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Highlights

- I create a new Keynesian model with search and matching frictions
- I use an unemployment norm that captures the true cost of unemployment
- The psychological cost of unemployment is large and important for model dynamics
- I also introduce rigidities in the labor market which add persistence
- The model matches impulse responses from a VAR on US data and solves various puzzles
- The psychological cost of unemployment can be important for policymakers interested in the unemployment - inflation trade-off.

Labor market dynamics when (un)employment is a social norm

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This draft: 4 October 2016

Abstract

This paper proposes a new Keynesian model with search and matching frictions in the labor market that can account for the cyclicality and persistence of vacancies, unemployment, job creation, inflation and the real wage, after a monetary shock. Motivated by evidence from psychology, unemployment is modeled as a social norm. The norm is the belief that individuals should exert effort to earn their living and free riders are a burden to society. Households pressure the unemployed to find jobs: the fewer unemployed workers there are, the more supporters the norm has and therefore the greater the pressure and psychological cost experienced by each unemployed searcher. By altering the value of being unemployed, this procyclical psychological cost hinders the wage from crowding out vacancy creation after a monetary shock. Thus, the model is able to capture the high volatility of vacancies and unemployment observed in the data, accounting for the Shimer puzzle. The paper also departs from the literature by introducing price rigidity in the labor market, inducing additional inertia and persistence in the response of inflation and the real wage after a monetary shock. The model's responses after a monetary shock are in line with the responses obtained from a VAR on US data.

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Abstract

This paper proposes a new Keynesian model with search and matching frictions in the labor market that can account for the cyclicality and persistence of vacancies, unemployment, job creation, inflation and the real wage, after a monetary shock. Motivated by evidence from psychology, unemployment is modeled as a social norm. The norm is defined here as the belief that individuals in society prioritize, or should prioritize the search for gainful employment, whereas those who do not are perceived as outside the norm and, consequently, stigmatized. Households pressure the unemployed to find jobs: the fewer unemployed workers there are, the more supporters the norm has and therefore the greater the pressure and psychological cost experienced by each jobseeker. As this psychological cost is procyclical, it hinders the wage from absorbing most of the effect of the shock. Thus, the model is able to capture the high volatility of vacancies and unemployment observed in the data, accounting for the Shimer puzzle. The paper also departs from the literature by introducing price rigidity in the labor market, inducing additional inertia and persistence in inflation and the real wage after a monetary shock. The model's responses after a monetary shock are in line with the responses obtained from a VAR on US data.

1 Introduction

Labor market conditions have deteriorated significantly since the financial crisis of 2007. In the US, from 2007 to 2009 around 8 million jobs were lost creating economic, social and political problems globally. Nonetheless, the attention of macroeconomists has, by and large, been confined to the effect of unemployment on earnings. The psychological cost of unemployment is overwhelmingly neglected. In his book, Layard (2006) finds that, on average, a spell of unemployment can produce the same disutility to an individual as certain health issues and illnesses. The significance of the psychological cost of unemployment is a motivation here to investigate the extent that this additional cost can affect the labor market and particularly the way firms and workers bargain to set the wage. Evidence shows that the psychological cost of unemployment tends to increase in the context of low unemployment throughout society (Clark 2003), hinting that there might be some interesting insights from a business cycle perspective. I demonstrate that modeling the psychological cost of unemployment in such a way accounts for the amplification puzzle in the search and matching literature.

I create a DSGE model with search and matching frictions incorporating the psychological cost of unemployment in the form of a social norm. The model explains empirical facts such as: the high volatility of vacancies and unemployment (amplification puzzle) and their strong persistence, the low volatility and the strong persistence of both the real wage and inflation. I identify a structural VAR on US data and compare the impulse responses implied by my model with the ones obtained by the VAR. I estimate some parameters to bring the model as close to the data as possible. The two key innovations that are vital to the results are the following:

Unemployment as a social norm. Households support the norm that individuals in society prioritize, or should prioritize the search for gainful employment, whereas those who do not are perceived as outside the norm and, consequently, stigmatized. This, in turn, exerts pressure on the unemployed to seek jobs. The fewer the unemployed in a group of people, the more the supporters of the norm and the greater the loss or reputation or psychological cost suffered by each unemployed person within the group. It is worth noting here, that there are two unemployment rates affecting workers' bargaining power, each having an opposite effect on the underlying wage. The first is the economy-wide unemployment rate and the second is the unemployment rate of "relevant others" (a person's immediate environment). On the one hand, an expansion causes a decrease in the economy-wide unemployment rate, reducing unemployment duration and strengthening workers' bargaining power as argued by Shimer (2005a). On the other hand, during an expansion, the decreasing unemployment rate of relevant others implies, according to the norm, a greater loss of reputation for the unemployed within a group, weakening the worker's bargaining power. The two opposite effects counterbalance each other preventing the wage from being too responsive to outside opportunities and hindering it from absorbing most of the effect of the shock. Although the social norm can provide enough amplification, it still fails to ensure a low volatility for the real wage or to improve the model's propagation. For those two tasks, the assumption of price rigidity in the labor market is prevalent.

Price rigidity in the labor market. The model put forward in this work assumes every worker is a firm, producing an intermediate differentiated good, facing monopolistic competition and price rigidity. Price rigidity in the intermediate goods sector not only adds inflation inertia (ala Christiano, Eichenbaum and Evans 2005) but also adds persistence in the model without the need to impose high degrees of price rigidity. Moreover, it smooths out the response of the real wage after a monetary shock, while significantly reducing the real wage's volatility, which tends to be excessively high when monetary shocks are introduced in a standard MP framework. It is important to note that this model assumes price rigidity for ongoing firms, while assuming no rigidities on new firms or on the bargained wage.

The contribution of this paper is twofold. First, it attempts to explore the dynamics of the psychological cost of unemployment. This exercise best addresses the Shimer puzzle which can be easily applied to any search and matching model. Second, it improves the fit of a New Keynesian model that can be used for policy analysis, exposing the true cost of unemployment for policy makers. Using such a model for policy analysis implies a different trade-off between unemployment and inflation for central banks as the cost of unemployment is more pronounced in this setup.

There are already a few attempts to modify a new Keynesian model with the search and matching framework in order to explain the aforementioned puzzles and provide a benchmark for policy analysis. The first attempt was made by Trigari (2004). Even though the model has no predictions for the responses of the wage, unemployment and vacancies, it shows how search frictions improve the performance of a basic new Keynesian model, to account for inflation and output dynamics after a monetary shock. After Trigari (2009), more new Keynesian models with search frictions appeared, such as Braun (2006) and Kuester (2010). The main element that amplifies the responses of vacancies and unemployment in both models is wage rigidity. However, Pissarides (2009) and Haefke, Sonntag and van Rens (2009), find that wages for new matches seem to be flexible in the data and should not be assumed as rigid.

To test the validity of the social norm assumption a welfare evaluation is performed, to find the percentage of income households are willing to give up to dispose of the effect of the norm and its fluctuations. Parameters obtained here are acceptable which can be indicated by the fact that the estimate is no greater than the values reported in the empirical literature where various authors run similar experiments. This shows that the parameters defining the social norm in the model are calibrated at acceptable levels. The empirical literature shows that the psychological cost of unemployment measured in forgone income to insure against it is very large and significant. In addition, the calibration of the proposed model is set apart from Hagedorn and Manovskii (2008), as a comparison indicates that it does not share the latter's "small surplus" calibration strategy.

The rest of the paper is structured as follows: Section 2 is a literature review on the Shimer puzzle. Section 3 presents the facts and empirical evidence supporting the existence of unemployment as a social norm. In section 4, the model is presented in detail, analyzing the behavior of each agent. Section 5 presents the calibration along with the estimation procedure and results. In the same section, details are provided on the welfare analysis to bring the calibrated parameters governing the social norm to the data.

