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# Labor Market Search, Sticky Prices, and Interest Rate Policies

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## Abstract

In this paper, a simple search model of the labor market is combined with sticky prices to investigate the dynamic response of the economy to nominal interest rate shocks. The framework allows the respective roles of labor market search, nominal price rigidities, and policy inertia in accounting for the impact of monetary policy shocks to be studied. Labor market rigidities introduced by the process of matching job seekers with job vacancies amplify the real impact and reduce the inflation impact of a monetary policy shock. As a result, significantly less price rigidity is required; for example, the dynamic response of output and inflation in the new Keynesian model with a Walrasian labor market and only 15% of firms optimally adjusting prices each period can be replicated in the labor market search model when a more realistic 50% of firms optimally adjust their price each period.

JEL: E52, E58

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# 1 Introduction

In recent years, monetary economists have increasingly employed dynamic stochastic general equilibrium (DSGE) models based on monopolistic competition and nominal rigidities to study the impacts of monetary policy. The work of Yun (1996), Rotemberg and Woodford (1997), Goodfriend and King (1997), McCallum and Nelson (1999), and others helped to popularize this “new Keynesian” approach. However, the first generation of these models proved unable to generate the persistent output and inflation responses to shocks that are displayed in the data. This was true of the response of inflation to monetary policy shocks (Nelson 1998, Chari, Kehoe, McGrattan 2000), as well as the response of real output (Estrella and Fuhrer 2002). In addition, the degree of price stickiness obtained in estimated new Keynesian Phillips curves is much higher than data on micro price adjustments suggest is plausible. For instance, estimates reported by Galí and Gertler (1999) imply an average duration between price changes of twenty months, and the estimates of Sbordone (2002) imply individual prices are fixed on average for nine months. Evidence from *CPI* surveys reported by Bils and Klenow (2002) suggests that the median time between price adjustment is closer to six months.

To address the shortcomings of the basic new Keynesian model, Dostey and King (2001) argue that “real flexibilities” are critical for generating realistic persistence. They focus on aggregate supply factors such as variable capital utilization and produced inputs. These factors all work to make real marginal cost less sensitive to output movements. Similarly, Christiano, Eichenbaum, and Evans (2001) argue that the interaction of real and nominal rigidities is critical. Christiano, Eichenbaum, and Evans (hereafter CEE) allow for variable capital utilization, but they also introduce demand-side factors such as habit persistence in consumption and investment adjustment costs, as well as both price and nominal wage stickiness.<sup>1</sup> They conclude that nominal wage rigid-

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<sup>1</sup>Fuhrer (2000) has also introduced habit persistence as a means of improving the match of a sticky-price model

ity is more important than price rigidity for matching U.S. aggregate data. Anderson (1998) and Huang and Liu (1999) also argue that nominal wage rigidity is necessary to generate persistent responses to policy shocks.

However, the the conclusion that nominal wage stickiness, as opposed to price stickiness, is necessary to generate persistent responses has also been questioned. Edge (2002) has shown that this result depends critically on the treatment of factor markets. Jeanne (1998), who combined a Calvo-type model of price stickiness with an ad-hoc specification of the equilibrium real wage, found that an increase in labor market real wage rigidity reduced the degree of price stickiness that was needed to match the response of output to a monetary shock. And Goodfriend and King (2001, p. 4) argue that “The labor market is characterized by long-term relationships where there is opportunity and reason for firms and workers to neutralize the allocative effects of temporarily sticky nominal wages.” To date, however, little work has been done to study the implications of these long-term relationships between firms and workers for models with nominal rigidities.

This neglect is perhaps surprising, because the specification of the labor market has been shown to be important for the ability of real business cycle models to match important macro data. Merz (1995) and Andolfatto (1996) find that real business cycle models that incorporate a Mortensen–Pissarides aggregate matching function (Mortensen and Pissarides 1994, Pissarides 2000) to represent the search process in the labor market provide a better match to the evidence on employment and real wages than models based on a traditional Walrasian specification of the labor market. Similarly, Hairault (2002) shows that labor market search improves the ability of international business cycle models to match the data. den Haan, Ramey and Watson (2000) show how a search model of the labor market can amplify and propagate productivity shocks. These models capture the long-term nature of employment relationships that Goodfriend and

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to the data.

King emphasize can alter the allocative implications of any observed rigidity in nominal wages.

Cooley and Quadrini (1999, 2000) have introduced money into a DSGE model with a matching model of the labor market, and they show that money growth rate shocks have highly persistent effects on inflation and the real economy. However, they assume prices are completely flexible, and persistent real effects arise, in part, because they assume nominal portfolios adjust slowly over time. Cheron and Langot (1999) introduce quadratic costs of adjusting prices into the model of Andolfatto (1996) to show that combining technology and money growth rate shocks can account for the negative correlation of unemployment with inflation and vacancies. Walsh (2003a) introduces Calvo-type price stickiness into a model with labor market search and studies the implications for the output effects of money growth rate shocks. The labor market specification is found to have significant effects on the magnitude and persistence of nominal shocks.

To date, the monetary models that have incorporated labor market search have focused on the role of money growth rate shocks, either with flexible prices (Cooley and Quadrini 1999, 2000) or with sticky prices (Cheron and Langot 1999, Walsh 2003a). However, most central banks implement monetary policy through the use of a short-term nominal interest rate, letting the money stock be determined endogenously. For that reason, almost all recent work on monetary policy has represented policy by a nominal interest rate rule, and policy shocks are identified with innovations to the nominal interest rate. In this paper, I incorporate a nominal interest rate policy rule into a sticky-price model with a Mortensen–Pissarides labor market matching process. As in other models based on sticky prices, nominal interest rate movements have temporary effects on the real interest rate that alter optimal consumption spending. The dynamic responses of employment, marginal cost, and inflation all depend on the labor market process by which jobs and workers are matched. This matching process contributes to persistence in both output and inflation, and the model provides a better match to output, employment, and inflation business

cycle statistics than does a new Keynesian model with a Walrasian labor market. In the standard Walrasian labor market model, an expansion of aggregate demand raises marginal cost, even with constant returns to scale, as firms must bid up wages to induce an increase in labor input. In a matching model with endogenous job destruction, an increase in demand leads fewer matches to break up; with more matches surviving to produce, output expands without an increase in marginal cost. Thus, the inflation impact of an expansion are muted and the model is better able to capture the delayed reaction of inflation to a policy shock. The demand expansion induces firms to post additional vacancies, leading to a rise in employment over time that depends on the labor market matching process.

The dynamic response to a policy shock is affected by the matching process, the inertia in the nominal interest rate rule, and the degree of nominal rigidity. All three aspects interact to account for persistence. A benchmark new Keynesian model with habit persistence, lagged inflation adjustment, and a calibrated policy rule yields a median output lag of only two quarters and a median inflation lag of five quarters in response to a nominal interest rate shock. In contrast, the model with labor market search produces a median output lag of four quarters and a median inflation lag of ten quarters. In fact, the benchmark new Keynesian model requires a high degree of nominal price stickiness, with prices adjusted optimally every 20 months, to match the dynamics for output and inflation after a policy shock that are implied by the labor market search model when prices adjust optimally every six months, a figure more in line with survey evidence on prices.

The basic model of labor market search is developed in section 2. The household's decision problem is studied in subsection 2.1. Subsection 2.2 sets out the specification of the labor market. In section 3, the dynamic adjustment of the economy to nominal interest rate shocks is examined. Results for the model with labor market search are compared to those from a new Keynesian

model based on a Walrasian labor market. Conclusions and some suggestions for further research are discussed in section 4.

