Credit Condition, Inflation and Unemployment*

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Abstract

We study the effects of the firm's credit condition on labor market performance and the relationship between expected inflation and unemployment in a new monetarist model. Better credit condition has a positive impact on the labor market as firms save on financing cost, improve profitability, and create more vacancies. Inflation affects unemployment through two opposing channels. First, inflation increases the firm's financing cost, which discourages job creation and increases unemployment. Second, inflation lowers wages because unemployed workers carry higher real balances and suffer more from inflation compared to unemployed workers. This encourages job creation. The overall effect of inflation on employment can be positive or negative and depends crucially on the firm's credit condition. We calibrate the model to match U.S. data before the great recession. The calibrated model suggests a small welfare cost of inflation and a downward-sloping Phillips curve with a flexible wage setting. We find that the firm's credit condition is as important as the nominal interest rate to understand the unemployment movement.

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1 Introduction

In the past forty years, the relationship between inflation and unemployment appears to have changed. Right before the Covid-19 hit the U.S. economy, the unemployment rate has dropped to the lowest level since the 1980s (see Figure 1), while inflation has not accelerated. Figure 2 shows the long-run Phillips curves, as the relationship between trend inflation and trend unemployment, in different decades since 1980. One can observe that price changes in response to unemployment has become weaker in recent years.

The flattening of the Phillips curve and the long-term decrease in the unemployment rate over this time period coincide with an increase in business debt and a decrease in the cost of firms holding liquid assets. Figure 1 demonstrates that non-financial business debt has increased significantly from 1980 to 2019, from roughly 50% to 80% of GDP. On the other hand, the cost of holding liquid assets, defined as 3-month treasury bill interest rate, has decreased from about 15% to 1%. Evidence such as the Financial Stress Index suggests that business debt has become easier to obtain and firm's credit condition is improving.

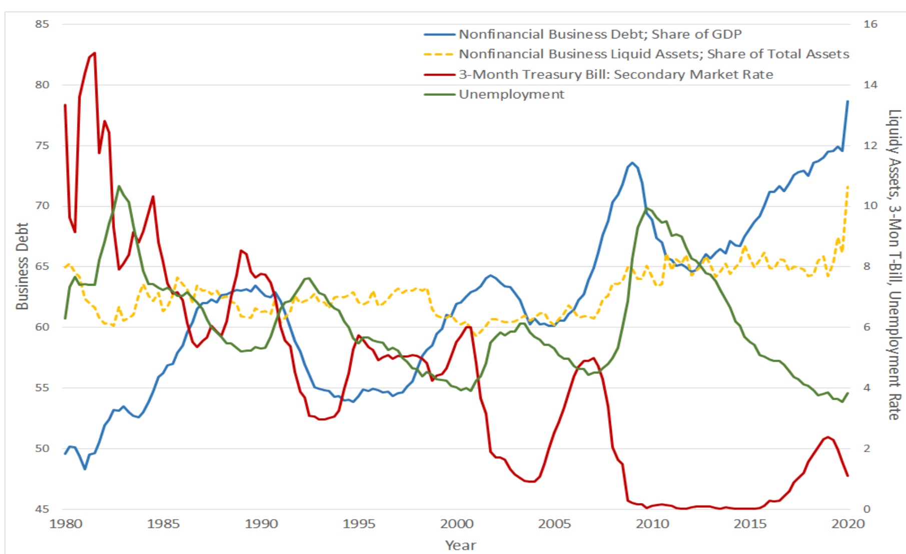


Figure 1: Business Debt, Liquid Assets, and Unemployment

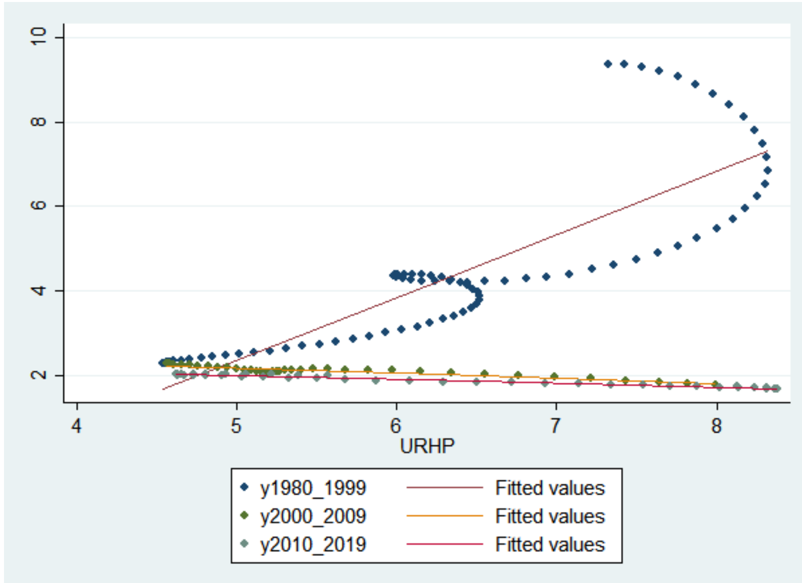


Figure 2: Phillips Curves

In this paper, we want to provide a general equilibrium model with trading frictions to analyze the relationship between business credit condition, money, and unemployment, as well as the long-term relationship between unemployment and inflation. We consider credit and money as two major forms of liquidity in the economy. We want to understand their relationship and their impact on the macroeconomic performance of monetary policy in influencing output and employment. Our model suggests that credit condition plays a critical role in determining the slope of the Phillips curve, and can help to explain the time-series and cross-sectional variation in the inflation-employment relationship.

To study the effect of credit condition on aggregate output and employment, we introduce capital to the model by Berentsen et al. (2011), which combines Mortensen-Pissarides (1994) type of labor market with the Lagos-Wright (2005) type of goods market. Our study focuses on the firm's credit condition and in particular, the ability of firms to finance working capital through secured credit. The importance of working capital financing is emphasized by Christiano et al. (2015), who show the bulks of movements in aggregate economic activity during the Great Recession could be attributed to the shocks to financial frictions that raised the cost of the working capital. Following the tradition of Kiyotaki and Moore (1997), we capture the firm's credit condition by the pledgeability of the firm's capital.[1]

Our findings are as follows. Given the inflation rate, firms' credit condition has a positive effect on labor market performance. If the firm's capital is more pledgeable, then 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 improves production efficiency, encourages more firms to enter, and lowers the unemployment rate. This result is consistent with the empirical evidence. For example, Acemoglu (2001) shows that the new firm's difficulty in accessing loans restricts job creation.

Given the credit condition, inflation affects the economy through two opposing channels. First, inflation increases the cost of holding cash. This is undesirable for both firms and workers. Higher wage financing cost reduces the firm's profit. Moreover, workers reduce their cash holdings and purchase less consumption good, which further reduces the firm's profit. Through this channel, inflation has a negative effect on job creation. We call this channel the cash-financing channel. This channel itself implies that the firms which have a larger share of cash in their total asset holdings are associated with a smaller size of employment, which is exactly what Bacchetta et al. (2019) find in firm-level data. Second, as employed workers earn wage income and carry lower real cash balances than their unemployed counterparts, inflation hurts unemployed workers more than employed workers. When inflation is higher, workers are willing to accept a lower wage, which increases the firm's profits and encourages job creation. We call this the wage-bargaining channel. The wage bargaining channel is consistent with the empirical result in Cardoso (1992) and Braumann (2004).

[1] 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 heterogenous agent model.

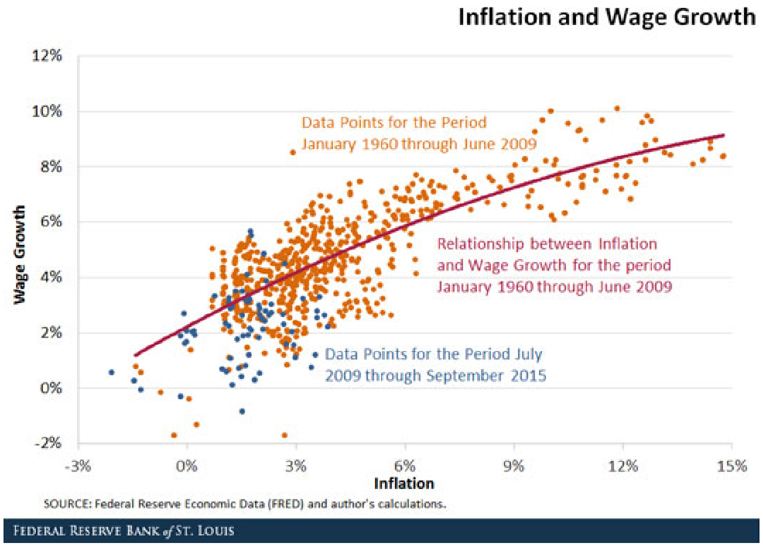


Figure 3: The Relationship between Wage Growth and Inflation, Sanchez (2015)

The relationship between inflation and real wage predicted by our model is consistent with the empirical observation in Sanchez (2015). Given that inflation affects wage through two channels, higher inflation lowers real wage growth and even reduces the real wage, as shown in Figure 3. On the other hand, inflation also affects employment through these offsetting channels, and the overall effect of inflation on unemployment could be positive or negative. In particular, the relationship between inflation and unemployment depends critically on the credit condition. When credit is abundant, firms do not use 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. In general, better credit conditions weaken the cash-financing channel and reduce the slope of the Phillips curve (with inflation on the horizontal axis).

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 trade-off 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%. On the other hand, raising the pledgeability of capital by 10% can lower the unemployment rate by 0.5%.

