

# Capital Pledgeability, Inflation and Unemployment\*

Chao Gu<sup>†</sup>                      Janet Hua Jiang<sup>‡</sup>  
University of Missouri      Bank of Canada

Liang Wang<sup>§</sup>  
University of Hawaii Manoa

October 13, 2019

## Abstract

We study the effects of firm's credit condition on (1) labor market performance and (2) the inflation and unemployment relationship, in a new monetarist model. Better credit condition has positive impact on labor market as firms save on financing cost, improve profitability, and thus create more vacancies. Inflation increases the financing cost and thus discourages job creation. On the other hand, inflation lowers wage as employed workers carry a lower real balance compared to the unemployed ones. This encourages job creation. The overall effect depends crucially on the credit condition. We show by examples that the Phillips curve can be upward or downward sloping, depending on the credit condition.

JEL Classification Nos: E24, E31, E44, E51.

Keywords: Money, credit, limited commitment, phillips curve, pledgeability.

---

\*For input we thank seminar participants at the St. Louis Fed Summer Workshop on Money, Banking, Payments and Finance, Conference on Market Frictions and Macroeconomics, Peking University, Bank of Canada Summer Workshop on Money, Banking and Finance for their inputs. We thank Benoit Julien for discussing our paper at 2015 Workshop of the Australasian Macroeconomic Society (WAMS) joint with the Laboratory for Aggregate Economic and Finance (LAEF). The views expressed in the paper are those of the authors. No responsibility for them should be attributed to the Bank of Canada.

<sup>†</sup>guc@missouri.edu

<sup>‡</sup>jjjiang@bankofcanada.ca

<sup>§</sup>lwang2@hawaii.edu

# 1 Introduction

Money and credit are two major forms of liquidity in the economy. Understanding their relationship and its impact on the macroeconomic performance are essential for policy design and implementation. In this paper, we build a model in which money and credit are competing means of payment to study the impact of credit condition and the effectiveness of monetary policy on aggregate output and labor market performance.

Figure 1 plots the U.S. unemployment rate and financial condition, measured by the Saint Louis Fed financial stress index, between 1994 and 2019. The higher the index, the more stressful the financial market is. It is obvious that unemployment and financial condition are positively correlated, especially in the recent business cycle. The empiric evidence on the tradeoff between inflation and unemployment in the U.S. and in other countries is mixed.<sup>1</sup> To try to understand how credit condition may affects the Phillips curve, we plot the detrended unemployment rate and GDP growth rate in Figure 2. The Phillips curve is positively sloped before 2003 with financial stress index being positive and negatively sloped after that with the index being negative except during the recent financial crisis. This suggests that the financial condition may matter for labor market performance and the slope of the Phillips curve. To investigate the evidence of the impact of financial condition on the Phillips curve, we run a simple regression between the slope of the Phillips curve and the financial development index compiled by IMF. The correlation is (significantly?) negative, which suggests the similar result using the time serie data in the U.S..

As is well-known in the literature, money has no role in the economy if credit is perfect (Kocherlakota 1998). The major friction in the model economy is limited

---

<sup>1</sup>For example, King and Watson (1994) show that inflation and unemployment exhibit strong negative correlation in the long-run data during 1954-1969, but no consistent pattern for the period of 1970-1987. However, Berentsen et al. (2011) show that inflation and unemployment are strongly positively correlated using the long run data from 1955-2005. Across countries, the relationship is positive in Spanish data from 1970-1977 and is reversed from 1977-1994 (Dolado and Jimeno 1997); it is negative in German data from 1977-2002 (Schreiber and Wolters 2007); the inflation expectation and unemployment are negatively correlated in Italian data from 2012-2018 (Coibion et al. 2019).

commitment. Since firms cannot commit to pay workers after selling their products, workers demand wage payments on the spot. In order to pay their wage bills, firms must hold cash and/or pledge their capital to acquire secured credit. The pledgeability of firm's capital is the credit condition considered in this paper.<sup>2</sup> The limited commitment friction also applies to the workers, who must finalize their purchase of goods on the spot. As our focus is to explore to what extent producer's credit affects the economy, we do not model consumer's credit.<sup>3</sup>

We follow Berentsen et al. (2011) to combine Mortensen-Pissaridize (1994) type of labor market with the Lagos-Wright (2005) type of goods market. Our findings are as follows. Given a monetary policy, firm's credit condition has a positive effect on labor market performance. This is intuitive. If firm's capital is more pledgeable, less cash is needed to finance the wage bill. Thus the firm can save on the inflation cost. Moreover, when the pledgeability is low, firms over accumulate capital to obtain more credit so the productivity of capital is low. Better credit condition thus improves the production efficiency, encourages more firms to enter, and lowers the unemployment rate. This result is consistent with the empiric evidence. For example, Acemoglu (2001) shows that the new firm's difficulty in accessing loans restricts job creation.

Given the credit condition, the monetary policy affects the economy in two opposite channels. First, inflation increases the cost of holding cash. This is bad for both firms and workers. Higher wage financing cost reduces firm's profit. Moreover, workers reduce their cash holding and purchase few goods, which further reduces firm's profit. So through this channel, inflation has a negative effect on job creation. We call this channel cash-financing channel. Second, as employed workers have access to more steady income and carry a lower real balance than their unemployed

---

<sup>2</sup>This follows the vast literature following Kiyotaki and Moore (1997). Buera and Moll (2015) and Buera et al. (2015), among others, study the effect of credit condition on the labor market in a heterogeneous agent model.

<sup>3</sup>Among others, Bethune et al. (2014) studies the relationship between the availability of unsecured credit to households and unemployment in a model based on Berentsen et al (2011) and endogenize the credit limit. They show that the availability of consumer credit reduces long-run unemployment. Herkenhoff (2017) shows that the access to consumer credit prolongs recessions, but it enhances welfare by reducing consumption volatility and improving job-match quality.

counterparts, inflation hurts unemployed workers more than employed workers. This induces workers to accept a lower wage when inflation is high, and encourages job creation. This is consistent with the empiric result by Cardoso (1992), Braumann (2004), Sanchez (2015) that higher inflation lower real wage growth even decrease the real wage. We call the second channel the wage bargaining channel. The overall effect of inflation on unemployment depends critically on the credit condition. When credit is abundant, firms do not need cash to finance their wage bill. Inflation decreases unemployment as the cash-financing channel shuts down. However, when credit is scarce, the effect is ambiguous, depending on which channel is dominant. By way of examples, we show the Philips curve can be U-shaped if credit is scarce but not too scarce.

Our model suggests that the effectiveness of monetary policy to achieve employment and output target depends on the financial condition. We calibrate the model to the U.S. data. The result is that there is a weak tradeoff between unemployment and inflation given the current firm's financial condition. If the inflation increases from 0 to 10%, the unemployment rate will be lowered by about 0.3% and output will increases by 5.8%, whereas real wage will drop by 6.3% (How much can we explain the data?) On the other hand, raising the pledgeability of capital by () can lower the unemployment by ().

Although our model applies the best to the economy in the long run, it sheds some light on the experience during the Great Recession. Christiano et al. (2015) show that the major shock to cause the bulks of movements in aggregate economic activity during the Great Recession was the financial friction that caused the rise in the cost of the working capital. We show that the calibrated U.S. Phillips curve becomes flat when the pledgeability goes down. This is consistent with the observation that the conventional monetary policy seemed to be ineffective during the Great Recession.

The paper is organized as follows. Section 2 sets up the baseline model. Section 3 solves the general equilibrium. Section 4 extends the model to include search friction in the goods market. Section 7 calibrates the model. Section 6 concludes.

## 2 The model

The environment is based on Berentsen et al. (2011), which introduces labor search friction in the spirit of Mortensen and Pissarides (1994) to Lagos and Wright (2005) monetary model. Time is discrete and infinite. In each period, three markets open sequentially. First a labor market (LM), followed by a decentralized goods market (DM) and finally a centralized goods market (CM). The CM is frictionless. LM and DM are with frictions detailed below.

There are two types of agents, workers and firms. Workers are endowed with one unit of labor. Firms are endowed with a production technology that transforms capital and one unit of labor into consumption good valued in the CM according to the production function  $f(k)$ , where  $f' > 0$ ,  $f'' < 0$  and  $f(0) = 0$ . The set of the workers is  $[0, 1]$ . The set of the firms is arbitrary large. But not all firms are active at any point of time.

Firms without workers meet with unemployed workers bilaterally in the LM after paying a cost to post the vacancies. Labor is indivisible and each firm can hire at most one worker. An employed worker separates from his job with probability  $s$  at the end of the LM, after he produces. An unemployed worker matches with a firm posting vacancy according to a matching function  $\mathcal{M}(u, v)$ , where  $u$  is the measure of unemployed worker and  $v$  is the measure of firms that post vacancies. The matching function is increasing, concave, twice differentiable, and homogeneous of degree 1. The labor market tightness is defined as  $\tau = v/u$ . Firms cannot commit to pay workers after they sell the products, and there is no monitoring device for any unsecured credit extended in the LM. So firms must use some payment instruments, say money or credit secured by capital, to pay workers in the LM.<sup>4</sup>

Firms can transform goods by a linear cost function and sell goods in the DM. Assume the marginal cost to be  $c$ . The DM is also subject to commitment problem in

---

<sup>4</sup>Although there is no monitoring device, the worker can punish the firm by quitting the job. So some unsecured credit in the spirit of Kehoe and Levin (1993) is feasible between the worker and the firm. For simplicity, we assume such unsecured credit cannot be used. Alternatively, we can assume that the pledgeability of capital to be larger than 1. So some of the wage payments is received in the CM, which is equivalent to unsecured credit.

the sense that the workers cannot commit to pay back any unsecured credit extended by the firms. So workers need some payment instrument, say cash and/or wage income to make transactions in the DM. In the CM, firms sell any unsold goods, and all agents adjust their money and capital holdings. Worker's instantaneous utility is  $x + (1 - j)\ell + \nu(q)$ , where  $x$  is the consumption of the CM good,  $\ell$  is leisure,  $j$  indicates one's labor status, with  $j = 0$  as being unemployed and  $j = 1$  as being employed,  $q$  is the consumption of DM good. Assume  $\nu' > 0$ ,  $\nu'' < 0$  and  $\nu(0) = 0$ . If  $x < 0$ , workers produce in the CM. Goods are not storable.

Agents discount between periods by  $\beta$ . Money supply grows at rate  $\pi$ . Changes in  $M$  are accomplished by lump-sum transfers if  $\pi > 0$  and lump-sum taxes if  $\pi < 0$ . The attention is restricted to  $\pi > \beta - 1$ , or the limit  $\pi \rightarrow \beta - 1$ ; there is no monetary equilibrium with  $\pi < \beta - 1$ .

## 2.1 Worker's problem

We solve the model by working backward. Let  $U_j$ ,  $V_j$ , and  $W_j$ ,  $j = 0, 1$ , denote the worker's value function in the LM, DM, and CM, respectively. For simplicity, we assume there is no capital market and the workers do not carry capital. Later we will show this assumption is innocuous.<sup>5</sup> A worker of type  $j$  entering the CM with real balance  $z$  and unspent labor income  $\omega$  solves the following problem at the beginning of the CM.

$$\begin{aligned} W_j(z, \omega) &= \max_{x, \hat{z}_j} [x + (1 - j)\ell + \beta U_j(\hat{z}_j)] \\ \text{st } x + (1 + \pi)\hat{z}_j + T &= z + \omega + (1 - j)b + \Delta \end{aligned}$$

where  $x$  is the consumption of the CM goods,  $\ell$  is utility of leisure,  $T$  is the lump sum tax (it is a transfer if negative),  $\Delta$  is dividend income,  $b$  is the unemployment benefits,  $\pi$  is the inflation rate, and  $\hat{z}_j$  is the real balance valued in the next period. As we focus on steady state, the inflation rate is the same as money growth rate. Note that workers may choose different amount of money according to their labor

---

<sup>5</sup>The equilibrium capital price includes its liquidity value and is above (or at least equal to) its marginal product. Capital is too expensive to hold for the workers because they do not use capital for transaction.

status as the employed workers anticipate labor income in the LM. The first-order condition wrt  $\hat{z}_j$  is

$$-(1 + \pi) + \beta U'_j(\hat{z}_j) \leq 0,$$

where the equality is strict iff  $\hat{z}_j > 0$ . The envelope conditions are  $\partial W_j / \partial z = \partial W_j / \partial \omega = 1$ , which implies  $W_j$  is linear in  $z + \omega$ .

In the LM, an employed worker receives wage  $w$ , which is determined bilaterally by the firm and the worker upon hiring. An employed worker keeps the job with probability  $s$  and gets separated from the job with probability  $1 - s$ . The value function of an employed worker thus is

$$U_1(\hat{z}_1) = (1 - s) V_1(\hat{z}_1, w) + s V_0(\hat{z}_1, w)$$

It follows that  $U'_1(\hat{z}_1) = (1 - s) \partial V_1 / \partial \hat{z}_1 + s \partial V_0 / \partial \hat{z}_1$ . Similarly, An unemployed worker matches with a firm with probability  $\lambda_h$ . His value function is

$$U_0(\hat{z}_0) = \lambda_h V_1(\hat{z}_0, 0) + (1 - \lambda_h) V_0(\hat{z}_0, 0)$$

and  $U'_0(\hat{z}_0) = \lambda_h \partial V_1 / \partial \hat{z}_0 + (1 - \lambda_h) \partial V_0 / \partial \hat{z}_0$ .