## 2 The model economy

The model consists of households, firms, and a monetary authority. Goods are produced in a competitive wholesale sector, and the production of wholesale goods requires that a firm and a worker be matched. Wholesale firms sell their output to retail firms, of which there are a continuum of mass one. Retail firms sell differentiated goods to households, and the retail sector is characterized by monopolistic competition and price stickiness; each period only a fraction of all retail firms optimally adjust their price.<sup>2</sup>

### 2.1 Households

The representative households purchases consumption goods, holds money, and supplies one unit of labor inelastically. Households are also the owners of all firms in the economy. Since some workers and firms will be matched, while others will not be, distributional issues arise. To avoid these issues, I assume households pool consumption, both market purchased consumption and any consumption goods produced by workers who do not have an employment match in period  $t$  (home production).<sup>3</sup>

Fuhrer (2000) and CEE have argued that habit persistence is important for matching the slow response of consumption to interest rate changes. Therefore, suppose preferences of the representative household are defined over  $\mathcal{C}_t$  and  $\mathcal{C}_{t-1}$ , where  $\mathcal{C}$  is a composite consumption good

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<sup>2</sup>Separating the goods market into a flexible price wholesale sector and a sticky price retail sector follows the approach of Bernanke, Gertler, and Gilchrist (1999).

<sup>3</sup>This assumption is also employed by Merz (1995), Andolfatto (1996), den Haan, Ramey, and Watson (2000), Cooley and Quadrini (1999, 2000), and Hairault (2002).

that depends on both market purchased goods and home production. Households maximize

$$\mathbb{E}_t \sum_{i=0}^{\infty} \beta^i [u(C_{t+i}, C_{t+i-1}) + \phi(m_{t+i})], \quad (1)$$

where  $\mathcal{C}_t = C_t + C_t^h$ , and  $C_t$  is a composite, market purchased consumption good consisting of the differentiated products produced by monopolistically competitive retail firms, while  $C_t^h$  is home produced consumption (assumed for simplicity to be a perfect substitute for market consumption  $C_t$ ).  $C_t$  is defined as

$$C_t = \left[ \int_0^1 c_{jt}^{\frac{\theta-1}{\theta}} dj \right]^{\frac{\theta}{\theta-1}} \quad \theta > 0.$$

Home produced consumption is given by

$$C_t^h = (1 - \chi_t)b - \chi_t l$$

where the variable  $\chi_t$  is an indicator variable, equal to 1 if the household's worker is employed and 0 otherwise. Thus,  $l$  measures the consumption value of the disutility of work, and  $b$  measures home production when unemployed. Utility also depends on the household's holdings of real money balances,  $m_t$ . Utility is assumed to be separable in consumption and money balances.

Households face a budget constraint give by

$$P_t Y_t + M_{t-1}^h + T_t + (1 + i_{t-1})B_{t-1} - P_t C_t - M_t^h - B_t \geq 0. \quad (2)$$

where  $M_t^h$  ( $B_t$ ) is the household's nominal holdings of money (bonds),  $P_t$  is the retail price index, and  $T_t$  is a lump-sum transfer received from the government. In the aggregate, this transfer is equal to  $M_t - M_{t-1} = (G_t - 1)M_{t-1}$  where  $M$  (without the superscript  $h$ ) is the aggregate nominal money stock. Bonds pay a nominal rate of interest of  $i_t$ , and  $Y_t$  is the household's real income, consisting of wage income and firm profits.

Given prices  $p_{jt}$  for the final goods, this preference specification implies the household's demand for good  $j$  is

$$c_{jt} = \left( \frac{p_{jt}}{P_t} \right)^{-\theta} C_t, \quad (3)$$



where the aggregate retail price index  $P_t$  is defined as

$$P_t = \left[ \int_0^1 p_{jt}^{1-\theta} dj \right]^{\frac{1}{1-\theta}}. \quad (4)$$

The following condition, obtained from the household's first order conditions, must also hold in equilibrium:

$$\frac{\lambda_t}{P_t} = \beta(1 + i_t)E_t \left( \frac{\lambda_{t+1}}{P_{t+1}} \right), \quad (5)$$

where  $\lambda_t$  denotes the total marginal utility of consumption at time  $t$  and is given by

$$\lambda_t \equiv u_1(\mathcal{C}_t, \mathcal{C}_{t-1}) + \beta E_t u_2(\mathcal{C}_{t+1}, \mathcal{C}_t). \quad (6)$$

Note that  $\lambda_t$  includes the impact of  $\mathcal{C}_t$  on both  $u(\mathcal{C}_t, \mathcal{C}_{t-1})$  and on  $u(\mathcal{C}_{t+1}, \mathcal{C}_t)$ .

## 2.2 The labor and goods markets

The production side of the model, and the labor market specification is based on den Haan, Ramey, and Watson (2000). Their focus is on the role of aggregate productivity shocks in a non-monetary economy, and, in order to simplify the model, I ignore the capital stock dynamics that they include.

### 2.2.1 The wholesale sector

At the beginning of the period, there are  $N_t$  matched workers and firms. Existing matches face an exogenous probability  $0 \leq \rho^x < 1$  that the match is terminated. For the  $(1 - \rho^x)N_t$  matches that survive, the worker and firm jointly observe the current realization of productivity and decide whether to continue the match. If the match continues, production occurs, with output equal to

$$y_{it} = a_{it}z_t, \quad (7)$$

where  $a_{it}$  is a match-specific productivity disturbance and  $z_t$  is a common, aggregate productivity disturbance. The means of both productivity disturbances are equal to 1 and both are bounded

below by zero. Wholesale firms sell their output in a competitive market at the price  $P_t^w$ .

Firms seeking workers must incur a cost of posting a vacancy, and workers seeking jobs must engage in a search process that takes time. As a consequence, existing matches can earn an economic surplus, and both the firm and the worker will wish to maintain a match with a positive expected surplus. The match's expected surplus depends, in part, on the value of the current output the match produces. The real value of this output, expressed in terms of time  $t$  consumption goods, is  $P_t^w a_{it} z_t / P_t = a_{it} z_t / \mu_t$ , where  $\mu_t = P_t / P_t^w$  is the markup of retail over wholesale prices. In addition, there is a continuation value of being part of an existing match that survives into period  $t + 1$ . Thus, the expected value of a match that produces in period  $t$  is

$$\left( \frac{a_{it} z_t}{\mu_t} \right) - l + g_{it}$$

where  $g_{it}$  is the expected present value of a match that continues into period  $t + 1$ .

The surplus generated by a match is the difference between  $(a_{it} z_t / \mu_t) - l + g_{it}$  and the alternative opportunities available to the firm and the worker. If the firm has no alternative opportunities, the match's opportunity cost,  $w_t^u$ , is equal to the value of home consumption an unmatched worker can produce plus the present value of future worker opportunities if unmatched in period  $t$ . Define  $q_t \equiv g_t - w_t^u$  as the expected excess value of a match that continues into period  $t + 1$ . Since all matches are identical, the subscript  $i$  has been suppressed. A match will be continued as long as  $(a_{it} z_t / \mu_t) - l + q_t \geq 0$ . Matches will endogenously separate if the firm specific productivity shock is less than  $\tilde{a}_t$ , where  $\tilde{a}_t$  is defined as

$$\tilde{a}_t = \frac{\mu_t (l - q_t)}{z_t}. \quad (8)$$

If  $l - q_t < 0$ , then matches would never endogenously end since the support of  $a$  is strictly positive. When  $l - q_t > 0$ , matches do endogenously breakup. In this case, a higher realization of the aggregate productivity shock  $z_t$  will, ceteris paribus, lower  $\tilde{a}_t$ , making it more likely that

existing matches produce. A higher  $z_t$  realization directly increases the production of all matched worker/firms (see equation 7). It also leads more matches to produce since fewer endogenously separate (see equation 8). Thus, the role of  $z_t$  in affecting  $\tilde{a}_t$  will tend to amplify the impact of the aggregate productivity shock on output, an effect emphasized by den Haan, Ramey, and Watson (2000). A rise in the markup of retail over wholesale prices reduces the profitability of wholesale production and increases  $\tilde{a}_t$ . These results are only partial equilibrium effects, however, since changes in aggregate productivity also affect  $q_t$ .

Let  $\rho_t^n$  be the aggregate fraction of matches that endogenously separate, and let  $F$  denote the cumulative distribution function of the match specific productivity shock. Since all matches are identical, the aggregate endogenous separation rate is the probability that  $a_t \leq \tilde{a}_t$ :

$$\rho_t^n = \Pr[a_t \leq \tilde{a}_t] = F(\tilde{a}_t). \quad (9)$$

The aggregate total separation rate  $\rho_t$  is equal to

$$\rho_t = \rho^x + (1 - \rho^x)\rho_t^n, \quad (10)$$

while the survival rate,  $\varphi_t \equiv (1 - \rho_t) = (1 - \rho^x)[1 - F(\tilde{a}_t)]$ , is decreasing in  $\tilde{a}$ .

