problem occurs because entrepreneurs can pledge at most a fraction of return to intermediaries.

The model features disturbances to the riskiness of projects, in short, uncertainty shocks. The uncertainty shocks change a wedge between a return to capital and risk-free rates, acting as exactly the same role as financial shocks considered by Hall (2010), Gilchrist, et al (2009) and Gilchrist and Zakresjek, (2010) among others. With asymmetric information the uncertainty shocks change the severity of adverse selection in financial markets and generate business fluctuations.

The model economy consists of four types of agents: households, intermediaries, firms and a government. There is a continuum of households with measure unity. Each single household consists of two types of family members: workers and entrepreneurs. Workers have monopolistic power over its specific labor, set nominal wages subject to Calvo (1983) type frictions as in Erceg, et al (2000), and earn wage income. Entrepreneurs own and trade capital, and earn capital income. The household, as a representative agent of the family members, decides how much to consume and save in deposits. The household provides perfect insurance among its members so that every member enjoys the same level of consumption. This setting allows me to model borrowers (entrepreneurs) and lenders (intermediaries) in a reasonable manner, keeping a representative agent framework.

[2]There are several analyses of the great recession that focus on adverse selection in credit markets. See, for example, Chari, Shourideh and Zetlin-Jones (2010), Fishman and Parker (2010).

Every period an entrepreneur runs a project with success probability, which is i.i.d. across entrepreneurs and over time. The success probability or the riskiness of the project constitutes private information to the entrepreneur. The entrepreneur has its own net worth, may get financed from intermediaries and purchase new capital to invest in the project. The entrepreneur has an agency problem: it can misbehave and walk away with a certain fraction of assets. This agency problem limits the amount of loan made by intermediaries while the private information causes adverse selection.

After the return or project realizes in the next period some entrepreneurs become workers and the same number of workers become entrepreneurs, so that the fraction of entrepreneurs in a household stays constant over time. An entrepreneur can transfer its wealth to the household to which it belongs in the beginning of any period while it brings all its wealth to the household when it becomes a worker.

Intermediaries take in deposits from households and lend to entrepreneurs in a competitive manner. The intermediaries, taking into account both asymmetric information and an agency problem, offer a schedule of loan contracts to entrepreneurs. The resulting optimal contract characterizes the amount of loan and the amount of payment as well as which entrepreneur get financed.

Firms consist of three types of firms: final good firms, intermediate goods firms and capital good firms. All firms behave in a competitive manner except intermediate goods firms, where I embed nominal rigidities as in Calvo (1983). Final good firms buy intermediate goods while intermediate good firms rent capital from entrepreneurs and hire labor. Capital good firms buy a final good, transform it into new capital goods.

A government consists of a fiscal authority and a monetary authority. The fiscal authority levies taxes and sets the amount of government spending. The monetary authority sets the nominal interest rate according to some monetary policy rules. The monetary authority, with the help of the fiscal authority, also conducts unconventional monetary policy which subsidizes the cost of intermediaries' funds.

3. Financial Contract: A Partial Equilibrium Model

I describe an optimal contracting problem between entrepreneurs (borrowers) and intermediaries (lenders), developed by Ikeda (2011). In the problem entrepreneurs and intermediaries take as given the price of capital, the expected return to capital and the interest rate on deposits. In the subsequent section I endogenize those as part of a general equilibrium model.

3.1. Environment

Overview: I consider a two-period financing problem between entrepreneurs and intermediaries. The financing problem evolves in four steps. Initially, at the beginning of time t

nature draws and assigns entrepreneur's type (private information) which characterizes the riskiness of entrepreneur's project. In the first step, an intermediary provides a schedule of contracts to entrepreneurs without knowing the riskiness of entrepreneur's project. In the second step, after observing the other intermediaries' schedules of contracts the intermediary decides whether to stay in the market or to leave the market.[3] In the third step, an entrepreneur chooses an intermediary and a contract and invests in its project. Finally, at the beginning of time $t+1$ the entrepreneur and the intermediary receive returns depending on the previous actions at time t.

The financing problem features both adverse selection and an agency problem. Adverse selection occurs due to entrepreneur's private information about the riskiness of project. An agency problem limits the amount loan made by intermediaries because entrepreneurs can pledge at most a fraction of return to an intermediary.

Entrepreneurs: There exist many entrepreneurs whose objective is to maximize their net worth in the next period. As I will explain in the general equilibrium model in the next section, entrepreneurs behave as if they were risk-neutral. At the beginning of time t an entrepreneur starts its business with net worth $N_{t,n}$ in unit of final goods, indexed by n. An entrepreneur has a project with its success probability p, which is private information to the entrepreneur and is drawn from distribution function $F_t : [\underline{p}_t, 1] \to [0,1]$ with $0 < \underline{p}_t < 1$, independently and identically across entrepreneurs. I assume that distribution $F_t(p)$ has full support. Subscript t in $F_t(\cdot)$ implies that the distribution can change due to disturbances, which I specify in the next section.

A set of index, (n,p), characterizes an entrepreneur, implying that the type-(n,p) entrepreneur has net worth $N_{t,n}$ and has a project with probability of success p. I assume there exist many entrepreneurs for each n so that distribution $F_t(\cdot)$ coincides with the distribution of the type-n entrepreneurs.

An entrepreneur chooses an intermediary to maximize its expected net worth in the next period. If the entrepreneur finds some intermediaries indifferent it chooses an intermediary randomly. The type-(n,p) entrepreneur receives loan $B_{t,n}(p)$ from the intermediary and purchases physical capital amounting to $\bar{K}_{t+1,n}(p)$ with real price of capital q_t:

$$q_t \bar{K}_{t+1,n}(p) = N_{t,n} + B_{t,n}(p). \tag{1}$$

Equation (1) describes the balance sheet of the entrepreneur. The left-hand-side of equation (1) denotes the entrepreneur's asset consisting of the purchased capital. The right-hand-

[3] As argued by Ikeda (2011), without this second step an intermediary may take advantage of the other intermediaries schedules which screen entrepreneurs by their private information. This feature reminds of the non-existence of equilibrium in competitive insurance markets analyzed by Rothchild and Stiglitz (1976). The second step in a loan making process in the model is inspired by Wilson (1977) and Hellwig (1987) who propose a similar idea to resolve the non-existence problem of Rothchild and Stiglitz (1976).

side of equation (1) denotes the entrepreneur's liability consisting of the net worth and the loan.

At the end of period t the type-p project results in a success or a failure. In case of success it will yield the gross return $\theta(p)R^k_{t+1}$ per unit of goods invested in the beginning of time $t+1$. In case of failure it will yield zero return. I assume $\theta(p) = 1/p$ so that the expected gross return, just after the realization of the outcome (success or failure) of project, becomes the same for all projects equal to $E_t R^k_{t+1}$, where E_t denotes the expectation operator conditional on information available at time t. This assumption simplifies the problem and allows me to focus on the riskiness of project, which plays a critical role in adverse selection in financial markets.

I impose two assumptions. First, the limited liability law protects entrepreneurs in such a way that entrepreneurs do not have any liability after paying to banks. Second, I assume, for simplicity, that only one-period contracts between borrowers and lenders are feasible as in BGG (1999). Consequently, because an intermediary does not know private information p, the intermediary offers a schedule of contracts specifying the amount of loan and payment $\{B_{t,n}(p), X_{t+1,n}(p)\}_p$ where $B_{t,n}(p)$ denotes the amount of loan and $X_{t+1,n}(p)$ denotes the amount of payment conditional on the success of project in the next period. The payment conditional on the failure of project must be zero because of the limited liability assumption.

Without loss of generality I restrict my attention to a truth-telling schedule of contracts such that the type-(n,p) entrepreneur chooses contract $\{B_{t,n}(p), X_{t+1,n}(p)\}$ voluntarily. Also, I assume, without loss of generality, that the payment schedule, $X_{t+1,n}(p)$, does not depend on states at time $t+1$. The assumption does not affect the nature of the problem because entrepreneurs behave as if they were risk-neutral.[4]

The entrepreneur repays $pX_{t+1,n}(p)$ in expected values. The entrepreneur can pledge at most fraction $1-\phi$ of its expected return to repay to an intermediary. This agency problem limits the amount of loan made by the intermediary.[5]

Intermediaries: There exist a small number of risk neutral intermediaries relative to entrepreneurs. Intermediaries are competitive in lending. That is, intermediaries compete in providing a schedule of contracts to attract entrepreneurs. At time t an intermediary takes in deposits from households with risk-free rate R_{t+1} and makes loans to entrepreneurs. In the process of making a loan contract, the intermediary first provides a schedule of contracts$\{B_{t,n}(p), X_{t+1,n}(p)\}_p$. Since the intermediary can observe the amount of net worth

[4]If households participated in state contingent markets for aggregate shocks, entrepreneurs would be able to make the payment, $X_{t+1,n}(p)$, state-non-contingent by participating in the state-contingent markets. In that case the payment would be $[E_t\Lambda_{t,t+1}X_{t+1,n}(p)]R_{t+1}$, where $\Lambda_{t,t+1}$ denotes the household preference discount factor.

[5]One interpretation of this pledgeable income in this framework is that an entrepreneur can walk way with fraction ϕ of returns, as studied by Ikeda (2011).

owned by entrepreneurs, the schedule also depends on the net worth indexed by n. In the second step, the intermediary observes the other intermediaries' schedules and decides whether to leave or stay in the market. The intermediary's profits become zero when the intermediary leaves the market.

3.2. Optimal Contracting Problem

I first define an equilibrium in a game-theoretic manner.[6] Then I solve for an equilibrium contract.

Subgame Perfection: A game I consider consists of two types of players: many entrepreneurs and a small number of intermediaries relative to entrepreneurs. The game evolves in three stages. Initially, nature draws and assigns type p, which characterizes the riskiness of project, to an entrepreneur. In the first stage, an intermediary, indexed by i, provides a schedule of contracts, $\{B^i_{t,n}(p), X^i_{t+1,n}(p)\}_p$, which specifies the amount of loan, $B^i_{t,n}(p)$, and the amount of payment in case of success of project, $X^i_{t+1,n}(p)$. In the second stage, the intermediary observes the schedules provided in the first stage, and decides whether to leave or stay in the market. In the third stage, entrepreneurs choose an intermediary and sign a contract.

I limit my attention to a deterministic strategy, yet I assume that an entrepreneur chooses an intermediary randomly if the entrepreneur finds some intermediaries indifferent. Also, without loss of generality, I limit my attention to a truth telling schedule such that the type-p entrepreneur chooses contract $\{B^i_{t,n}(p), X^i_{t+1,n}(p)\}$ voluntarily among the schedule. Now I define an equilibrium of this contracting problem.

Definition 1: A *subgame-perfect equilibrium* for the financing problem consists of a set of intermediaries strategies: a schedule of contracts in the first stage and a strategy whether to leave or stay in the market in the second stage, satisfying (i) entrepreneurs choose the best intermediary to maximize its expected net worth, (ii) given the offered schedules of contracts in the first stage and the other intermediaries' strategies in the second stage, an intermediary chooses to stay if and only if the expected profits from doing so is non-negative, (iii) given the other intermediaries' schedule of contracts and strategies in the second stage, an intermediary chooses a schedule of contracts to maximize its profits. An equilibrium is *symmetric* if and only if the strategy in the first stage is the same for all intermediaries.

Symmetric Equilibrium: In deriving an equilibrium I limit my attention to a symmetric equilibrium in which all intermediaries employ the same strategy. In the following I derive an equilibrium strategy in the first stage, that is, I solve problem (iii) in Definition 1,

[6] Ikeda (2011) provides the characterization of an equilibrium more in detail.

taking into account intermediaries' strategies in the second stage and entrepreneurs' best responses in the third stage.

I make a conjecture that there exists threshold p_t^* such that entrepreneurs with $p > p_t^*$ do not get funded, as in Stiglitz and Weiss (1981). Ikeda (2011) shows that under some mild conditions a schedule, $\{B_{t,n}^i(p), X_{t+1,n}^i(p)\}_p$, and a threshold, p_t^*, satisfying the following conditions constitutes a symmetric equilibrium strategy:

$$0 = V_{t+1,n}(p_t^*) = \int_{\underline{p}_t}^{p_t^*} [pX_{t+1,n}(p) - R_{t+1}B_{t,n}(p)]dF_t(p), \tag{2}$$

$$W_{t,n}(p) \equiv E_t R_{t+1}^k B_{t,n}(p) - pX_{t+1,n}(p) \geq 0, \quad \forall p, \tag{3}$$

$$E_t R_{t+1}^k B_{t,n}(p) - pX_{t+1,n}(p) \geq E_t R_{t+1}^k B_{t,n}(\tilde{p}) - pX_{t+1,n}(\tilde{p}), \quad \forall p, \tilde{p}, \tag{4}$$

$$pX_{t+1,n}(p) = (1-\phi)E_t R_{t+1}^k [N_{t,n} + B_{t,n}(p)], \quad \forall p, \tag{5}$$

Condition (2) is an intermediary's zero profits condition. Because intermediaries are competitive in lending, the zero profits condition must hold in equilibrium. An intermediary's profits are given by revenues, $pX_{t+1,n}(p)$, minus the cost of funds, $R_{t+1}B_{t,n}(p)$, integrated over p from $\underline{p}_t$ to p_t^* with distribution $F_t(p)$. In a symmetric equilibrium all intermediaries offer the same schedules of contracts, so that entrepreneurs choose an intermediary randomly. As a result the distribution of entrepreneurs faced by an intermediary becomes $F_t(p)$ up to a constant scaling factor.