The rest of the paper is organized as follows. Section 2 sets up the baseline model with a competitive goods market. Section 3 characterizes the general equilibrium. Section 4 extends the model to include search friction in the goods market. Section 5 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. Our innovation is the introduction of capital, which can be combined with labor to produce output and used as collateral to acquire loans.

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 $f(0) = 0$. Labor is indivisible and each firm can hire at most one worker. 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 are owned by workers and each worker has an equal share of each firm.

In the LM, firms with workers produce output. After production, an employed worker separates from his job with probability s. Firms without workers meet with unemployed workers bilaterally after paying a cost to post vacancies. 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 $\tau = v/u$. Newly-matched firm-worker pairs start producing in the next LM.

In the DM, firms can transform goods produced in the LM by a linear cost function into DM goods. The marginal cost is $c > 0$. Workers value DM good according to $\upsilon(q)$, with $\upsilon' > 0$, $\upsilon'' < 0$ and $\upsilon(0) = 0$. For now, assume that the DM is competitive and there is no search friction (we will relax this assumption in section 4).

In the CM, firms sell any unsold goods, and all agents adjust their money and capital holdings. Workers have linear utility in the CM good x. If $x < 0$, then workers produce in the CM. Unemployed workers also enjoy leisure valued at ℓ. Worker's instantaneous utility is $x + (1 - j)\ell + \upsilon(q)$. Agents discount between periods by $0 < \beta < 1$.

There are two payment instruments, money and credit.[2] 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 that leads to the use of money is limited commitment. First, in the LM, firms cannot commit to pay workers after selling their products in the DM, so 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.[3] Workers also have limited commitment: in the DM, workers cannot commit to pay back any unsecured credit extended by the firms. As a result, workers also need some payment instruments to transact in the DM. As we focus on the firm's credit condition in this paper, we do not model the household's credit

[2]Rocheteau and Rodriguez-Lopez (2014) consider a broader scope of liquidity including government bonds and claims on firm's profit as possible components of one's portfolio. Here we focus on the traditional monetary policy instead and model fiat money and secured credit backed by firm's asset.

[3]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.

condition and assume that households must use cash or wage income to purchase consumption goods.[4]Money supply grows at a (net) rate π. 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 $\pi \to \beta - 1$; there is no monetary equilibrium with $\pi < \beta - 1$.

2.1 Worker's Problem

Let U_j, V_j, and W_j, $j = 0, 1$, denote the worker's value function in the LM, DM, and CM, respectively. The subscript j represents the employment status, with 0 representing unemployed and 1 representing employed. For simplicity, assume workers do not carry capital.[5] A worker of type j entering the CM with real balance z and unspent labor income ω solves the following problem at the beginning of the CM,

$$W_j(z,\omega) = \max_{x,\hat{z}_j} \left[x + (1-j)\,\ell + \beta U_j(\hat{z}_j)\right]$$
$$\text{s.t. } x + (1+\pi)\,\hat{z}_j + T = z + \omega + (1-j)\,b + \Delta$$

where x is the consumption of the CM goods, ℓ is utility of leisure, T is the lump sum tax (it is a transfer if negative), Δ is dividend income, b is the unemployment benefits, π is the inflation rate, and $\hat{z}_j$ is the real balance in terms of good x in the next period. Note that the subscript of W represents employment status in the following LM. As we focus on the steady state, the inflation rate is the same as money growth rate, which gives rise to the term $1+\pi$ before $\hat{z}_j$. Note that workers may choose different amounts of money according to their employment status in the coming LM because employed workers anticipate labor income in the LM. The

[4]See Bethune et al. (2014) and Herkenhoff (2019) for the effect of consumer credit condition. Bethune et al. (2014) study 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 (2019) shows that the access to consumer credit prolongs recessions, but it enhances welfare by reducing consumption volatility and improving job-match quality.

[5]The equilibrium capital price includes its liquidity value and is above (or at least equal to) its marginal product. We assume that only firms can pledge capital to acquire credit, while the workers cannot. As in Aruoba et al. (2011), the underlying friction is that workers cannnot bring physical capital to the goods market and they can counterfeit certificate of the capital costlessly.

first-order condition w.r.t. $\hat{z}_j$ is

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

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 works and receives wage w, which was determined bilaterally by the firm and the worker upon hiring. After production, an employed worker separates from the job with probability s. The value function of an employed worker is

$$U_1\left(z_1\right)=\left(1-s\right)V_1\left(z_1,w\right)+sV_0\left(z_1,w\right).$$

It follows that $U_1'\left(z_1\right)=\left(1-s\right)\partial V_1/\partial z_1+s\partial V_0/\partial z_1$. An unemployed worker does not earn wage income. He/she looks for a job and matches with a firm with probability λ_h (if matched, he/she will start working in the next LM) with the value function given by

$$U_0\left(z_0\right)=\lambda_h V_1\left(z_0,0\right)+\left(1-\lambda_h\right)V_0\left(z_0,0\right),$$

and $U_0'\left(z_0\right)=\lambda_h\partial V_1/z_0+\left(1-\lambda_h\right)\partial V_0/\partial z_0$. Note that the subscript of V represents the employment status in the next LM.

In the DM, workers can use cash earned in the previous CM and wage income in the previous LM to pay for goods q. DM is a Walrasian market. As a result of competition, the price of the DM good is equal to the marginal cost c. The worker's value function in the DM is

$$\begin{aligned} V_j\left(z_j,\omega\right) &= \max_{q,z',\omega'}\left[\upsilon\left(q\right)+W_j\left(z_j-z',\omega-\omega'\right)\right] \\ \text{s.t. } cq &= z'+\omega',\ z'\leq z_j,\ \omega'\leq\omega \end{aligned}$$

where z' and ω' 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

$$V_j\left(z_j,\omega\right)=\max_q\left[\upsilon\left(q\right)-cq+W_j\left(z_j,\omega\right)\right]\ \text{st } cq\leq z_j+\omega$$

Let q^* solve $\upsilon'(q^*) = c$. The FOC w.r.t. q is $q = q^*$, if $z_j + \omega \geq cq^*$ and $q = (z_j + \omega)/c$ otherwise. The derivative $\partial V_j / \partial z_j = 1$ if $z_j + \omega \geq cq^*$ and $\partial V_j / \partial z_j = \upsilon'(q)/c$ otherwise.

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

$$\begin{array}{lll} q_1 = q_i & \text{and } z_1 = cq_i - w, & \text{if } w < cq_i, \\ q_1 = w/c & \text{and } z_1 = 0, & \text{if } cq_i \leq w < cq^*, \\ q_1 = q^* & \text{and } z_1 = 0, & \text{if } w \geq cq^*, \end{array} \tag{1}$$

where q_i solves $\upsilon'(q_i) = (1+i)c$ 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

$$q_0 = q_i \text{ and } z_0 = cq_i. \tag{2}$$

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

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

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

and

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

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

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

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 the 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_f and capital k. It adjusts money and capital holdings. Its expected life-time value is

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

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

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

where the equality is strict iff $\hat{z}_f > 0$. The envelope conditions are $\partial\tilde{W}_j/\partial z_f = \partial\tilde{W}_j/\partial y = 1$ 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 χ 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 χ 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

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

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

For a firm without a worker, carrying money or capital is useless. Therefore, its money and capital holdings are zero. The firm has probability λ_f to meet with an unemployed worker if it pay a cost κ 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

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

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:

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

In Regime 1, firm's liquidity constraint is tight. The firms use capital and money to pay workers. The capital is over accumulated. In Regime 2, the liquidity constraint still binds. But firms only use capital to finance wage. In Regime 3, The liquidity constraint does not bind. The capital accumulation is at its first-best, and it is sufficient to be pledged to pay for wage.

Note that k is not monotone in χ in the entire range. As χ increases from 0, capital per firm first increases from k^* (Regime 1), then decreases (in Regime 2), and finally becomes constant at k^* (Regime 3). When χ increases from 0, firms start to over accumulate capital for its liquidity function and capital increases as it can save more on cash. As χ 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 χ increases even further, the economy moves to Regime 3. 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

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

For firms without workers, the expected value is

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

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

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

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_f by holding cash and saves on job posting cost κ. 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 ρ. The surplus of the worker and the firm satisfies:

$$\frac{S_h}{S_f} = \frac{\rho}{1-\rho} \tag{10}$$

To solve for λ_f and λ_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

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

As

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

and

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

From (12) and (13), $d\lambda_f/d\lambda_h < 0$ and λ_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

$$u = \frac{s}{\lambda_h + s} \tag{14}$$

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

2.3 Government Policy

The government consumes G, pays b to unemployed workers, levies tax T and receives seigniorage πz, where $z \equiv uz_0 + (1-u)(z_1 + z_f)$ is the total demand for real balances. The government runs a balanced budget so $G+bu = T+\pi z$ in each period. In the steady state, targeting the nominal interest rate is equivalent to targeting the money growth rate.