Define the joint surplus of a worker-firm pair who are matched at the start of  $t + 1$  and do not separate as

$$s_{it+1} = \left( \frac{a_{it+1}z_{t+1}}{\mu_{t+1}} \right) - l + q_{t+1}. \quad (11)$$

Note that this is expressed in terms of the present value as of the beginning of period  $t + 1$ .

Let  $\eta$  denote the share of this surplus received by the worker; the firm receives  $1 - \eta$  of the joint surplus. These share parameters are assumed to be constant. If an unmatched worker in period  $t$  succeeds in making a match that produces in period  $t + 1$ , she receives her opportunity utility  $w_{t+1}^u$  plus the fraction  $\eta$  of the joint surplus, or  $\eta s_{it+1} + w_{t+1}^u$ . The probability of this occurring is  $k_t^w(1 - \rho_{t+1})$ , where  $k_t^w$  is the period  $t$  probability an unmatched worker finds a job

and  $1 - \rho_{t+1}$  is the probability that the match actually produces in period  $t + 1$ . With probability  $1 - k_t^w(1 - \rho_{t+1})$  the worker either fails to make a match or makes a match that fails to survive to produce in  $t + 1$ . In either case, the worker is unmatched in  $t + 1$  and receives  $w_{t+1}^u$ . Therefore, letting  $\Delta_{t,t+i} = \beta^i (\lambda_{t+i}/\lambda_t)$ , the expected discounted value to an unmatched worker in the labor matching market is

$$w_t^u = b + \text{E}_t \Delta_{t,t+1} \left[ k_t^w (1 - \rho^x) \int_{\bar{a}_{t+1}}^{\bar{a}} \eta s_{it+1} f(a_i) da_i + w_{t+1}^u \right], \quad (12)$$

since an unmatched worker is assumed to produce home consumption  $b$  while unmatched.

For a worker and firm who are already matched, the joint discounted value of an existing match is

$$g_t = \text{E}_t \Delta_{t,t+1} \left[ (1 - \rho^x) \int_{\bar{a}_{t+1}}^{\bar{a}} s_{it+1} f(a_i) da_i + w_{t+1}^u \right]. \quad (13)$$

Hence,

$$q_t = g_t - w_t^u = (1 - \rho^x)(1 - \eta k_t^w) \text{E}_t \Delta_{t,t+1} \left[ \int_{\bar{a}_{t+1}}^{\bar{a}} s_{t+1} f(a_i) da_i \right] - b. \quad (14)$$

Unmatched firms can post vacancies at a cost of  $\gamma$  per period. If an unmatched firm does post a vacancy and succeeds in making a match that produces in period  $t + 1$ , it receives  $(1 - \eta)s_{t+1}$ . Otherwise (i.e., if no match is made or if the match separates before production), the firm receives nothing. If  $k_t^f$  is the probability a vacancy is filled, free entry ensures that firms post vacancies until

$$\text{E}_t \Delta_{t,t+i} \left[ k_t^f (1 - \rho^x) \int_{\bar{a}_{t+1}}^{\bar{a}} (1 - \eta) s_{t+1} f(a) da \right] - \gamma = 0. \quad (15)$$

Combining (14) and (15),

$$q_t = \frac{\gamma(1 - \eta k_t^w)}{(1 - \eta) k_t^f} - b. \quad (16)$$

Increases in either  $k^w$  or  $k^f$  reduce the value of continuing in an existing match by making it easier to find a new match.

A total of  $\rho_t N_t$  matches dissolve prior to engaging in production. If the worker is not part of an existing match, or if her current match ends, she travels to the labor matching market. A total of

$$u_t \equiv U_t + \rho_t N_t = 1 - (1 - \rho_t)N_t \quad (17)$$

workers will be searching for a new match. Based on an aggregate matching function, a fraction of job-seeking workers and firms posting vacancies establish new matches. These, plus the worker-firm matches that produced during the period, constitute the stock of matches that enter period  $t + 1$ . Thus, the total number of matches evolves according to

$$N_{t+1} = (1 - \rho_t)N_t + m(u_t, V_t), \quad (18)$$

where  $m(u_t, V_t)$  is the aggregate matching function and  $V_t$  is the number of posted vacancies.

The probability an unemployed worker makes a match,  $k_t^w$ , is

$$k_t^w = \frac{m(u_t, V_t)}{u_t}. \quad (19)$$

Similarly, the probability a firm with a posted vacancy finds a match,  $k_t^f$ , is

$$k_t^f = \frac{m(u_t, V_t)}{V_t}. \quad (20)$$

The aggregate output of the wholesale sector is obtained by aggregating over all matches that actually produce:

$$\begin{aligned} Q_t &= \text{E}_t [a_t \mid a \geq \tilde{a}_t] z_t \varphi_t N_t \\ &= \left[ \int_{\tilde{a}_t}^{\infty} a_t \left( \frac{f(a)}{1 - F(\tilde{a}_t)} \right) da \right] z_t \varphi_t N_t. \end{aligned} \quad (21)$$

den Haan, et. al. assume that firms experiencing exogenous separations immediately repost the vacancy that is created, while firms with matches that ended endogenously do not. Thus,  $\rho^x N_t$  job separations are reposted in period  $t$  and  $k^f \rho^x N_t$  of those are filled. Total job creation is

defined then as  $k^f V_t - k^f \rho^x N_t$ , the total number of new matches created net of those exogenous separations that are refilled within the period. The job creation rate is

$$JCR_t = k_t^f \left( \frac{V_t}{N_t} \right) - k_t^f \rho^x. \quad (22)$$

Similarly, total job destruction is  $\rho_t N_t - k^f \rho^x N_t$ , and the job destruction rate is

$$JDR_t = \rho_t - k_t^f \rho^x. \quad (23)$$

### 2.2.2 The retail section

Firms in the retail sector purchase output from wholesale producers at the price  $P_t^w$  and sell directly to households. For simplicity, assume retail firms have no other inputs or costs. Given the structure of demand facing each retail firm (see equation 3), all retail firms would charge the same price in a flexible price equilibrium, and the retail price would be a constant markup  $\theta/(\theta - 1)$  over wholesale prices. I adopt a Calvo specification in which the probability a retail firm optimally adjusts its price each period is  $1 - \omega$ . In the standard Calvo model, the prices of the remaining fraction are fixed.

Each retail firm's nominal marginal cost is just  $P_t^w$ . Real marginal cost is equal to the inverse of the markup  $\mu_t$ . Let  $p_{jt}$  be the price of retail firm  $j$ , and let  $p_t^*$  be the price chosen by all firms who set prices in period  $t$ . (All retail firms setting prices in period  $t$  will chose the same price.) Using equation (3), the firm's decision problem then involves picking  $p_t^*$  to maximize

$$\mathbb{E}_t \sum_{i=0}^{\infty} \omega^i \Delta_{t,t+i} \left[ \left( \frac{p_t^*}{P_{t+i}} \right)^{1-\theta} - \left( \frac{1}{\mu_{t+i}} \right) \left( \frac{p_t^*}{P_{t+i}} \right)^{-\theta} \right] C_{t+i}.$$

The first order condition implies<sup>4</sup>

$$\left( \frac{p_t^*}{P_t} \right) = \left( \frac{\theta}{\theta - 1} \right) \frac{\mathbb{E}_{t-1} \sum_{i=0}^{\infty} \omega^i \Delta_{i,t+i} \left[ \left( \frac{1}{\mu_{t+i}} \right) \left( \frac{P_{t+i}}{P_t} \right)^{\theta} C_{t+i} \right]}{\mathbb{E}_{t-1} \sum_{i=0}^{\infty} \omega^i \Delta_{i,t+i} \left[ \left( \frac{P_{t+i}}{P_t} \right)^{\theta-1} C_{t+i} \right]}. \quad (24)$$

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<sup>4</sup>See, for example, Sbordone (1999) for a more complete derivation.

The aggregate retail price index is

$$P_t^{1-\theta} = (1 - \omega)(p_t^*)^{1-\theta} + \omega P_{t-1}^{1-\theta}. \quad (25)$$

Equations (24) and (25) jointly determine  $p_t^*$  and  $P_t$ .