Workers can use cash earned in the previous CM and wage income in the previous DM to pay for the goods in the DM.<sup>6</sup> DM is a Walrasian market. As a result of competition, the price of the DM good is  $c$ .

$$\begin{aligned} V_j(\hat{z}_j, \omega) &= \max_{q, z', \omega'} [\nu(q) + W_j(\hat{z}_j - z', \omega - \omega')] \\ \text{st } cq &= z' + \omega', \quad z' \leq \hat{z}_j, \quad \omega' \leq \omega \end{aligned}$$

where  $z'$  and  $\omega'$  are the transfer of real balance and wage income to the sellers,  $\omega = w$  if the worker is employed, and  $\omega = 0$  if not. By the linearity of  $W_j$ , we can write the DM value function as

$$V_j(\hat{z}_j, \omega) = \max_q [\nu(q) - cq + W_j(\hat{z}_j, \omega)] \quad \text{st } cq \leq \hat{z}_j + \omega$$

---

<sup>6</sup>To ease the model, we assume workers cannot use capital as means of payments as in Aruoba et al. (2011). The underlying friction is that workers cannot bring physical capital to the goods market and they can counterfeit certificate of the capital costlessly. On the contrary, we allow the firms to use capital to pay for the workers as firm's certificate of capital cannot be counterfeited and is recognized everywhere.

Let  $q^*$  solve  $v'(q^*) = c$ . The FOC wrt  $q$  is  $q = q^*$ , if  $\hat{z}_j + \omega \geq cq^*$  and  $q = (\hat{z}_j + \omega)/c$  otherwise. The derivative  $\partial V_j / \partial \hat{z}_j = 1$  if  $\hat{z}_j + \omega \geq cq^*$  and  $\partial V_j / \partial \hat{z}_j = v'(q)/c$  otherwise.

Combining the first-order conditions and the envelope conditions, we get the following solution to an employed worker's problem:

$$\begin{aligned} q_1 &= q_i & \text{and } \hat{z}_1 &= cq_i - w, & \text{if } w < cq_i \\ q_1 &= w/c & \text{and } \hat{z}_1 &= 0, & \text{if } cq_i \leq w < cq^* \\ q_1 &= q^* & \text{and } \hat{z}_1 &= 0, & \text{if } w \geq cq^* \end{aligned} \quad (1)$$

where  $q_i$  solves  $\nu'(q_i) = (1+i)c$  and  $i = (1+\pi)/\beta - 1$  is the nominal interest rate by Fisher equation. Note that  $q_i$  is decreasing in  $i$  and independent of  $w$  as cash matters at the margin. If  $w$  is higher than  $cq^*$ , employed workers is not liquidity constrained as  $w$  is sufficient to pay for optimal  $q$ . When  $w \in [cq_i, cq^*)$  employed workers are liquidity constrained. However, since acquiring money is too costly compared with the marginal benefit, they do not demand money.

For unemployed workers, we have

$$q_0 = q_i \text{ and } \hat{z}_0 = cq_i \quad (2)$$

Since the unemployed workers are more liquidity constrained, their consumption and DM trade surplus,  $v(q) - cq$ , is (weakly) lower than that of the employed.

Simplify the value functions to get the following in steady state.

$$W_1(0,0) = -T + \beta \{w - iz_1 + \nu(q_1) - cq_1 + (1-s)W_1(0,0) + sW_0(0,0)\} \quad (3)$$

and

$$W_0(0,0) = -T + b + \ell + \beta \{\nu(q_i) - (1+i)cq_i + \lambda_h W_1(0,0) + (1-\lambda_h)W_0(0,0)\} \quad (4)$$

Subtract (4) from (3) to get the surplus of a worker in a match with a firm. Let  $S_h \equiv W_1(0,0) - W_0(0,0)$ ,

$$S_h = \frac{-(b+\ell) + \beta \{w + [\nu(q_1) - cq_1 - iz_1] - [\nu(q_i) - (1+i)cq_i]\}}{1 - \beta(1-s-\lambda_h)} \quad (5)$$



Being employed has three advantages: employed workers earn more, get more trade surplus in the DM as they are less liquidity constrained and they save on the inflation cost by holding less cash across time. Given  $w$ , the difference in the value given by (5) increases with  $i$  as the unemployed worker's trade surplus decreases in  $i$  and the inflation cost is higher.

## 2.2 Firm's problem

We turn to firm's problem in this section. Let  $\tilde{W}_j$ ,  $\tilde{U}_j$  and  $\tilde{V}_j$  denote the value of the firm of type  $j$  at the beginning of CM, LM and DM, respectively, where firms with workers are type 1 and without workers are type 0. A firm enters the CM with output  $y$ , real balance  $z$  and capital  $k$ . It adjusts money and capital holdings. Its expected life-time value is

$$\tilde{W}_j(z, k, y) = y + z + (1 - \delta)K + \max_{\hat{z}, \hat{k}} \left[ - (1 + \pi) \hat{z} - \hat{k} + \beta \tilde{U}_j(\hat{z}, \hat{k}) \right]$$

where  $\delta$  is the capital depreciation rate,  $\hat{z}$  and  $\hat{k}$  are the real balance and capital carried to the next LM, respectively. The FOCs are

$$\begin{aligned} \hat{k} &: -1 + \beta \partial \tilde{U}_j(\hat{z}, \hat{k}) / \partial \hat{k} = 0 \\ \hat{z} &: -(1 + \pi) + \beta \partial \tilde{U}_j(\hat{z}, \hat{k}) / \partial \hat{z} \leq 0 \end{aligned}$$

where the equality is strict iff  $\hat{z} > 0$ . The envelope conditions are  $\partial \tilde{W}_j / \partial z = \partial \tilde{W}_j / \partial y = 1$  and  $\partial \tilde{W}_j / \partial \hat{k} = 1 - \delta$ .

In the LM, a firm with a worker pays wage using money and its own capital as collateral. We can interpret the payment backed by  $k$  as claims on capital. As claims may be counterfeited, the firm can only issue claims on  $\chi$  fraction of capital (see Lester et al. 2012). Alternatively, we can interpret that the firms can pledge capital to receive a secured credit as in Kiyotaki and Moore (1997) from some financial intermediaries, and  $\chi$  is the pledgeability of capital. The firm retains the worker with probability  $1 - s$  and loses the worker with probability  $s$  at the end of LM. Let  $z'$  be the real balance paid to the worker and  $k$  be the capital pledged. Firm's

expected value in the LM is represented by

$$\tilde{U}_1(\hat{z}, \hat{k}) = (1-s)\tilde{V}_1(\hat{z} - z', \hat{k} - k', y) + s\tilde{V}_0(\hat{z} - z', \hat{k} - k', y)$$

where  $w = z' + (1-\delta)k' \leq \hat{z} + (1-\delta)\chi\hat{k}$  and  $y = f(\hat{k})$ . The envelope conditions are  $\partial\tilde{U}_1/\partial\hat{z} = (1-s)\partial\tilde{V}_1/\partial\hat{z} + s\partial\tilde{V}_0/\partial\hat{z}$  and  $\partial\tilde{U}_1/\partial\hat{k} = (1-s)\partial\tilde{V}_1/\partial\hat{k} + s\partial\tilde{V}_0/\partial\hat{k}$ .

For a firm without a worker, carrying money or capital is useless. Therefore, its money and capital holdings are zero. The firm has probability  $\lambda_f$  to meet with an unemployed worker if it pay a cost  $\kappa$  to post the vacancy. It does not produce in the current period and does not participate in the following DM. Its expected value is

$$\tilde{U}_0 = -\kappa + \lambda_f\tilde{W}_1(0, 0, 0) + (1-\lambda_f)\tilde{W}_0(0, 0, 0)$$

In the DM, firms transform some of their products to DM goods by a linear cost function. Since DM is competitive, firms do not make profits in the DM. By the linearity of  $\tilde{W}$ , producing firm's DM value is

$$\tilde{V}_j(\hat{z}, \hat{k}, y) = \tilde{W}_j(\hat{z}, \hat{k}, y)$$

Let  $k^*$  solve  $f'(k^*) = r^*$ , where  $r^* = 1/\beta - 1 + \delta$  and  $k_i$  solve  $f'(k_i) = r^* - i\chi(1-\delta)$ . By concavity of  $f$ ,  $k_i > k^*$ . Also note that  $k_i$  is increasing in  $i$ . Combining the first-order conditions and the envelope conditions, we get the solution to the firm's problem is in one of the three regimes:

$$\begin{aligned} \text{Regime 1: } & \hat{k} = k^* & \text{and } \hat{z} = 0, & \text{if } w < \chi(1-\delta)k^* \\ \text{Regime 2: } & \hat{k} = w/\chi(1-\delta) & \text{and } \hat{z} = 0, & \text{if } \chi(1-\delta)k^* \leq w < \chi(1-\delta)k_i \\ \text{Regime 3: } & \hat{k} = k_i & \text{and } \hat{z} = w - \chi(1-\delta)k_i, & \text{if } w \geq \chi(1-\delta)k_i \end{aligned} \tag{6}$$

In regime 1, firm's capital is sufficient to pay the worker. The capital accumulation is at its first best. In regime 2, the liquidity constraint is tight. The firms accumulate more capital to use as payments but they do not use money. In regime 3, the liquidity constraint is tighter and the firms use capital and money to pay workers. In regimes 2 and 3, capital is over accumulated.

Note that  $k$  is not monotone in  $\chi$  in the entire range. As  $\chi$  increases from 0, capital per firm first increases from  $k^*$  (regime 3), then decreases (in regime 2),

and finally becomes constant at  $k^*$ . When  $\chi$  increases from 0, firms start to over accumulate capital for its liquidity function and capital increases as it can save more on cash. As  $\chi$  increases further, the economy moves to regime 2 in which firms no longer need money to pledge for wage. Firms start to dump some of their capital as the marginal cost of over accumulated capital is too much. As  $\chi$  increases even further, the economy moves to regime 1. The efficient level of capital alone is sufficient enough to pay the workers and firms do not need to over accumulate capital.

Notice that the capital market will be inactive even if we allow for such a market. Since workers or inactive firms do not use capital, they lend iff  $r = r^* \equiv 1/\beta - 1 + \delta$ . As active firms can pay only  $r \leq r^*$ , there is no active lending and borrowing in the capital market. At  $r = r^*$ , firms are in regime 1 and are indifferent between borrowing capital from others and self-financing. So without loss of generality, we assume there is no capital market.

By linearity, the value function for producing firms can be written as

$$\begin{aligned} \tilde{W}_1(0, 0, 0) = & \beta \{-iz + f(k) - r^*k - w + \\ & + (1 - s)\tilde{W}_1(0, 0, 0) + s\tilde{W}_0(0, 0, 0)\} \end{aligned} \quad (7)$$

For firms without workers, the expected value is

$$\tilde{W}_0(0, 0, 0) = \beta \left[ -\kappa + \lambda_f \tilde{W}_1(0, 0, 0) + (1 - \lambda_f) \tilde{W}_0(0, 0, 0) \right] \quad (8)$$

Subtract (8) from (7) to get the surplus of a firm in a match in the LM. Let  $S_f = \tilde{W}_1(0, 0, 0) - \tilde{W}_0(0, 0, 0)$ .

$$S_f = \frac{\beta [f(k) - r^*k - w + \kappa - iz]}{1 - \beta(1 - s - \lambda_f)} \quad (9)$$

which is the production surplus of a firm in a match with a worker. The producing firm produces  $f(k)$ , pays  $w$  to the worker, incurs  $r^*k$  as the opportunity cost of holding  $k$ , bears an inflation cost  $iz$  by holding cash and saves on job posting cost  $\kappa$ . Given  $w$ , a producing firm's surplus decreases in  $i$  (check).

Let us turn to wage determination. We assume that the worker and the firm split the production surplus according to Kalai bargaining solution. Let worker have bargaining power  $\rho$ . The surplus of the worker and the firm satisfies:

$$\frac{S_h}{S_f} = \frac{\rho}{1 - \rho} \quad (10)$$

To solve for  $\lambda_f$  and  $\lambda_h$ , we use the zero-profit condition for firm and the law of motion for unemployment. The zero-profit condition requires that  $\tilde{W}_0(0, 0) = 0$ , or

$$\lambda_f = \frac{\kappa(1/\beta - 1 + s)}{f(k) - r^*k - w - iz} \quad (11)$$

As

$$\lambda_f = \mathcal{M}(1/\tau, 1) \quad (12)$$

and

$$\lambda_h = \mathcal{M}(1, \tau) \quad (13)$$

From (12) and (13),  $d\lambda_f/d\lambda_h < 0$  and  $\lambda_h$  is well defined as a function of  $w$  and  $k$ .

The law of motion for unemployment is  $u_{t+1} = u_t(1 - \lambda_h) + (1 - u_t)s$ . In steady state, the measure of unemployed workers remains constant, which results in

$$u = \frac{s}{\lambda_h + s} \quad (14)$$

It follows that  $du/d\lambda_h < 0$ .

## 2.3 Government policy

The government consumes  $G$ , pays  $b$  to unemployed workers, levy tax,  $T$  and receives seigniorage  $\pi z$ . The government runs a balanced budget so  $G + bu = T + \pi z$  in each period. In steady state, targeting nominal interest rate is equivalent to targeting money growth rate.

## 3 Equilibrium

A stationary equilibrium a list of  $(w, k, z, z_1, z_0, q_1, q_0, \lambda_f, \lambda_h, \tau)$  that solves (1), (2), (6) and (10)-(13). Plug (12) and (13) into (10) and (11). The steady state can be

characterized by a pair of  $(w, \tau)$  that solves

$$\frac{-(b + \ell) / \beta + w + \nu(q_1) - cq_1 - iz_1 - \nu(q_i) + (1 + i) cq_i}{f(k) - r^*k - w - iz + \kappa} \frac{1/\beta - 1 + s + \mathcal{M}(1/\tau, 1)}{1/\beta - 1 + s + \mathcal{M}(1, \tau)} = \frac{\rho}{1 - \rho} \quad (15)$$

and

$$\frac{\kappa(1/\beta - 1 + s)}{f(k) - r^*k - w - iz} = \mathcal{M}(1/\tau, 1) \quad (16)$$

where  $k, q_1, z_1$  and  $z$  are functions of  $w$  and described in (1) and (6). Equation (15) implies  $w = h_1(\tau)$ , where  $h'_1 > 0$ , and equation (16) implies that  $w = h_2(\tau)$ , where  $h'_2 < 0$ . We first show that the equilibrium exists if the entry cost is not too big.