3 Equilibrium

A stationary equilibrium a list of $(w, k, z_f, z_1, z_0, q_1, q_0, \lambda_f, \lambda_h, \tau)$ 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, τ) that solves

$$
\begin{aligned}
& \frac{-(b+\ell)/\beta + w + v(q_1) - cq_1 - iz_1 - v(q_i) + (1+i)cq_i}{f(k) - r^*k - w - iz_f + \kappa} \frac{1/\beta - 1 + s + \mathcal{M}(1/\tau, 1)}{1/\beta - 1 + s + \mathcal{M}(1, \tau)} \\
= & \frac{\rho}{1-\rho} \qquad (15)
\end{aligned}
$$

and

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

where k, q_1, z_1 and z_f 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 $\kappa \to 0$. We have $h_2(0) > h_1(0) > 0$ and $h_2(\infty) = -\infty$. So there exists a positive steady state if $\kappa \to 0$. With an increase in κ, h_1 shifts up and h_2 shifts down. When $\kappa \to \infty$, 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^*, τ^*) is shown in Figure 4. When κ increases, h_1 shifts up and h_2 shifts down as shown in red curves. For κ 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 3, increasing in χ does not change the equilibrium. If the economy is in Regimes 1 or 2, increasing in χ raises w and τ and lowers u.*

Proof. If the economy is in Regime 3, $k = k^*$ and increasing χ 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 χ. So is for (15). The same argument applies to Regime 1. Both h_1 and h_2 rotate up at $w = \chi(1-\delta)k^*$. So the equilibrium w is higher. To see that τ is higher, Plug (16) into (15) to get

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

$$= \frac{\rho}{1-\rho}$$

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

Figures 5a and 5b depict the effect on w and τ after χ 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 χ rises. Figure 5b shows the opposite case in which both w and τ increase.

Given w, a change in χ do not affect worker's surplus. It increases firm's surplus in Regime 1 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 1 and 2, firms are more profitable and are more willing to enter the labor market, which results in higher τ and lower u. In Regime 3, 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 $\upsilon(q) = A_\upsilon q^\alpha$, 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 $A_\upsilon = 1.5$, $\alpha = 0.6$, $A_f = 1$, $\theta = 0.3$, $A_m = 0.35$ 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 χ increases from 0 to 1. The economy switches regimes where the kinks present. As χ increases, the economy moves from Regime 1 to 2 and to 3, w, τ, and u move in the way that Proposition 2 states. Capital increases in Regime 1 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 3 as capital is plenty. In this example, since more firms are operating in Regimes 1 and 2, DM output increases in χ. 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 2 or 3, u increases in i.*

Proof. In the economy is in Regime 1, both h_1 and h_2 shift down as i increases. Therefore, the equilibrium w is lower (though the effect on τ is ambiguous). If the economy is in Regime 2 or 3 and i increases, h_1 shifts down but h_2 stays the same. Therefore, w and τ 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 lower regimes to higher 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 1 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 2 or 3 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 1. 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 3. Though each producing firm produces the same quantity, more firms are operating. In Regimes 1 and 2, the effect is ambiguous. In Regime 1, 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. Figures 7a is drawn for $\chi = 0$. In this example, $k = k^*$ for all i and u increases in i. As the increase in inflation out weighs 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 1 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 χ, becomes non monotone as χ gets bigger, and is strictly decreasing. DM output is strictly decreasing, whereas CM output exhibits different patterns corresponding to different χ. In Figure 7e, let $\chi = 0.4$. The economy is in Regime 1 for low inflation and switches to Regime 2 for high inflation. Unemployment decreases with i in this case.

If we increase χ further to 0.5 as shown in Figure 7f, the economy stays in Regime 3 for all i. Wage falls 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 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 ψ. Let $g(q) = (1-\psi)\upsilon(q) + \psi cq$, which is the buyer's payment in Kalai bargaining. Worker's DM value function is

$$\begin{aligned} V_j(z_j, \omega) &= \max_q \{\sigma_h[\upsilon(q_j) - cq_j] + W_j(z_j, \omega)\} \\ \text{st } g(q_j) &\leq z_j + \omega \end{aligned}$$

Unemployed workers choose $q_0 = q_i$, where q_i solves $\upsilon'(q_i)/g'(q_i) = 1 + i/\sigma_h$, and $z_0 = g(q_i)$. For unemployed workers, if $w \geq g(q^*)$, $q_1 = q^*$ and $z_1 = 0$. If $g(q_i) \leq w < g(q^*)$, $q_1 = g^{-1}(w)$ and $z_1 = 0$. If $w < g(q_i)$, $q_1 = q_i$ and $z_1 = g(q_i) - w$. Worker's surplus in the LM is

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

The firm's expected profit in the DM is

$$A \equiv \sigma_f\{(1-u)[\upsilon(q_1) - cq_1)] + u[\upsilon(q_i) - cq_i)]\}.$$

Its DM value function is

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

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

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

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

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

and λ_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 κ 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

We want to confront the model with data and then understand the inflation and unemployment trade-off 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 $\upsilon(q) = A_\upsilon q^\alpha$ and the production function is $q = y/c$. 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 ι_{DM} and A_n normalized to 1, as in Kiyotaki-Wright (1993).

5.1 Data

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 data set, 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.[6] 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 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%.

[6] The FRED data about labor market tightness can be found at https://fredblog.stlouisfed.org/2015/08/labor-market-tightness/

5.2 Calibration

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 β 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 π is determined by the annual inflation rate. The capital depreciation rate δ 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 χ 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 ℓ. 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 ℓ, the literature has not reached a consensus on how to calibrate this value. Shimer (2005) sets $\ell = 0$. Hagedorn and Manovskii (2008) calibrate ℓ 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 θ 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 ι 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 κ to match the labor market tightness.

In the DM, we assume price taking mechanism in the baseline model and hence

	Parameter	Target	Value
ℓ	leisure	zero	0
s	job separation	$u = 5.6\%$	0.0495
ι	LM matching	mon. $\lambda_h = 0.45$	0.7134
χ	k pledgeability	business debt 59.68%	0.2746
δ	depreciation	I/K ratio	0.07
θ	production	$w/Y = 0.707$	0.1446
A_f	production	$K/Y = 2.337$	0.00044
b	EI benefit	replacement 43.5%	0.0000425
κ	entry cost	$\tau = 0.53$	0.000295
ρ	worker bargaining	DM market share 25.64%	0.1796
A_v	DM utility	average MD 0.89	0.4729
α	DM utility	MD elasticity -0.11	0.9108

Table 1: All Parameters

we do not need to calibrate ψ, since the DM markup is 1. The marginal cost of the firm's production/transformation technology is normalized to $c = 1$. In the extension, we will calibrate ψ to match the DM markup directly.

For the rest of the parameters, we jointly choose the LM bargaining power ρ and the CM utility parameters A_v and α 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

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., $z_f > 0$, 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 6 and the kink in money demand is due to regime change, i.e., when the nominal interest rate is high enough, firms stop to hold cash and only use capital as the collateral for wage payment.

Figure 6 shows the welfare cost of inflation measured by compensating inflation. Notice that our model predicts that the welfare cost of 10% annual inflation is worth less than 1% consumption, in line with Lucas (2000), despite the fact that our model features multiple frictions in the LM and the DM. In Figure 6, 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 1, 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 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 τ. 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 6 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 χ 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 χ 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 χ 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 6, we plot the Phillips curves using different values of χ. The slope decreases with χ. 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 Section 3