The inflation adjustment equation that results from (24) and (25) has been criticized for failing to adequately capture the short-run dynamics of inflation (Estrella and Fuhrer 2000). To address this shortcoming, Christiano, Eichenbaum, and Evans (2001) develop a Calvo-pricing model in which price setting decisions are made prior to observing current period shocks and all firms adjust their prices each period, but only the fraction  $1 - \omega$  fully optimize. The remaining fraction simply adjust their prices according to the most recent aggregate rate of inflation, setting their prices according to  $p_{it} = \pi_{t-1} p_{it-1}$ . Under this specification, (25) is replaced by

$$P_t^{1-\theta} = (1 - \omega)(p_t^*)^{1-\theta} + \omega (\pi_{t-1} P_{t-1})^{1-\theta}. \quad (26)$$

and expectations in (24) are dated  $t-1$ . This CEE specification is used in the simulation exercises of section 3.

### 2.2.3 Goods market equilibrium

Aggregate household income is equal to production net of vacancy posting costs:

$$Y_t = Q_t - \gamma V_t. \quad (27)$$

Equilibrium requires that  $Y_t = C_t$ .

## 2.3 The monetary authority

Most central banks implement monetary policy by controlling a short-term nominal rate of interest, and empirical work has also focused on the impact of interest rate shocks as a means of identifying the role of monetary policy (Christiano, Eichenbaum, and Evans 1999). However, one

cannot simply specify arbitrary, exogenous (stationary) rules for the nominal interest rate; the nominal rate must react endogenously to inflation in a sticky price model to ensure the existence of a unique, stationary, rational expectations equilibrium (Svensson and Woodford 2003). Thus, it is common in recent sticky price models to require that the policy rule satisfy the “Taylor Principle” under which the nominal interest rate responds more than one-for-one to changes in either actual or expected inflation. I assume, therefore, that the nominal rate of interest follows the process

$$R_t = R_{t-1}^{\rho_R} \left( \frac{P_t}{P_{t-1}} \right)^{\phi_\pi(1-\rho_R)} e^{\phi_t} \quad (28)$$

where  $\phi_t$  is a serially uncorrelated, mean zero stochastic process and  $\phi_\pi > 1$ . Given this rule for the nominal rate of interest, the nominal quantity of money adjusts endogenously to satisfy the demand for money.

### 3 Model evaluation

The model is evaluated by studying the properties of a linearized version of the model, expressed in terms of percentage deviations around the steady-state. The next subsection discusses the functional forms employed and the baseline calibration. Then, the quantitative properties of the model are examined. These are compared to summary business cycle statistics for the U.S. and to the quantitative properties of a new Keynesian model with habit persistence and the CEE dynamics inflation adjustment but with a Walrasian labor market.

#### 3.1 Functional forms and calibration

In solving the model, the utility function for consumption is assumed to be

$$u(C_t, C_{t-1}) = \frac{(C_t - hC_{t-1})^{1-\sigma}}{1-\sigma}; \quad \sigma > 0$$



where  $\sigma$  is the coefficient of relative risk aversion, and  $h$  is a measure of the degree of habit persistence in consumption.

The other functional form that needs to be specified is that of the aggregate matching function.<sup>5</sup> This function is taken to be Cobb-Douglas with constant returns to scale:

$$m(u_t, V_t) = \mu u_t^a V_t^{1-a}, \quad 0 < a < 1. \quad (29)$$

Constant returns to scale is consistent with the empirical evidence (see Petrongolo and Pissarides 2001).

The model is characterized by five sets of parameters—those describing 1) household preferences, 2) the aggregate matching function and the labor market, 3) the degree of price rigidity at the retail level, 4) the behavior of the nominal interest rate, and 5) the stochastic distribution of the exogenous shocks. Parameter values are chosen to be largely consistent with those standard in nonmonetary models and with estimated new Keynesian models.

**Preferences** The discount rate ( $\beta$ ) and the coefficient of relative risk aversion ( $\sigma$ ) appear in standard DSGE models. Choosing the time period to correspond to a quarter,  $\beta$  is set equal to 0.989. A value of 2 is chosen for  $\sigma$ , implying greater risk aversion than log utility. The parameter  $\theta$  determines the elasticity of demand for the differentiated retail goods; this elasticity in turn determines the markup  $\mu$ . The steady-state markup is set equal to 1.1, corresponding to  $\theta = 11$ . CEE’s estimate of 0.67 is employed for  $h$ . The value of home production while unemployed,  $b$ , is set equal to zero.

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<sup>5</sup>Because monetary policy is represented by an interest rate rule, the function  $\phi(m)$  giving the utility value of money holdings plays no role except to determine the nominal stock of money. Since the focus here is not on the stock of money, it will not be necessary to specify the functional form of  $\phi$ .

**Matching and the labor market** I follow den Haan, et. al. (2000) in setting the steady-state separation rate  $\rho^s$  equal to 0.1. This is based on Hall’s conclusion that “around 8 or 10 percent of workers separate from their employer each quarter” (Hall, 1995, p.235) and the Davis, Haltiwanger, and Schuh (1996) finding of about an 11 percent quarterly separation rate. This is higher than the 0.07 value adopted by Merz (1995), but lower than the 0.15 used by Andolfatto (1996). Given a value of 10 percent for  $\rho^s$ , den Haan, Ramey, and Watson use evidence on permanent job destruction to calibrate the exogenous separation probability  $\rho^x$  as 0.068. I use this value for the baseline simulations. These values for  $\rho^x$  and  $\rho$  imply an endogenous separation probability  $\rho^n$  of 0.0343. From this value, and the assumed distribution function for the match specific productivity shock, the steady-state value of the cut-off productivity realization  $\tilde{a}$  can be derived. I assume  $\tilde{a}$  is log normally distributed, serially uncorrelated, with standard deviation 0.15; this last value is somewhat higher than the value used by den Haan, et. al.

For the matching function (29), I adopt the standard values of  $a = 0.4$  based on the estimates of Blanchard and Diamond (1989).<sup>6</sup> Both Cooley and Quadrini and den Haan, et. al. fix the steady-state value of the vacancy-filling probability  $k^f$  at 0.7. Cooley and Quadrini cite Cole and Rogerson (1999) to set the average duration of unemployment at 1.67 quarters, which implies a steady-state value of 0.6 for  $k^w$ . It is common in labor search models with a labor-leisure choice to treat unemployment and out of the labor force as equivalent (Andolfatto 1976, Hairault 2002) and set the steady-state value of  $N$  equal to 0.57, normalizing the population size to 1. Because I ignore the labor-leisure choice, I normalize the labor force size to 1 and set  $N = 0.94$ , implying a steady-state unemployment rate of 0.06 and a value of 0.154 for  $u$ , the steady-state number of workers searching each period. These values imply a steady-state value of 0.132 for  $V$ . The share

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<sup>6</sup>This value is also used by Merz (1995), Andolfatto (1996), Cheron and Langot (1999), Cooley and Quadrini (1999, 2000), and Hairault (2002).

of a match surplus that the worker receives,  $\eta$ , is set equal to 0.5. This value is fairly standard.<sup>7</sup>

The steady-state value of a match  $q$ , is obtained from (16). Given  $q$ , equation (8) can be used to calculate  $l$ , the disutility of work. Finally, (14) is used to calibrate  $\gamma$ . the resulting value of  $\gamma$  implies job posting costs are 1.1% of steady-state output, somewhat higher than the 1% value used by Hairault (2002) to calibrate the cost of creating a job.

**Price rigidity** The degree of nominal rigidity is determined by  $\omega$ , the fraction of firms each period that do not optimally adjust their price. Empirical estimates of forward-looking price setting models of the type employed here suggest prices are fixed for extended periods of time (Galí and Gertler 1999, Sbordone 2002). For the baseline parameter values, I adopt a value for  $\omega$  of 0.85 based on Galí and Gertler’s estimates.