**Proposition 1** *There exists a  $\hat{\kappa}$  such that if  $\kappa < \hat{\kappa}$ , there exists a unique equilibrium.*

**Proof.** Let  $\kappa \rightarrow 0$ . We have  $h_2(0) > h_1(0) > 0$  and  $h_2(\infty) = -\infty$ . So there exists a positive steady state if  $\kappa \rightarrow 0$ . With an increase in  $\kappa$ ,  $h_1$  shifts up and  $h_2$  shifts down. When  $\kappa \rightarrow \infty$ , there does not exist a positive  $w$  that solves (16). Therefore, there exists a cutoff  $\hat{\kappa}$  below which there exists a unique steady state and above which there does not exist a steady state. ■

The equilibrium  $(w^*, \tau^*)$  is shown in Figure 4. When  $\kappa$  increases,  $h_1$  shifts up and  $h_2$  shifts down as shown in red curves. For  $\kappa$  large enough,  $h_2$  will start below  $h_1$  and the steady state does not exist.

The existence result is standard in the literature. Regarding the effects of capital pledgeability, we provide the following proposition.

**Proposition 2** *If the economy is in regime 1, increasing in  $\chi$  does not change the equilibrium. If the economy is in regimes 2 or 3, increasing in  $\chi$  raises  $w$  and  $\tau$  and lowers  $u$ .*

**Proof.** If the economy is in regime 1,  $k = k^*$  and increasing  $\chi$  does not change equations (15) and (16). Therefore, the equilibrium allocation is not affected. If the economy is in regime 2,  $k = w / [\chi(1 - \delta)]$  and  $z^f = 0$ . The denominator of the LHS of (16) is increasing in  $\chi$ . So is for (15).  $f(k) - r^*k$  or 3, increasing  $\chi$  increases  $k$ . Both  $h_1$

and  $h_2$  rotate up at  $w = \chi(1 - \delta)k^*$ . So the equilibrium  $w$  is higher. To see that  $\tau$  is higher, Plug (16) into (15) to get

$$\frac{-(b + \ell)/\beta + w + \nu(q_1) - cq_1 - iz_1 - \nu(q_i) + (1 + i)cq_i}{\kappa} \frac{\mathcal{M}(1/\tau, 1)}{1/\beta - 1 + s + \mathcal{M}(1, \tau)} = \frac{\rho}{1 - \rho}$$

It follows that an increase in  $w$  results in a higher  $\tau$ . By (14),  $u$  is decreased. ■

Figures 5a and 5b depict the effect on  $w$  and  $\tau$  after  $\chi$  increases. Both curves rotate up around  $\chi(1 - \delta)k^*$ . In Figure 5a, pledgeable capital can pay for equilibrium  $w$ . The equilibrium  $w$  does not change after  $\chi$  rises. Figure 5b shows the opposite case in which both  $w$  and  $\tau$  increase.

Given  $w$ , a change in  $\chi$  do not affect worker's surplus. It increases firm's surplus in regime 3 as capital can save more cash; it increases firm's surplus in regime 2 as the firm dumps over accumulated capital and improves efficiency. Therefore, the total surplus increases and  $w$  has to increase to rebalance the shares of surplus. As higher pledgeability improves firm's efficiency in regimes 2 and 3, firms are more profitable and are more willing to enter the labor market, which results in higher  $\tau$  and lower  $u$ . In regime 1, firm's liquidity constraint does not bind. An increases in pledgeability does not affect firm's surplus, and the equilibrium remains unchanged.

In all our examples, we use the utility function  $\nu(q) = A_v q^\alpha$ , production function  $F(K, L) = A_f K^\theta L^{1-\theta}$  and LM matching function  $\mathcal{M}(u, v) = A_m u^\iota v^{1-\iota}$ .

**Example 1** Let  $A_v = 1.5, \alpha = 0.6, A_f = 1, \theta = 0.3, A_m = 0.35$  and  $\iota = 0.7$ . Other parameters are  $\beta = 0.96, i = 0.05, b = \ell = 0, c = 1, \delta = 0.15, \kappa = 0.05, s = 0.05$ , and  $\rho = 0.7$ . Figure 6 shows the equilibrium variables when  $\chi$  increases from 0 to 1. The economy switches regimes where the kinks present. As  $\chi$  increases, the economy moves from Regime 3 to 2 and to 1,  $w, \tau$ , and  $u$  move in the way that Proposition 2 states. Capital increases in Regime 3 as  $k_i$  increases in  $i$ . It decreases in Regime 2 because capital can be pledged for more credit than the increase in wage. It stays at  $k^*$  in Regime 1 as capital is plenty. In this example, since more firms are operating in Regimes 3 and 2, DM output increases in  $\chi$ . LM output moves with  $k$  as the output per firm has the first-order effect here. Cash/asset ratio decreases mainly because less cash is needed when capital can be pledged for more credit.

The higher pledgeability can be due to the improvement in the technology to verify the genuineness of the asset, or due to the enhanced enforcement of debt repayment. This advancement diminishes the liquidity friction on the firm's side and improves the allocation unambiguously. On the contrary, the effect of  $i$  on the economy is not clear. However, we can state the following:

**Proposition 3** *As  $i$  increases,  $w$  decreases. If the economy is in regime 1 or 2,  $u$  increases in  $i$ .*

**Proof.** In the economy is in regime 3, both  $h_1$  and  $h_2$  shift down as  $i$  increases. Therefore, the equilibrium  $w$  is lower (though the effect on  $\tau$  is ambiguous). If the economy is in regime 1 or 2 and  $i$  increases,  $h_1$  shifts down but  $h_2$  stays the same. Therefore,  $w$  and  $\tau$  are lower. Consequently  $u$  is higher. ■

As  $w$  decreases with  $i$ , the economy transitions between regimes. It is easy to show that

**Corollary 1** *As  $i$  increases, the economy moves from higher regimes to lower regimes.*

The intuition behind Proposition 3 and its corollary is as follows. Given  $w$ , being unemployed becomes a worse option with higher  $i$  as unemployed workers have to acquire all the cash in the CM and bear the higher inflation cost. An employed worker's surplus in LM increases as the threat point of the worker is lowered in wage bargaining. Given  $w$ , a producing firm in regime 3 is worse off with higher  $i$  because it has to bear higher inflation tax by acquiring cash to pay the worker in the CM. A producing firm in regime 1 or 2 is not affected, though. To maintain a constant share of the total surplus,  $w$  has to fall.

The ex-ante cost of wage can change in either direction in regime 3. As  $i$  goes up, the firm pays more inflation cost but the worker's threat point falls. So the change in total surplus is ambiguous and the direction of  $u$  depends on the parameters. Since the output per producing firm is constant, total output moves in the opposite direction to the unemployment.

An increase in  $i$  increases output in regime 1. Though each producing firm produces the same quantity, more firms are operating. In regimes 3 and 2, the effect is ambiguous. In regime 3, firms accumulate more capital as  $i$  increases, so unit output increases. But the measure of producing firms can change in either way. In regime 2, unit output decreases as  $k$  decreases, but more firms are producing.

We give a series of numeric examples to show how the equilibrium changes in response to changes in  $i$ .

**Example 2** Continue with Example 1. Figure 7a is drawn for  $\chi = 0$ . In this example,  $k = k^*$  for all  $i$  and  $u$  increases in  $i$ . As the increase in inflation outweighs the saving on wage, fewer firms post vacancies and the unemployment rate goes up. Output in the LM and DM drops since the cash-financing channel is the only channel operating in this special case.

In Figures 7b-7d, let  $\chi = 0.02, 0.05$ , and  $0.2$ , respectively. The economy is in Regime 3 for these values of pledgeability,  $k$  is strictly increasing and  $w$  is strictly decreasing in  $i$  as stated in Proposition 3. The wage-bargaining channel and cash-financing channel both are operating. It is hard to say in general what happens to macro variables. In these examples, unemployment is strictly increasing at low  $\chi$ , becomes non monotone as  $\chi$  gets bigger, and is strictly decreasing. DM output is strictly decreasing, whereas CM output exhibits different patterns corresponding to different  $\chi$ . In Figure 7e, let  $\chi = 0.4$ . The economy is in regime 3 for low inflation and switches to regime 2 for high inflation. Unemployment decreases with  $i$  in this case.

If we increase  $\chi$  further to  $0.5$  as shown in Figure 7f, the economy stays in Regime 1 for all  $i$ . Wage drops through the wage-bargaining channel, and unemployment decreases.

These examples imply that the Phillips curve is sensitive to credit condition. Under good credit condition, the Phillips curve is upward sloping. Under tight credit condition, the slope of the Phillips curve is ambiguous, depending on the parameters.



## 4 Search in the DM

To compare our results with Berentsen et al. (2011), we consider search friction in the DM. A worker meets a firm with probability  $\sigma_h = \mathcal{N}(1, 1 - u)$  and a firm meets a worker with probability  $\sigma_f = \mathcal{N}(1/1 - u, 1)$ , where  $\mathcal{N}$  is the matching function in the DM. The DM terms of trade are determined by Kalai bargaining, and the worker's bargaining power is  $\psi$ . Let  $g(q) = (1 - \psi)u(q) + \psi c(q)$ , which is the buyer's payment in Kalai bargaining. Worker's DM value function is

$$\begin{aligned} V_j(\hat{z}_j, \omega) &= \max_q \{ \sigma_h [v(q_j) - c(q_j)] + W_j(\hat{z}_j, \omega) \} \\ \text{st } g(q_j) &\leq \hat{z}_j + \omega \end{aligned}$$

Unemployed workers choose  $q_0 = q_i$ , where  $q_i$  solves  $v'(q_i)/g'(q_i) = 1 + i/\sigma_h$ , and  $\hat{z}_0 = g(q_i)$ . For unemployed workers, if  $w \geq g(q^*)$ ,  $q_1 = q^*$  and  $\hat{z}_1 = 0$ . If  $g(q_i) \leq w < g(q^*)$ ,  $q_1 = g^{-1}(w)$  and  $\hat{z}_1 = 0$ . If  $w < g(q_i)$ ,  $q_1 = q_i$  and  $\hat{z}_1 = g(q_i) - w$ . Worker's surplus in the LM is

$$S_h = \frac{-(b + \ell) + \beta \{ w + \sigma_h [v(q_1) - g(q_1)] - iz_1 - \sigma_h [v(q_i) - (1 + i/\sigma_h) g(q_i)] \}}{1 - \beta(1 - s - \lambda_h)} \quad (17)$$

The firm's expected profit in the DM is

$$A \equiv \sigma_f \{ (1 - u)[v(q_1) - c(q_1)] + u[v(q_i) - c(q_i)] \}.$$

Its DM value function is

$$\tilde{V}_j(\hat{z}, \hat{k}, y) = A + \tilde{W}_j(\hat{z}, \hat{k}, y)$$

As in the baseline model, there are three cases regarding firms choice of money and capital. The conditions for each of the cases are the same as in the baseline model. Firm's surplus in the LM is

$$S_f = \frac{\beta [f(k) - r^*k - w + A + \kappa - iz]}{1 - \beta(1 - s - \lambda_f)}$$

The equilibrium  $w$  solves  $S_h/S_f = \rho/(1 - \rho)$ , where

$$\lambda_f = \frac{\kappa [1 - \beta(1 - s)]}{\beta [f(k) - r^*k - w + A - iz]}$$

and  $\lambda_h$  and  $u$  are determined by the LM matching function and steady state condition as in the baseline model. It can be shown that if  $\kappa$  is sufficiently small, equilibrium exists. There is strategic complementarity between firms and workers: If more firms post vacancies, it is easier to find a job and more firms are active. As workers are more likely to find sellers in the DM, they acquire more cash in the CM, which increases the transaction amount in the DM and thus the total surplus. This encourages more firms to enter. There may result in multiple equilibria as in Berentsen et al. (2011).

We redo Examples 1 and 2 using Kalai bargaining in Appendix B. The examples show that the economy exhibits similar pattern although adding search friction in the DM results in some difference in level.

## 5 Quantitative Results

(This section is edited by LW)

We want to confront the model with data and then understand the inflation and unemployment tradeoff implied by the model. The model includes two major aspects of an economy, the monetary side and the labor side. We want to fit the model-generated statistics with key empirical facts in the labor market and the money demand. We consider money demand as defined in Lucas (2000), which is  $L_i = z/Y$ , where  $z$  is the average money demand and  $Y$  is the total GDP over three markets. The formula for all calibration objects are given in the Appendix.

The production function in the LM is  $y = f(k) = A_f k^\theta$ . In the DM, the household's utility function is  $v(q) = A_v q^\alpha$  and the production function is a linear transformation technology,  $q = y/a$ , and  $c(q) = aq$ . The household's utility function in the CM is given by  $u(x) = x + \ell$ . The labor market matching function is given by

$$\mathcal{M}(u, v) = A_m u^\iota v^{1-\iota},$$

We truncate  $\mathcal{M}(u, v)$  to keep probabilities below 1. The DM matching function is

$$\mathcal{N}(1, 1 - u) = A_n \frac{1 - u}{[1 + (1 - u)^{\iota_{DM}}]^{1/\iota_{DM}}}$$

with  $\iota_{DM}$  and  $A_n$  normalized to 1, as in Kiyotaki-Wright (1993).

## 5.1 Data

(This section is edited by LW)

For money demand, we use the best available data in the literature, i.e., the M1 series in Lucas and Nicolini (2015). They adjust M1 for money-market deposit accounts so that their data reflect a stable relationship between money demand and nominal interest rates (3-month T-Bill). Lucas and Nicolini (2015) have a quarterly series from 1984-2016 and an annual series from 1915-2008. Since our model is quarterly, we use their quarterly series to calculate our calibration targets for money demand. The quarterly average money demand is 1.1188 at a quarterly nominal interest rate of 0.0408, and the elasticity of money demand -0.1107 is estimated at  $i = 0.0408$ .