Condition (4) is an incentive constraint which limits the schedule of contracts to a truth telling schedule. That is, type-p entrepreneur chooses contract $\{B_{t,n}(p), X_{t+1,n}(p)\}$ voluntarily. The left-hand-side of (4) denotes an entrepreneur's return from getting loans when choosing pair $\{B_{t,n}(p), X_{t+1,n}(p)\}$ and the right-hand-side of (4) denotes a return when choosing the other pair.

Condition (3) is an entrepreneur's participation constraint which requires that an entrepreneur should voluntarily participate in the loan contract. If (3) did not hold, the entrepreneur would walk away from the contract because getting loans would result in a negative expected return.

Finally, condition (5) is a pledgeable income restriction with inequality held with equality. The left-hand-side of (5) denotes the amount of expected repayment, while the right-hand-side of (5) denotes a pledgeable income.

The Optimal Contract: I describe an equilibrium contract and explain intuitively why the solution to conditions, (2)-(5), constitutes an equilibrium. Ikeda (2011) provides the detail in the text and its appendix. The procedure to solve the problem consists of five steps. First, I start from a guess that there exists threshold p_t^* such that entrepreneurs with $p > p_t^*$ do not get loans. Second, I replace condition (4) by a local incentive compatibility constraint and a monotonicity constraint as in a standard mechanism design problem. Third, I express the profits of entrepreneurs, denoted by $W_{t,n}(p) \equiv E_t R_{t+1}^k B_{t,n}(p) - pX_{t+1,n}(p)$, as a function of payment schedule $X_{t+1,n}(p)$ using the local incentive compatibility constraint and the envelope theorem as follows:

$$W_{t,n}(p) = \int_{p}^{p_t^*} X_{t+1,n}(x)dx. \tag{6}$$

Using (6) and the definition of profits, $W_{t,n}(p) \equiv E_t R_{t+1}^k B_{t,n}(p) - pX_{t+1,n}(p)$, I express loan schedule $B_{t,n}(p)$ as a function of $X_{t+1,n}(p)$. Then, using the loan schedule I express the profits of intermediaries as follows:

$$V_{t+1,n}(p_t^*) = \int_{\underline{p}_t}^{p_t^*} \omega_t(p) X_{t+1,n}(p)dp,$$

where $\omega_t : (\underline{p}_t, 1) \to \mathcal{R}$ is given by

$$\omega_t(p) = pf_t(p) - \frac{R_{t+1}}{E_t R_{t+1}^k} pf_t(p) - \frac{R_{t+1}}{E_t R_{t+1}^k} F_t(p). \tag{7}$$

Fourth, using the loan schedule obtained in the third step I rewrite condition (5) as

$$X_{t+1,n}(p) = \frac{(1-\phi)}{\phi p} E_t R_{t+1}^k N_{t,n} + \frac{(1-\phi)}{\phi p} \int_{p}^{p_t^*} X_{t+1,n}(x)dx, \tag{8}$$

This equation constitutes an integral equation. I solve the equation for $X_{t+1,n}(p)$. Fifth, I pin down threshold p_t^* using the intermediary's zero profits condition.

I summarize the solution to conditions, (2)-(5), in the following proposition.

Proposition 1: Assume that $\omega_t(p)$, given by (7), crosses a zero line only once. The solution to conditions, (2)-(5), is given by: for $p \leq p_t^*$,

$$B_{t,n}(p) = \frac{1-\phi}{\phi} \left\{ 1 + \frac{1}{1-\phi} \left[\left(\frac{p_t^*}{p} \right)^{\frac{1-\phi}{\phi}} - 1 \right] \right\} N_{t,n}, \tag{9}$$

$$X_{t+1,n}(p) = \left[\frac{(1-\phi) E_t R_{t+1}^k}{\phi} (p_t^*)^{\frac{1-\phi}{\phi}} \right] \left(\frac{1}{p} \right)^{\frac{1}{\phi}} N_{t,n}, \tag{10}$$

$$V_{t+1,n}(p_t^*) = \int_{\underline{p}_t}^{p_t^*} \omega_t(p) X_{t+1,n}(p)dp = 0, \tag{11}$$

and for $p > p_t^*$, $B_{t,n}(p) = X_{t+1,n}(p) = 0$.

Hereafter I simply assume that the solution, given by Proposition 1, uniquely exists. That is, I assume that there exists a unique p_t^* such that $V_{t+1,n}(p_t^*) = 0$, given by (11). If there is no profitable deviation from the solution, the solution constitutes a symmetric subgame perfect equilibrium. Intuitively, there is no profitable deviation because the solution maximizes entrepreneur's profits. To see this point, note that a pledgeability constraint is not condition (5) but condition (5) with equality replaced by $\geq$. So, condition (5) implies that payment schedule $X_{t+1,n}(p)$ is maximized for each p among those satisfying a pledgeability constraint. From the expression for entrepreneur's profits, (6), maximizing $X_{t+1,n}(p)$ for each p implies maximizing the type p entrepreneur's profits for $p \leq p^*$. If an intermediary deviated from the solution, it would not be able to attract entrepreneurs, or it would result in negative profits without leaving out of markets. There remain subtle issues about an intermediary's deviation taking advantage of this separating schedule. See Ikeda (2011) for more in detail.

3.4. Aggregate Implications

The loan contract in equilibrium, summarized in Proposition 1, has two nice properties for aggregation. First, threshold p_t^* does not depend on the amount of net worth. This property implies that the same threshold applies to all entrepreneurs. Second, both loan schedule (9) and payment schedule (10) are linear in net worth. This implies that I can aggregate loan and payment without paying attention to the distribution of net worth.

As a consequence of the above two properties, the aggregate loan has a simple expression. From loan schedule (9) I can express the aggregate loan, B_t, as

$$\begin{aligned} B_t &= \int_n \int_{\underline{p}_t}^{p_t^*} B_{t,n}(p) dF_t(p) dH_t(n), \\ &= \frac{1-\phi}{\phi} \left[\frac{1}{1-\phi} \int_{\underline{p}_t}^{p_t^*} \left(\frac{p_t^*}{p} \right)^{\frac{1-\phi}{\phi}} dF_t(p) - \frac{\phi}{1-\phi} F_t(p_t^*) \right] N_t, \end{aligned} \tag{12}$$

where N_t denotes the aggregate net worth, $F_t(\cdot)$ denotes the distribution of p and $H_t(\cdot)$ denotes the distribution of net worth indexed by n. Using the intermediary's zero profit condition, (11), I can also express B_t as

$$\begin{aligned} B_t &= \frac{1}{R_{t+1}} \int_n \int_{\underline{p}_t}^{p_t^*} p X_{t+1,n}(p) dF_t(p) dH_t(n), \\ &= \frac{1-\phi}{\phi} \frac{E_t R_{t+1}^k}{R_{t+1}} \left[\int_{\underline{p}_t}^{p_t^*} \left(\frac{p_t^*}{p} \right)^{\frac{1-\phi}{\phi}} dF_t(p) \right] N_t, \end{aligned} \tag{13}$$

From equations (12) and (13) I obtain a simple expression for the aggregate loan:

$$B_t = \frac{(1-\phi)(E_t R_{t+1}^k / R_{t+1})}{1-(1-\phi)(E_t R_{t+1}^k / R_{t+1})} F_t(p_t^*) N_t. \tag{14}$$

The aggregate loan is increasing in the discounted return to capital, $E_t R_{t+1}^k / R_{t+1}$, and is increasing in threshold p_t^*. From (14) the aggregate loan is bounded from above as

$$B_t < \frac{(1-\phi)(E_t R_{t+1}^k / R_{t+1})}{1-(1-\phi)(E_t R_{t+1}^k / R_{t+1})} N_t,$$

because $F_t(p_t^*) < 1$. The upper bound turns out to be the aggregate loan without asymmetric information, as shown in Ikeda (2011).

The expression for the aggregate loan, (14), summarizes the effect of asymmetric information. With asymmetric information entrepreneurs with $p > p_t^*$ can not get loans because the borrowing interest rate implied by the offered contract is too high to earn non-negative profits, reflecting the high default rates of the other risky entrepreneurs. Asymmetric information causes a lemons problem and drops the aggregate loan by $[1 - F(\bar{p}_t)] \times 100$ percent relative to the aggregate loan without asymmetric information.

Aggregating the balance sheet relationship, (1), I obtain: $q_t \bar{K}_{t+1} = N_t + B_t$, where $\bar{K}_{t+1}$ denotes the aggregate physical capital. Substituting out for aggregate loan B_t using equation (14) I obtain:

$$q_t \bar{K}_{t+1} = \left[1 + \frac{(1-\phi)(E_t R^k_{t+1}/R_{t+1})}{1-(1-\phi)(E_t R^k_{t+1}/R_{t+1})} F_t(p_t^*) \right] N_t. \tag{15}$$

The term in bracket in equation (15) denotes a leverage: how much assets one unit of net worth allows an entrepreneur to purchase.

After aggregation only two equations summarize the macroeconomic implications of financial markets with adverse selection and an agency problem. The intermediary's zero profit condition, (11), determines threshold p_t^*. Equation (15) determines the leverage and the aggregate asset. In a dynamic general equilibrium model in the next section I use those two equations as part of a system of equations.

4. General Equilibrium

Now I embed imperfect financial markets analyzed in the previous section into a monetary business cycle model in line with CEE (2005). The resulting model features both adverse selection and an agency problem in financial markets as well as some original features of the monetary business cycle model: nominal rigidities in both prices and wages, investment adjustment costs, variable capital utilization rates and a monetary policy rule. In contrast to CEE (2005) I do not include an internal consumption habit formation because it does not play a critical role in my model.

4.1. Firms

Firms consist of three types of firms: final goods firms, intermediate goods firms and capital goods firms. All firms behave in a competitive manner except intermediate goods firms. All firms are owned by households. I describe those firms' problems one by one.

Final Goods Firms: A final goods firm has a CES aggregation technology, given by

$$Y_t = \left(\int_0^1 Y_t(i)^{\frac{1}{\lambda_p}} di \right)^{\lambda_p}, \quad \lambda_p > 1, \tag{16}$$

where Y_t denotes the final goods at time t and $Y_t(i)$ denotes the i-th intermediate goods at time t for $i \in (0,1)$. Given the price of final goods, P_t, and the prices of intermediate goods, $\{P_t(i)\}$, the firm chooses the amount of inputs and the amount of output to maximize its profits, that is,

$$\max_{\{Y_t, Y_t(i)\}} P_t Y_t - \int_0^1 P_t(i) Y_t(i) di, \tag{17}$$

subject to its technology, (16).

The solution to problem (17) yields the demand for the i-th intermediate goods,

$$Y_t(i) = \left(\frac{P_t(i)}{P_t} \right)^{\frac{\lambda_p}{1-\lambda_p}} Y_t, \tag{18}$$

where the price of final goods has the following expression,

$$P_t = \left(\int_0^1 P_t(i)^{\frac{1}{1-\lambda_p}} di \right)^{1-\lambda_p}.$$

Intermediate Goods Firms: Intermediate goods firms are monopolistically competitive in intermediate goods markets. They use capital and labor as input, produce intermediate goods and sell those goods to final goods producers. In so doing they set prices subject to price change frictions as in Calvo (1983).

For each $i \in (0,1)$ the i-th intermediate goods firm combines effective capital $K_t(i)$ and homogeneous labor $L_t(i)$ to produce, according to a Cobb-Douglas production function, given by

$$Y_t(i) = A_t K_t(i)^{\alpha} L_t(i)^{1-\alpha}, \quad 0 < \alpha < 1, \tag{19}$$

where A_t denotes the level of neutral technology. The effective capital is the product of physical capital and capital utilization rates. I assume that A_t follows a stationary AR(1) process,

$$\log(A_t) = \rho_a \log(A_{t-1}) + \epsilon_{A,t}, \quad 0 \le \rho_a < 1. \tag{20}$$

where $\epsilon_{A,t}$ denotes an exogenous disturbance to the neutral technology, in short, a technology shock.

The i-th intermediate goods firm maximizes its profits by choosing the amount of inputs and the price of the intermediate goods. In so doing the firm takes the aggregate variables such as the price level, P_t, as given because the firm is small enough not to affect those variables. I divide the firm's problem into two: a cost minimization problem and a price setting problem. In the first problem the firm minimizes its real cost of production given factor prices, that is,

$$\min_{\{K_t(i), L_t(i)\}} w_t L_t(i) + r_t^k K_t(i), \tag{21}$$

subject to its production technology, (19), where w_t denotes the real wage and r_t^k denotes the real rental rate of capital. The solution yields the real marginal cost, mc_t, given by

$$mc_t = \frac{1}{A_t}\left(\frac{r_t^k}{\alpha}\right)^{\alpha}\left(\frac{w_t}{1-\alpha}\right)^{1-\alpha}.$$

In the second problem the firm chooses the price of the intermediate goods to maximize its expected profits subject to price change frictions as in Calvo (1983). Specifically, every period the firm can change the price with probability, $1-\xi_p$, independently across states and over time, where $0<\xi_p<1$. With probability ξ_p the firm cannot reset its price so that $P_t(i)=P_{t-1}(i)$. When the steady state gross inflation rate differs from 1, the model has the price dispersion of intermediate goods around steady state.