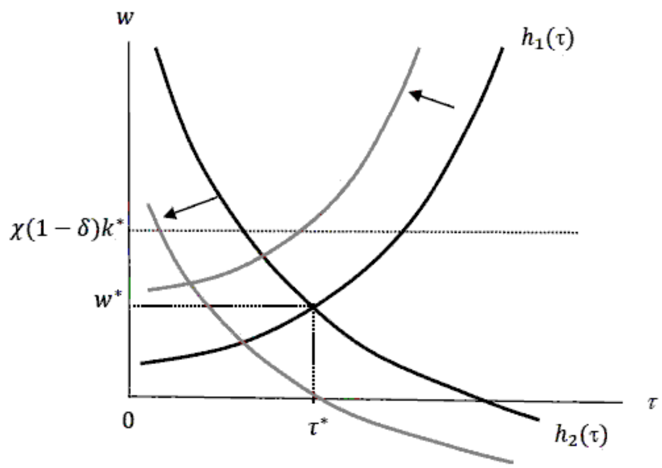


Figure 4: Equilibrium

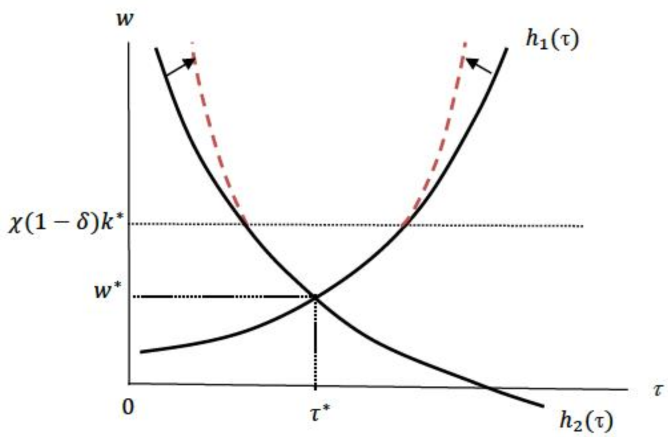


Figure 5a: $w < \chi(1-\delta)k^*$

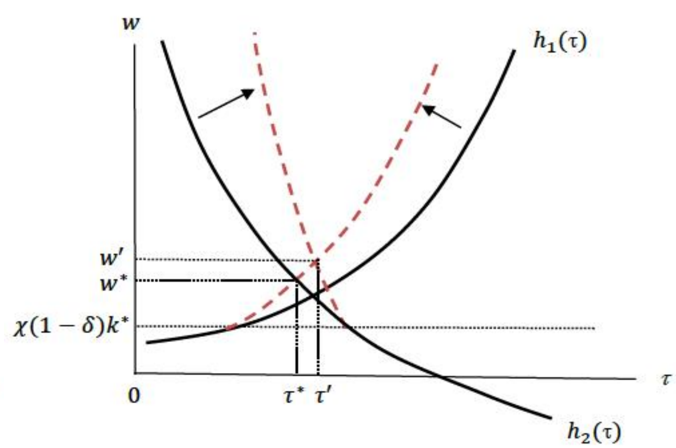


Figure 5b: $w > \chi(1-\delta)k^*$

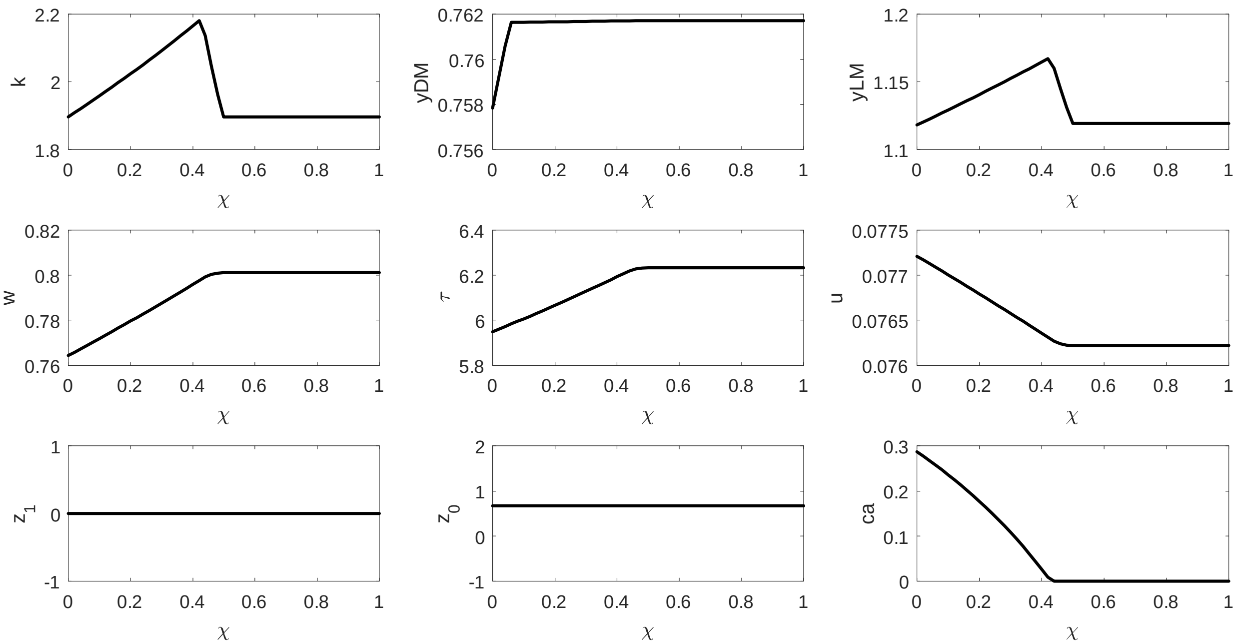


Figure 6: The Effects of χ

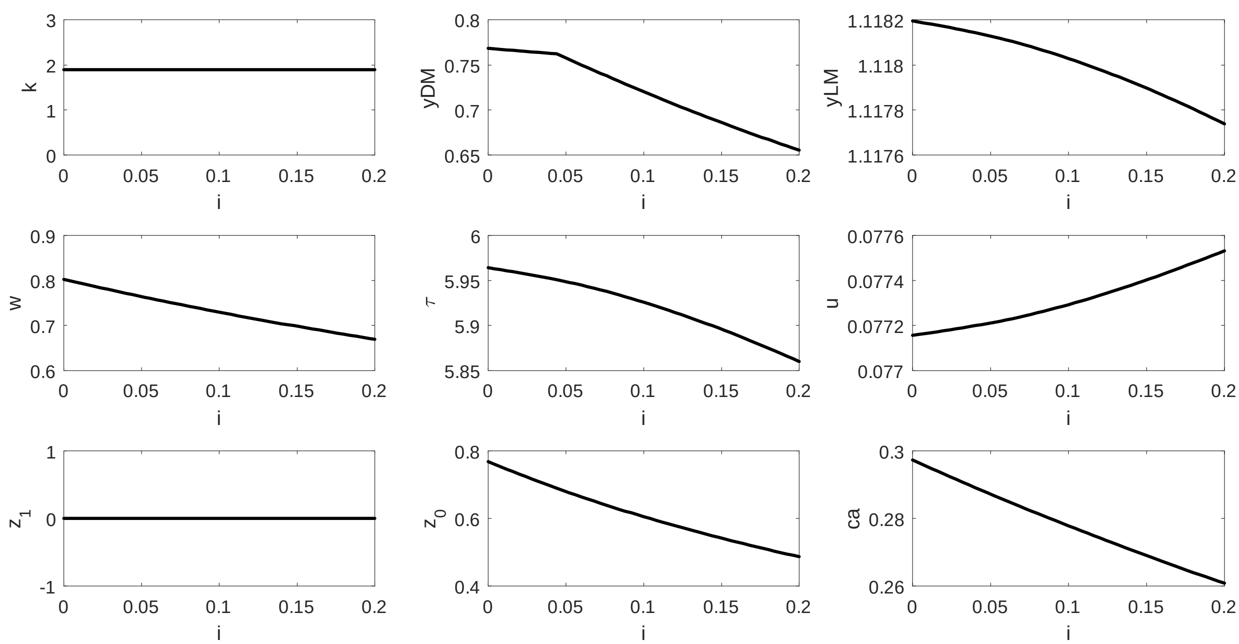


Figure 7a: The Effects of i ($\chi = 0$, Regime 1, $du/di > 0$)

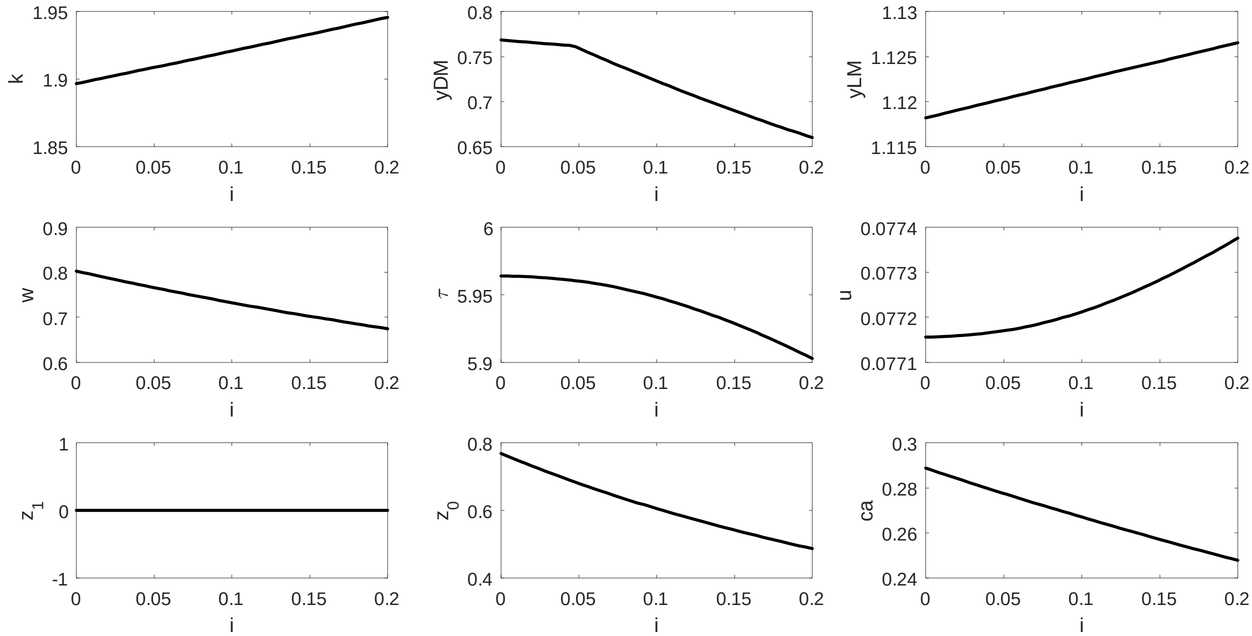


Figure 7b: The Effects of i ($\chi = 0.02$, Regime 1, $du/di > 0$)