**Policy** The interest rate rule for monetary policy given by equation (28) is a modified Taylor rule in which the nominal rate responds to inflation but not to output. I adopt the same parameter values used by Bernanke, Gertler, and Gilchrist (1999). They argue that the long-run nominal rate response to a 100 basis point increase in inflation is about 110 basis points. The parameter  $\phi_\pi$ , therefore, is set equal to 1.10. The baseline calibration of equation (28) sets  $\rho_R = 0.9$ , a value consistent with empirical evidence on the high degree of inertia displayed by central bank policy rules. See Clarida, Galí, and Gertler (2000) for evidence on central bank policy rules.

**Shocks** There are two exogenous aggregate shocks in the model; the monetary policy shock and the aggregate productivity shock. The standard deviation of the policy shock  $\phi_t$  is set to 0.002;

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<sup>7</sup>Merz (1995) and Andolfatto (1996) consider a social planner’s problem, setting  $\eta = a$  which Hosios (1990) showed implies that the steady-state unemployment rate is efficient. With  $\eta > a$  in the baseline calibration, steady-state unemployment is inefficiently high. Cooley and Quadrini evaluate their model for much lower values of  $\eta$ , setting this share parameter to 0.1 and 0.01.

this is consistent with estimated federal funds rate equations. The log aggregate productivity shock is assumed to follow an  $AR(1)$  process:

$$\log(z_t) = \rho_z \log(z_{t-1}) + \varepsilon_t.$$

This is a standard choice in the *RBC* literature. The serially correlation coefficient  $\rho_z$  is set equal to 0.95 while the standard deviation of  $\varepsilon_t$  is set at 0.01. This value for  $\sigma_\varepsilon$  is chosen to provide a rough match between the model's prediction for the standard deviation of output to the standard deviation of U. S. real *GDP*.<sup>8</sup>

Table 1 summarizes the baseline values for the key parameters of the model.

### 3.2 Model results

Table 2 presents standard deviations based on U. S. data, expressed relative to the standard deviation of output. These values are taken from den Haan, et. al. and Cooley and Quadrini and are based on quarterly H-P filtered data. Row 2 of the table shows the results from the labor search model. With the exception of the magnitude of the standard deviation of the job creation rate, the model does a good job matching the U.S. data. Job creation is too volatile in the model, but the model does predict that job destruction is more volatile than job creation. The model implies slightly more employment and inflation volatility than observed in the data.

The last two rows of Table 2 provide a comparison with a new Keynesian model that incorporates a Walrasian labor market. This model includes the same CEE dynamic inflation adjustment equation and habit persistence in consumption as in the labor search model. With a Walrasian labor market, sticky prices, and flexible wages, marginal cost is related to the marginal rate of substitution between leisure and consumption and the marginal product of labor. I assume util-

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<sup>8</sup>It is common to set  $\sigma_\varepsilon = 0.007$ , and this is the value used by den Haan, et. al. In the model most similar to the present one, Cooley and Quadrini set  $\sigma_\varepsilon = 0.0033$ .

ity is separable in consumption and leisure and denote the elasticity of utility with respect to work by  $\zeta$ . As is well known, this parameter is critical for the model's predictions; a small value implies a large real wage elasticity of labor supply and, as a consequence, marginal cost will be relatively insensitive to output movements. A large value of  $\zeta$  implies an inelastic labor supply, making marginal cost sensitive to output movements. I report results for two different values of  $\zeta$ . Calibration is otherwise the same as in the labor search model.<sup>9</sup>

A more elastic labor supply (a smaller  $\zeta$ ) produces larger employment and smaller inflation fluctuations. However, for both values of  $\zeta$ , the new Keynesian model with a Walrasian labor market predicts employment and inflation variability that is too high relative to that of output. To reduce the relative volatility of employment to a level that matches the labor market search model requires a value  $\zeta = 300$ , but such a large value for  $\zeta$  produces inflation volatility that is 2.47 times that of output.

Table 3 illustrates the different effects that productivity and nominal interest rate shocks have on the labor search economy. The first row repeats the U.S. data and the second row shows the relative standard deviations predicted by the model when only productivity shocks are present. The third row considers the case when only nominal interest rate shocks are present. Productivity shocks, by directly affecting the endogenous job destruction margin (see equation 8), raise the volatility of job destruction relative to job creation; nominal interest rate shocks have the opposite effect. Interestingly, the model predicts that inflation is quite stable when only nominal interest rate shocks are included. The final row of Table 3 shows the effect of reducing the degree of nominal rigidity from  $\omega = 0.85$  to  $\omega = 0.5$ ; all other parameters are held at their baseline values. Inflation becomes much more volatile, while employment becomes less so. Greater price flexibility, like an increase in the importance of nominal interest rate shocks, raises the volatility of the job

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<sup>9</sup>The details of the model are contained in the appendix.

creation rate relative to that of the job destruction rate.

Impulse response functions can be used to illustrate the impact of shocks in the model economy. Figure 1 shows the response of output, employment, and inflation in the labor search model to a 1 percentage point positive nominal interest rate shock. All three variables display the hump-shaped responses that are typically associated with VAR estimates of the impact of a nominal interest rate shock on real variables. Figure 2 shows that vacancies drop immediately in reaction to the contractionary monetary policy shock. The number of job seekers, however, follows a hump-shaped path, rising for the first year after the shock. In response to the shock, the job finding probability falls for workers and rises for firms that do post vacancies, reflecting the rise in the number of searching workers relative to vacancies.

The response of the new Keynesian model with a Walrasian labor market to a similar interest rate shock is shown in Figure 3 for the case  $\zeta = 0.5$ . Output reacts less strongly and inflation more strongly in the absence of the labor market search process. When  $\zeta = 2.0$ , the muted output response and exaggerated inflation responses are even more pronounced.

### **3.3 Policy, nominal rigidity, and search**

The baseline model incorporating labor market search displays highly persistent responses to a serially uncorrelated nominal interest rate shock. In this subsection, the contributions of three potential sources of this persistence are investigated. First, the dynamic response to monetary policy shocks depends on the degree of nominal rigidity. The baseline calibration assumed, in line with empirically estimated new Keynesian models, that the average time between price changes was quite long. Second, persistence may arise from the inertia in the nominal interest rate process itself. While the shocks to the nominal interest rate equation used to generate Figures 1 - 3 were serially uncorrelated, the policy rule placed a large coefficient (0.9) on the lagged nominal interest

rate. Third, the search process in the labor market contributes to the way output and inflation respond to shocks.

As was noted in the introduction, the degree of nominal rigidity implied by estimated new Keynesian inflation adjustment equations is quite high. Based on the work of Galí and Gertler (1999) and Sbordone (2002), the baseline calibration set  $\omega = 0.85$ , implying that only 15% of all firms adjust their price optimally each period. Bils and Klenow (2002) report, based on micro data from the consumer price index that prices are fixed on average for six months, implying a value of  $\omega = 0.5$  in a standard Calvo-type sticky price model. Christiano, Eichenbaum, and Evans (2001), in a model with price and wage stickiness, obtain an estimate of  $\omega$  on the order of one half.

Figure 4 shows how the introduction of the labor market search process can reduce the degree of nominal rigidity needed to capture output and inflation dynamics. The lines labeled LM,  $\omega = 0.85$  and New Keynesian,  $\omega = 0.85$  represent the response of inflation to a positive nominal interest rate shock under the baseline calibrations for the two models.<sup>10</sup> The line labeled LM,  $\omega = 0.5$  shows the response in the labor market search model when the degree of nominal price stickiness is significantly reduced by lowering  $\omega$  to 0.5. As the figure shows, the introduction of a search-based labor market allows the model to capture the same dynamics as in a Walrasian model with significantly less nominal rigidity. Figure 5 shows that the same conclusion holds for output. The labor market search model needs much less price stickiness to obtain the same magnitude and persistence of output in response to a policy shock as in a standard new Keynesian model with a Walrasian labor market.