2 Literature review on amplification puzzle

There are many attempts to account for the volatility puzzle in a search and matching model. According to Cardullo (2009), the different approaches to account for the amplification puzzle can be split into three broad categories. The first approach goes at the heart of the problem by introducing various kinds of rigidity in the wage to be able to amplify firm profits and vacancy creation. However, there is a serious critique on the empirical validity of this first approach. Wage rigidity for new matches has been rejected by Pissarides (2009) and Haefke, Sonntag and van Rens (2009) on the basis that only the volatility of wages in new matches is important for job creation and vacancies. Empirical evidence shows that there is no rigidity in the wages for new matches even though wages can be rigid for ongoing jobs.

The second approach includes models that use the "small surplus" calibration as in Hagedorn and Manovskii (2008). Even though this method provides the simplest fix for the search and matching model, it leads to the counterfactual prediction that unemployment benefit policy is extremely effective. In addition, it predicts a very low worker surplus, implying that the welfare of the unemployed and the employed is almost the same.

The third approach seeks to provide a solution to the Shimer puzzle without aiming at Nash wage bargaining or "small surplus" calibration. Silva and Toledo (2009) assume turnover costs, others introduce on the job search such as Nagypal (2005). Garibaldi (2006) introduces firm heterogeneity and Constein and Reiter (2007) introduce technological change.

Other authors use monetary shocks to investigate the performance of a search and matching model. Barnichon (2007) concludes that the Shimer puzzle might indicate that productivity shocks are not the main driving force[1]. Andres, Domenech, and Ferri (2006) use price rigidity in the retail sector. Closer to this model, is the work of Braun (2006) and Kuester (2010) that also use a new Keynesian framework. Both authors employ wage rigidity to create amplification, an assumption that is subject to the same critique as the studies that fall under the first approach.

This model belongs to the third category, which uses monetary shocks to explain various facts in the data in a new Keynesian environment. By addressing the amplification puzzle in the simplest way, the model, and therefore the fix proposed herein can be applied to any model regardless of level of complexity. Moreover, I provide a model ready for policy analysis that captures a more realistic trade-off between inflation and unemployment as the psychological cost of unemployment is given its due consideration in the measurement of welfare.

[1] Barnichon (2007) finds that monetary shocks can explain half the volatility of tightness in the data.

3 The social norm mechanism

By treating unemployment as a social norm, its psychological cost is incorporated in the model. Norms are rules of behavior that members of a social group are expected to follow and distinguish appropriate behavior from the inappropriate. Failure to follow the rule or code may entail many adverse consequences on the individual, including but not limited to loss of reputation, feelings of isolation and guilt as well as psychological pressure exerted by the group. The severity of said consequences depends on how strong the support of the norm is among the group members. A stronger support of the norm, or a sudden increase in the supporters of the norm, exacerbates the loss of reputation or the psychological cost experienced by those who deviate from the code. Akerlof (1980) and (2006) investigates the importance of norms in restoring the missing element of motivation in macroeconomics[2]. A more recent example of the implications of a social norm for wage determination can be found in Danthine and Kurmann (2011), where the norm is the need to reward a positive action with another action (reciprocity).

The more significant the percentage of unemployed workers within a group, the fewer the supporters of the norm and therefore, the less severe is the loss of reputation or psychological cost suffered by each unemployed individual. As the percentage of unemployed relevant others rise, the feelings of disutility experienced by the unemployed individual lessen.

Empirical evidence supports that unemployment hurts less the more of it there is around. Clark (2003) uses as a proxy for utility the general health questionnaire[3] (GHQ), which is a measure of mental well-being (Goldberg 1972). Clark's goal, among others, is to examine the effect of relevant others' unemployment on one's own unemployment experience. The unemployment of relevant others is defined in three ways: the regional unemployment rate, the unemployment status of the partner of the individual and the unemployment status of adults within the same household. Irrespective of the definition used for relevant others, Clark reports that increases in the unemployment rate of relevant others increases the psychological well-being of the individual unemployed worker. For example, Clark finds that when an unemployed person moves to a region with a higher unemployment rate, it usually alleviates some of the negative feelings associated with being unemployed.