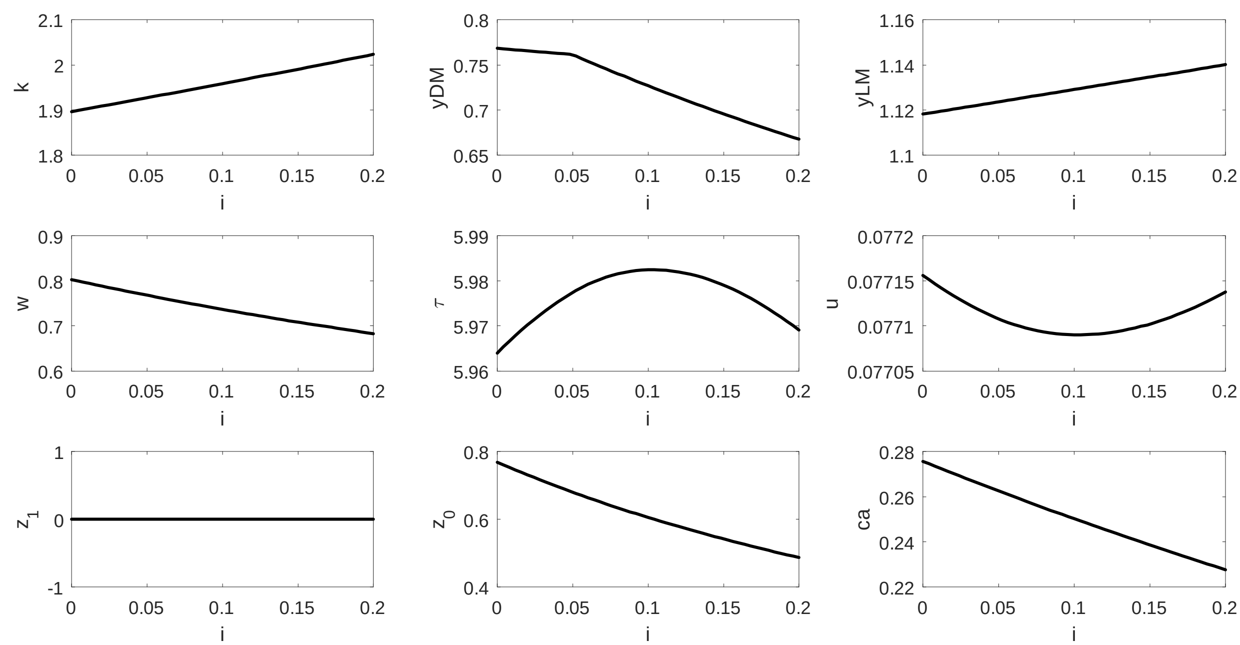


Figure 7c: The Effects of i ($\chi = 0.05$, Regime 1, $du/di >$ or < 0)

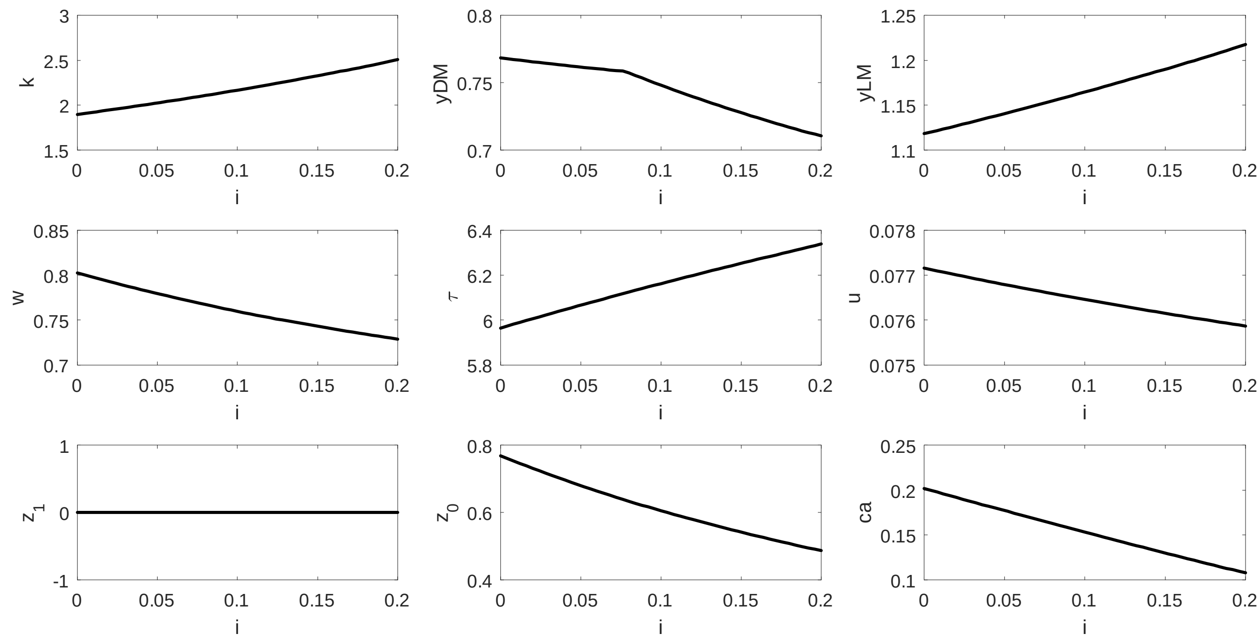


Figure 7d: Effects of i ($\chi = 0.2$, Regime 1, $du/di < 0$)

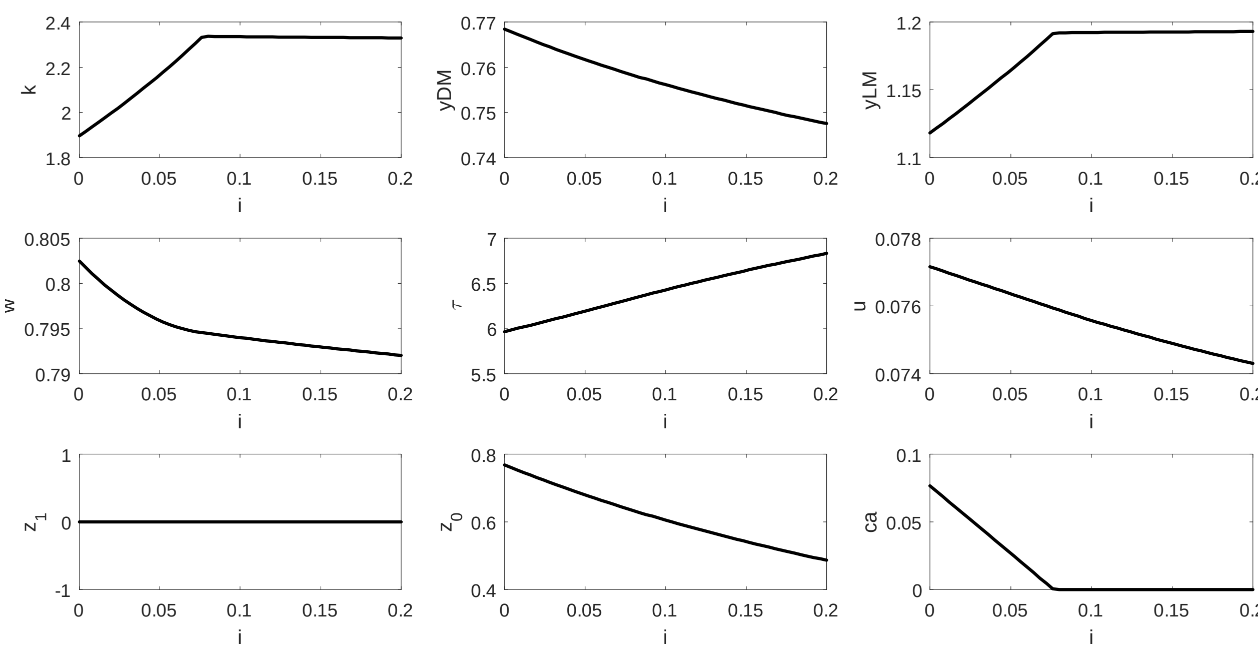


Figure 7e: Effects of i ($\chi = 0.4$, Regimes 1 and 2, $du/di < 0$)

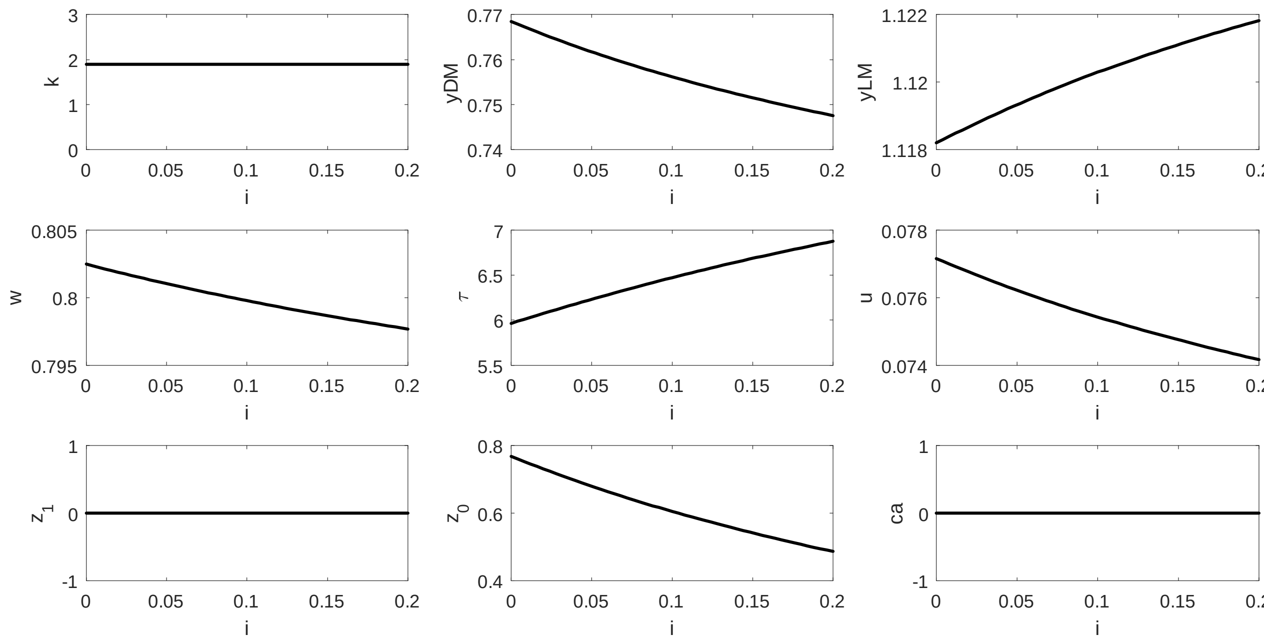


Figure 7f: Effects of i ($\chi = 0.5$, Regime 3, $du/di < 0$)

Appendix B: Search in the DM

In each graph, the solid line represents Walrasian pricing, and the dash line represents Kalai bargaining. 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 $7a - 7f$.