While Figures 4 and 5 illustrate the role of the labor market versus price stickiness in affecting dynamics responses to monetary policy shocks, the simulations held constant the policy rule for

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<sup>10</sup>For the new Keynesian model,  $\zeta = 0.5$ .

the nominal rate of interest. Cochrane (1998) has argued that the persistent real responses to monetary policy shocks may reflect the persistence displayed by monetary policy itself rather than reflecting sluggish adjustment by the private economy. To investigate the role of policy persistence,  $\rho_R$  is decreased from its baseline value of 0.9 to the much smaller value of 0.5. All other parameters are kept at their baseline values. The importance of policy inertia for the magnitude and the persistence of the output and inflation responses to policy shocks is shown in Figure 6. The solid lines show the output paths when  $\rho_R = 0.9$  (the line with open diamonds) and  $\rho_R = 0.5$  (the line with filled diamonds). The dashed lines show the inflation paths when  $\rho_R = 0.9$  (the line with open boxes) and  $\rho_R = 0.5$  (the line with filled boxes). Clearly, persistence in the policy rule has a major impact on the impulse response functions.

The lagged responses of output and inflation to nominal interest rate shocks can also be characterized in terms of their mean and median lags. Table 4 reports these statistics for output, together with the total impact effect, for combinations of high and low nominal rigidity and for different degrees of nominal interest rate inertia. The top half of the table shows the results for the new Keynesian model with a Walrasian labor market; the bottom half shows the results for the labor search model. Table 5 reports similar statistics for inflation. Focusing first on the results for output (Table 4) reveals that the new Keynesian model generates neither significant output persistence nor a large output effect unless policy is very inertial ( $\rho_R = 0.9$ ).<sup>11</sup> More interesting are the results for the labor search model. The median lags are double those of the model with a Walrasian labor market, except when both  $\omega$  and  $\rho_R$  equal 0.5. Increasing nominal rigidity (increasing  $\omega$  from 0.5 to 0.85) *or* increasing policy inertia (increasing  $\rho_R$  from 0.5 to 0.9)

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<sup>11</sup>The mean output lag is defined as  $\Sigma ia_i / \Sigma a_i$  where  $a_i$  is the coefficient at lag  $i$  on the nominal interest rate innovation in the moving average representation for output. The mean lags are negative for the new Keynesian model because, while the sum  $\Sigma a_i$  is negative, the lag coefficients turn positive after the first several periods, and these positive coefficients receive large weights in calculating the mean lag.



doubles the median lag. However, the last row of the table suggests that it is the combination of nominal rigidity and policy inertia that appears to be necessary to produce a large total impact on output.

The results for inflation are reported in Table 5. Not surprisingly, both models show that it is policy inertia that produces a large total effect on inflation. The labor search model produces significantly longer lags in the response of inflation to policy shocks for all the parameter combinations reported.

## 4 Conclusions

This paper has incorporated nominal price stickiness into a model of labor market search to study the dynamic impact of nominal interest rate shocks. The model produces real output and inflation responses to nominal interest rate shocks that display the hump shaped pattern typically seen in estimated VARs. Labor market rigidities introduced by the process of matching job seekers with job vacancies amplify the real impact and reduce the inflation impact of a monetary policy shock. As a consequence, much less nominal rigidity is necessary in the labor market search model than in the corresponding new Keynesian model; the dynamic response of output and inflation in the new Keynesian model when only 15% of firms optimally adjusted prices each period could be replicated in the labor market search model when a more realistic 50% of firms optimally adjusted their price each period.

The present paper has assumed prices are sticky but that wages adjust to ensure workers and firms receive constant shares of the match surplus. Other researchers have argued that price rigidities cannot generate realistic dynamics and that wage rigidity is critical for capturing macroeconomic dynamics, but Edge (2002) shows that the specification of factor markets is critical for this conclusion. Goodfriend and King (2001) have emphasized that the long-term

nature of employment matches means observed wage stickiness may have few implications for resource allocations. The present paper is the first to employ an aggregate matching process to capture the long-term nature of employment relationships in a model with sticky prices and a nominal interest rate rule to reflect monetary policy. While the degree of nominal rigidity and the labor market specification are important for determining the economy's response to policy shocks, the inertia in the nominal interest rate rule is also critical.

There are several possible extensions of the model. The model ignores capital and any labor-leisure choice. Recent work by Christiano, Eichenbaum, and Evans (2001) and Dotsey and King (2001) suggest variable capital utilization may help models with nominal rigidities match inflation dynamics. Only the degree of policy inertia was varied in the policy experiments, but the effects of the interest rate reaction to inflation and issues of optimal policy design could be addressed using the model. Finally, while the model provided a better match with basic business cycle data than did the benchmark new Keynesian model, the parameters of the model were calibrated rather than estimated from the data.

## 5 Appendix

### 5.1 The linearized model

Let  $\hat{x}$  denote the percentage deviation around the steady-state of a variable  $x_t$ . The labor market search model, expressed in terms of percentage deviations around the steady-state, consists of the following equations:

$$\hat{v}_t = \rho_R \hat{v}_{t-1} + (1 - \rho_R) \phi_\pi \hat{\pi}_t + \phi_t \tag{30}$$

$$\hat{n}_{t+1} = \varphi \hat{\varphi}_t + \varphi \hat{n}_t + \left( \frac{vk^f}{N} \right) \hat{v}_t + \left( \frac{vk^f}{N} \right) \hat{k}_t^f \tag{31}$$

$$\hat{a}_t = \hat{\mu}_t - \left( \frac{\mu q}{\tilde{a}} \right) \hat{q}_t - \hat{z}_t \tag{32}$$

$$\hat{\varphi}_t = - \left( \frac{\rho^n}{1 - \rho^n} \right) e_{F,a} \hat{a}_t \quad (33)$$

$$\hat{u}_t = - \left( \frac{\varphi N}{u} \right) \hat{n}_t - \left( \frac{\varphi N}{u} \right) \hat{\varphi}_t \quad (34)$$

$$\hat{k}_t^f = a \hat{u}_t - (1 - \xi) \hat{v}_t \quad (35)$$

$$\hat{v}_t + \hat{k}_t^f = \hat{u}_t + \hat{k}_t^w \quad (36)$$

$$\hat{k}_t^f = - \left( \frac{\eta k^w}{1 - \eta k^w} \right) \hat{k}_t^w - \left( \frac{q}{q + h} \right) \hat{q}_t \quad (37)$$

$$jcr_t = \hat{k}_t^f + \left( \frac{k^f V}{CRRER} \right) (\hat{v}_t - \hat{n}_t) \quad (38)$$

$$jdr_t = - \left( \frac{\varphi N}{DES} \right) \hat{\varphi}_t - \left( \frac{\rho^x k^f N}{DES} \right) \hat{k}_t^f \quad (39)$$

$$\hat{y}_t = \left( \frac{Output}{Y} \right) (e_{H,a} \hat{a}_t + \hat{\varphi}_t + \hat{n}_t + z_t) - \left( \frac{\gamma V}{Y} \right) \hat{v}_t \quad (40)$$

$$\hat{\lambda}_t = E_t \hat{\lambda}_{t+1} + \hat{u}_t - E_t \hat{\pi}_{t+1} \quad (41)$$

$$\hat{\lambda}_t = \left[ \frac{\sigma b}{(1-b)(1-\beta b)} \right] \left[ \beta E_t \hat{y}_{t+1} - \left( \frac{1 + \beta b^2}{b} \right) \hat{y}_t + \hat{y}_{t-1} \right], \quad (42)$$

$$\pi_t = E_{t-1} \left[ \left( \frac{\beta}{1 + \beta} \right) \pi_{t+1} - \left( \frac{\kappa}{1 + \beta} \right) \mu_t \right] + \left( \frac{1}{1 + \beta} \right) \pi_{t-1}. \quad (43)$$

$$\begin{aligned} \hat{q}_t &= A (e_{H,a} E_t \hat{a}_{t+1} - E_t \mu_{t+1} + E_t z_{t+1}) + \left( \frac{q + h}{q} \right) (E_t \varphi_{t+1} + E_t \hat{\lambda}_{t+1} - \hat{\lambda}_t) \\ &\quad - \left( \frac{\eta k^w}{1 - \eta k^w} \right) \left( \frac{q + h}{q} \right) \hat{k}_t^w + (1 - \eta k^w) \beta \varphi E_t \hat{q}_{t+1}, \end{aligned} \quad (44)$$

where

$$A = \frac{(1 - \rho^x)(1 - \eta k^w) \beta \int_{\tilde{a}} a f(a) da}{\mu R q} = \frac{(1 - \eta k^w) \beta \varphi H(\tilde{a})}{\mu R q}.$$

Equation (30) is the monetary policy rule. The evolution of the number of matches is given by equation (31). The endogenous job destruction margin equation (8) becomes (32). Using equation (9), the survival rate  $\varphi_t = 1 - \rho_t$  satisfies (33). Equation (34) gives the number of unemployed job seekers, from equation (17). Equation (35) is the linearized version of equation (20) for the probability a vacancy is filled. Equation (36) requires that the number of vacancies filled equal the number of workers finding matches. The job posting condition equation (16) is given by

(37). Equations (38) and (39) are derived from the job creation rate definition (22) and the job destruction rate definition (23). The output equation (27) becomes (40). The Euler condition equation (5) from the household's optimization problem becomes (41), and the definition of  $\lambda_t$  is given by equation (42). With the specification of CEE, the inflation equation from the retail firms' pricing decisions equations (24) and (26) yields (43). Finally, equation (14) for the present value condition for matches is used to derive (44).