The effect of relevant others on one's own unemployment becomes more pronounced when Clark alternatively defines others' unemployment as the unemployment rate of other household members instead of regional unemployment, since the former definition provides a more accurate picture of the worker's immediate home environment. Therefore, the model put forward here chooses to assume this same mechanism, that is to say, relevant others are

[2]External habit formation (catching up with the Joneses), can also be thought as a manifestation of a social norm in macroeconomic models. Failure to match others' consumption results in loss of reputation.

[3]GHQ is an indicator of psychological health and is used extensively in medical, psychological and socioeconomic research.

the members of the same household.

There is an abundance of evidence supporting the idea that the unemployment of others imposes a positive externality on the individual unemployed. In a similar exercise, Clark (2009) reports the same evidence for OECD data and Clark, Knabe and Ratzel (2008) confirm the result in the case of German regions. Powdthavee (2007) also comes to the same conclusion in a study with South African regions. However, even though the authors control for differences in income

Unemployment as a social norm is also explored by Stutzer and Lalive (2004), where the impact of the social norm is measured by votes in favor of lowering unemployment benefits from a referendum in Switzerland in 1997. In regions which favored lowering of unemployment benefits, indicating a strong adherence to the norm, the unemployed reported significantly lower psychological well-being. Similar results supporting unemployment as a social norm are reported by Shields and Price (2005) and Shields, Price and Wooden (2008). As those studies compare the welfare of the unemployed in different groups, the underlying psychological cost is net of any effects decreases in income and labor hours or benefits from social welfare can impose on the unemployed. The existence of the norm is supported by evidence of lower welfare for the unemployed in areas where the norm is strong, compared to the unemployed in the areas where the norm is weaker.

These results are also in line with other studies in unemployment psychology that define well-being differently to GHQ. For example Jackson and Warr (1987), report better mental health for the unemployed in higher unemployment rate regions. Similar claims are made by other authors using suicide and para-suicide rates, reporting that such attempts are most prevalent in low unemployment regions e.g. Platt, Micciolo and Tansella (1992); Platt and Kreitman (1990) and Neeleman (1998).

3.1 Unemployment as a social norm

The way the social norm is introduced in the model is close to Akerlof (1980). Akerlof defines a social norm by augmenting a usual utility function with the reputation function:

$$R = R(A, \mu) \tag{1}$$

where A is a dummy variable that determines an agent's obedience or disobedience to the community's behavior rules and μ is the portion of the group's population that supports the rule. Akerlof's social norm specification suggests that an individual who disobeys the rule has to suffer disutility from reputation loss, while the weight of this loss is governed by the measure of group members adhering to the rule.

Alternatively, the externality of the others' unemployment on the individual unemployed can be interpreted in another way, without the social norm definition. For example, in an expansion, jobs can be filled by less suitable employees because of the tightness of the market, which results in lower productivity and wages. Although the unemployed can find jobs more easily, they might not be the best candidates to fill such positions, leading to relatively lower earnings. Therefore, job and worker heterogeneity introduced in this way can also explain the externality of others' unemployment[4].

Following Akerlof, a social norm is introduced in the utility function as follows:

$$G^u\left(\frac{\phi}{U_{ht}^{\xi}}\right) = \frac{\phi}{U_{ht}^{\xi}} \tag{2}$$

where U_{ht} is the unemployment rate of relevant others, the unemployment rate in an individual's immediate environment, which includes friends, other household members and family. The parameter ϕ controls the relative importance of the social norm in the utility function for the individual. The parameter ξ determines the extent to which the reputation effect depends on the supporters of the norm. The greater ξ is, the greater the impact of the unemployment of relevant others on the psychological well-being of the respective unemployed person. I call the parameter ξ the Relevant Others' Psychological Effect (hereafter ROPE).

Every unemployed worker in my model suffers disutility from loss of reputation within their own household according to equation (2). The larger the unemployment of relevant others U_{ht} within the group, the less is the loss of reputation experienced by the unemployed individual. The unemployment rate U_{ht} corresponds to μ in Akerlof's social norm specification, equation (1).