We use the U.S. Census Bureau Annual Retail Trade Report 1992-2008 to get the markup data, since we interpret the DM as the retail sector, standard in the literature. In this dataset, the gross margins of sales range from 1.17 to 1.44. We take the average value at 1.3, implying a markup of 1.39. We also choose an average markup in the overall economy of 1.1, as in Basu and Fernald (1997). Notice that the DM markup of 1.39 together with an overall markup of 1.1 imply that the DM production contributes to 25.64% of the total output in the model.

To specify the labor market tightness, we use the data on Total Unfilled Job Vacancies for the U.S. and Unemployment Level from FRED.<sup>7</sup> We find an average market tightness of 0.50511 for the period of December 2000 to November 2018, although the data series show a lot of fluctuations. Bethune et al (2015) use the Job Openings and Labor Turnover Survey (JOLTS) data from 2000 to 2007 to pin

---

<sup>7</sup>The FRED data about labor market tightness can be found at <https://fredblog.stlouisfed.org/2015/08/labor-market-tightness/>

down labor market tightness. They find that there were 0.523 job openings for every unemployed worker and hence labor market tightness is 0.51.

Finally, we use the annual cash-asset ratio from Compustat to calibrate the parameter for capital pledgeability. Bates, Kahle, and Stulz (2009) show that the average value for the period of 1980 to 2006 is 17.25%.

## 5.2 Calibration

(This section is edited by LW)

When we calibrate the model, some parameters can be directly taken from the data or set to match an individual target, while others have to be jointly chosen. The time period is a quarter and  $\beta$  is calibrated to match the annual real interest rate, which is determined by the nominal interest rate of 4.5% and the inflation rate of 3%. Hence,  $\beta = 0.9964$ . Net money growth rate  $\pi$  is determined by the annual inflation rate. The capital depreciation rate  $\delta$  is set at 0.07 to match the investment-capital ratio as in Aruoba et al. (2011).

The job separation rate is taken from Shimer (2005), based on the employment-to-unemployment rate. The capital pledgeability ratio  $\chi$  is to be calibrated to match the cash-asset ratio. Related to the labor market, we need to specify unemployment insurance benefit  $b$  and the utility of leisure  $\ell$ . Following Nakajima (2012), we set  $b$  to match an average UI replacement rate of 43.5%, i.e.,  $b = 0.435w$ . In Berentsen et al. (2011), this target is 50%. Regarding the value of leisure  $\ell$ , the literature has not reached a consensus on how to calibrate this value. Shimer (2005) sets  $\ell = 0$ . Hagedorn and Manovskii (2008) calibrate  $\ell$  to match  $(b + \ell)/Y = 0.95$ . Hall and Milgrom (2008) set  $(b + \ell)/Y = 0.71$ . We follow Shimer (2005) in the baseline calibration.

In the LM,  $A_f$  is calibrated to match the capital-output ratio as in Aruoba et al. (2011), and another parameter of the production function  $\theta$  is calibrated to match a labor share of 0.707, also following Aruoba et al. (2011). We set the scale parameter of the LM matching function to be one, i.e.,  $A_m = 1$ , and calibrate the matching elasticity  $\iota$  to match the monthly unemployment-to-employment rate,

implying a quarterly rate of 0.8336. While Berentsen et al. (2011) assume the Hosios condition holds and set the worker’s bargaining power to equal to the elasticity of matching function, i.e.,  $\rho = \iota$ , we separate the two parameters and calibrate them independently. We also calibrate the firm’s cost of opening a vacancy  $\kappa$  to match the labor market tightness.

In the DM, we assume price taking mechanism in the baseline model and hence we do not need to calibrate  $\psi$ , since the DM markup is 1. The marginal cost of the firm’s production/transformation technology is normalized to  $a = 1$ . In the extension, we will calibrate  $\psi$  to match the DM markup directly.

For the rest of the parameters, we jointly choose the LM bargaining power  $\rho$  and the CM utility parameters  $A_v$  and  $\alpha$  to match several targets simultaneously, including the average level and the elasticity of money demand, and the DM market share, implied by the average aggregate markup and the DM markup.

### 5.3 Results

(This section is edited by LW)

When we solve the model, we focus on the equilibrium with an overall positive average money balance of households and firms, which is what we observe in the real data. This condition implies that we focus on the case where matched firms always bring money, i.e.,  $z > 0$ , since unmatched firms never bring money to the LM. While on the household side, employed workers may bring zero or positive real balance, since the unemployed always holds cash in the DM. The calibration results are shown in Table 1.

The calibrated money demand is depicted in Figure 10 and the kink in money demand is due to regime change, i.e., when the nominal interest rate is low enough, even employed workers start to hold cash. In Figure 11, we demonstrate the changes of key variables in the economy when we vary  $i$ , under the calibrated parameters. Recall that the calibration exercise focuses on Regime 3, where firms use both credit and cash to pay wage. Hence, both the wage-bargaining and the cash-financing channel are active. We see that as  $i$  increases, unemployment goes down, and we

	Parameter	Target	Value
$\ell$	leisure	zero (Shimer)	0
$s$	job separation	$u = 5.6\%$ (Shimer)	0.0495
$\iota$	LM matching tech	mon. $\lambda_h = 0.45$ (Shimer)	0.7297
$\chi$	$K$ pledgeability	cash-asset ratio 17.25%	0.1398
$\delta$	depreciation	$I/K$ ratio (AWW)	0.07
$\theta$	production	$w/Y = 0.707$ (AWW)	0.1596
$A_f$	production	$K/Y = 2.337$ (AWW)	0.0003
$b$	EI benefit	replacement 43.5% (Nakajima)	0.000024
$\kappa$	entry cost	$\tau = 0.523$	0.00015
$\rho$	worker bargaining	DM market share 25.64%	0.1965
$A_v$	DM utility	average MD 1.12	0.2007
$\alpha$	DM utility	MD elasticity $-0.11$	0.8082

Table 1: All Parameters

have a downward sloping Phillips curve under the baseline calibration. The effect of the wage-bargaining channel is stronger. We also notice that as  $i$  increases, both capital investment and the output in the LM are increasing, and hence firm's profit increases. The reason behind a lower unemployment rate is due to the extensive margin, i.e., more vacancies are created, as one can observe from the rise of  $\tau$ . As the cost of holding money increases, employed workers first stop to carry cash and use wage income to pay for their DM consumption. This explains the kink in the aggregate money demand function.

We then turn to Figure 12 to show the effect of changing the capital pledgeability. First, we can clearly see that firms change the approach to finance their wage bills, as the regime change discussed in Section 2.2. When  $\chi$  is low, the firm's ability to use capital as collateral to pay for wage is weak, and so they have to hold cash. The amount of firm's cash holding slowly decreases as  $\chi$  increases. In this regime, the firm also has the incentive to invest more in capital. Hence, the LM output increases, so do profit and wage. Firms create more vacancies and unemployment rate falls. As  $\chi$  keeps increasing, at some point the firm will solely rely on credit against collateralized capital to pay for wage bills. Now firms do not have the incentive to over-accumulate capital for the purpose of wage payment, since capital is now a very valuable collateral, and we observe the investment level falls to the

optimal level and so does the LM output. Since the firm saves on wage-financing cost and the productivity of capital rises, its profit and worker's wage actually increases. Finally, the capital pledgeability is so high that firms invest at the optimal level of capital, which generates enough credit to pay for wage bills.

In Figure 13, we plot the Phillips curves using different values of  $\chi$ . The slope decreases with  $\chi$ . One of the facts during the recent financial crisis is that the unemployment rate did not respond to monetary policy. Our study provides an explanation: As the credit market received a negative shock, the firms faced higher financing cost. It discouraged job creation even if wage-bargaining effect is strong.

## 6 Conclusion

We provide a search theoretical model to study how firm's credit condition affects labor market performance and the effectiveness of the monetary policy on combating unemployment. The improvement in the credit condition reduces unemployment given a monetary policy. However, the slope of the Phillips curve is ambiguous and is sensitive to the credit condition. The findings imply that a combination of expansionary monetary and credit policy may be able to achieve higher employment under some circumstances, but not others.

Obviously, other features of credit, labor and goods markets, such as search frictions, tax and unemployment benefit, etc., can matter for the results. Even though our results cannot match all the empirical evidence, we provide a model to sort out the channels through which capital pledgeability affects the macroeconomic variables. Our future research will focus on the empirical side and establish quantitatively the importance of the capital pledgeability.

# Appendix A – Figures in Sections 1-3

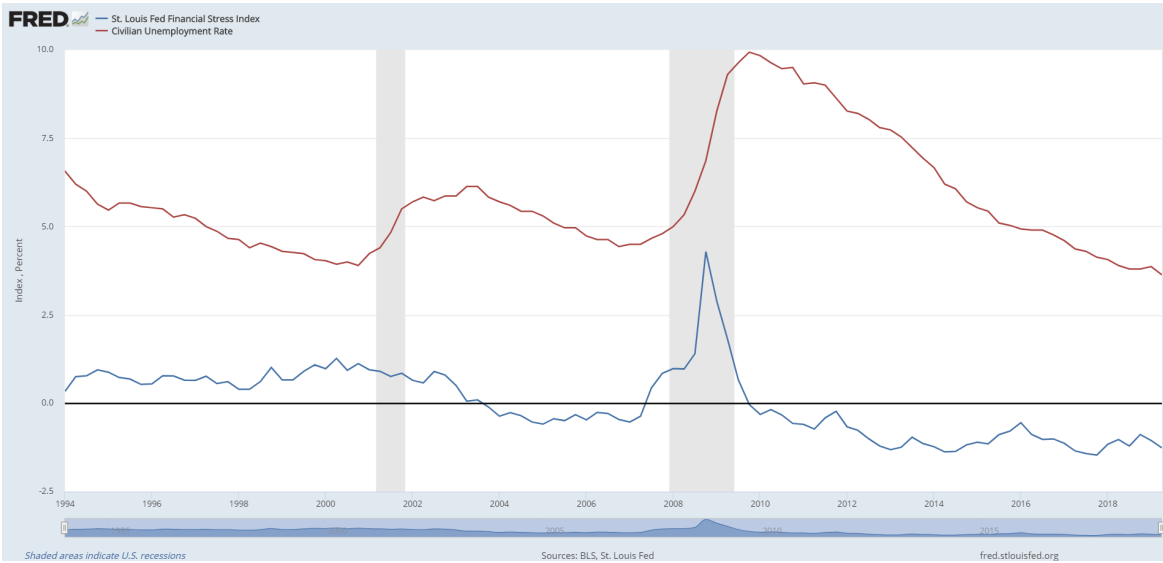


Figure 1: St. Louis Fed Financial Stress Index and Unemployment (FRED)

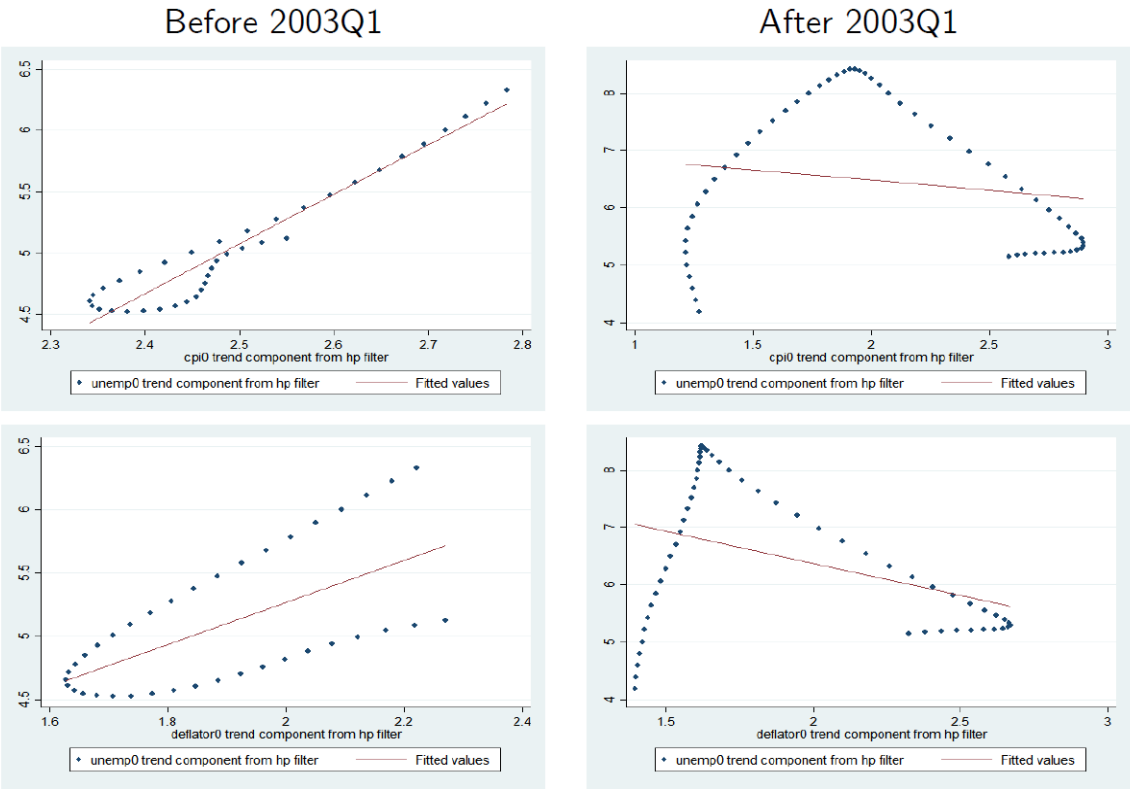


Figure 2: Phillips Curve (upper: CPI; lower: GDP deflator)