Given aggregate variables, the i-th intermediate goods firm chooses its price to maximize its expected profits, taking into account the possibility that it may not be able to change the price in the future, that is,

$$\max_{\{\tilde{P}_t(i)\}} E_t \sum_{s=0}^{\infty} \xi_p^s \frac{\beta^s \lambda_{t+s}}{\lambda_t}\left[\frac{\tilde{P}_t(i)}{P_{t+s}} Y_{t+s}(i) - mc_{t+s} Y_{t+s}(i)\right], \tag{22}$$

subject to the demand curve, (18).

In problem (22) the firm uses the stochastic discount factor of the household, $\beta^s\lambda_{t+s}/\lambda_t$, in discounting the real profits, where λ_t denotes the marginal utility of real income. The fact that households own the firm rationalizes the use of household's discount factor.

Capital Goods Firms: A capital goods firm conducts two types of business. First, it produces new capital goods. Second, it purchases depreciated capital goods from entrepreneurs and sells new and depreciated capital goods to entrepreneurs.

The capital goods firm purchases final goods, I_t, and transforms it into new capital goods, $\bar{I}_t$, using the following technology,

$$\bar{I}_t = \left[1 - S\left(\frac{I_t}{I_{t-1}}\right)\right] I_t, \tag{23}$$

where function $S(\cdot)$ denotes investment adjustment costs satisfying $S = S' = 0$ and $S'' > 0$ in steady state. This functional form, introduced by CEE (2005), allows the model to generate a hump-shaped response of investment and output to various shocks, consistent with VAR-based evidence.

The capital goods firm purchases depreciate capital goods from entrepreneurs, combine them with newly produced capital goods and produce capital goods, using the linear technology,

$$\bar{K}_{t+1} = (1-\delta)\bar{K}_t + \bar{I}_t, \tag{24}$$

where $0<\delta<1$ denotes capital depreciation rates. Then the capital goods firm sells the capital goods with real price q_t to entrepreneurs. Given the price of capital, q_t, the capital goods firm chooses the amount of investment to maximize the expected profit, that is,

$$\max_{\{I_t\}} E_t \sum_{s=0}^{\infty} \frac{\beta^s \lambda_{t+s}}{\lambda_t} \left\{ q_{t+s} K_{t+s+1} - [I_{t+s} + q_{t+s}(1-\delta) K_{t+s}] \right\}, \tag{25}$$

subject to production technologies, (23) and (24). Because of linearity in producing capital goods in (24) the perfect competition results in the same price of new capital goods and old capital goods. The capital goods firm purchases old capital goods at time t with price q_t and sells new capital goods with the same price as in (25).

4.2. Households

A continuum of household lives in the economy, each endowed with a specialized type of labor indexed by $j \in (0, 1)$. Each single household, with measure unity, consists of the large number of family members who are either workers or entrepreneurs with their population f and $1 - f$ respectively where $0 < f < 1$. Family members switch their job occupation randomly. Specifically, entrepreneurs become workers randomly with probability $1 - \gamma$ where $0 < \gamma < 1$. I call γ as the surviving probability of entrepreneurs. The same number of workers become entrepreneurs randomly so that the proportion of workers or entrepreneurs stays constant over time.

The household, as a representative agent of the family members, consume and save. The household provides the perfect consumption insurance among its family members. The household does not have an access to capital markets and can save only through risk-free intermediary's deposits. Workers within the household supply a specialized labor and earn wage income. Entrepreneurs within the household trade capital and earn capital income, which I will describe later in this section.

Workers have a monopolistic power and set nominal wages subject to Calvo price change frictions as in Erceg, et al (2000). I assume that all workers in a household share the same opportunity of wage change. The assumption implies that all workers in a household choose the same level of wage and labor supply. A household participates in a state contingent market on the opportunity of wage changes, so that a difference in wages does not affect an allocation, keeping the framework of a representative household.

Competitive employment agencies combine all household's specialized labor and transform into a homogeneous labor. Then, they provide the homogeneous labor to intermediate goods firms.

I divide the household problem into three: consumption and saving problems, an employment agency's problem and a worker's wage setting problem. I describe the three household problems below.

Consumption and Saving Problem: The j-th household chooses consumption, C_t, and risk-free deposits, B_t, to solve a utility maximization problem,

$$\max_{\{C_t, B_t\}} E_t \sum_{s=0}^{\infty} \beta^s \left[\log(C_t) - \tilde{\psi} \frac{L_{t+s}(j)^{1+1/\nu}}{1+1/\nu} \right], \tag{26}$$

subject to the flow budget constraint,

$$C_t + B_t \leq w_t(j) L_t(j) + R_t B_{t-1} + T_t + \Pi_t + \Theta_t(j),$$

where $w_t(j)$ denotes real wages, $L_t(j)$ denotes labor supply per unit of household, T_t denotes lump-sum taxes, Π_t denotes the sum of the profits of firms and the net transfer from entrepreneurs, and $\Theta_t(j)$ denotes the net cash flow of state-contingent securities on the opportunity of wage changes. Structural parameters satisfy $0 < \beta < 1$, $\nu > 0$ and $\tilde{\psi} > 0$.

Employment Agencies: Competitive employment agencies transform a collection of household specific labor, $\{L_t(j)\}$, into a homogeneous labor, L_t, and sell it to intermediate goods firms, using a CES aggregation technology, given by

$$L_t = \left(\int_0^1 L_t(j)^{\frac{1}{\lambda_w}} dj \right)^{\lambda_w}, \quad \lambda_w > 1, \tag{27}$$

Given nominal wage W_t and nominal wages for household-specific labor $\{W_t(j)\}$, the employment agency chooses the amount of specific labor input to maximize its profits, that is,

$$\max_{\{L_t(j)\}} W_t L_t - \int_0^1 W_t(j) L_t(j) dj, \tag{28}$$

subject to its technology, (27).

The solution to problem (28) yields a demand curve,

$$L_t(j) = \left(\frac{W_t(j)}{W_t} \right)^{\frac{\lambda_w}{1-\lambda_w}} L_t, \tag{29}$$

where the nominal wage is expressed as,

$$W_t = \left(\int_0^1 W_t(j)^{\frac{1}{1-\lambda_w}} dj \right)^{1-\lambda_w}.$$

Wage Setting Problem: A worker in the j-th household has a monopolistic power over its specialized labor and sets nominal wages subject to price change frictions. Specifically, every period the worker can change nominal wages with probability, $1 - \xi_w$, independently across states and over time, where $0 < \xi_w < 1$. With probability ξ_w the worker cannot reset nominal wages so that $W_t(j) = W_{t-1}(j)$. If the gross inflation rate in steady state differs from 1, the model yields nominal wage dispersions around steady state.

The worker, facing utility maximization problem (26), chooses the level of nominal wage and the amount of labor. If the worker provides $\tilde{L}_t(j)$ amount of labor, the labor per unit of household becomes $L_t(j) = f\tilde{L}_t(j)$ because there exist fraction f of workers in the household and all workers in the household provide the same level of labor. Then, the worker solves the following maximization problem:

$$\max_{\{\tilde{W}_t(j)\}} E_t \sum_{s=0}^{\infty} (\beta\xi_w)^s \left[\lambda_{t+s} \frac{\tilde{W}_t(j)}{P_{t+s}} L_{t+s}(j) - \psi \frac{L_{t+s}(j)^{1+1/\nu}}{1+1/\nu} \right], \tag{30}$$

subject to the demand curve for specialized labor, (29), where $\psi = \tilde{\psi}(1/f)^{1+1/\nu}$.

In problem (30) the worker sets the nominal wage such that it maximizes the expected discounted sum of the utility from supplying labor $L_{t+s}(j)$. The utility consists of utility from wage income, the first term in bracket in (30), and the disutility from supplying labor, the second term in bracket in (30). In writing the worker's wage setting problem, (30), I substitute out for the individual worker's labor, $\tilde{L}_{t+s}$, with the labor per unit of household, $L_{t+s}(j) = f\tilde{L}_{t+s}(j)$, resulting in the rescaling of parameter $\psi = \tilde{\psi}(1/f)^{1+1/\nu}$ in problem (30).

4.3. Entrepreneurs and Intermediaries

I now embed imperfect financial markets analyzed in Section 3 into a general equilibrium framework. At time t an entrepreneur starts its business with some amount of net worth. The entrepreneur, as a family member of one of a continuum of households, can transfer its net worth to the household to which it belongs at the beginning of period t. The entrepreneur chooses to accumulate its net worth over time and transfers its net worth when it becomes to a worker, because the average return from a unit of goods invested in its project is strictly greater than risk-free rates earned by the household who makes deposits in intermediaries. While the entrepreneur faces a risk associated with its own project, the household only cares about the average return because there are many family members of entrepreneurs within the household. The law of large numbers holds and the i.i.d. risk is perfectly diversified among entrepreneurs within the household. This modeling device implies that the entrepreneur would behave as if the entrepreneur were risk-neutral.

The entrepreneur makes a one-period contract with an intermediary and receives some amount of loan from the bank. Combining the net worth with the loan the entrepreneur purchases capital goods from capital goods producers with real price q_t. At the end of time t the entrepreneur invests the capital goods in its project with success probability p and transforms the capital goods into specialized capital goods readily to be used as production input. I assume that on average one unit of capital goods generates one unit of specialized capital goods for all entrepreneurs.

If the project fails the entrepreneur has nothing at hand. If the project succeeds the entrepreneur sets capital utilization rates u_{t+1} with cost $a(u_{t+1})$ per unit of specialized capital goods. The entrepreneur rents out the specialized capital goods to intermediate goods firms and earns rental rate $r^k_{t+1}u_{t+1}$ per unit of specialized capital goods at the beginning of time $t+1$. Then, the entrepreneur sells the depreciated capital goods to capital goods firms with price q_{t+1}. Consequently, on average the real return from investing one unit of final goods is given by

$$R^k_{t+1} = \frac{r^k_{t+1}u_{t+1} + q_{t+1}(1-\delta) - a(u_{t+1})}{q_t}. \tag{31}$$

As in CEE (2005) the cost of capital utilization rates satisfy $a(1) = 0$ and $a'(u_t), a''(u_t) > 0$. The entrepreneur sets the capital utilization rate to maximize its return. Then, the capital utilization rate satisfies:

$$r^k_t = a'(u_t). \tag{32}$$

The capital utilization rate, u_t, is increasing in the net return on capital, r^k_t.

After getting some returns the entrepreneur pays interest payment to the intermediary following a contract. The remaining amount of goods constitutes the net worth at time $t+1$. Then, an idiosyncratic occupation shock hits the entrepreneur and it switches its job to a worker randomly with probability $1-\gamma$, and it stays an entrepreneur with probability γ, where $0 < \gamma < 1$. If the entrepreneur becomes a worker, it brings the net worth to the household to which it belongs. If the entrepreneur remains to be an entrepreneur, it starts its business with its net worth at time $t+1$ again. Those who just have become entrepreneurs from workers and those who do not have net worth receive a small amount of final goods from the household to which they belong, so that they run their projects.

As I analyzed in Section 3, an entrepreneur has both private information and an agency problem. The entrepreneur has a project and private information about the success probability of the project, or the riskiness of the project, p. The entrepreneur can pledge at most fraction $1-\phi$ of its expected return to repay in expected values to an intermediary. An intermediary, recognizing the two source of problems, offers a schedule of contracts to the entrepreneur in a competitive manner.

I assume that the distribution of p follows a uniform distribution, given by

$$F_t(p) = \frac{p - \underline{p}_t}{1-\underline{p}_t}, \quad \underline{p}_t \equiv \underline{p}e^{\upsilon_t}, \quad 0 < \underline{p} < 1, \tag{33}$$

where υ_t denotes uncertainty shocks, following a stationary AR(1) process with coefficient $0 \leq \rho_\upsilon < 1$. The negative uncertainty shocks, $\upsilon_t < 0$, lower $\underline{p}_t$ and make the distribution more dispersed, increasing asymmetric information in financial markets.

As I derived in Section 3 the optimal contract between entrepreneurs and intermediaries implies the aggregate relationship, (11), and (15), which I rewrite here respectively taking into account the functional form of $F_t(p)$, given by equation (33):

$$q_t \bar{K}_{t+1} = \left[1 + \frac{(1-\phi)s_t}{1-(1-\phi)s_t}\frac{p_t^* - \underline{p}_t}{1-\underline{p}_t}\right] N_t, \tag{34}$$

$$0 = \frac{\phi}{2\phi - 1}\left(1 - \frac{2}{s_t}\right)\left[(p_t^*)^{\frac{2\phi-1}{\phi}} - \underline{p}_t^{\frac{2\phi-1}{\phi}}\right] - \frac{\underline{p}_t}{s_t}\frac{\phi}{1-\phi}\left[(p_t^*)^{-\frac{1-\phi}{\phi}} - \underline{p}_t^{-\frac{1-\phi}{\phi}}\right], \tag{35}$$

where s_t denotes a discounted return to capital, $s_t = E_t R_{t+1}^k / R_{t+1}$ and $\underline{p}_t \equiv \underline{p} e^{v_t}$. Given s_t, the uncertainty shocks change threshold p_t^* from equation (35) and affect a leverage and the price of capital in equation (34).