Specifically, the norm affects the wage equation by reducing the value of unemployment to the worker. In an expansion, the norm becomes stronger and thus the worker accepts a lower wage than she otherwise would without the norm, boosting firm profits and leading to higher job creation. In a nutshell, the norm hinders the wage from rising and eliminating all incentives to create additional jobs. A microfounded model of the job market where equation (2) arises naturally is presented in the following section.

3.2 The job market and the social norm

As in the standard MP model, potential employers are posting vacancies in every period. Each unemployed worker provides ϕ application units to employers, to claim a position in the job openings[5]. The fixed application units per unemployed worker is also in line with Shimer's (2005a) findings which, in accordance to CPS data, indicate that search intensity is acyclical.

[4] Such a model requires further heterogeneity in jobs, which along with the heterogeneity induced by price rigidity can make the model quite complicated.

[5] The rational for having ϕ fixed is that putting more effort in job searching does not imply greater disutility. The additional cost in time and resources to search for an extra job is negligible to the unemployed, while the psychological cost of a change in the unemployment norm is not.

The matching function in each period is $H_t = \tilde{\Xi} F_t^{\alpha} V_t^{1-\alpha}$ where F_t is the total application units provided each period by households. In total, the application units demanded by a given household are $F_{ht}^D = \phi U_{ht}$ where $U_{ht} = 1 - N_{ht}$ is the unemployment rate within the h^{th} household.

Workers can produce the $F_{ht}^D = \phi U_{ht}$ units of aggregate application units within the household, by putting effort according to the following production function $F_{ht}^S = L_{ht}^u$. The aggregate effort supplied, L_{ht}^u is produced by combining each unemployed worker's individual effort as in the following function:

$$L_{ht}^u = A_t^u \left[\int_{U_{ht}} l_{hjt}^{u \frac{\theta_u - 1}{\theta_u}} dj \right]^{\frac{\theta_u}{\theta_u - 1}} \tag{3}$$

where l_{hjt}^u is the effort provided by the j^{th} unemployed worker which induces $G^u(l_t^u)$ units of disutility for each unemployed worker. In addition, $A_t^u \equiv U_{ht}^{\xi - \frac{1}{\theta_u - 1}}$ controls the "love for variety"[6]. When ξ becomes larger, it becomes more efficient to search in the labor market using many workers than providing the same search effort using a single worker. Every worker puts the same amount of effort, thus from equation (3) labor effort supply becomes $F_{ht}^S = L_{ht}^u = U_{ht}^{1+\xi} l_{ht}^u$ and must equal effort demand $F_{ht}^D = \phi U_{ht}$. This implies the equilibrium labor effort is

$$l_{ht}^u = \frac{\phi}{U_{ht}^{\xi}} \tag{4}$$

The above effort implies $G^u\left(\frac{\phi}{U_t^{\xi}}\right)$ units of disutility for the household giving rise to equation (2). The parameter ϕ corresponds to the application units to participate in the job market and the complementarity parameter ξ measures the degree of ROPE. The effort demanded by each unemployed worker to participate in the job market is inversely related to the size of the unemployment pool as the empirical evidence suggests.

4 The Model

There are four agents in the proposed model: households, intermediate firms (labor market), final good firms or retail firms and a government (including a monetary authority). There is a large number of identical households in the economy comprised of workers that may be either

[6] The parameter ξ enters equation (3) as a parameter governing the complementarity in the production of aggregate effort. It is the elasticity with respect to U_{ht} of the following function: $M = \frac{k_e U_{ht}^{1+\xi}}{k_e U_{ht}} = U_{ht}^{\xi}$ The numerator is the aggregate search effort from having U_{ht} individuals put k_e units of effort each. The denominator is the aggregate search effort produced, by having only a single worker putting $k_e U_{ht}$ units of effort. The elasticity of M with respect to U_{ht} which is ξ, determines how much more efficient it is for the household to produce the aggregate effort units from many different unemployed workers, rather than producing all the aggregate effort units from a single individual.

employed or unemployed. Households create job vacancies and also have unemployed workers searching for jobs. If an unemployed worker finds a job, a differentiated intermediate firm is created. A worker and vacancy match can only be broken at an exogenous rate. Unemployed workers also suffer from a reputation loss due to being unemployed. The aggregate output of intermediate firms, the labor service, is used by retail firms as inputs for the production of the final consumption good. There is a continuum of retail firms and since there is no entry or exit, the retail sector has a unit measure. The monetary authority and government are responsible for monetary and fiscal policy, respectively.