## 5.2 The new Keynesian model

The benchmark new Keynesian model consists of (30), (41), (42), (43), where the marginal cost term in (43) is now defined as

$$\mu_t = -(\sigma + \zeta) \left[ \hat{y}_t - \left( \frac{1 + \zeta}{\sigma + \zeta} \right) \hat{z}_t \right], \quad (45)$$

where  $(1 + \zeta)z_t/(\sigma + \zeta)$  is equilibrium output under flexible prices.<sup>12</sup>

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<sup>12</sup>Note that the minus sign appears because in the labor search model,  $\mu$  was defined such that a rise in  $\mu$  reflected a fall in marginal cost. The details of the derivation of (45) can be found in Walsh (2003b).

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Table 1

Calibrated Parameters: Baseline Values

<b>A. Preferences</b>							
$\beta$	$\sigma$	$\theta$	$h$	$b$			
0.989	2	11	0.67	0			
<b>B. Labor Market</b>							
$\rho^s$	$\rho^x$	$a$	$\chi$	$k^f$	$k^w$	$N$	$\eta$
0.10	0.068	0.4	0.6	0.7	0.6	0.94	0.5
<b>C. Price rigidity</b>							
$\omega$							
0.85							
<b>D. Policy</b>							
$\sigma_\phi$		$\rho_R$		$\phi_\pi$			
0.002		0.9		1.10			
<b>E. Productivity</b>							
$\sigma_\varepsilon$		$\rho_z$		$\sigma_a$			
0.01		0.95		0.15			

**Table 2****Business cycle properties ( $\sigma_i/\sigma_y$ )**

	Employment	Job creation rate	Job destruction rate	Inflation
U.S. data ( $\sigma_Y = 1.60$ )	0.62	2.89	4.26	0.35
Labor Search Model ( $\sigma_Y = 1.69$ )	0.68	4.03	4.27	0.39
NK Model $\zeta = 0.5$ ( $\sigma_Y = 0.72$ )	1.86			0.58
NK Model $\zeta = 2.0$ ( $\sigma_Y = 0.79$ )	1.61			0.70

**Table 3****Labor Search Model: Business cycle properties ( $\sigma_i/\sigma_y$ )**

	Employment	Job creation rate	Job destruction rate	Inflation
U.S. data	0.62	2.89	4.26	0.35
Labor Search Model ( $\sigma_\phi = 0$ )	0.68	3.80	4.59	0.52
Labor Search Model ( $\sigma_\varepsilon = 0$ )	0.67	4.94	2.33	0.10
Labor Search Model ( $\omega = 0.5$ )	0.56	3.14	2.20	0.62

**Table 4****Effects of parameter variation on output response**

---

	Mean lag	Median lag	Total impact
New Keynesian Model			
$\omega = 0.5, \rho_R = 0.5$	-0.03	1	-0.07
$\omega = 0.5, \rho_R = 0.9$	-0.07	1	-0.57
$\omega = 0.85, \rho_R = 0.5$	-0.14	1	-0.14
$\omega = 0.85, \rho_R = 0.9$	-0.96	2	-1.67
Labor Search Model			
$\omega = 0.5, \rho_R = 0.5$	0.81	1	-0.24
$\omega = 0.5, \rho_R = 0.9$	0.77	2	-0.13
$\omega = 0.85, \rho_R = 0.5$	2.44	2	-0.24
$\omega = 0.85, \rho_R = 0.9$	4.06	4	-4.86

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**Table 5****Effects of parameter variation on inflation response**

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	Mean lag	Median lag	Total impact
New Keynesian Model			
$\omega = 0.5, \rho_R = 0.5$	2.19	2	-0.78
$\omega = 0.5, \rho_R = 0.9$	1.71	2	-7.69
$\omega = 0.85, \rho_R = 0.5$	5.40	5	-0.39
$\omega = 0.85, \rho_R = 0.9$	3.52	5	-6.31
Labor Search Model			
$\omega = 0.5, \rho_R = 0.5$	11.50	9	-0.08
$\omega = 0.5, \rho_R = 0.9$	4.15	5	-6.00
$\omega = 0.85, \rho_R = 0.5$	11.99	11	-0.04
$\omega = 0.85, \rho_R = 0.9$	10.44	10	-4.29

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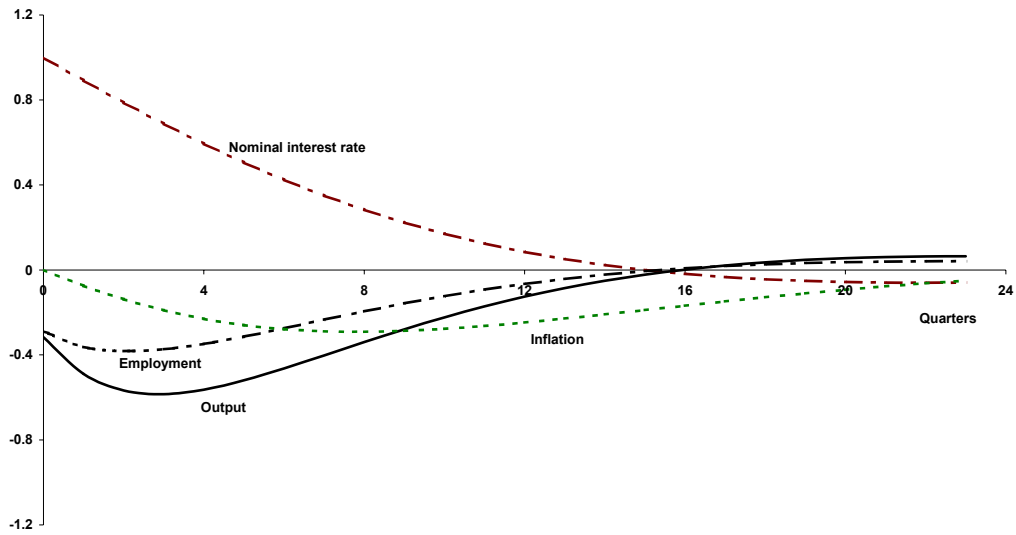


Figure 1: Impulse response in labor market search model (baseline calibration)

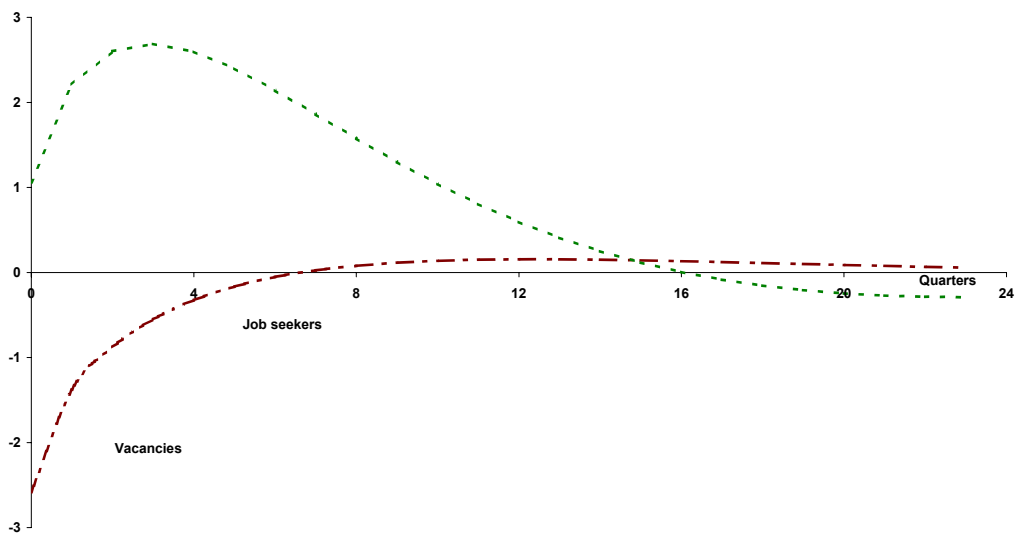


Figure 2: Impulse responses of vacancies and job seekers in labor market search model (baseline calibration)