Conditional on the success of project an entrepreneur pays back to an intermediary following the payment schedule, (10). Aggregating payment (10) over probability p and net worth $N_{t,n}$, I obtain the aggregate payment conditional on the success of project,

$$\begin{aligned} X_{t+1} &= \int_n \int_{\underline{p}_t}^{\bar{p}_t} X_{t+1,n}(p) dF_t(p) dH_t(n), \\ &= \frac{E_t R_{t+1}^k}{1-\underline{p}_t}\left[\left(\frac{\bar{p}_t}{\underline{p}_t}\right)^{\frac{1-\phi}{\phi}} - 1\right] N_t \end{aligned} \tag{36}$$

I define the average loan interest rate as the ratio of the aggregate payment to the aggregate loan: $R_{t+1}^b = X_{t+1}/B_t$, where $B_t = q_t K_{t+1} - N_t$ is given by (34). Then I can express the external finance premium, EFP_t, defined as the ratio of the cost to a borrower of raising funds externally, R_{t+1}^b, to the opportunity cost of internal funds, R_{t+1}, as follows:

$$\text{EFP}_t = \frac{R_{t+1}^b}{R_{t+1}} = \frac{1-(1-\phi)s_t}{(1-\phi)(p_t^* - \underline{p}_t)}\left[\left(\frac{p_t^*}{\underline{p}_t}\right)^{\frac{1-\phi}{\phi}} - 1\right]. \tag{37}$$

The external finance premium depends only on states at time t because both R_{t+1} and R_{t+1}^b do so.[7]

In aggregate entrepreneurs earn capital return $R_{t+1}^k(N_t + B_t)$ and pay back $R_{t+1}B_t$ to intermediaries at the beginning of time $t+1$. The unconditional aggregate payment amounts to $R_{t+1}B_t$ because the intermediary's zero profit condition holds.[8] A fraction, $1-\gamma$, of entrepreneurs become workers and bring their net worth to households. The same number of workers become new entrepreneurs. The new entrepreneurs and those who

[7]Without asymmetric information the external finance premium would become $\text{EFP}_t = [(1-\underline{p}_t)^{-1}\log(1/\underline{p}_t) - 1]R_{t+1}$, which purely reflects the default risk of entrepreneurs.

[8]Intermediaries take in deposits B_t from households with risk-free interest rate R_{t+1} and lend to entrepreneurs. The intermediary's zero profit condition results in the unconditional aggregate payment equal to $R_{t+1}B_t$, as shown in the first equation in (13), where the right-hand-side denotes the unconditional aggregate payment divided by R_{t+1}.

do not have any net worth receive a small start up fund from households. I assume that the aggregate transfer from household is proportional to output, given by ξY_{t+1}, where $0 < \xi < 1$. Then I can write the law of motion for aggregate net worth as

$$N_{t+1} = \gamma[(R^k_{t+1} - R_{t+1})B_t + R^k_{t+1}N_t] + \xi_t Y_{t+1}, \tag{38}$$

where $B_t = q_t K_{t+1} - N_t$ is given by (34)

Three equations (34), (35) and (38) summarize the aggregate consequences of the entrepreneur's and intermediary's problems. Given a discounted return to capital, s_t, zero profit condition (11) determines threshold p^*_t above which type-p entrepreneurs do not get funded. With the threshold balance sheet equation (34) determines a leverage and affects the price of capital, q_t. Because the current return to capital depends on q_t as shown in equation (31), the law of motion for net worth, (38), implies that the current net worth, N_t, changes in response to a change in q_t. Again, balance sheet equation (34) implies that the price of capital changes in response to a change in net worth. This cycle continues and propagates an initial effect. This process, so called a balance sheet channel, works through three equations (34), (35) and (38), and characterizes a financial accelerator in this model.

4.4. Government

A government consists of a fiscal authority and a monetary authority. The fiscal authority spends final goods amounting to G_t and finance it by lump-sum tax on households. The monetary authority sets the net nominal interest rate, i_t, following a simple Taylor rule,

$$\frac{1+i_t}{1+i} = \left(\frac{1+i_{t-1}}{1+i}\right)^{\rho_{mp}} \left[\left(\frac{\pi_t}{\pi}\right)^{r_\pi}\right]^{1-\rho_{mp}} \left(\frac{Y_t}{Y_{t-1}}\right)^{r_{dy}} e^{\epsilon_{mp,t}} \tag{39}$$

where $\epsilon_{mp,t}$ denotes an exogenous disturbance to monetary policy, $0 \leq \rho_{mp} < 1$, $r_\pi > 1$ and $r_{dy} \geq 0$. As a baseline I consider the simple rule, according to which the central bank adjusts the current nominal interest rate in response to the current inflation rate, the current growth rate of output and the lagged interest rate. I will consider a modified monetary policy rule incorporating financial variables in Section 6 where I discuss the effect of monetary policy to tackle a simulated financial crisis.

A change in nominal interest rate affects a real economy through the following Fisher equation relating nominal interest rates and real interest rates,

$$1 + i_t = E_t\left(R_{t+1}\pi_{t+1}\right). \tag{40}$$

Because prices and nominal wages exhibit some degrees of stickiness, a change in nominal interest rates i_t affects real interest rates, R_{t+1}, which eventually affects all the economy.

4.5. Equilibrium

I close the model by stating market clearing conditions and define a recursive competitive equilibrium.

Market Clearing: The aggregate demand for the final goods consists of consumption, investment, government spending and the cost associated with variable capital utilization rates. In equilibrium the aggregate demand coincides with the aggregate output,

$$Y_t = C_t + I_t + G_t + a(u_t)\bar{K}_t. \tag{41}$$

where Y_t denotes the aggregate output.

In this economy there could exist both price and wage dispersions, which make aggregation complicated. For example, producers with high prices produce less and those with low prices produce more, resulting in an inefficiency of production. I follow Yun (1996) to describe a relationship between aggregate variables and an efficiency loss accrued from both price and wage dispersions as follows:

$$\begin{aligned} Y_t &= (\Delta_{p,t})^{\frac{\lambda_p}{\lambda_p - 1}} A_t K_t^{\alpha} L_t^{1-\alpha}, \\ L_t &= (\Delta_{w,t})^{\frac{\lambda_w}{\lambda_w - 1}} L_t^*, \end{aligned}$$

where $K_t \equiv u_t \bar{K}_t = \int_0^1 K_t(i)di$ denotes the aggregate effective capital and $L_t^* = \int_0^1 L_t(j)dj$ denotes the average hours worked. Those two equations define the aggregate output, Y_t.

The terms, $\Delta_{p,t} \leq 1$ and $\Delta_{w,t} \leq 1$, summarize the inefficiency loss due to price or wage dispersion, given by:

$$\Delta_{p,t} = \left[\int_0^1 \left(\frac{P_t(i)}{P_t} \right)^{\frac{\lambda_p}{1-\lambda_p}} di \right]^{\frac{1-\lambda_p}{\lambda_p}}, \quad \Delta_{w,t} = \left[\int_0^1 \left(\frac{W_t(j)}{W_t} \right)^{\frac{\lambda_w}{1-\lambda_w}} dj \right]^{\frac{1-\lambda_w}{\lambda_w}}. \tag{42}$$

When there is no price dispersion, that is, when $P_t(i) = P_t$ for all $i \in (0, 1)$, dispersion term $\Delta_{p,t}$ becomes unity and there is no output loss. The same logic applies to nominal wages.

Competitive Equilibrium: In defining a competitive equilibrium I suppose that the economy starts from period 0. Given the set of initial condition of state variables, a fiscal and a monetary policy, and the processes of shocks, a *recursive competitive equilibrium* consists of the decision rules for the allocation, $\{Y_t,\, C_t,\, I_t,\, \bar{K}_t,\, L_t^*,\, u_t,\, N_t,\, B_t,\, p_t^*\}$, and the pricing rules for the set of prices $\{R_t, i_t, r_t^k,\, R_t^k,\, w_t,\, q_t,\, \pi_t,\, \Delta_{p,t},\, \Delta_{w,t}\}$, where the both rules are the functions of the states of the economy, satisfying:

- Given the pricing rules, the decision rules solve the final goods firm's problem, (17), the intermediate goods firm's problem, (21) and (22), the capital goods producer's problem, (25), and the household's problems, (26), (28) and (30). In addition, the decision rules satisfy the equilibrium conditions of entrepreneurs and intermediaries, (31), (32), (34), (35) and (38).

- All markets clear. That is, (24) and (41) hold, and the Fisher equation, (40), holds

5. Simulation

I log-linearize the model around its steady state and explore the model quantitatively. I show that uncertainty shocks generate significant business fluctuations consistent with business cycles. Similar to Ikeda (2011) who studies the non-monetary version of the model, counter-cyclical markups play a crucial role in amplifying the uncertainty shocks. I also explore how adverse selection in financial markets affect dynamics in response to technology and monetary policy shocks.

In the following I first parameterize the model. Next, I study impulse responses to the uncertainty shocks and make clear amplification mechanisms embedded in the model. Finally, I discuss whether adverse selection amplifies or dampens technology and monetary shocks.

5.1. Model Parameterization

I list the choice of parameters values for the model in Table 1. Out of twenty parameters five $\{\phi, \underline{p}, \gamma, \xi, \rho_u\}$ are specific to the model and the others are conventional to the DSGE literature.

I begin with conventional parameters related to the real factors of an economy. I set a preference discount factor as $\beta = 0.993$, so that net real risk-free rates become 3 percent annual rate in steady state. I set the coefficient of the disutility of labor so that the average hours worked is normalized to be unity. I choose conventional values for a labor supply elasticity ($\nu = 1$), a capital income share ($\alpha = 0.36$) and capital depreciation rates ($\delta = 0.025$). I set the curvature of the CEE (2005) investment adjustment costs to $S'' \equiv S''(1) = 0.3$. There is little guidance in the empirical literature about the appropriate values of S''. I set the curvature so that the impulse response of output to the uncertainty shocks coincides with the VAR evidence of Bloom (2009), Gilchrist and Zakresjek (2010) and Kiley and Sim (2011).[9] According to them, output responses to uncertainty shocks are hump-shaped with peak (bottom) reached in from four to eight periods after the shocks.[10] I

[9] A reason why CEE (2005) first introduced the CEE adjustment costs has to with hump-shaped responses to monetary policy shocks. Later, the adjustment costs have become popular in the DSGE literature because the adjustment costs generate hump-shaped responses to various shocks, which help a model fit aggregate time series data quite well.

[10] Gilchrist and Zakresjek (2010) estimate responses to financial shocks. As shown in Ikeda (2011), the financial shocks coincide with the uncertainty shocks in this paper after log-linearization.

Table 1: Structural parameters values

Parameter	Description	Value	Parameter	Description	Value
β	discount factor	0.993	ν	labor supply elasticity	1
α	capital income share	0.36	δ	depreciation rate	0.025
S''	adjustment costs	0.3	$a''(1)/a'(1)$	capital utilization costs	2
λ_p	price markup	1.05	λ_w	wage markup	1.05
γ_p	slope of price Phillips curve	0.014	ξ_w	Calvo wage	0.8
r_π	Taylor rule, inflation	1.5	r_{dy}	Taylor rule, growth	0.1
π	target gross inflation rate	1	ρ_{mp}	Taylor rule, persistence	0.8
ρ_a	AR(1), technology shock	0.95			
ϕ	moral hazard	0.55	$\underline{p}$	parameter of $F(\cdot)$	0.993
γ	survival rates	0.99	ξ	transfers	0.001
ρ_u	AR(1), uncertainty shocks	0.90			

assume that the government spending is constant over time and the ratio of the government spending to output is 0.22 in steady state. I set the curvature of the cost of capital utilization rates as $a''(1)/a'(1) = 2$ following Altig, Christiano, Eichenbaum and Linde (2010, ACEL hereafter) who estimate a medium scale monetary business cycle model by matching impulse response functions. I set the AR(1) coefficient of the technology shock $\rho_a = 0.95$ following King and Rebelo (1999).

Next I proceed to conventional parameters related to the nominal factors of an economy. I set the parameters values consistent with the estimate of ACEL (2010). I set $\lambda_p = \lambda_w = 1.05$ for the markups of prices and wages. For the Calvo wages parameter I set $\xi_w = 0.8$. Instead of setting the Calvo prices parameter I set the slope of the price Phillips curve as $\gamma_p = (1 - \beta\xi_p)(1 - \xi_p)/\xi_p = 0.014$. The implied value of ξ_p is quite high: 0.89. According to ACEL (2004, 2010) and Woodford (2005), the relatively flat slope of Phillips curve is consistent with low value of ξ_p if a model has firm-specific capital. There exist the other sources which make the price Phillips curve flat without relying on high price stickiness.[11]

As a benchmark monetary policy rule I set the coefficient of inflation, $r_\pi = 1.5$, as in Taylor (1993) and set the coefficient of output growth as $r_{dy} = 0.10$, while I set the coefficient of the lagged interest rate as $\rho_{mp} = 0.8$. I set target gross inflation rates equal to $\pi = 1$, so that there is no price and wage dispersions.