4.1 Households

There is a large number of identical households in this economy. Each household has the same fraction of members who are employed and unemployed. A representative household maximizes utility which can be separated into three arguments:

$$U\left(C_t, L_{jt}, N_t\right) = \frac{\left(C_t - \chi C_{t-1}\right)^{1-\sigma}}{1-\sigma} - \varpi \int\limits_{N_t} \frac{L_{jt}^{1+\delta}}{1+\delta} dj - \left(1-N_t\right) G_t^u\left(U_t\right) \tag{5}$$

where $U_t = 1 - N_t$, the unemployment rate as N_t is the employment level, $G_t^u = \phi U_t^{-\xi}$ the social norm, C_t is aggregate consumption, C_{t-1} is the aggregate consumption of the previous period which is exogenous to the household[7] and L_{jt} is the labor hours of the j^{th} worker. The household maximizes the above objective function, subject to the following budget constraint:

$$C_t + D_t + K_t V_t = U_t b_t + \int\limits_{N_t} w_{jt} L_{jt} dj + \int\limits_{N_t} \Pi_{jt}^w dj + T_t + P_t \int\limits_0^1 \Pi_{it} di + \left(1 + i_{t-1}\right) D_{t-1}$$

where $K_t = k_v \left(\frac{V_t}{V_{t-1}}\right)^{\psi}$, is the adjustment cost in vacancy creation[8]. The variable D_t represents the nominal bond holdings of the household, i_t is the nominal interest rate and $K_t V_t$ is the real cost of opening V_t vacancies[9]. The real hourly wage of the j^{th} worker is w_{jt}, b_t is the unemployment benefit and T_t represents transfers from the government. Households are entitled to dividends Π_{it} and Π_{jt}^w from holding shares of retail and intermediate firms respectively.

[7] External habit formation is assumed.

[8] K_t is a function of the economy-wide number of vacancies and thus out of the household's control.

[9] Households and intermediate firms are different agents, even though the household posts the vacancies. Each job is one firm; therefore, a vacancy does not currently provide any cash flows and there is a need for someone to fund firm ideas until they materialize. In the event of a match, households provide the fee for the vacancy in exchange of the firm's shares in the event of a match. The household then trades those shares for shares of a mutual fund that holds all the shares of intermediate firms. Thus, a household cannot benefit it's own workers by opening vacancies.

The law of motion for the number of firms the household creates is given by

$$N_{t+1} = (1-\lambda) N_t + q_t^v V_t \tag{6}$$

where λ is the exogenous job destruction rate. Matching is handled by a usual matching function $H_t = hU_t^{\alpha} V_t^{1-\alpha}$, where h is a constant for matching efficiency. New matches depend on the number of vacancies opened by the household V_t and the probability of a vacancy to become a match, $q_t^v = \frac{H_t}{V_t} = h\vartheta_t^{-\alpha}$ where ϑ_t is the market tightness. Analogously, the probability $q_t^u = \frac{H_t}{U_t} = h\vartheta_t^{1-\alpha}$, is the probability, at a given period, of an unemployed worker to enter the labor force. The household's problem[10] is the maximization of the household's utility function (5) subject to the constraints, by choosing consumption C_t, bond holdings D_t and vacancies V_t.