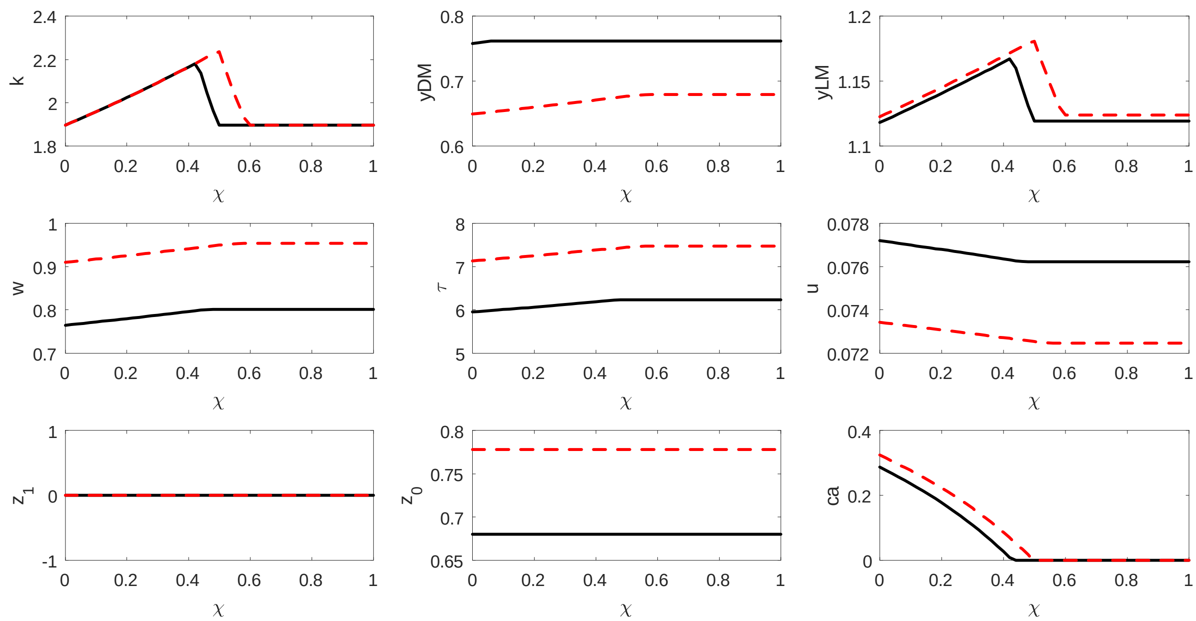


Figure 8: Effect of χ, Kalai

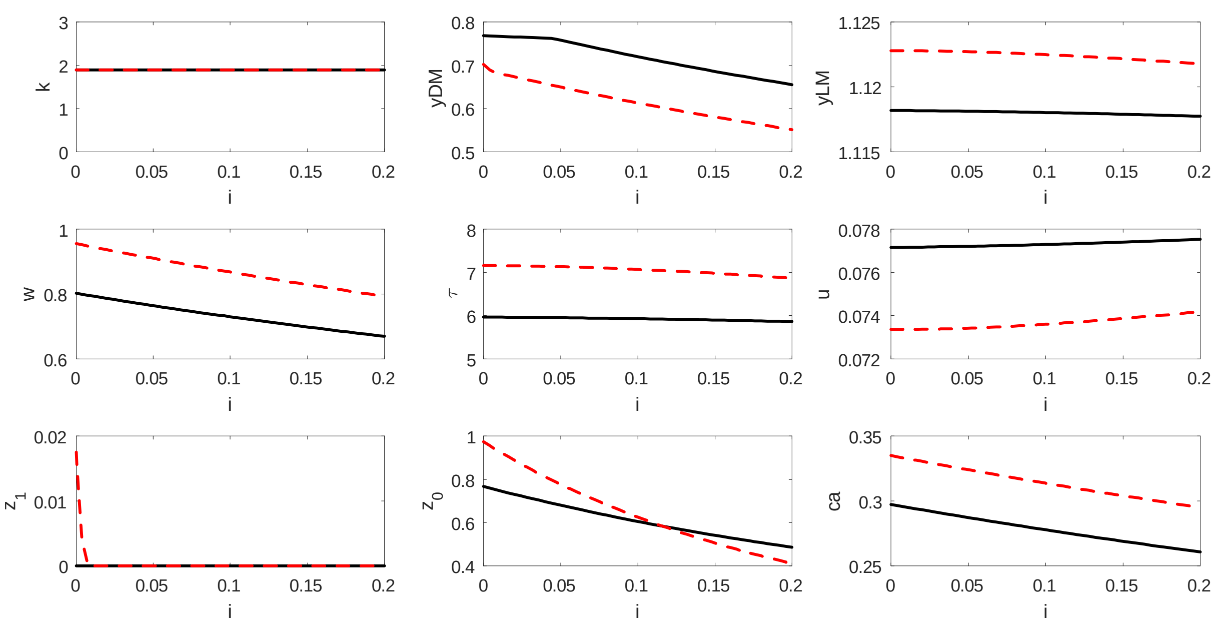


Figure 9a: Effects of i ($\chi = 0$), Kalai

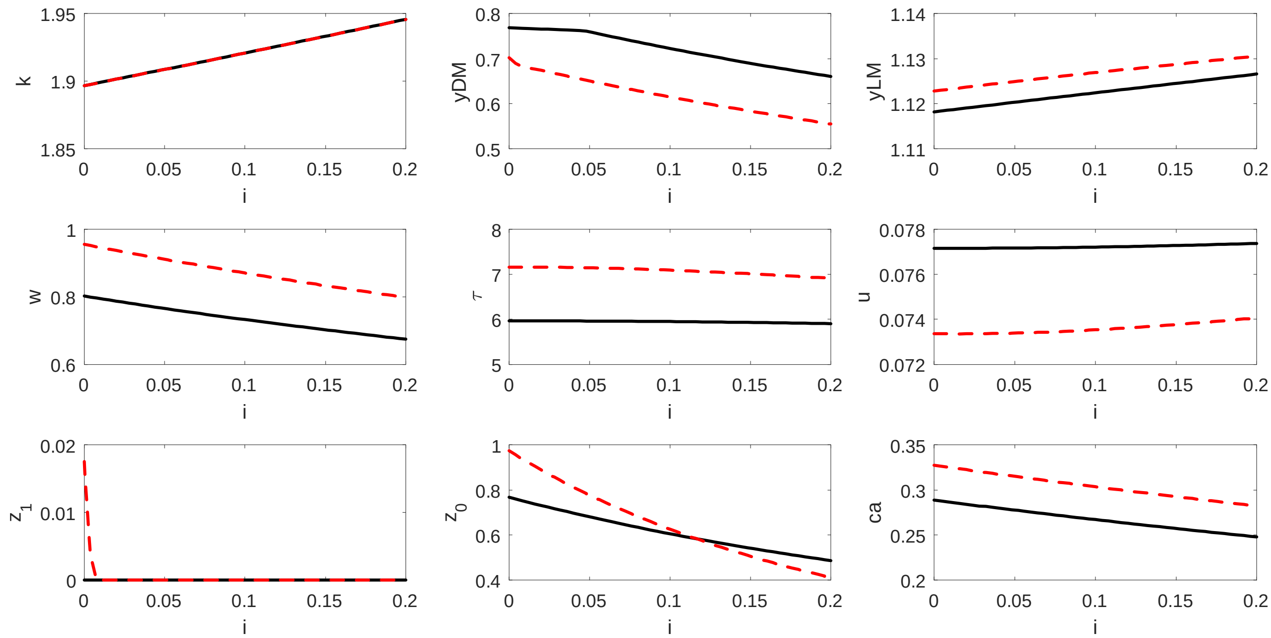


Figure 9b: Effects of i ($\chi = 0.02$), Kalai

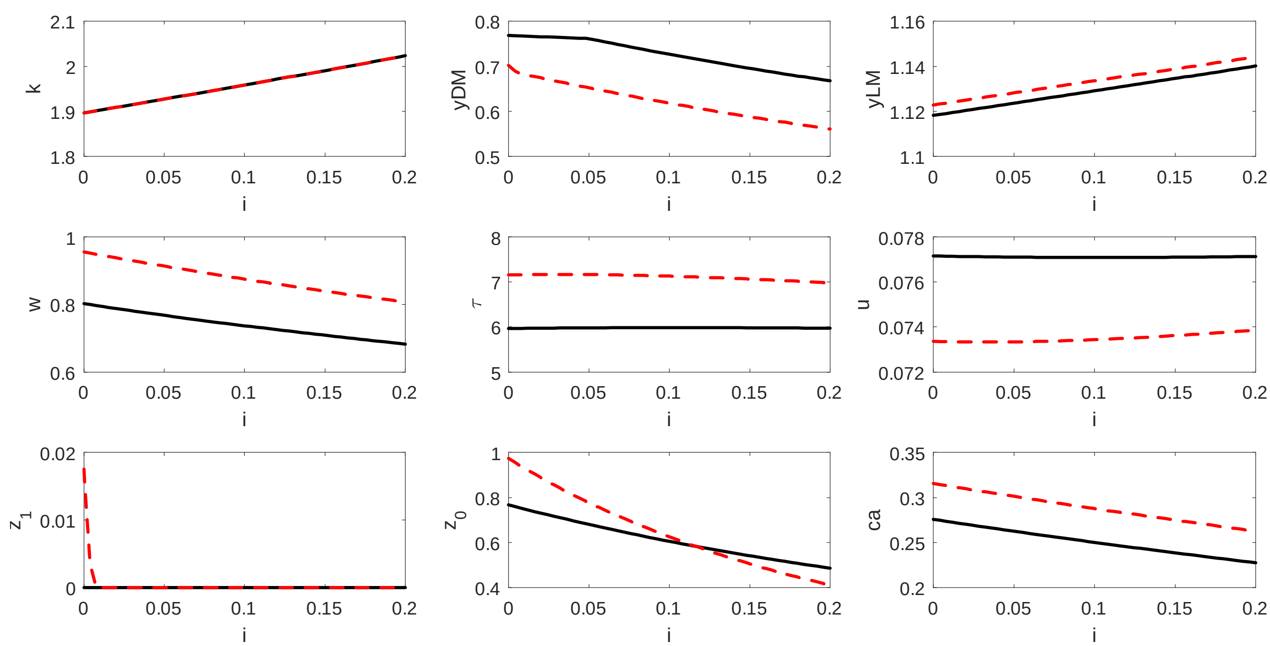


Figure 9c: Effects of i ($\chi = 0.05$), Kalai