Finally I finish with the parameters specific to the model, $\{\phi, \underline{p}, \gamma, \xi, \rho_u\}$. I set pa-

[11]For example, a kinked demand curve (Kimball, 1995) and nominal price dispersion (Ascari, Guido and Ropele, 2007) make the price Phillips curve flat. For the other factors affecting the slope of the price Phillips curve, see Woodford (2003, Chapter 3).

rameter $\xi = 0.001$ which determines the amount of lump-sum transfers from households to entrepreneurs. As in Carlstrom and Fuerst (1997) I make the transfers small so that the transfers do not add additional dynamics. I set the AR(1) coefficient of uncertainty shocks $\rho_u = 0.90$. As Ikeda (2011) shows the uncertainty shocks in this model plays the exactly same role as financial shocks and almost similar role to risk shocks. This value lies between the AR(1) coefficient of financial shocks analyzed by Hall (2010) and Gilchrist and Zakresjek (2010) and the AR(1) coefficient of risk shocks estimated by CMR (2009).

I set the remaining three parameters to hit the following three targets in steady state: the leverage ratio of 1.5, the external finance premium of 2 percent annual rate, and the expected equity premium of 1 percent annual rate. The target value of the leverage ratio is lower than the literature.[12] But it is consistent with U.S. Flow of Funds Accounts according to which the debt net worth ratio of non-farm non-financial corporate business is around 0.5, implying a leverage ratio of 1.5. Recently Ajello (2010) reports the low value of leverage equal to 1.33 using the data of capital expenditures of the U.S. public non-financial companies in Compustat. The target value of the external finance premium is close to the average spread of corporate bonds with various credit quality relative to comparable maturity Treasury yield from 1990 to 2008 of 1.92 percent, analyzed by Gilchrist, Yankov and Zakrajsek (2009). The target value of the expected equity premium does not mean to match any numbers but suggests that there exists a discrepancy between the return of capital and the risk-free rate due to credit frictions.

5.2. The Effect of Uncertainty Shocks

I study responses to uncertainty shocks and the amplification mechanisms of uncertainty shocks. First, I show that the uncertainty shocks generate significant fluctuations consistent with business cycles. Second, I analyze how the uncertainty shocks affect the model economy analytically. Third, I make clear the role of nominal rigidities, or the role of countercyclical markups, as the amplification mechanisms of the uncertainty shocks. I also discuss investment adjustment costs which generate hump-shaped responses to the uncertainty shocks while they dampen the impact of the shocks.

Before looking at the result I would like to emphasize the unique nature of the uncertainty shocks. The shocks have real effect because of adverse selection. With symmetric information adverse selection would disappear and the uncertainty shocks would not have any real effect.

Responses to Uncertainty Shocks: Figure 1 plots the impulse responses of main variables to the negative uncertainty shock. The horizontal axis shows periods. The economy is in steady state in period 0 and is hit by the shock in period 1. The vertical axis shows percent deviation from steady state (denoted as %) or APR difference from steady state (denoted as

[12]For example, the leverage ratio in steady state is 2 in BGG (1999) and 4 in Gertler and Karadi (2010).

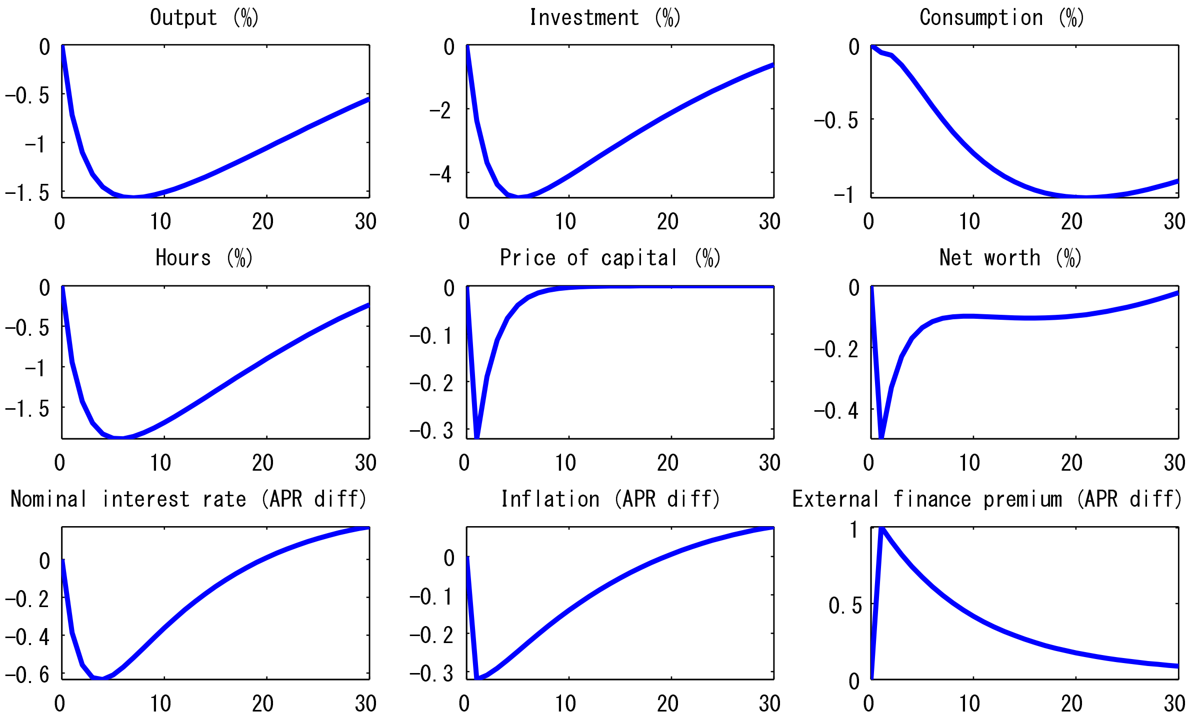


Figure 1: Impulse Responses to Uncertainty Shock

APR diff). The variables include output (Y_t), investment (I_t), consumption (C_t), average hours worked (L_t^*), capital utilization rates (u_t), the price of capital (q_t), net worth (N_t), external finance premium (EFP_t) defined by (37), and nominal interest rate (R_t). I set the magnitude of the shock such that the external finance premium rises 1 percent annual rate relative to the steady state level.[13]

In response to the negative uncertainty shock which increases the external finance premium by 1 percent annual rate, the output falls gradually and reaches its bottom of -1.6 percent after seven periods after the shock. Investment and hours show the similar shape of response to that of output, while the response of investment is about three times as great as output and the response of hours is slightly greater than output.

In contrast to output, investment and hours, consumption shows more persistent response. At the impact consumption falls about 0.05 percent and reaches the negative peak of -1 percent around twenty-two periods after the shock hits the economy. Both the price of capital and the net worth drop at the impact of the shock and move back to its steady state.

Inflation falls by 0.3 percentage points in annual rate initially and slowly move back to its steady state. In response to a fall in inflation and a fall in output, nominal interest rate falls and reaches its bottom of more than 0.6 percentage points in annual rate after four

[13]The actual value of υ_t at the initial impact is $-0.015/4$.

periods.

Overall, the responses to the uncertainty shock are consistent with business cycles: all variables except the external finance premium are pro-cyclical. Also, the responses show significant fluctuations. The uncertainty shock which increases the external finance premium by 1 percentage point causes 1.6 percent fall in output, 4.8 percent fall in investment, 1 percent fall in consumption and 1.9 percent fall in hours, at the bottom.

Anatomy of Uncertainty Shocks: How do the uncertainty shocks affect an economy? To understand the mechanisms, I log-linearize equations (34) and (35), substitute out for $\hat{p}_t^*$ and summarize the two equations as follows:

$$\hat{s}_t = -\chi_1 \left(\hat{N}_t - \hat{q}_t - \hat{\bar{K}}_{t+1} \right) - \chi_2 \upsilon_t, \quad \chi_1, \chi_2 > 0, \tag{43}$$

where $\hat{x}_t$ denotes the deviation of variable x_t from its steady state. (See Ikeda, 2011, for the derivation). Equation (43) shows that the uncertainty shock, υ_t, changes a wedge between the return to capital and the risk-free rate, $\hat{s}_t$, given the net worth, the price of capital and the physical capital. After log-linearization, the uncertainty shock becomes equivalent to financial shocks considered by Hall (2010), Gilchrist and Zakresjek (2010) among others.

The negative uncertainty shock, $\upsilon_t < 0$, increases uncertainty about the riskiness of entrepreneurial projects. There exit more risky entrepreneurs and they tend to repay less to intermediaries. Intermediaries cut back loans, $B_t = q_t \bar{K}_{t+1} - N_t$, to make zero profits. Given net worth N_t, a fall in loans decreases the price of capital, q_t, which, in turn, decreases investment, $\bar{I}_t = \bar{K}_{t+1} - (1-\delta)\bar{K}_t$. A fall in q_t decreases the current net worth, N_t, from the law of motion for net worth, (38). A fall in net worth increases the excess return to capital, s_t, from equation (43). A rise in $s_t \equiv E_t R_{t+1}^k / R_{t+1}$ is mainly driven by a fall in q_t from equation (31). This, in turn, decreases the current net worth, and this cycle continues. In the end, the price of capital, the net worth and investment drop sharply. Amplified by another mechanisms the uncertainty shock also affects output, hours and consumption severely as discussed below.

The Role of Nominal Rigidities: I have shown in Figure 1 that the uncertainty shock generates business cycles. Now I investigate what factor embedded in my model help the uncertainty shock generate responses consistent with business cycles.

As argued by Ikeda (2011), a counter-cyclical markup in wages play a crucial role in amplifying the uncertainty shock. While Ikeda (2011) employs an exogenous counter-cyclical markup in wages, it is nominal rigidities in wages that make the markup counter-cyclical in this model. Also, nominal rigidities in prices make a markup in prices counter-cyclical. In order to quantify the role of nominal rigidities I change the value of parameters controlling the degree of nominal rigidities and look at changes in impulse responses.

First, consider nominal wage rigidities. Under the baseline parameter value of $\xi_w = 0.8$, output falls by 1.6 percent at the bottom reached after seven periods after the shock. The consumption falls initially and persistently decline until twenty-one periods. In contrast to the baseline, for $\xi_w = 0.7, 0.5, 0.01$, output falls by 1.4 percent, 1.3 percent and 1.2 percent respectively; output reaches its bottom in six periods, five periods and four periods respectively. Nominal wage rigidities not only amplify the effect of uncertainty shock but also make the response of output persistent. More importantly, consumption *increases* by 0.1 percent, 0.3 percent and 0.4 percent initially for $\xi_w = 0.7, 0.5, 0.01$ respectively. With those parameter values the response of consumption exhibits an opposite sign to that implied by business cycles. This fact highlights the importance of high nominal wage rigidities.

Next, consider nominal price rigidities. In parameterizing the model I set the slope of the price Phillips curve as $\gamma_p = 0.014$ based on the evidence from ACEL (2010). In the model the implied value of price rigidities is $\xi_p = 0.89$. In response to the uncertainty shock, for $\xi_p = 0.8, 0.5, 0.01$, output falls by 1.1 percent, 0.8 percent and 0.75 percent respectively; output reaches its bottom in five periods, eight periods and eight periods respectively, in contrast to 1.6 percent fall in output with its bottom reached in seven periods under the baseline. While nominal price rigidities amplify the effect of uncertainty shock, they do not necessarily make the response of output persistent.

Both nominal wage and price rigidities put together, nominal rigidities serve as important amplification and persistence mechanisms in the model. Without nominal rigidities, markups in wages and prices are no more counter-cyclical and the model neither exhibits significant fluctuations nor generates business cycles.[14]

The Role of Investment Adjustment Costs: The CEE (2005) adjustment costs make the response of various variables including output and investment hump-shaped and persistent. In the baseline I set the adjustment costs parameter as $S'' = 0.3$. In response to the same uncertainty shock in Figure 1, for $S'' = 1, 2, 5$, output falls by 1.2 percent, 0.9 percent and 0.6 percent respectively; output reaches its bottom in nine periods, ten periods and twelve periods respectively, in contrast to 1.6 percent fall in output with its bottom reached in seven periods under the baseline.

The result highlights the role of the adjustment costs. While the adjustment costs make the response persistent, the costs dampen the effect of uncertainty shock. Because nominal rigidities add enough persistence to the model as we saw above, I do not have to rely heavily on the adjustment costs to make responses persistent. Because there is little micro evidence on the adjustment costs parameter values, I use the value of $S'' = 0.3$ which

[14]If one considers a shock other than neutral technology (or preference) shocks as a candidate to drive business cycles, he or she must overcome the substitution effect of consumption, implied from a simple equation which equates the marginal rate of substitution between consumption and labor (MRS) and the marginal product of labor (MPL). Nominal rigidities can offset and reverse the substitution effect of consumption. Justiniano, Primiceri and Tambalott (2009) provide a nice explanation why nominal rigidities are important for investment shocks to be a major source of business cycles.

allows the model to exhibit enough persistence and hump-shaped responses.