4.2 Intermediate firms

There are N_t intermediate firms producing the differentiated labor service x_{jt}, with the production function $x_{jt} = Z_t L_{jt}$ where L_{jt} is the labor effort and Z_t is the productivity parameter. All currently employed workers together produce the aggregate intermediate good X_t, which is used as input by the retail firms.

$$X_t = \left[\int_{N_t} x_{jt}^{\frac{\theta_w - 1}{\theta_w}} dj \right]^{\frac{\theta_w}{\theta_w - 1}} \tag{7}$$

where θ_w is the elasticity of substitution between the different good varieties. The price charged to the retail firms for the composite good X_t is

$$P_t^w = \left[\int_{N_t} p_{jt}^{w\,1-\theta_w} dj \right]^{\frac{1}{1-\theta_w}} \tag{8}$$

The demand for each intermediate good x_{jt} from the retail firms is determined by the usual expenditure minimization problem

$$x_{jt} = \left(\frac{p_{jt}^w}{P_t^w} \right)^{-\theta_w} X_t \tag{9}$$

[10]The first-order conditions involve the usual Euler equation $\frac{1}{1+i_t} = \beta E_t \frac{\mu_{t+1}}{\mu_t} \frac{P_t}{P_{t+1}}$ where $\mu_t = (C_t - \chi C_{t-1})^{-\sigma}$. The vacancy posting condition obtained from maximizing the household's objective with respect to V_t, is presented in the intermediate firm section below.

4.2.1 The Bellman equations

The value of a vacant job to the household is characterized by the following Bellman equation:

$$F_t^V = -K_t + E_t Q_{t,t+1} \left\{ q_t^v F_{t+1}^J \left(p_{t+1}^{w^*} \right) + (1 - q_t^v) F_{t+1}^V \right\} \tag{10}$$

where F_t^V is the value of a vacant job and K_t is the cost of keeping a vacancy open. One period ahead the job opening remains vacant with probability $1 - q_t^v$, or can be transformed to a match with value $F_{t+1}^J \left(p_{t+1}^{w^*} \right)$ weighted by probability q_t^v. Prices with stars are currently optimized. A matched job starts producing next period and always uses the optimal price[11]. In equilibrium, vacancies are freely posted until the value of a vacancy is zero, so $F_t^V = F_{t+1}^V = 0$, which transforms equation (10) to:

$$\frac{K_t}{q_t^v} = E_t Q_{t,t+1} \left\{ F_{t+1}^J \left(p_{t+1}^{w^*} \right) \right\} \tag{11}$$

The value of a job to the owner of the firm that is optimizing its price in the current period, is characterized by the following Bellman equation:

$$F_t^J \left(p_t^{w^*} \right) = \Pi_t^w \left(p_t^{w^*} \right) + (1 - \lambda) E_t Q_{t,t+1} \left\{ (1 - \gamma_w) F_{t+1}^J \left(p_{t+1}^{w^*} \right) + \gamma_w F_{t+1}^J \left(p_t^{w^*} \frac{P_t^w}{P_{t-1}^w} \right) \right\} \tag{12}$$

where $\Pi_t^w \left(p_t^{w^*} \right) = \frac{p_t^{w^*}}{P_t} x_t \left(p_t^{w^*} \right) - \frac{W_t}{P_t} L_t \left(p_t^{w^*} \right)$ is the profit of an intermediate firm currently adjusting its price. The value of a job to the firm is equal to the current profits, plus the present discounted value of the firm in case it survives the next period. Over the next period, the firm re-adjusts it's price with probability $1 - \gamma_w$, while with probability γ_w it keeps the previous period's price, indexing it to the latest intermediate good inflation.

The value of a job to the worker in a currently adjusting firm is

$$W_t^E \left(p_t^{w^*} \right) = w_t L_t - \frac{G(L_t)}{\mu_t} + E_t Q_{t,t+1} \left\{ \begin{array}{c} (1 - \lambda)(1 - \gamma_w) W_{t+1}^E \left(p_{t+1}^{w^*} \right) \\ + \gamma_w (1 - \lambda) W_{t+1}^E \left(p_t^{w^*} \frac{P_t^w}{P_{t-1}^w} \right) + \lambda W_{t+1}^U \end{array} \right\} \tag{13}$$

This Bellman equation states that the asset value of a job to the worker in a firm currently adjusting its price is the wage payment, minus the disutility of work in terms of the real good, plus the present discounted value of the job in the next period. The following period, the worker belongs to either a price adjusting or non-adjusting firm. With probability λ the job is destroyed and the value of unemployment to the worker is W_{t+1}^U.