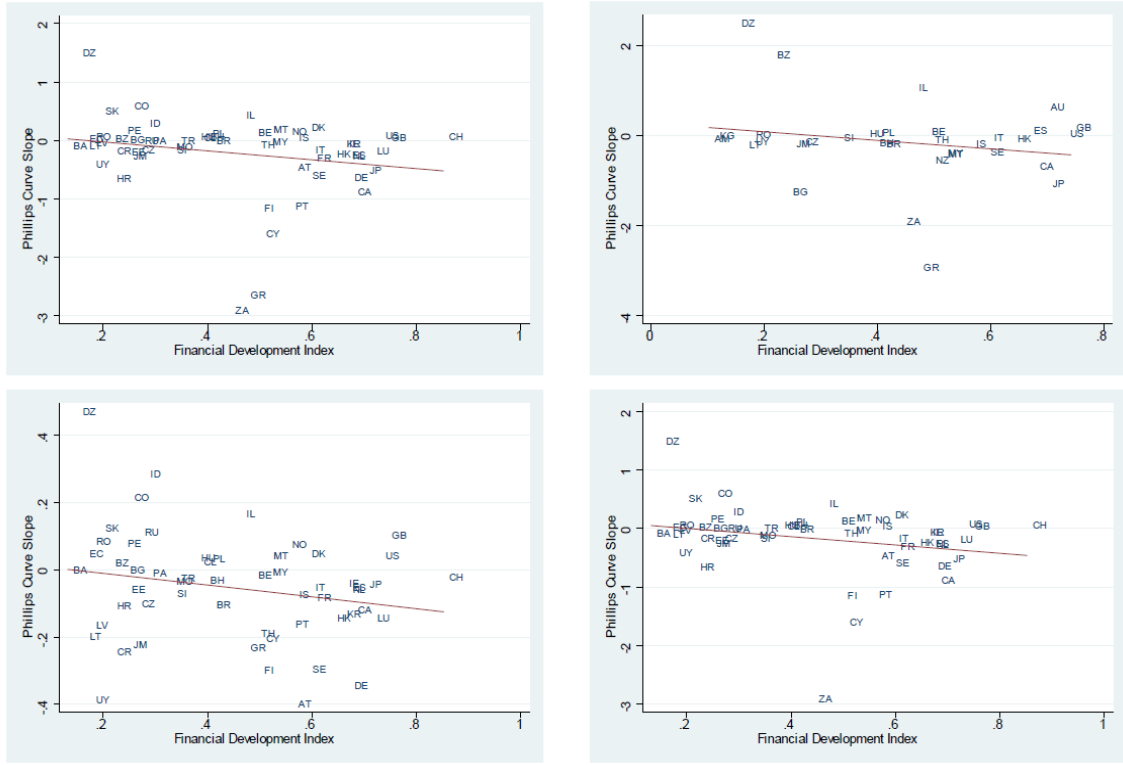


Figure 3: Slope of the Phillips Curve v.s. Financial Development Index

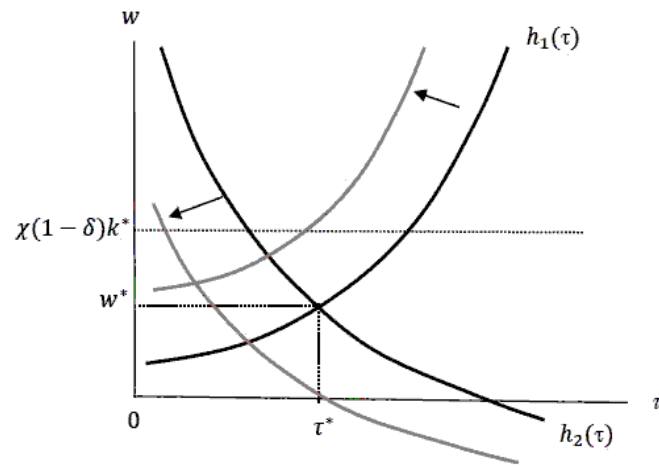


Figure 4: Equilibrium

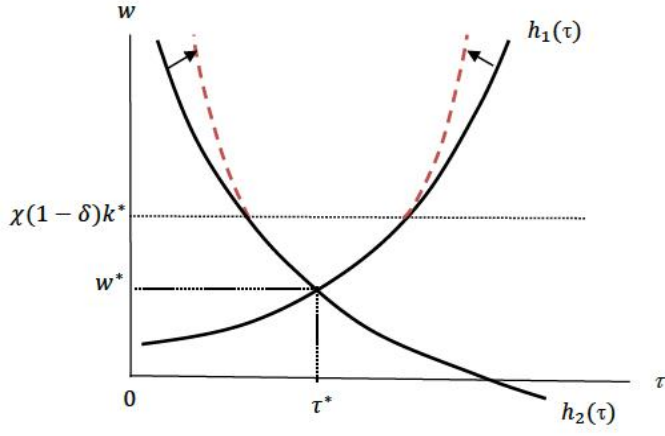


Figure 5a:  $w < \chi(1 - \delta)k^*$

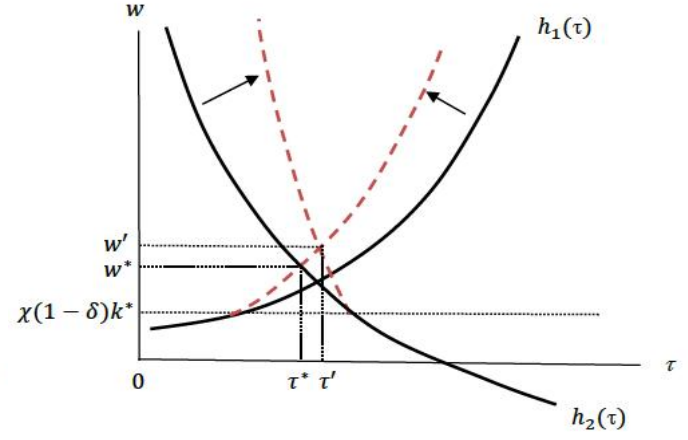


Figure 5b:  $w > \chi(1 - \delta)k^*$

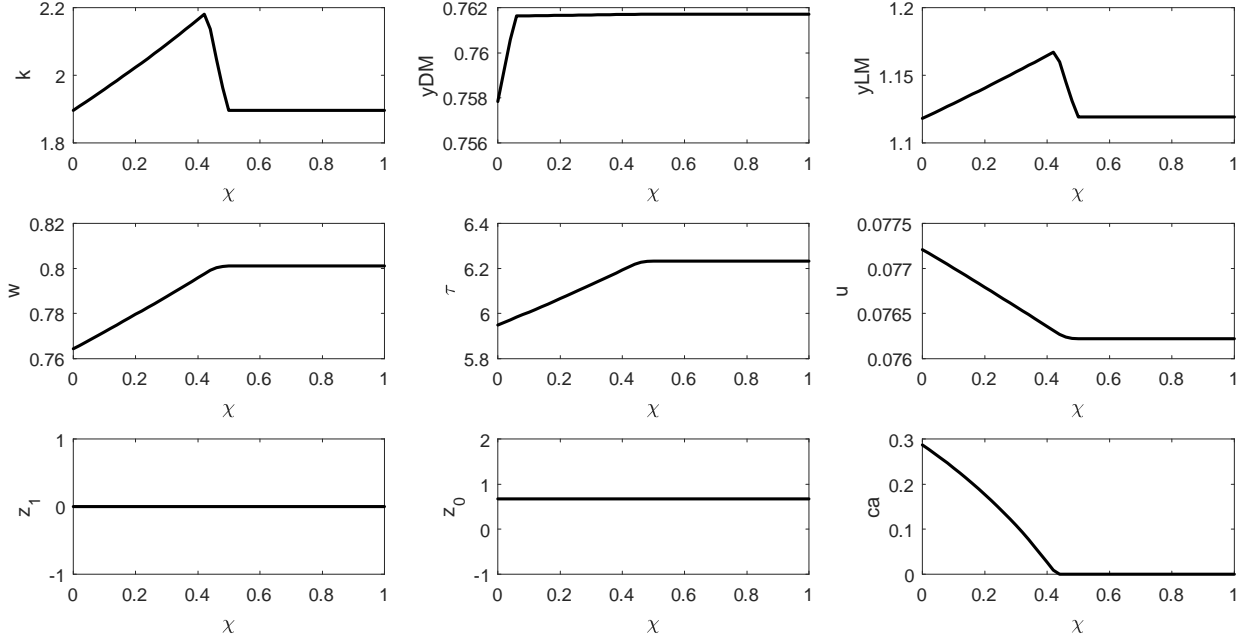


Figure 6: The Effects of  $\chi$

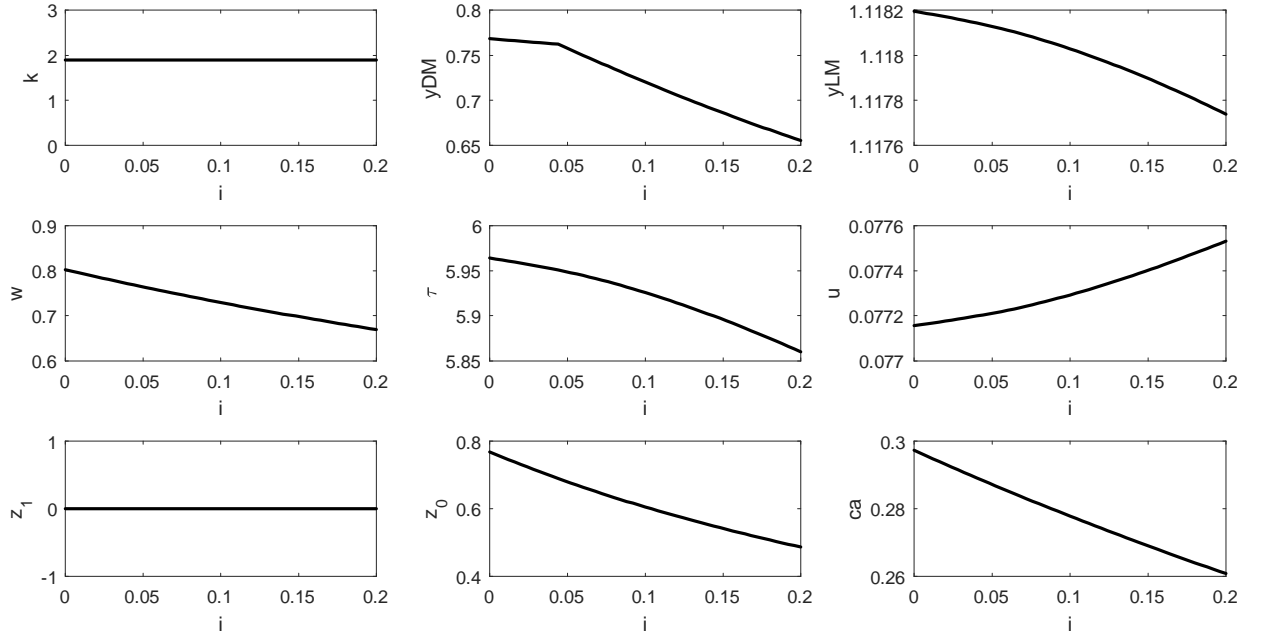


Figure 7a: The Effects of  $i$  ( $\chi = 0$ , regime 3,  $du/di > 0$ )

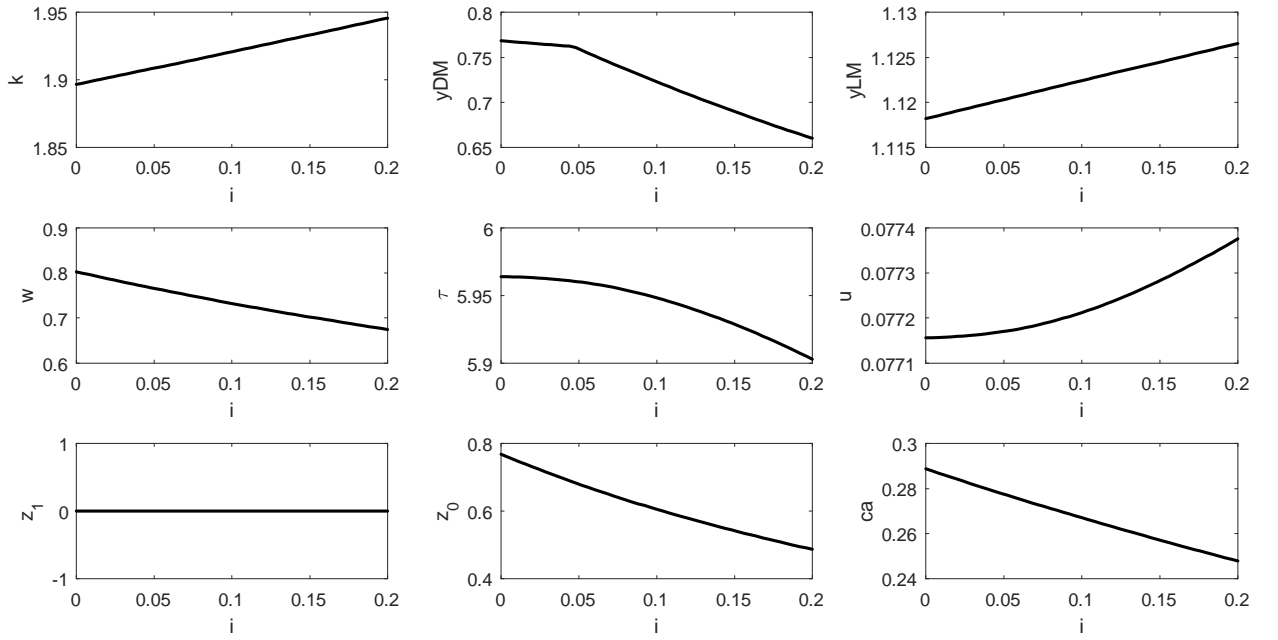


Figure 7b: The Effects of  $i$  ( $\chi = 0.02$ , regime 3,  $du/di > 0$ )