5.3. Adverse Selection: Amplifier or Dampener?

So far I have focused on responses to uncertainty shocks. Now I change my focus to the role of adverse selection as the propagation mechanisms of the other shocks. Here I consider transitory neutral technology shocks and monetary policy shocks

In order to isolate the role of adverse selection, I compare the baseline (asymmetric information) model with a symmetric information model. The symmetric information model is characterized by the same equations as the baseline model with threshold p_t^* replaced by unity. I add a constant tax rate on net worth to the symmetric information model in such a way that the steady state coincides with that of the baseline model.

Before looking at numerical results I find it useful to make clear a difference between the two models analytically. The difference appears only in one equation which determines the demand for capital. The equation in the baseline model is given by (34), while the equation in the symmetric information model is given by (34) with $(p_t^* - \underline{p}_t)/(1 - \underline{p}_t) \equiv F_t(p_t^*)$ replaced by a constant, $1 - \tau_n = F(p^*)$, where τ_n denotes a tax rate on net worth. For the sake of argument here I ignore the uncertainty shock temporarily in this subsection. Log-linearizing equations (34) and (35), the two models share the same equation with the different value of coefficient:

$$E_t \hat{R}^k_{t+1} - \hat{R}_{t+1} = -\chi_1 \left(\hat{N}_t - \hat{\hat{K}}_{t+1} - \hat{q}_t \right), \quad 0 < \chi < \chi_{\text{sym}}, \tag{44}$$

where χ_1 and χ_{sym} corresponds to the baseline model and the symmetric information model respectively. If coefficient χ_1 were zero, the model would collapse to a model without credit frictions in which the net worth plays no role.

The baseline model has a smaller coefficient in absolute values than does the symmetric information model: $\chi_1 < \chi_{sym}$ in equation (44). This attributes to the presence of $F_t(p_t^*)$ in equation (34), which adds a flexibility to the demand for capital. Because threshold p_t^* is increasing in $s_t \equiv E_t R^k_{t+1}/R_{t+1}$ from equation (35), the demand for capital or the aggregate loan responds more to a certain change in s_t relative to the symmetric information model. [15] In other words, s_t responds less to a certain change in the aggregate loan in the baseline model relative to the symmetric information model, as shown in equation (44).

Keeping equation (44) in mind, I analyze impulse responses to technology and monetary policy shocks. Figure 2 plots the two responses in a panel: a solid line and a dashed line correspond to the baseline model and the symmetric information model respectively. I start from responses to sudden 1 percent rise in nominal interest rates (left panel). The panel shows that the response of the baseline model exhibits stronger and more persistent

[15] The term in parenthesis in (44) can be expressed in terms of the aggregate loan and the net worth. Because $q_t K_{t+1}/N_t = 1 + B_t/N_t$, I can write $\hat{q}_t + \hat{K}_{t+1} - \hat{N}_t = [N/(N+B)](\hat{B}_t - \hat{N}_t)$.

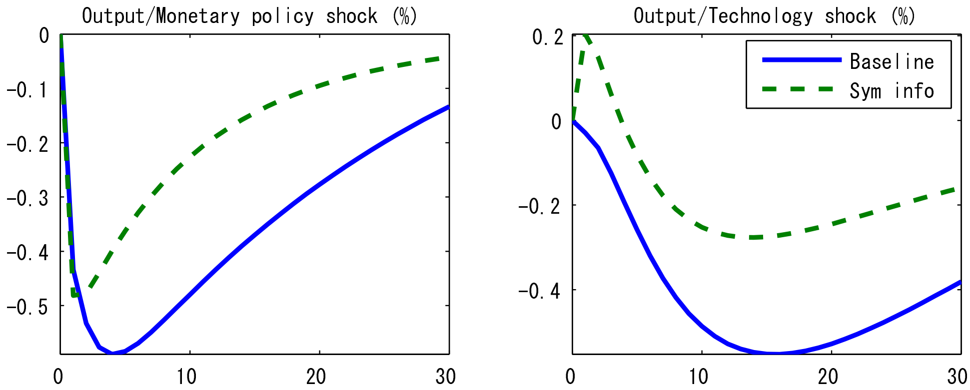


Figure 2: Impulse Responses to Monetary and Technology Shocks

response of output than that of the symmetric information model. In the baseline (the symmetric information) model output falls by 0.59 (0.49) percent at its bottom and the effect is halved around twenty (ten) periods after a shock hits the economy.

Equation (44) provides a key idea why the baseline model makes the responses more persistent and stronger. In response to a negative monetary policy shock the real interest rate, R_{t+1}, rises. With the right-hand-side of (44) kept constant (zero) for a moment, an increase in R_{t+1} should raise the expected return to capital, $E_t R^k_{t+1}$, which is mainly driven by a fall in the price of capital, q_t, because $R^k_{t+1} = [r^k_{t+1} u_{t+1} + (1-\delta) q_{t+1} - a(u_{t+1})]/q_t$. A fall in q_t has two opposite effect on the expected equity premium, $s_t \equiv E_t R^k_{t+1}/R_{t+1}$. First, it directly decreases s_t from the right-hand-side of equation (44). Second, it decreases the net worth, N_t, from the law of motion of net worth, (38), which increases s_t from the right-hand-side of equation (44). The second effect dominates the first and increases s_t. Again this causes a fall in q_t and further decreases q_t as this process is repeated. This is so-called the financial accelerator. In the end a fall in q_t results in a decrease in investment and output.

The effect of the accelerator I have described above depends on χ in equation (44). The higher the value of χ_1 is, the greater the effect on q_t is. The change in q_t has two opposite effects. First, the greater a change in q_t is, the greater a change in the current net worth,N_t, from the law of motion of net worth, (38). Second, the greater a change in q_t is, the smaller a change in the future net worth, N_{t+1}. If q_t drops sharply today, the return to capital R^k_{t+1} increases and helps the future net worth recover quickly. The effect of the accelerator depends on the value of χ_1 in a non-linear manner. For too small values of χ_1, there is no financial accelerator effect. For too great values of χ_1, the second effect overwhelms the first, which makes responses smaller and less persistent. The latter applies to what happens in the symmetric information model where χ_{sym} is much greater than χ_1 in the baseline model.

Next I discuss responses to a negative technology shock. The right panel in Figure 2 shows that the baseline model exhibits persistent negative responses while the symmetric information model exhibits positive responses initially. The positive response in the symmetric information is at odd with a conventional wisdom about neutral technology shocks. In response to a negative technology shock the real interest rate falls. Now the financial accelerator I discussed for a monetary policy shock works in an opposite way. Specifically, in the symmetric information mode, a rise in the price of capital, q_t, caused by a fall in the real interest rate is so great that it boosts the economy and increases output initially.

The above discussion shows that the higher value of χ_1 in equation (44) does not necessarily implies the greater financial accelerator effect in response to technology and monetary policy shocks. The financial accelerator effect depends not only the value of χ_1 but also the other features including the law of motion of net worth, nominal rigidities and so on. Under the baseline parameter values in Table 1, the baseline (asymmetric information) model exhibits the greater and more persistent responses than does the symmetric information model, while the former has the lower value of χ_1 than does the latter.

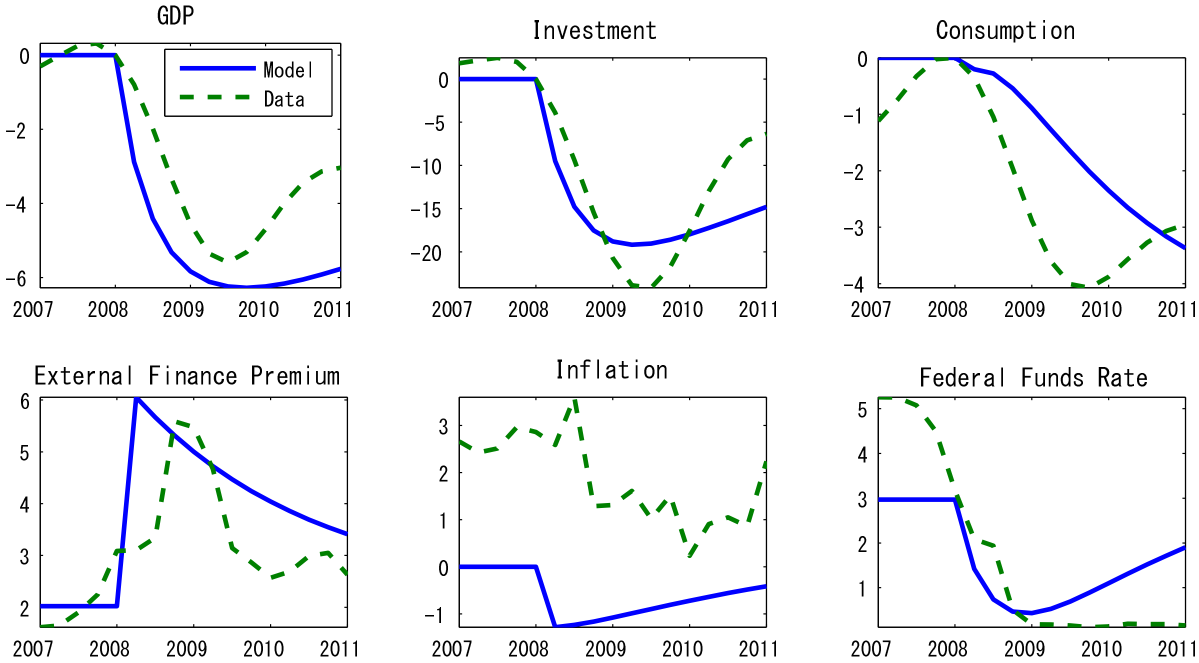
6. Monetary Policy in a Crisis

In this section I study the effect of monetary policy to tackle a simulated financial crisis triggered by uncertainty shocks. First, I simulate a financial crisis which matches some silent features of the great recession in the U.S. starting in Winter 2008. Second, I study the effect of Taylor rule augmented with financial variables in response to the simulated crisis. Third, I study the effect of unconventional monetary policy which subsidizes the cost of intermediaries' funds.

6.1. Crisis Simulation

I simulate the model and consider uncertainty shocks as the trigger of financial crisis. I use the same parameter values as shown in Table 1. To see how a simulated crisis is comparable to the great recession, I construct the crisis in a following manner. I assume that the model economy is in a steady state until the first quarter in 2008, because the great recession started in December 2007 according to the NBER's Business Cycle Dating Committee. In the second quarter in 2008, an unexpected one-time uncertainty shock hits the economy. I set the magnitude of the shock so as to generate a rise in the external finance premium by four percentage points, consistent with data as we see below.

Figure 3 plots simulated series (solid line) and U.S. data (dashed line). The figure shows that the simulated financial crisis matches, to some extent, the silent features of U.S. great recession. The simulated crisis matches a fall in GDP (output) quite well, though it slightly overstates the data. The simulated investment understates the magnitude implied by the data. Still it generates a huge drop by nearly 20 percent from the steady state. The simulated consumption falls more persistently than does the data, while it matches the



Note: All data are downloaded from FRED, Federal Reserve Bank of St. Louis. GDP, investment and consumption are detrended by Band Pass filter discussed by Christiano and Fitzgerald (1999), with frequency between 2 to 10 years. Investment is defined by gross private domestic investment plus personal consumption expenditures on durable goods, divided by GDP deflator. Consumption is defined by personal consumption expenditures on non-durable goods and services, divided by GDP deflator. External finance premium is defined by Moody's seasoned Baa corporate bond yield minus 10-year Treasury rate. Inflation is calculated from CPI excluding food and energy. Federal funds rate denotes the effective federal funds rate.

Figure 3: Crisis Simulation

magnitude of the fall at least in 2011. The simulated external finance premium rises by four percentage points, consistent with the data defined by a difference between Moody's seasoned Baa corporate bond yield and 10-year Treasury rate. The simulated external finance premium shows a more persistence than that implied by the data. The simulated inflation falls sharply from 0 percent to more than -1 percent. It fails to match the level of actual inflation.[16] Also, the actual inflation falls more slowly and accompanied with fluctuations. The simulated interest rate falls from 3 percent to 0.5 percent and returns to the steady state level gradually, while the actual federal funds rate drops from 5 percent

[16] I could match the level of the actual inflation rate by setting the steady state inflation to, say, two percent. Here I stick to zero inflation rate in steady state for two reasons. First, non-zero inflation rate in steady state generates nominal price and wage dispersions. The dispersions result in a highly non-linear system, which, in turn, makes even second-order approximations inaccurate to a greater extent. Second, while adding nominal price and wage indexation makes dispersions disappear, the indexation makes responses less persistent and less amplified. Specifically, with indexation the response of consumption becomes weaker and understates the actual data.

to 0 percent and stays at 0 percent.

Overall the model succeeds, to some extent, in generating a financial crisis consistent with the great recession. Below I explore the effect of various monetary policy to tackle the simulated financial crisis.