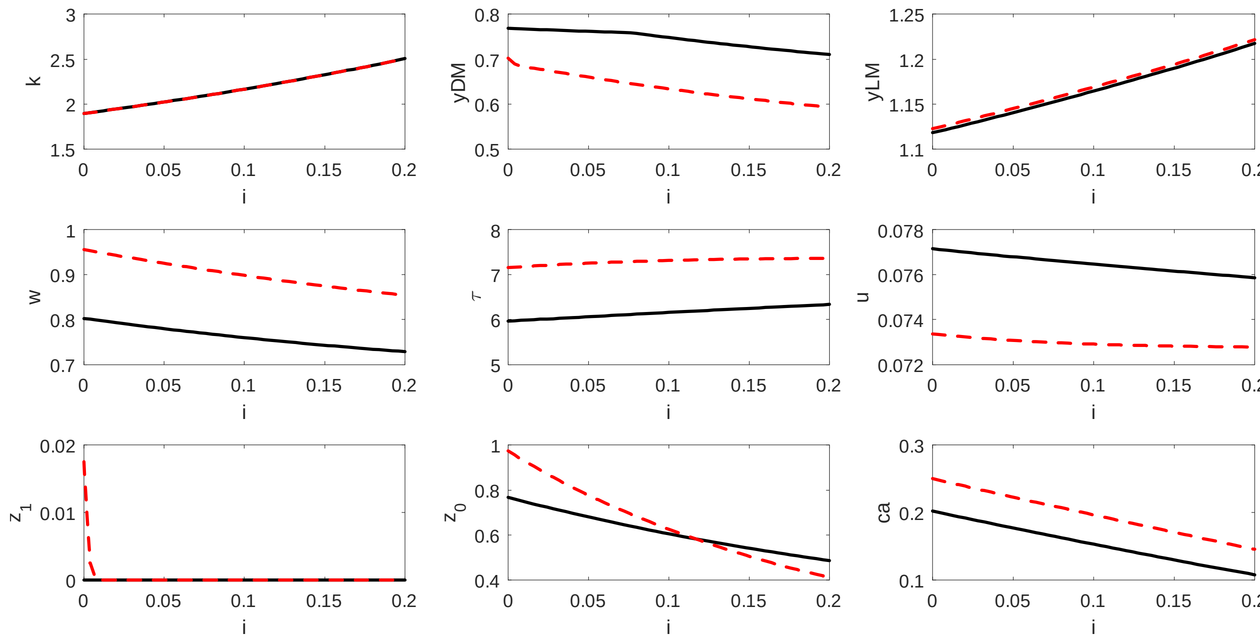


Figure 9d: Effects of i ($\chi = 0.2$), Kalai

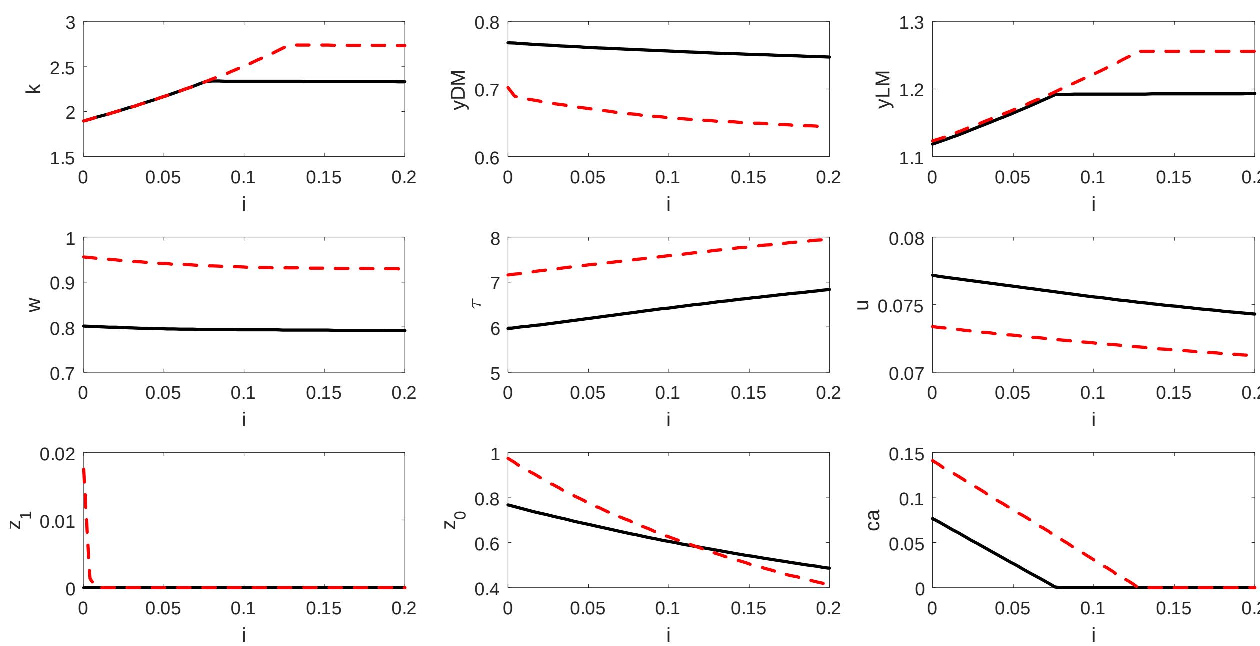


Figure 9e: Effects of i ($\chi = 0.4$), Kalai

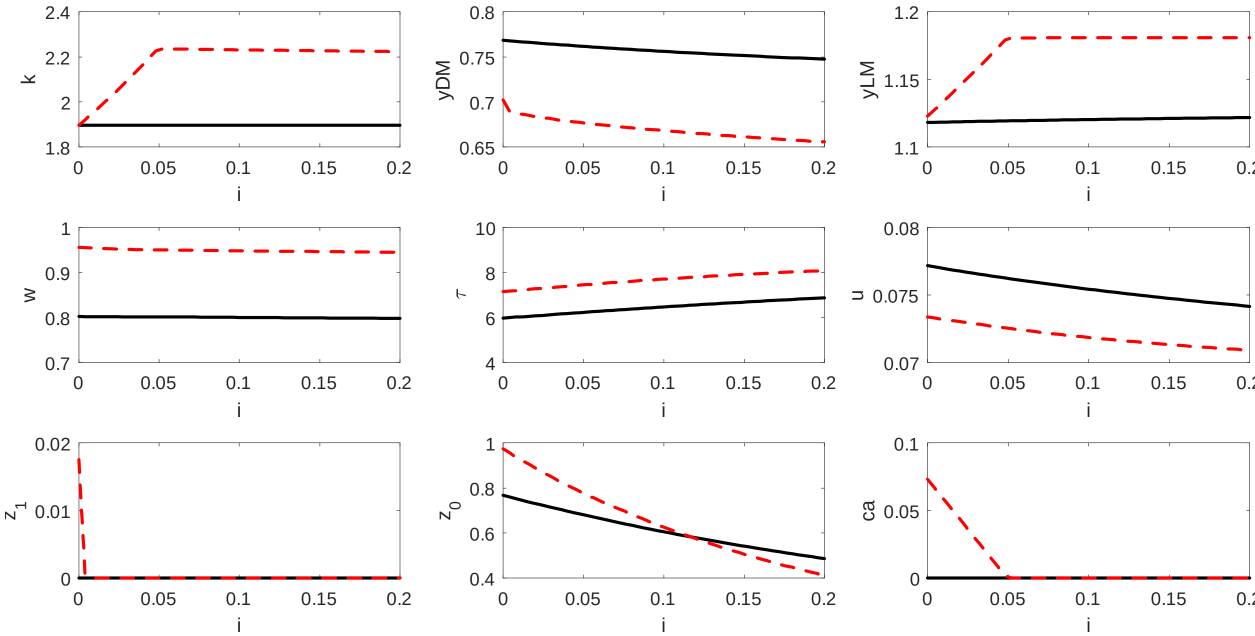
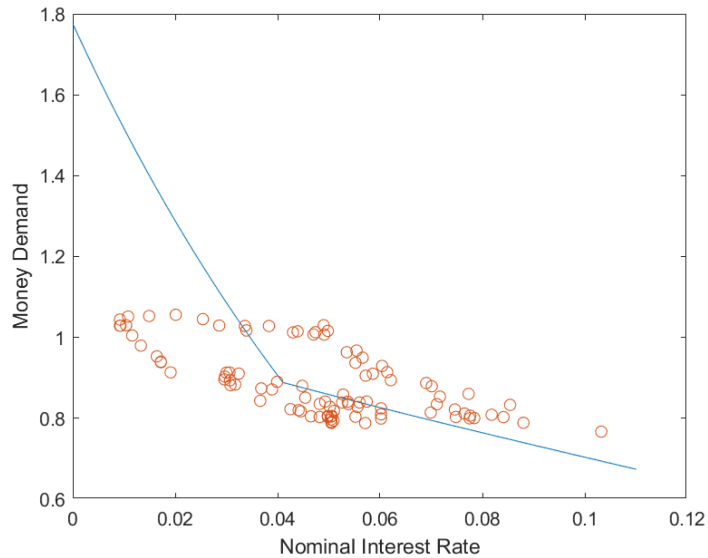
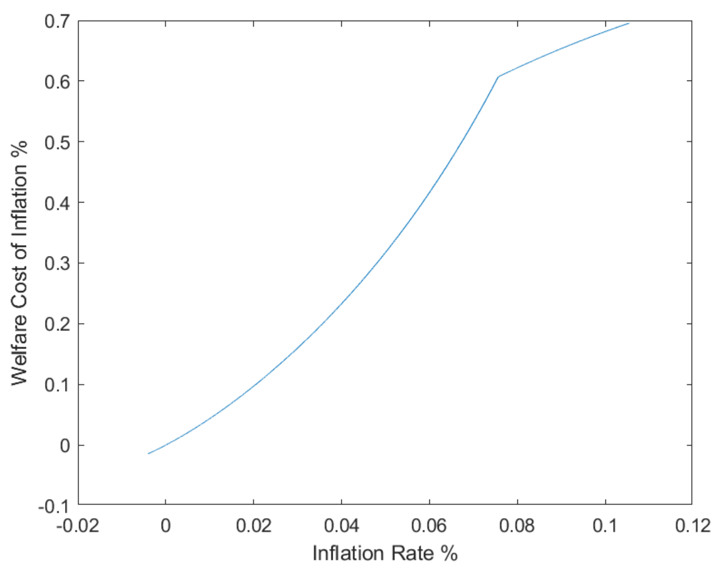