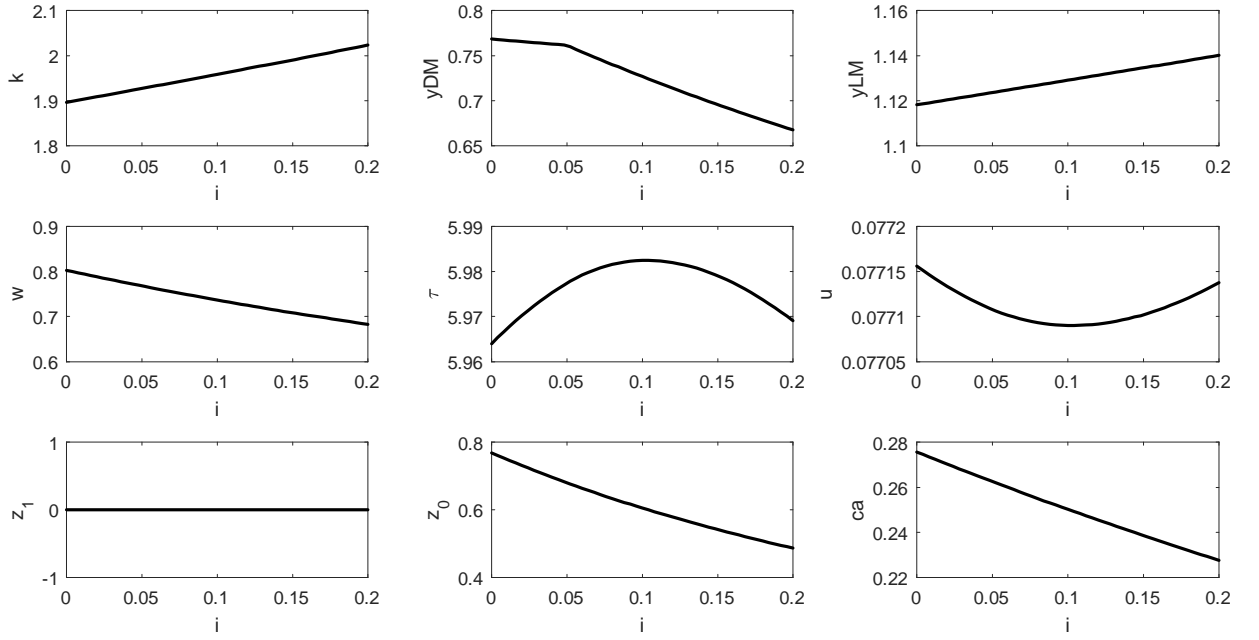


Figure 7c: The Effects of  $i$  ( $\chi = 0.05$ , regime 3,  $du/di > 0$ )

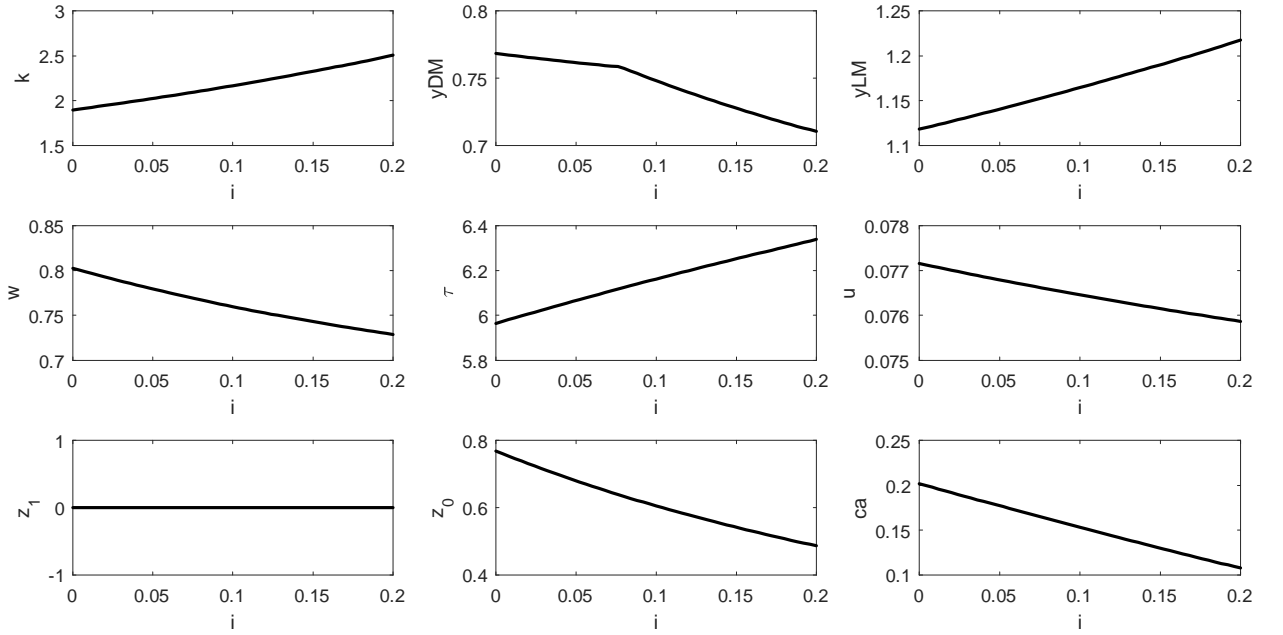


Figure 7d: Effects of  $i$  ( $\chi = 0.2$ , regime 3,  $du/di < 0$ )

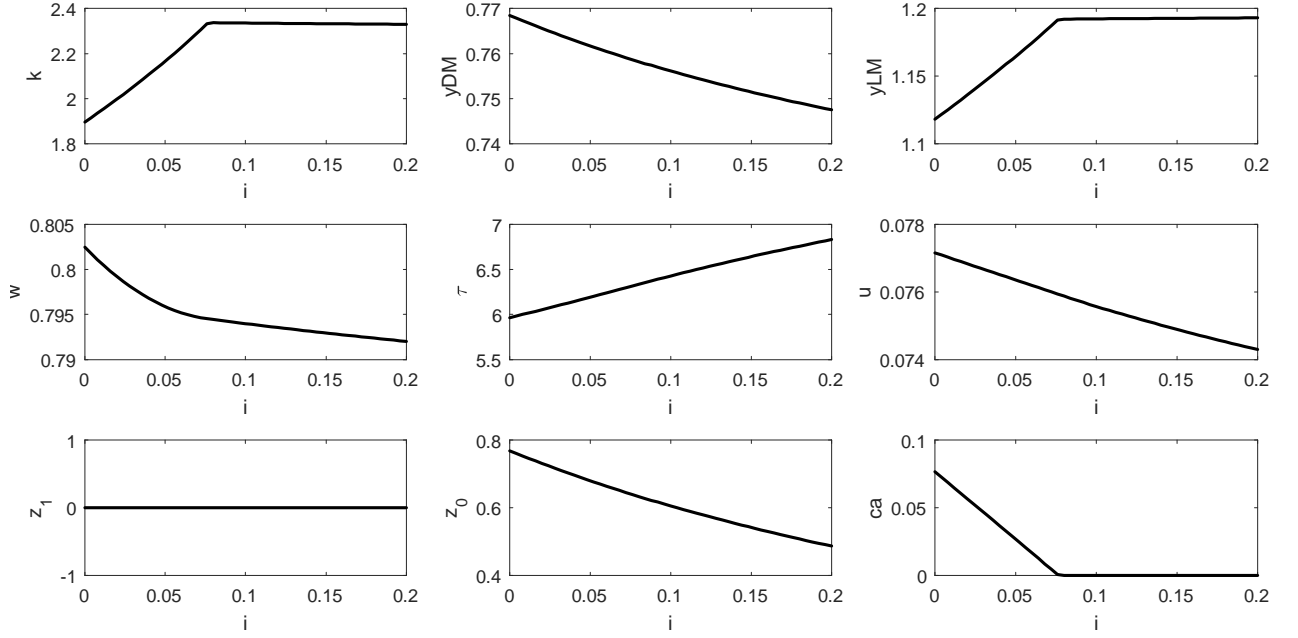


Figure 7e: Effects of  $i$  ( $\chi = 0.4$ , regime 3 and 2,  $du/di < 0$ )

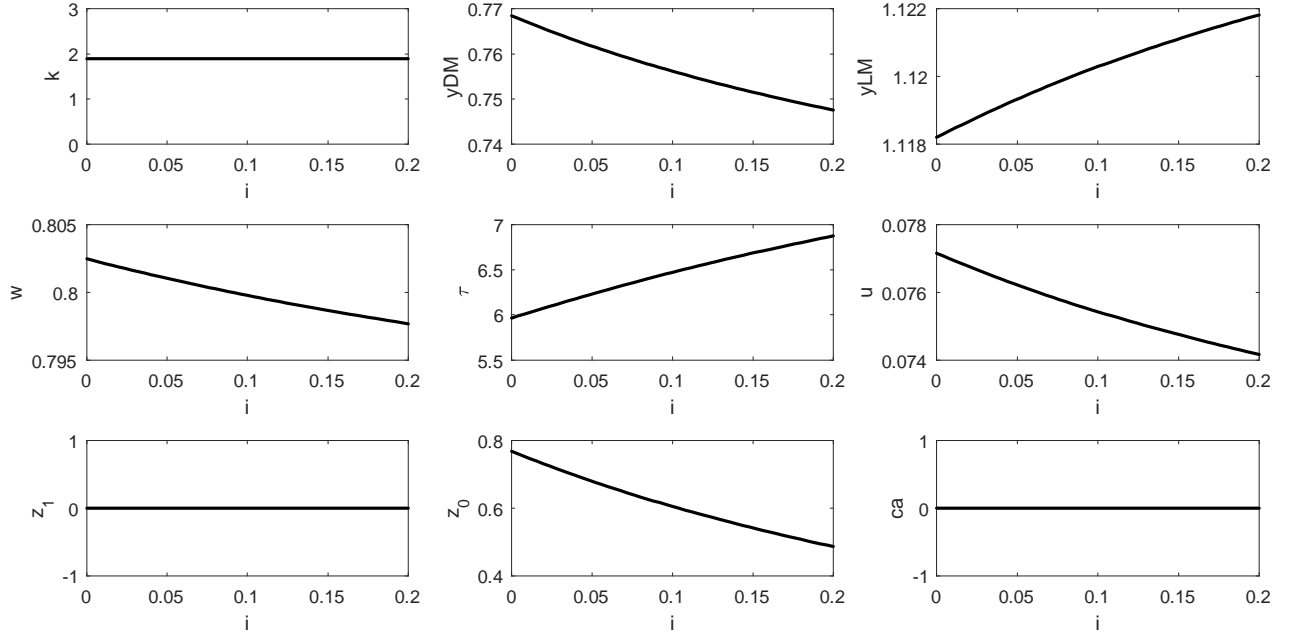


Figure 7f: Effects of  $i$  ( $\chi = 0.5$ , regime 1,  $du/di < 0$ )

## Appendix B – Search in the DM

In each graph, the solid line represents Walrasian pricing, and the dash line represents Kalai. Let  $\mathcal{N}(B, S) = 1.5BS/(B + S)$  and  $\psi = 0.6$ . Other parameter values and functions are the same as used in Figures 6 and 7a –  $f$ .