6.2. Taylor Rule Augmented with Financial Variables

I consider a modified Taylor rule augmented with external finance premiums and credits as proposed by Taylor (2008) and Christiano, et al (2010) respectively. I show that the modified Taylor rules helps resolve a simulated financial crisis and improves welfare significantly.

Welfare Criterion: In order to evaluate the effect of a modified Taylor rule, I begin by writing the (average) household utility function in recursive form[17], following Schmitt-Grohé and Uribe (2004) and Gertler and Karadi (2010):

$$W_t = \left[\log(C_t) - \psi \frac{(\Delta^*_{w,t})^{\frac{\lambda_w(1+\nu)}{1-\lambda_w}} (\Delta_{w,t})^{\frac{\lambda_w(1+\nu)}{\lambda_w - 1}} (L^*_t)^{1+\nu}}{1+\nu} \right] + \beta E_t W_{t+1}.$$

where $L^*_t \equiv \int_0^1 L_t(j)dj$ denotes the average hours worked, $\Delta_{w,t}$ denotes the nominal wage dispersion, given by (42) and $\Delta^*_{w,t}$ is given by

$$\Delta^*_{w,t} = \left[\int_0^1 \left(\frac{W_t(j)}{W_t} \right)^{\frac{\lambda_w(1+\nu)}{1-\lambda_w}} dj \right]^{\frac{1-\lambda_w}{\lambda_w(1+\nu)}}$$

I take a second order approximation of this objective function and the whole system of equations about the steady state. Then I express this function as a second order function of the state variables and shocks to the system. I evaluate the welfare of an economy based on the approximated objective function at the onset of a simulated financial crisis. I quantify the effect of a modified Taylor rule by computing how much consumption would have to increase in each period in an economy with a baseline Taylor rule to be indifferent with an economy with a modified Taylor rule.

In the following simulation I focus on a coefficient on financial variables in a modified Taylor rule and keep the other parameters fixed as in the crisis simulation presented in the previous subsection.

External Finance Premiums: As proposed by Taylor (2008) I consider a modified Taylor rule augmented with external finance premiums:

$$\frac{1+i_t}{1+i} = \left(\frac{1+i_{t-1}}{1+i} \right)^{\rho_{mp}} \left[\left(\frac{\pi_t}{\pi} \right)^{r_\pi} \left(\frac{EFP_t}{EFP} \right)^{-r_e} \right]^{1-\rho_{mp}} \left(\frac{Y_t}{Y_{t-1}} \right)^{r_{dy}}, \tag{45}$$

[17] The (average) household utility is given by equation (26) integrated from $j = 0$ to 1.

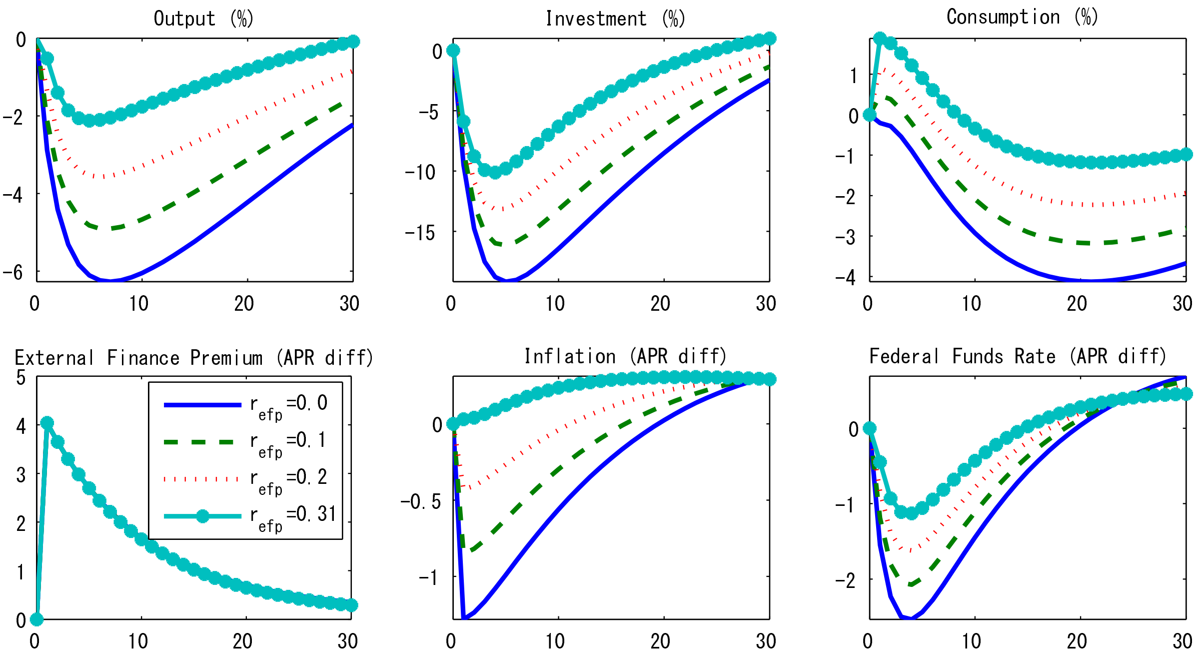


Figure 4: The Effect of Taylor Rule with External Finance Premiums

where $r_e \geq 0$. The modified Taylor rule works in a way that the nominal interest rate falls in response to a rise in the external finance premium relative to its steady state value.

Figure 4 plots responses in a crisis scenario with different value of coefficient, r_e, in modified Taylor rule (46). The Figure shows that the modified Taylor rule helps resolve a crisis. The economy stabilizes as the coefficient increases from 0 (baseline crisis scenario). When the coefficient is chosen to maximize welfare ($r_e = 0.32$), output falls only by 2 percent, investment falls by 10 percent and consumption rises initially by 2 percent. Inflation is almost stabilized and the nominal interest rate (Federal Funds rate) falls only by 1 percentage points. Because the external finance premium is mainly driven by the uncertainty shock, it shows no difference among different modified Taylor rules.

The modified Taylor rule serves as a powerful tool to combat a crisis triggered by uncertainty shocks. The welfare gain from introducing the optimal modified Taylor rule amounts to 1.23 percent of consumption in each year in an economy with a baseline Taylor rule. An introduction of external finance premiums in a Taylor rule changes a whole system of equations. In this model the external finance premium serves as the accurate signal of uncertainty shocks. Expecting that the nominal interest rate is adjusted in response to a change in the external finance premium, agents understand that the modified Taylor rule affects an economy not only today but also all future dates. Expectations about future, in turn, affect today's decisions. By working on expectations the modified Taylor rule has a powerful effect on the simulated financial crisis.

Credits: As proposed by Christiano, et al (2010) I consider a modified Taylor rule augmented with credit growth:

$$\frac{1+i_t}{1+i} = \left(\frac{1+i_{t-1}}{1+i}\right)^{\rho_{mp}} \left[\left(\frac{\pi_t}{\pi}\right)^{r_\pi} \left(\frac{B_t}{B_{t-1}}\right)^{r_b}\right]^{1-\rho_{mp}} \left(\frac{Y_t}{Y_{t-1}}\right)^{r_{dy}}, \tag{46}$$

where B_t denotes the aggregate loan (credits), given by equation (14), and $r_b \geq 0$. The modified Taylor rule works in a way that the nominal interest rate falls in response to a fall in the growth rate of credits.

This modified Taylor rule also helps resolve a simulated financial crisis. In response to uncertainty shocks both the price of capital and the net worth decrease, resulting in a decrease in the credits. Similar to external finance premiums, the credits serve as the accurate signal of uncertainty shocks. The coefficient maximizing welfare is $r_b = 0.36$ and the welfare gain amounts to 1.40 percent of consumption in an economy with a baseline Taylor rule. While the modified Taylor rule performs slightly better than a modified Taylor rule with external financial premiums, the performance depends on the parameters values of the model. Though I do not explore the robustness of the result comprehensively in the model, the credit growth can work well as suggested by Christiano, et al (2010).

6.3. Unconventional Monetary Policy

The U.S. government conducted large scale purchases of assets and implemented policies that reduced the cost of funds to financial institutions in the great recession. In this subsection I explore the effect of unconventional monetary policy which shares similar features with the actual policies. First, I define the unconventional monetary policy in the model. Then, I evaluate two policies which differ in a way how to conduct the unconventional monetary policy.

Subsidies to Intermediaries' Cost of Funds: A problem in a simulated financial crisis lies in a shrink in credits. A massive increase in uncertainty about the riskiness of entrepreneurial projects makes lending less attractive and causes a fall in credits. This affects the price of capital and the net worth, and, in turn, affects credits. As a result of the vicious cycle, the credits shrink sharply and a financial crisis arises.

As shown by Christiano and Ikeda (2011), subsidies to intermediaries' cost of funds help resolve a financial crisis in various credit frictions models. Actually, the policy works in the model too. To see this point I rewrite the intermediary's zero profit condition in Problem (2) as follows:

$$0 = \int_{\underline{p}_t}^{p_t^*} [pX_{t+1,n}(p) - (1-\tau_t)R_{t+1}B_{t,n}(p)]dF_t(p), \tag{47}$$

where τ_t denotes a subsidy, $X_{t+1,n}(p)$ denotes a payment schedule for entrepreneurs with net worth $N_{t,n}$ and $B_{t,n}$ denotes a loan schedule. In response to the negative uncertainty shock, $B_{t,n}(p)$ falls, otherwise the intermediary has to bear the negative profits. A rise in subsidy τ_t mitigates a fall in $B_{t,n}(p)$ by lowering the cost of funds.

A policy maker implements the subsidy policy by asset purchases with higher prices than the fundamentals. The zero profit condition, (47), can be expressed as follows:

$$0 = \int_{\underline{p}_t}^{p_t^*} \left[\frac{pX_{t+1,n}(p)}{1-\tau_t} - R_{t+1}B_{t,n}(p) \right] dF_t(p).$$

The term, $pX_{t+1,n}(p)$, denotes the expected repayment, or the fundamental value of loan. The subsidy policy is equivalent to the government purchases of security assets backed by the loan with price $pX_{t+1,n}(p)/(1-\tau_t)$.

Following Gertler and Karadi (2010) I assume that a government sets subsidy τ_t in response to financial variables, according to a certain feedback rule which I specify below. A government finances resources required for the subsidy by levying lump-sum taxes on household.

External Finance Premiums: I consider a feedback rule responding to external finance premiums as follows:

$$\tau_t = -\zeta_e \log\left(\frac{EFP_t}{EFP}\right). \tag{48}$$

Subsidy τ_t rises in response to a fall in external finance premiums. Here I implicitly assume that the subsidy is zero in steady state. While the positive value of subsidy could eliminate adverse selection and improve welfare as discussed in Christiano and Ikeda (2011), I do not explore it because my interest here lies in how adverse selection becomes severe in response to uncertainty shocks and how the subsidy policy mitigates adverse selection.

Figure 4 plots responses in a crisis scenario with different value of coefficient, ζ_e, in feedback rule (48). The figure shows that the unconventional monetary policy, (48), has powerful effect on the economy under a simulated financial crisis. With the value of coefficient which maximizes welfare ($\zeta_e = 0.97$), the subsidy rate, τ_t, rises to 0.5 percent and decreases gradually. Output, investment, consumption and inflation are almost all stabilized. The welfare gain from introducing this policy is 1.56 percent of consumption in a baseline crisis case, higher than the welfare gain from introducing a modified Taylor rule.

A rise in external finance premiums becomes a half of that without the policy. In contrast to a modified Taylor rule, the unconventional monetary policy decreases the external finance premium. The subsidy lowers the cost of intermediaries' funds and lowers the cost of entrepreneurial loans. Also the subsidy makes more loans available. As a result, the borrowing interest rate, the cost of loans per unit of loan, decreases and the external finance premium shrinks.