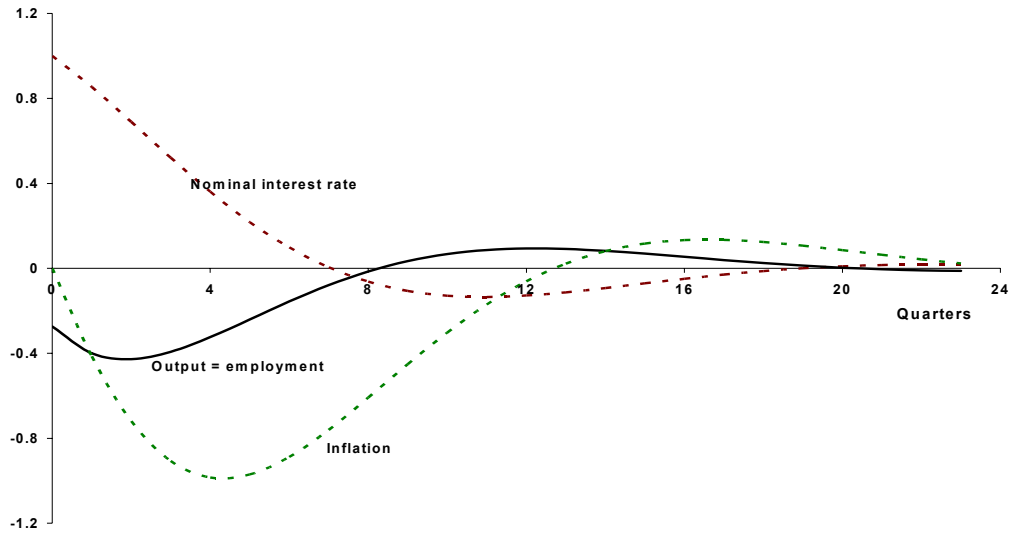


Figure 3: Impulse response in a new Keynesian model (baseline calibration)

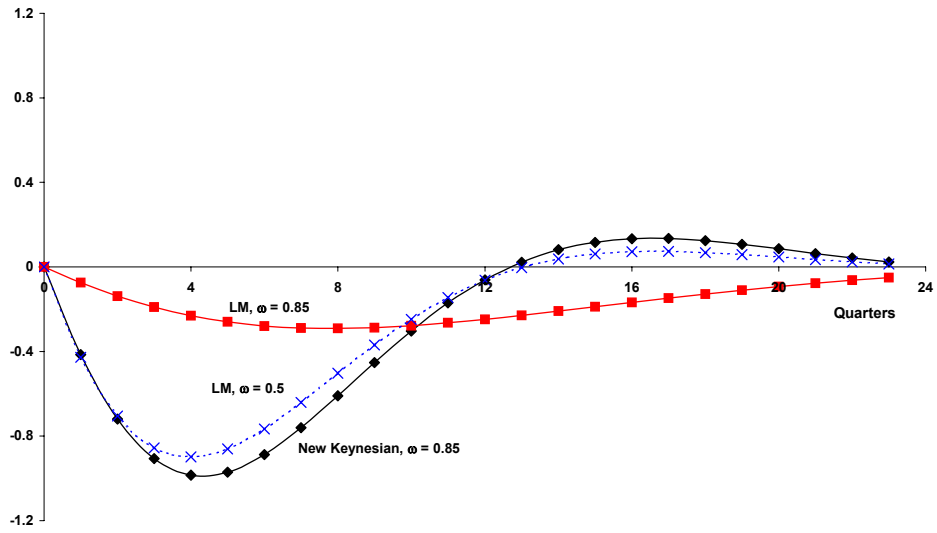


Figure 4: Response of inflation in labor market search and new Keynesian models

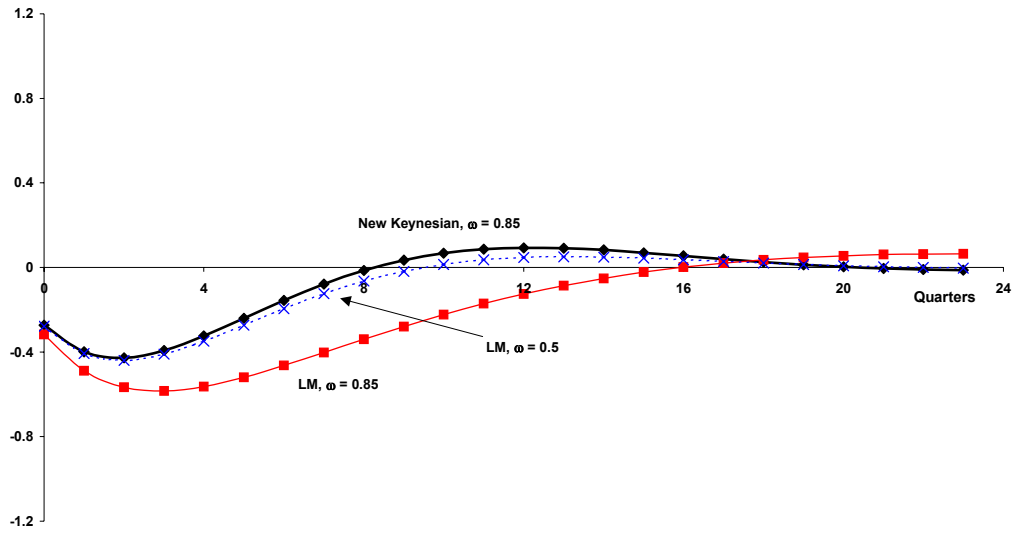


Figure 5: Response of output in labor market search and new Keynesian models

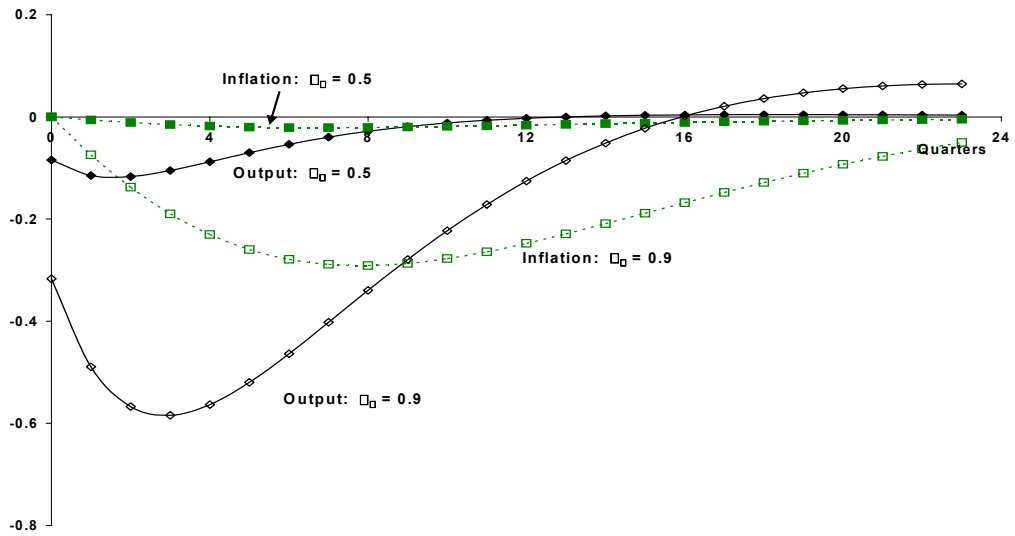


Figure 6: The effects of policy inertia