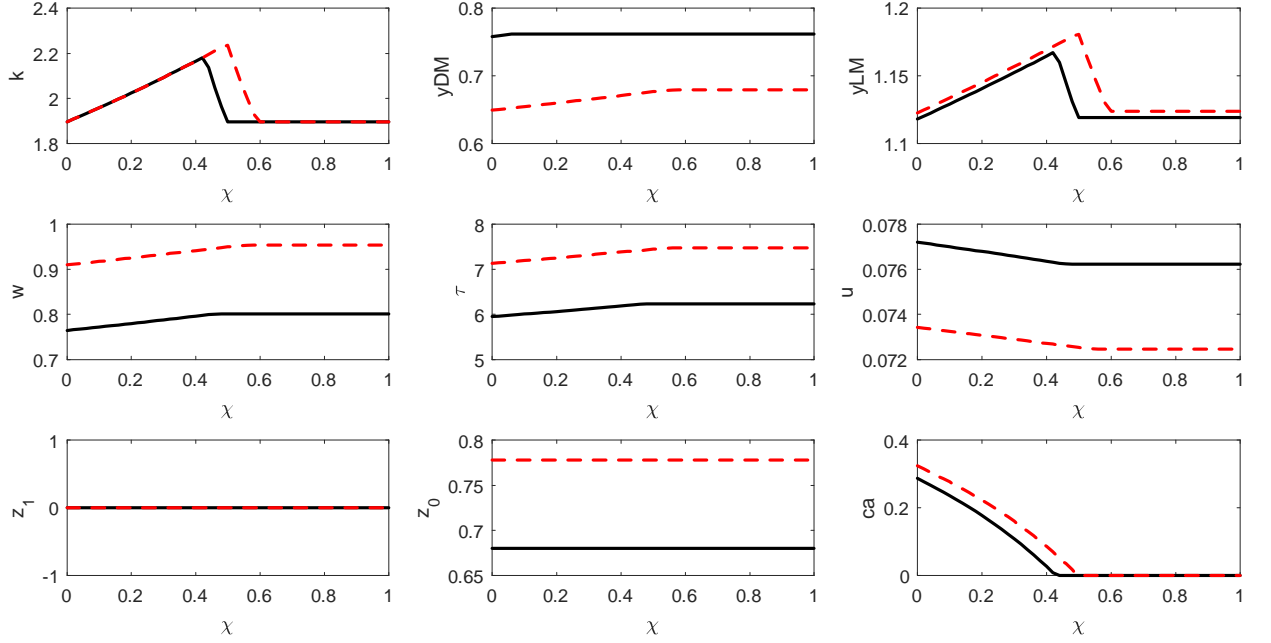


Figure 8: Effect of  $\chi$ , Kalai

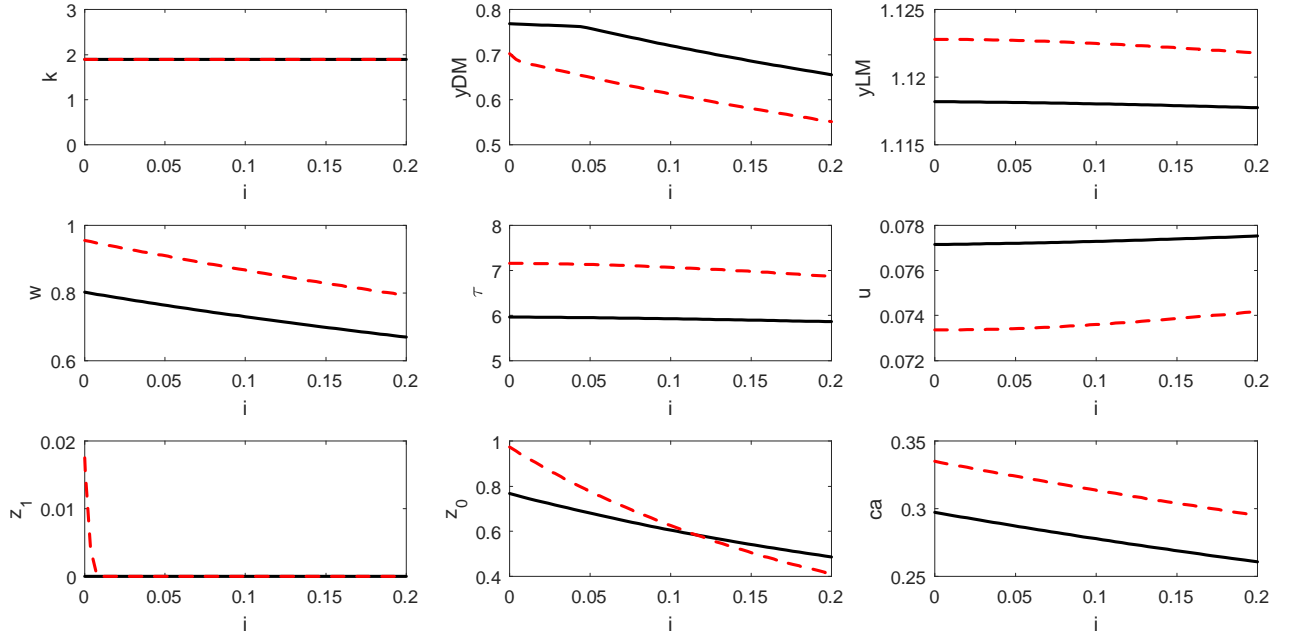


Figure 9a: Effects of  $i$  ( $\chi = 0$ ), Kalai

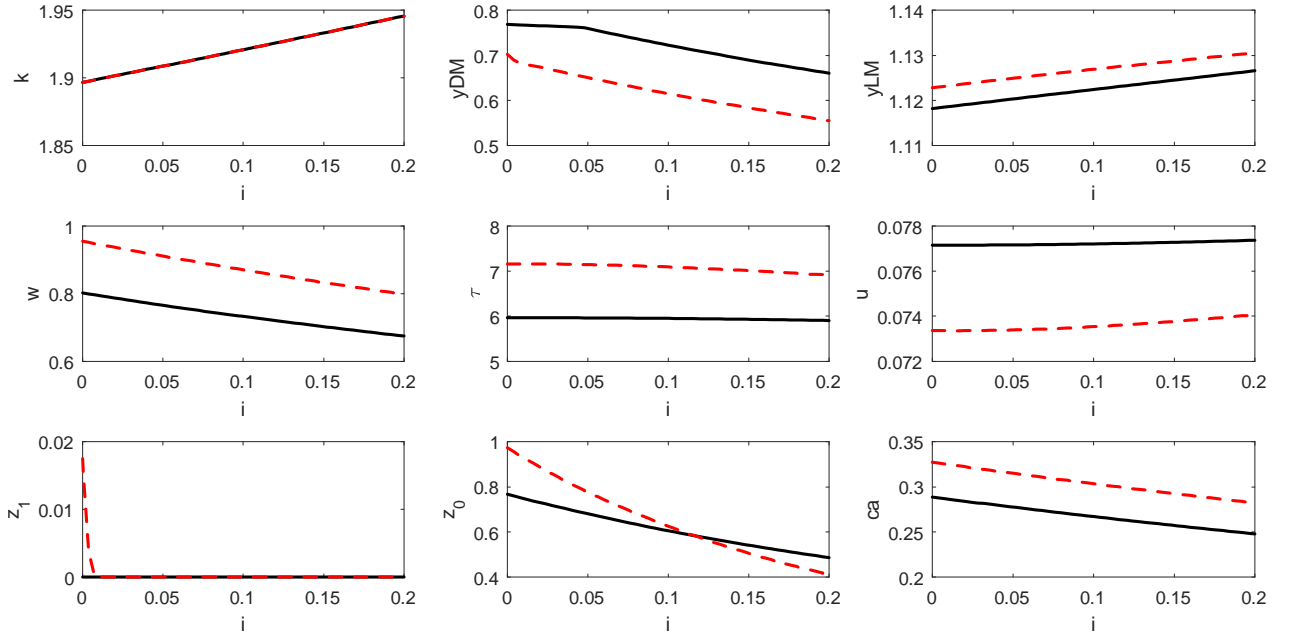


Figure 9b: Effects of  $i$  ( $\chi = 0.02$ ), Kalai

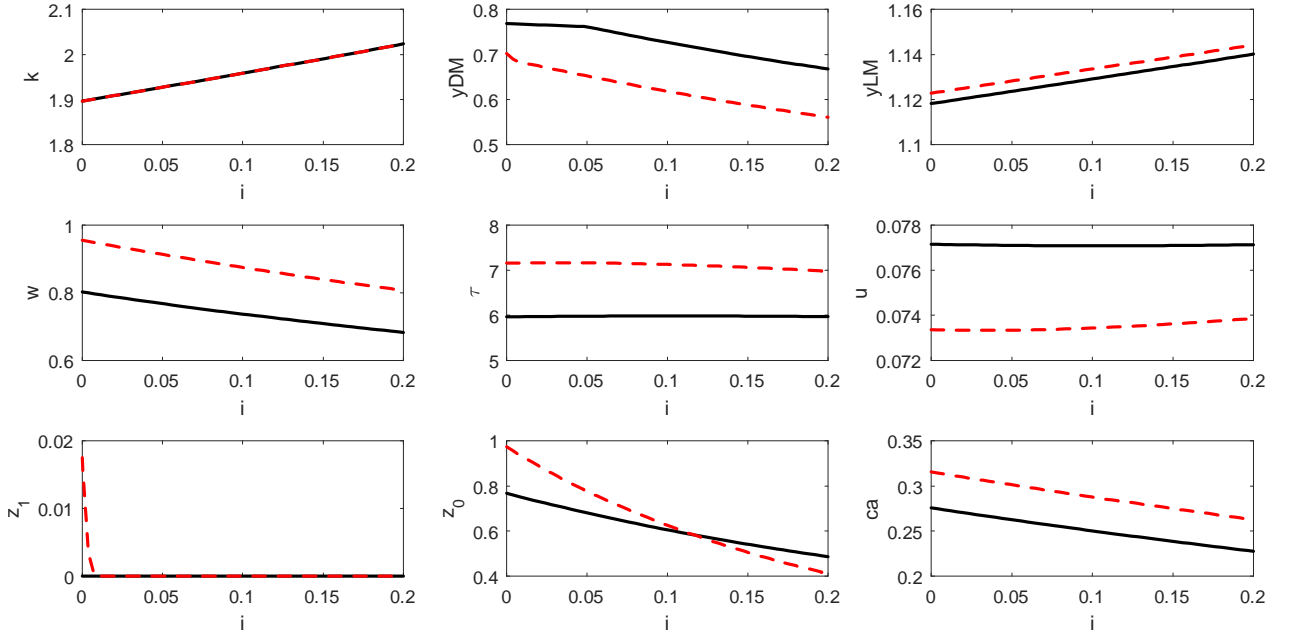


Figure 9c: Effects of  $i$  ( $\chi = 0.05$ ), Kalai

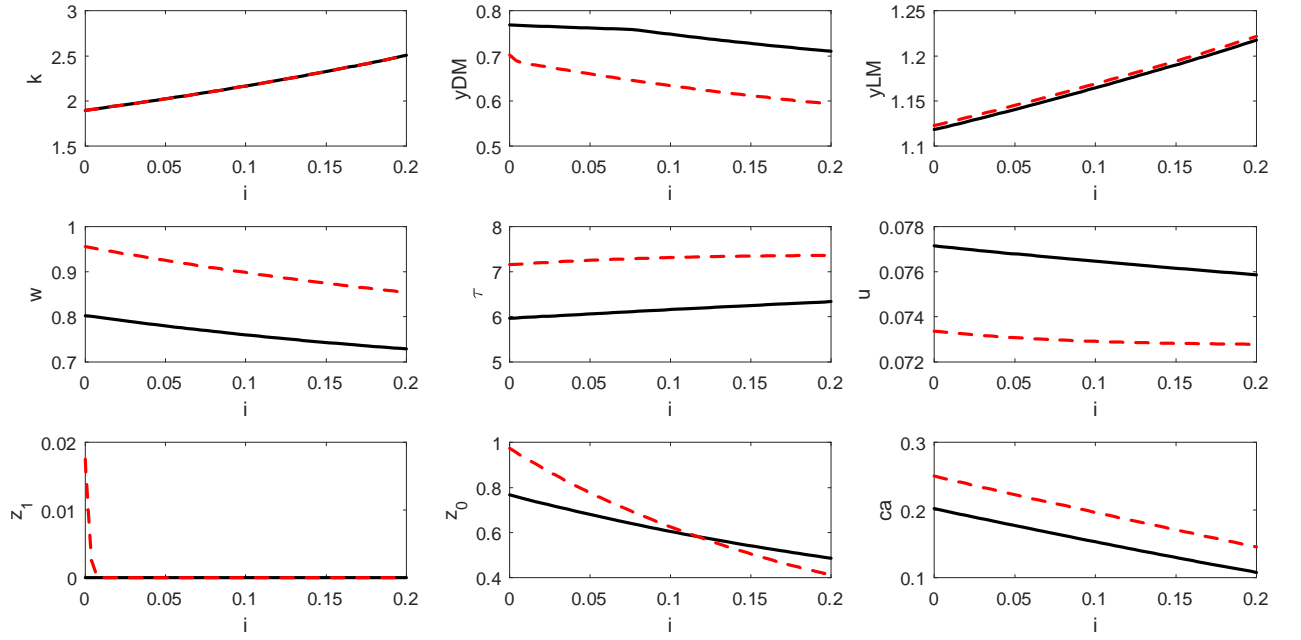


Figure 9d: Effects of  $i$  ( $\chi = 0.2$ ), Kalai

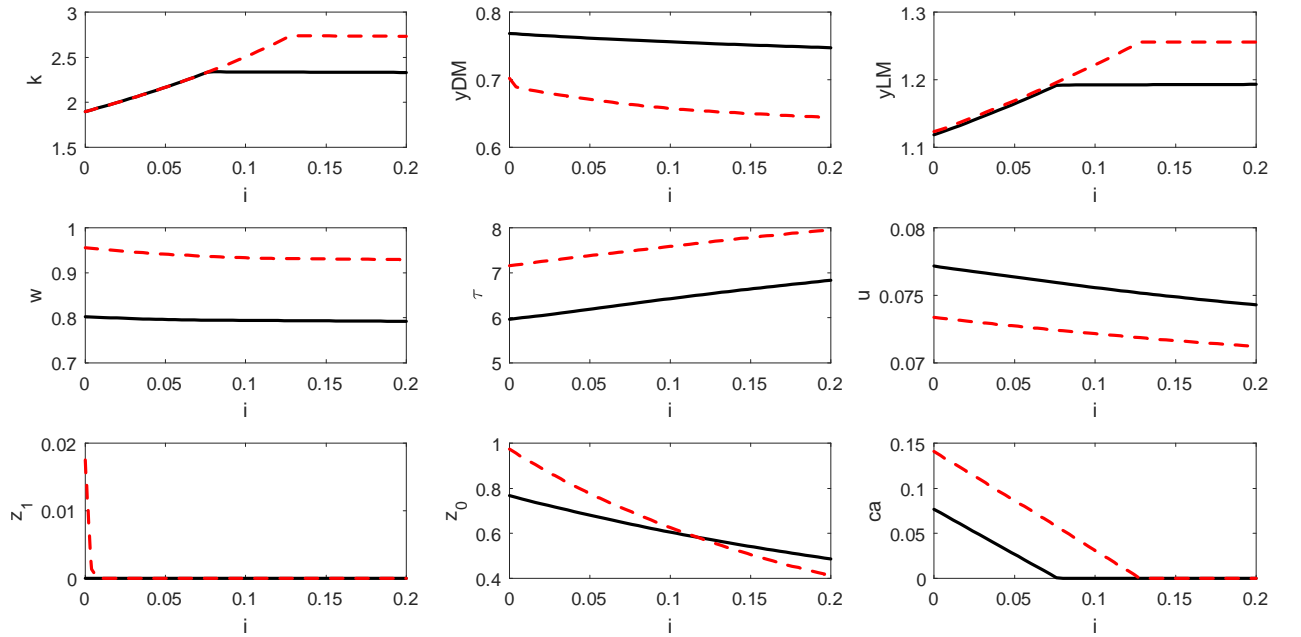


Figure 9e: Effects of  $i$  ( $\chi = 0.4$ ), Kalai



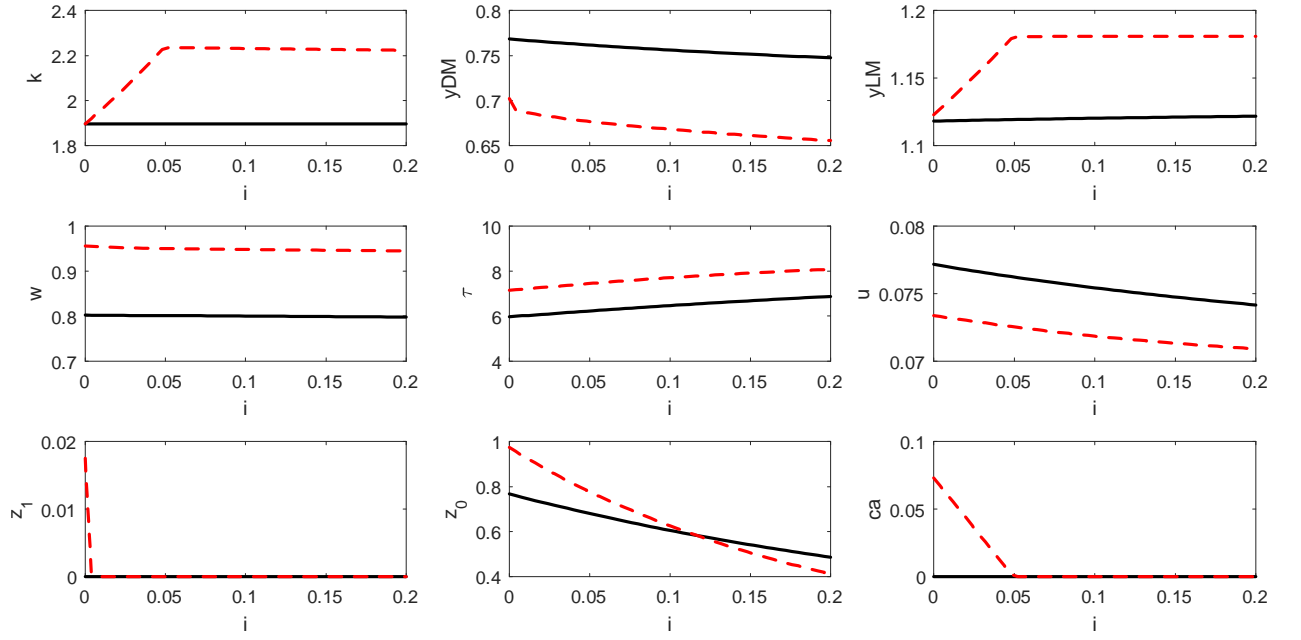


Figure 9f: Effects of  $i$  ( $\chi = 0.5$ ), Kalai

## Appendix C – Calibrated Results

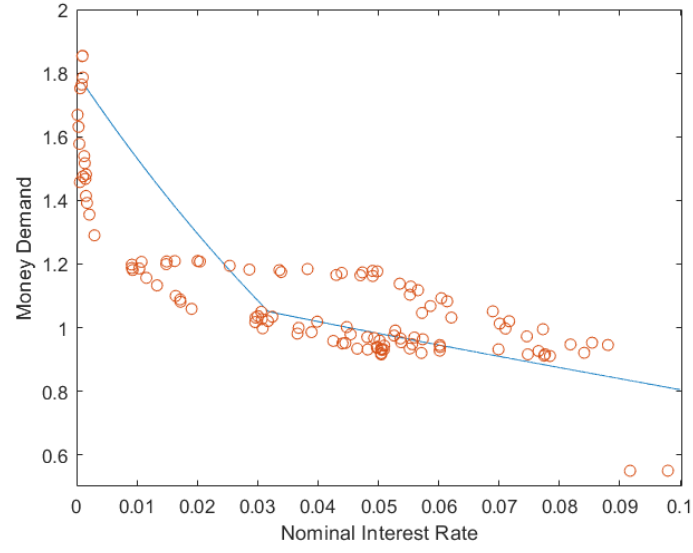


Figure 10: Calibrated Money Demand

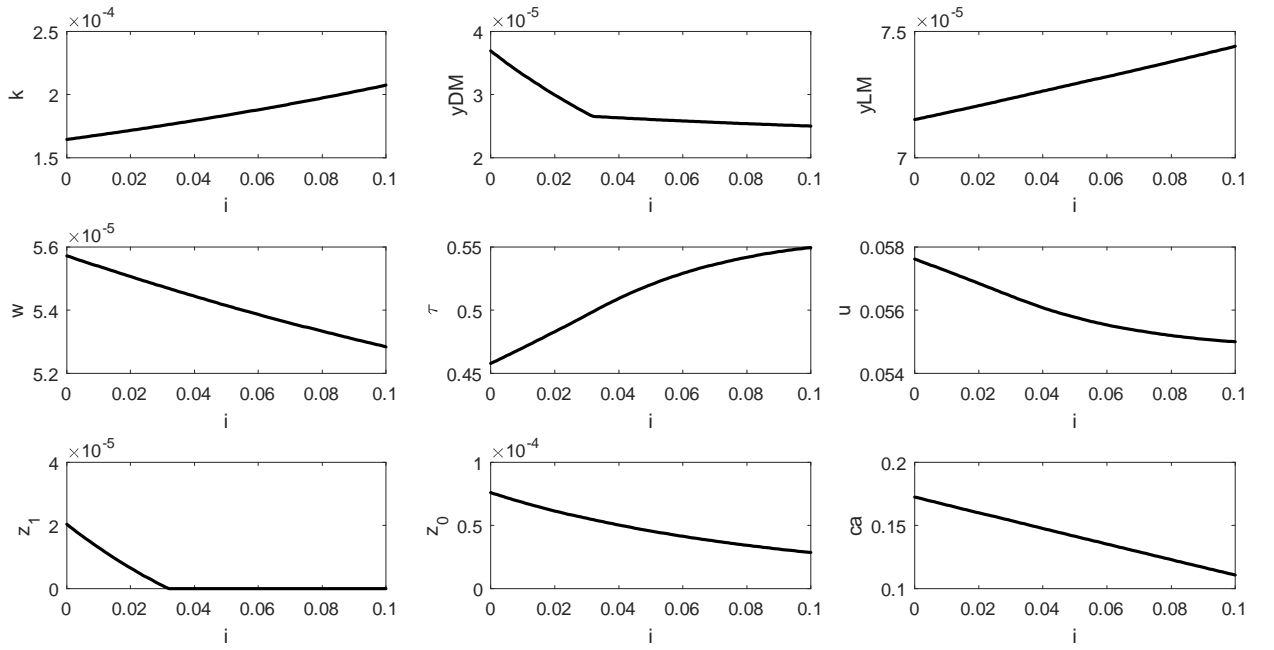


Figure 11: Calibrated Effect of  $i$

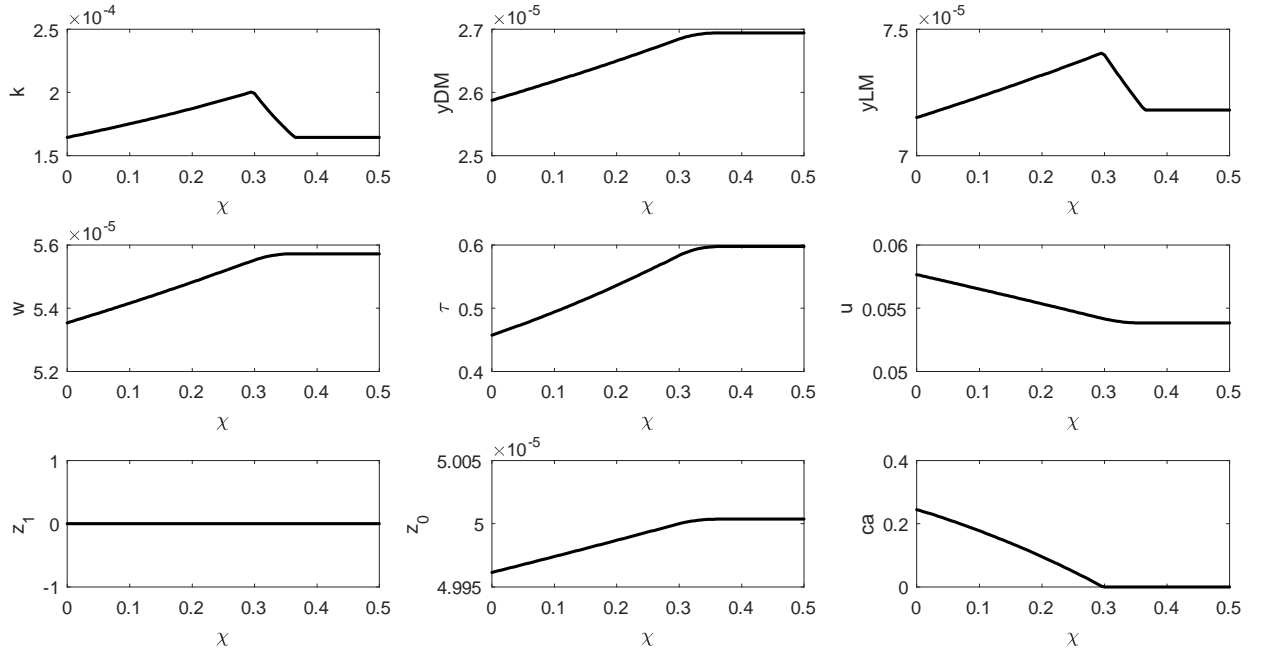


Figure 12: Calibrated Effect of  $\chi$

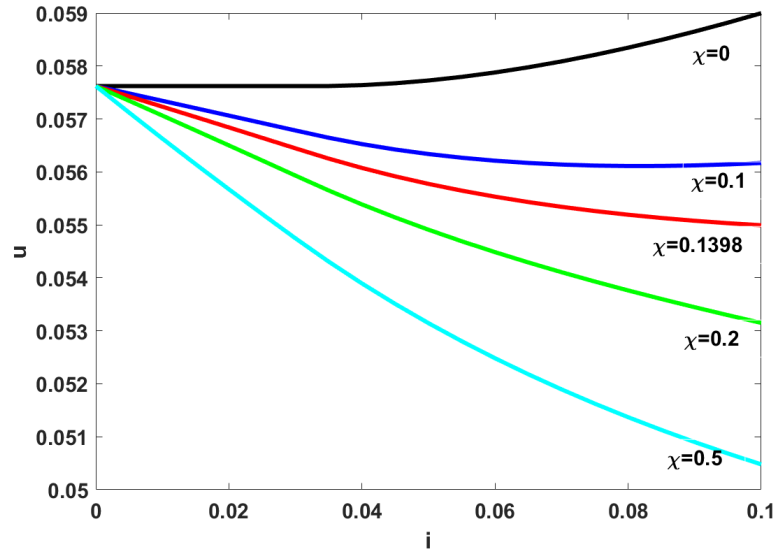


Figure 13: Calibrated Phillips Curves

## References

- [1] Acemoglu, Daron. 2001. "Credit Market Imperfections and Persistent Unemployment." *European Economic Review* 45, 665-679.
- [2] Aruoba, S. Boragan, Christopher Waller, and Randall Wright. 2011. "Money and Capital." *Journal of Monetary Economics*, 58(2): 98-116.
- [3] Berentsen, Aleksander, Guido Menzio, and Randall Wright. 2011. "Inflation and Unemployment in the Long Run." *American Economic Review*, 101(1): 371-98.
- [4] Bethune, Zachary, Guillaume Rocheteau, and Peter Rupert. 2015. "Aggregate Unemployment and Household Unsecured Debt." *Review of Economic Dynamics* 18(1): 77-100
- [5] Buera, Francisco and Benjamin Moll. 2015. "Aggregate Implications of a Credit Crunch: The Importance of Heterogeneity." *American Economic Journal: Macroeconomics* 7(3): 1-42.
- [6] Buera, Francisco, Roberto Fattal-Jaef and Yongseok Shin. 2015. "Anatomy of a credit crunch: From capital to labor markets." *Review of Economic Dynamics* 18(1):101-117.
- [7] Christiano, Lawrence J, .Martin S. Eichenbaum and Mathias Trabandt. 2015. "Understanding the Great Recession." *American Economic Journal: Macroeconomics* 7: 110-167.