Credits: I consider a feedback rule responding to the credit growth as follows:

$$\tau_t = -\zeta_b \log\left(\frac{B_t}{B_{t-1}}\right). \tag{49}$$

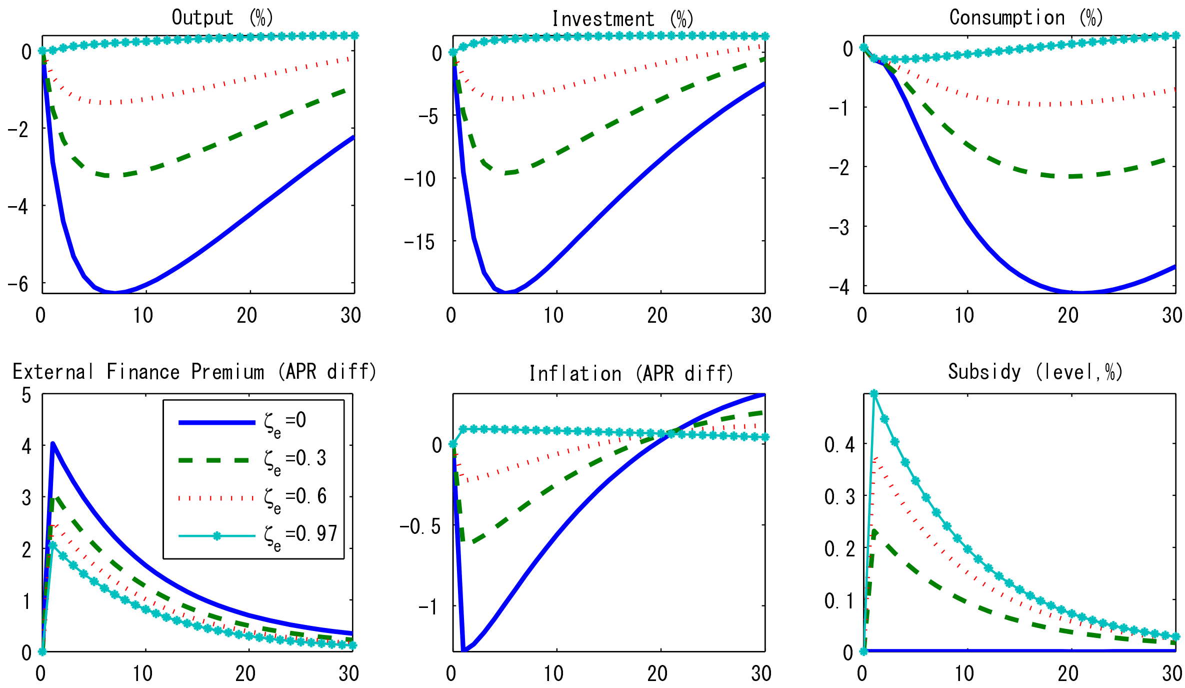


Figure 5: The Effect of Unconventional Monetary Policy

Subsidy τ_t rises in response to a fall in credit growth. Similar to external financial premiums, a feedback policy based on credit growth also helps dissolve a simulated financial crisis. With a coefficient maximizing welfare ($\zeta_b = 3.82$), output, investment, consumption and inflation are almost stabilized and the welfare gain of the policy is 1.53 percent of consumption in a baseline crisis case.

7. Conclusion

In this paper I expand a model developed by Ikeda (2011) and study a dynamic monetary economy in which imperfect financial markets materialize uncertainty shocks. The uncertainty shocks change a degree of asymmetric information and affect the severity of adverse selection in financial markets. I show that nominal price and wage rigidities serve as the powerful amplification mechanisms of the uncertainty shocks. Amplified by the nominal rigidities, the uncertainty shocks generate not only business cycles but also a financial crisis roughly consistent with the U.S. great recession.

I then study the effect of the two types of monetary policy to tackle the simulated financial crisis. First, as proposed by Taylor (2008) and Christiano, et al (2010), a modified Taylor rule augmented with financial variables helps mitigate the crisis. Second, as analyzed by Christiano and Ikeda (2010) in a simple general equilibrium framework, unconventional monetary policy which subsidizes the intermediaries' cost of funds has a dramatic effect in resolving the crisis. Because the policy is equivalent to government purchases of intermediaries' assets, the result may provide a rationale for asset purchases conducted by the U.S. government in the great recession.

Although I show that the uncertainty shocks generate a financial crisis roughly consistent with the U.S. great recession, it does not necessarily implies that the great recession is caused by the uncertainty shocks. While there are some evidence on the importance of uncertainty shocks in the great recession (Bloom, et al, 2010), there remain a lot of work to be done to understand the causes of the great recession in a dynamic general equilibrium framework.

The similar caveat applies to the effectiveness of the two types of monetary policy. The results presented in this paper are far from comprehensive. The effectiveness of the policy depends on models and model's parameters values. While Christiano and Ikeda (2010) find that the unconventional monetary policy studied in this paper is effective in four different credit frictions models, it remains unknown whether the policy is effective in other models such as models with occasionally binding collateral constraint (Mendoza, 2009, and Bianchi, 2011). Also, there are little empirical evidence on what type of credit frictions is relevant in practice. This paper provided just one model among many (unexplored) credit frictions models to understand the causes of the great recession and the effectiveness of monetary policy.

References

[1] **Altig, David, Lawrence J. Christiano, Martin Eichenbaum, and Jesper Linde** (2005), "Firm-Specific Capital, Nominal Rigidities, and the Business Cycle," NBER wp.11034, January 2005.

[2] **Ascari, Guido, and Tiziano Ropele** (2007), "Optimal Monetary Policy under Low Trend Inflation," *Journal of Monetary Economics*, 54, pp.2568-83.

[3] **Barro, R. J., and King, R. G.** (1984), "Time-Separable Preference and Intertemporal-Substitution Models of Business Cycles," *Quarterly Journal of Economics*, Vol. 99 No.4, pp.817-839.

[4] **Bernanke, Ben and Gertler, Mark** (1990), "Financial Fragility and Economic Performance, " *The Quarterly Journal of Economics*, Vol. 105, No. 1, Feb, pp. 87-114

[5] **Bernanke, Ben, Gertler, Mark, and Gilchrist, Simon** (1999), "The Financial Accelerator in a Quantitative Business Cycle Framework," In: Taylor, J.B., Woodford, M. (Eds.), Handbook of Macroeconomics, vol. 1C. North-Holland, Amsterdam.

[6] **Bianchi, Javier** (2011), "Overborrowing and Systemic Externalities in the Business Cycle," forthcoming, *American Economic Review.*

[7] **Bigio, Saki** (2010), "Financial Risk Capacity," *manuscript*, New York University.

[8] – – –– (2011), "Endogenous Liquidity and the Business Cycle," *manuscript*, New York University.

[9] **Bloom, Nicholas** (2009), "The Impact of Uncertainty Shocks," *Econometrica* Vol. 77, No. 3, May, 623-685.

[10] **Bloom, Nicholas, Floetotto, Max, and Jaimovich, Nir** (2010), "Really Uncertain Business Cycles," *manuscript*, Stanford University.

[11] **Calvo, Guillermo** (1983), "Staggered Prices in a Utility-Maximizing Framework," *Journal of Monetary Economics* 12, September 1983, 383-98.

[12] **Carlstrom, Charles T. and Fuerst, Timothy** (1997), "Agency Costs, Net Worth, and Business Fluctuations: A Computable General Equilibrium Analysis," *The American Economic Review*, Dec., 1997, 87(5), pp.893-910.

[13] **Chari, V. V., Shourideh, Ali and Zetlin-Jones, Ariel** (2010), "Analyzing Policies to Repair Credit Markets," *manuscript*, Federal Reserve Bank of Minneapolis.

[14] **Christiano, Lawrence J., Eichenbaum, Martin and Evans, Charles L.** (2005), "Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy," *Journal of Political Economy*, 2005, 113(1), pp.1-45.

[15] **Christiano, Lawrence J. and Fitzgerald ,Terry J.** (1999), "The Band Pass Filter," *International Economic Review*, 1999,

[16] **Christiano, Lawrence J. and Ikeda, Daisuke** (2010), "Government Policy, Credit Markets and Economic Activity," manuscript, Northwestern University.

[17] **Christiano, Lawrence J., Motto, Roberto, and Rostagno, Massimo** (2010), "Financial Factors in Business Fluctuations," manuscript, Northwestern University.

[18] **Christiano, Lawrence J, Ilut, Cosmin, Motto, Roberto and Rostagno, Massimo** (2010), "Monetary Policy and Stock Market Booms," Macroeconomic Challenges: the Decade Ahead, A Symposium Sponsored by the Federal Reserve Bank of Kansas City Jackson Hole.

[19] **Clarida, Richard, Gali, Jordi, and Gertler, Mark** (2000), "Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory," *Quarterly Journal of Economics*, 115(1), pp.147-180

[20] **Clurdia, Vasco and Woodford, Michael** (2010), "Credit Spreads and Monetary Policy," manuscript, Columbia University.

[21] **Del Negro, Marco, Eggertsson, Gauti, Ferrero, Andrea and Kiyotaki, Nobuhiro** (2010), " The Great Escape? A Quantitative Evaluation of the Fed's Non-Standard Policies," *manuscript*, Federal Reserve Bank of New York.

[22] **Eisfeldt, A. L.** (2004), "Endogenous liquidity in asset markets," *Journal of Finance* 59(1), pp.1-30.

[23] **Erceg, Christopher J., Henderson, Dale, W., and Andrew T. Levin** (2000), "Optimal Monetary Policy with Staggered Wage and Price Contracts," *Journal of Monetary Economics*, 2000, 46, pp.281-313.

[24] **Fishman, Michael and Parker, Jonathan** (2010), "Valuation and the Volatility of Financing and Investment," *manuscript*, Northwestern University.

[25] **Gertler, Mark and Peter Karadi** (2010), "A Model of Unconventional Monetary Policy," forthcoming in *Journal of Monetary Economics*

[26] **Gilchrist, Simon and Egon Zakrajsek** (2010), "Monetary Policy and Credit Supply Shocks," manuscript, Boston University.

[27] **Gilchrist, Simon, Vladimir Yankov and Egon Zakrasjek** (2009), "Credit Market Shocks and Economic Fluctuations: Evidence from Corporate Bond and Stock Markets," manuscript, Boston University.

[28] **Greenwood, J., Hercowitz, Z., and Huffman, G. W.** (1988), "Investment, Capacity Utilization, and the Real Business Cycle," *American Economic Review*, Vol.78, No.3, pp.402-417.

[29] **Hall, Robert E.** (2010), "The High Sensitivity of Economic Activity to Financial Frictions," forthcoming in *Economic Journal.*

[30] **Hellwig, M.** (1987), "Some Recent Development in the Theory of Competition in Markets with Adverse Selection," *European Economic Review*, 31, pp.319-25.

[31] **House, Christopher L.** (2006), "Adverse Selection and the Financial Accelerator," *Journal of Monetary Economics*, 53, pp.1117-1134.

[32] **Ikeda, Diasuke** (2011), "Adverse Selection, Uncertainty Shocks and Business Cycles," *manuscript*, Northwestern University.

[33] **Justiniano, Alejandro, Primiceri, Giorgio E. and Tambalott, Andrea** (2009), "Investment Shocks and Business Cycles," *manuscript* (forthcoming in Journal of Monetary Economics), Northwestern University, 2009.

[34] **Kiley, Michael T. and Sim, Jae W.** (2011), "Financial Capital and the Macroeconomy: A Quantitative Framework," *manuscript*, Federal Reserve Board.

[35] **Kimball, Miles S.** (1995), "The Quantitative Analytics of the Basic Neomonetarist Model," *Journal of Money, Credit and Banking*, 27, pp.1241-1277.

[36] **King, Robert G. and Rebelo, Sergio T.** (1999), "Resuscitating Real Business Cycles," In: Taylor, J.B., Woodford, M. (Eds.), Handbook of Macroeconomics, vol. 1B. North-Holland, Amsterdam.

[37] **Kurlat, Pablo** (2010), "Lemons, Market Shutdowns and Learning," *manuscript*, Stanford University.

[38] **Mankiw, N. Gregory** (1986), "The Allocation of Credit and Financial Collapse," *The Quarterly Journal of Economics*, Vol. 101, No. 3, August, pp. 455-470.

[39] **Mendoza, Enrique G.** (2009), "Sudden Stops, Financial Crises and Leverage," forthcoming, *American Economic Review.*

[40] **Rothchild M., and Stiglitz, J.** (1976), "Equilibrium in Competitive Insurance Markets: An Essay on the Economics of Imperfect Information," *The Quarterly Journal of Economics*, 90, pp.630-649.

[41] **Schmitt-Grohé, Stephanie and Uribe, Martin** (2004), "Optimal Fiscal and Monetary Policy under Sticky Prices," *Journal of Economic Theory*, 114, Feb., pp.198-230.

[42] **Stiglitz, J. E. and Weiss, A.** (1981), "Credit Rationing in Markets with Imperfect Information," *American Economic Review* 71(3), 393-410.

[43] **Taylor, John B.** (1993) "Discretion versus Policy Rules in Practice," *Carnegie-Rochester Conference Series on Public Policy* 39, pp.195-214.

[44] **Taylor, John B.** (2008), "Monetary Policy and the State of the Economy," testimony before the Committee on Financial Services, U.S. House of Representatives, February 26, 2008.

[45] **Townsend, Robert** (1979), "Optimal Contracts and Competitive Markets with Costly State Verification, " *Journal of Economic Theory*, 21, pp.265-93.

[46] **Williamson, Stephen** (1987), "Financial Intermediation, Business Failures and Real Business Cycles," *Journal of Political Economy*, Vol.95, No.6, Dec.,pp.1196-1216.

[47] **Wilson, C.** (1977), "A Model of Insurance Markets with Incomplete Information," *Journal of Economic Theory*, 16, pp.167-207.

[48] **Woodford, Michael** (2003), "Interest and Prices: Foundations of a Theory of Monetary Policy," Princeton: Princeton University Press.

[49] **Woodford, Michael** (2005), "Firm-Specific Capital and the New-Keynesian Phillips Curve," *International Journal of Central Banking* Vol.1, No.2, Jan., pp.1-46.

[50] **Yun, Tack** (1996), "Nominal Price Rigidity, Money Supply Endogeneity, and Business Cycles," *Journal of Monetary Economics*, 37(2), pp.345-370.