Figure 9f: Effects of i ($\chi = 0.5$), Kalai

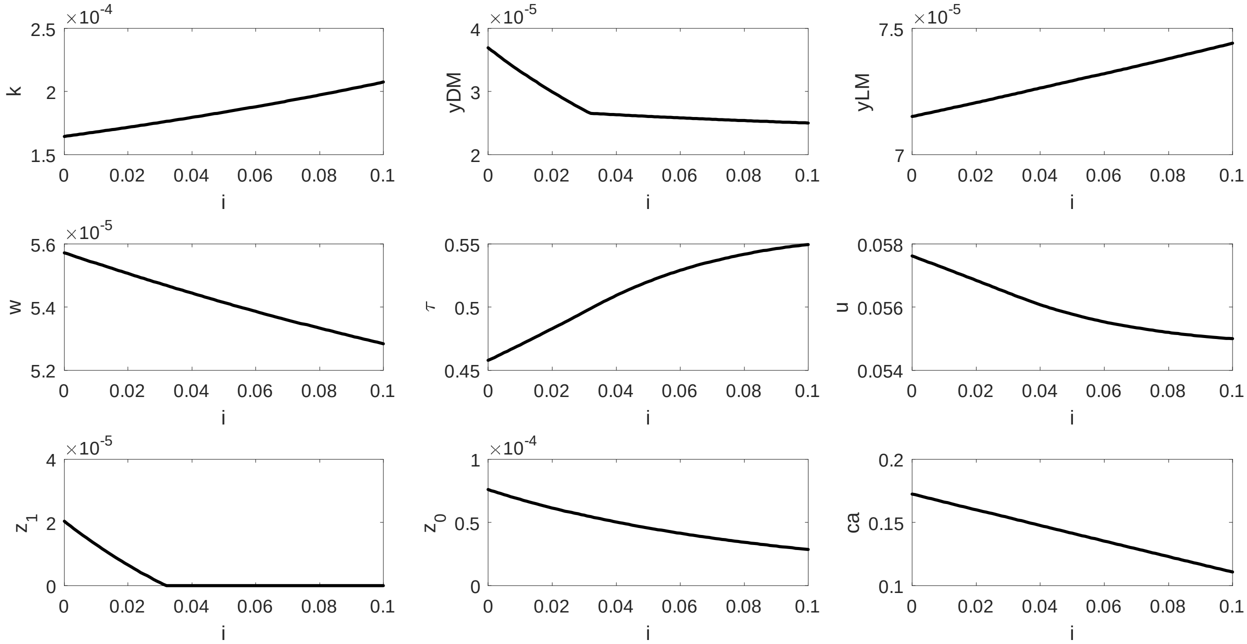
Appendix C: Calibrated Results



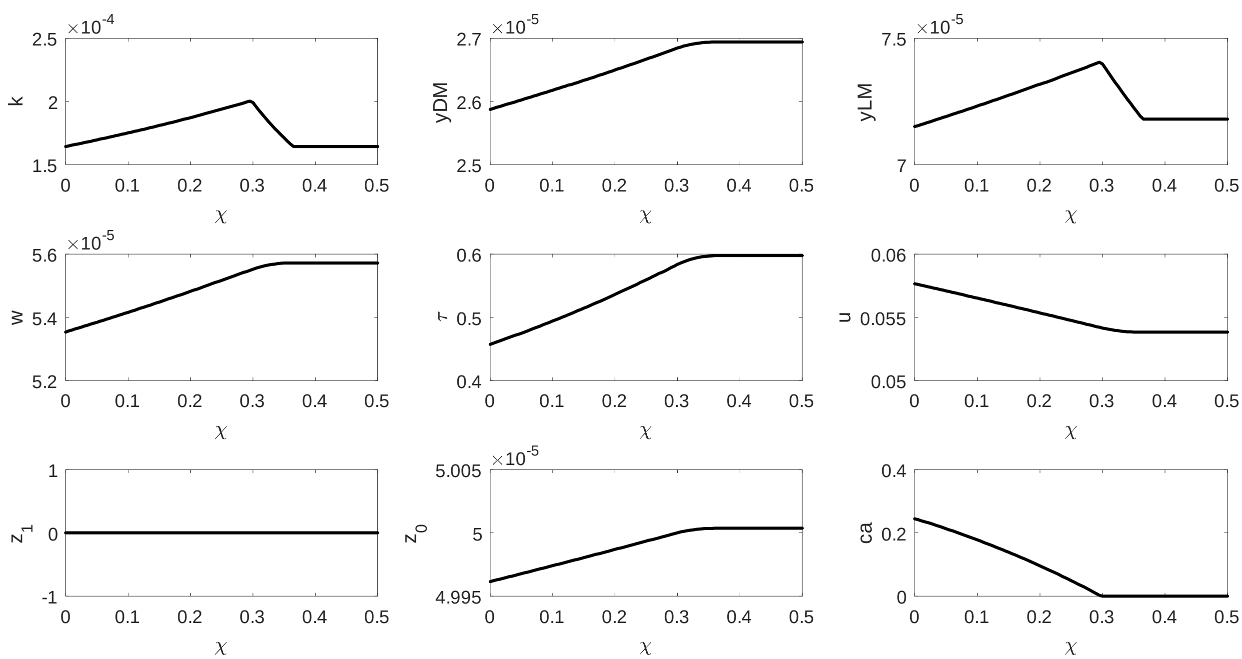
Calibrated Money Demand



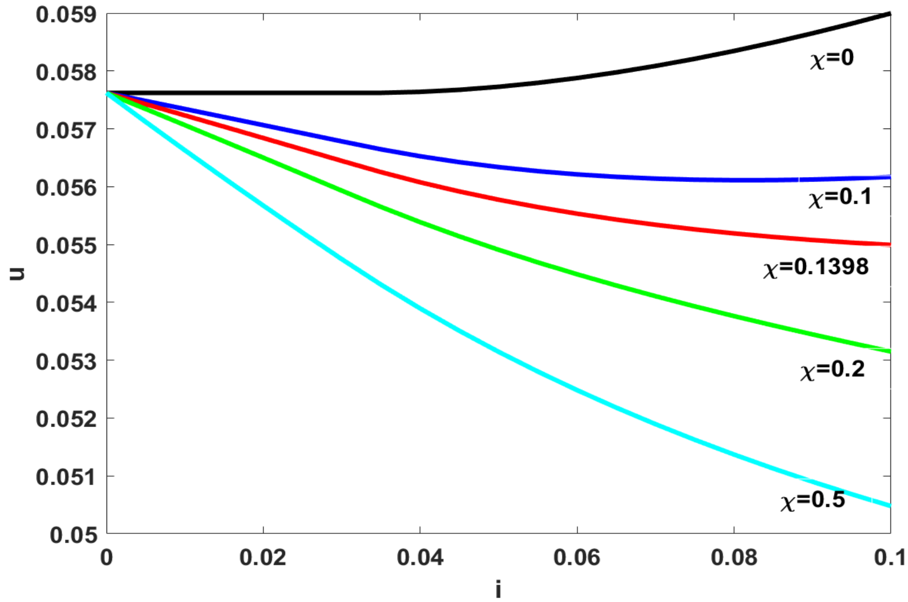
Welfare Cost of Inflation



Calibrated Effect of i



Calibrated Effect of χ



Calibrated Phillips Curves

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