- [8] Dolado, Juan, and Juan F. Jimeno. 1997. "The causes of Spanish unemployment: A structural VAR approach." *European Economic Review* 41: 1281-1307.
- [9] Herkenhoff, Kyle. "The Impact of Consumer Credit Access on Unemployment." *Review of Economic Studies*, forthcoming.

- [10] Karanassou, Marika, Hector Sala and Dennis Snower. 2010 "Phillips Curve and Unemployment Dynamics: A Critique and A Holistic Perspective." *Journal of Economic Surveys* 24: 1-51.
- [11] Kehoe, Timothy, and David Levine. 1993. "Debt-Constrained Asset Markets." *Review of Economic Studies* 60: 865-88.
- [12] Kiyotaki, Nobuhiro, and John Moore. 1997. "Credit Cycles." *Journal of Political Economy* 105, 211-248.
- [13] King, Robert, and Mark Watson. "The post-war U.S. Phillips curve: a revisionist econometric history." *Carnegie-Rochester Conference Series on Public Policy* 41: 157-219.
- [14] Kocherlakota, Narayana. 1998. "Money Is Memory." *Journal of Economic Theory* 81(2): 232-51.
- [15] Lagos, Ricardo, and Randall Wright. 2005. "A Unified Framework for Monetary Theory and Policy Analysis." *Journal of Political Economy*, 113(3): 463-484.
- [16] Lester, Benjamin, Andrew Postlewaite and Randy Wright. 2012. "Information, Liquidity, Asset Prices, and Monetary Policy." *Review of Economic Studies*, 79 (3), 1208-1238.
- [17] R. Lucas (2000) "Inflation and Welfare," *Econometrica* 68, 247-274.
- [18] Lucas, Robert E. and Nicolini, Juan Pablo, 2015. "On the stability of money demand," *Journal of Monetary Economics*, 73, 48-65.
- [19] Mortensen, Dale T., and Christopher A. Pissarides. 1994. "Job Creation and Job Destruction in the Theory of Unemployment." *Review of Economic Studies*, 61: 397-415.
- [20] Schreiber Sven and Jurgen Wolters. 2007. "The long-run Phillips curve revisited: Is the NAIRU framework data-consistent?" *Journal of Macroeconomics* 29: 355-367

- [21] Venkateswaran, Venky, and Randall Wright. 2013 “Pledgeability and Liquidity: A New Monetarist Model of Macro and Financial Activity,” *NBER Macroeconomics Annual* 28: 227-270.
- [22] Wasmer, Etienne, and Philippe Weil. 2004. “The Macroeconomics of Labor and Credit Market Imperfections.” *American Economic Review* 94, 944-963.