The value of unemployment to the worker is:

[11] This condition guarantees that the price of a new firm which is a part of the wage is flexible, to avoid the criticism by Pissarides (2009) and Haefke et al. (2009)

$$W_t^U = b - \frac{G^u(U_t)}{\mu_t} + E_t Q_{t,t+1}\left\{q_t^u W_{t+1}^E\left(p_{t+1}^{w*}\right) + (1-q_t^u) W_{t+1}^U\right\} \tag{14}$$

where b is the unemployment benefit and q_t^u is the probability of an unemployed worker to join the labor force. The norm implies a loss of reputation of $G^u\left(U_t^\xi\right)$ and is defined by equation (2). The value of unemployment to the worker in the next period is $W_{t+1}^E\left(p_{t+1}^{w*}\right)$ considering that a new job is always a price adjusting firm. Also there is a probability $1-q_t^u$ that the worker is still unemployed in the next period with value W_{t+1}^U.

By using the vacancy posting condition (11), along with the value of a job to the firm, equation (12), the following job creation condition emerges:

$$\frac{K_t}{q_t^v} = E_t Q_{t,t+1}\left[\Pi_{t+1}^w\left(p_{t+1}^{w*}\right) + (1-\lambda)\frac{K_{t+1}}{q_{t+1}^v} + \gamma_w(1-\lambda)E_{t+1}Q_{t+1,t+2}\Delta_{t+2}^w\left(p_{t+1}^w, p_{t+2}^{w*}\right)\right] \tag{15}$$

where $\Delta_{t+1}^w\left(p_{jt}^w, p_{t+1}^{w*}\right) = F_{t+1}^J\left(p_{jt}^w \frac{P_t^w}{P_{t-1}^w}\right) - F_{t+1}^J\left(p_{t+1}^{w*}\right)$. The proof of the above is given in the Appendix A. Intuitively, the above condition states that the optimal number of vacancies should be at the point where the cost of the extra vacancy (left hand side of equation (15)), equals the present discounted value of future cash flows from a successful match (right hand side of equation (15)).

4.2.2 The bargaining and the wage

The search and matching process creates economic rent/surplus that needs to be distributed among workers and firms each period. The surplus of a match, S_t, is divided by Nash bargaining between workers (ζS_t) and firms ($(1-\zeta)S_t$), and is the sum of the surplus of a job to the firm $F_t^J - F_t^V$ and the surplus of a job to the worker $W_t^E - W_t^U$. Intermediate firms currently adjusting their price solve the following problem:

$$S_t\left(p_t^{w*}\right) = \max_{p_t^w, w_t}\left\{\left(F_t^J(p_t^w) - F_t^V\right)^{1-\zeta}\left(W_t^E(p_t^w) - W_t^U\right)^\zeta\right\} \tag{16}$$

and firms not currently adjusting their price, solve the same problem, maximizing the surplus only with respect to w_t. Maximizing the above with respect to w_t gives the following first-order condition for every firm $j \in [0, N_t]$, price adjuster or not:

$$(1-\zeta)\left(W_t^E\left(p_{jt}^w\right) - W_t^U\right) = \zeta\left(F_t^J\left(p_{jt}^w\right) - F_t^V\right) \tag{17}$$

Maximizing equation (16) with respect to p_t^w, is equivalent to maximizing the profit of the firm

$$\max_{p_t^w}\sum_{k=0}^{\infty}\gamma_w^k(1-\lambda)^k E_t Q_{t,t+k}\left[\frac{p_t^w}{P_{t+k}}\frac{P_{t+k-1}^w}{P_{t-1}^w}x_{t+k}\left(p_t^w\frac{P_{t+k-1}^w}{P_{t-1}^w}\right) - MRS_{t+k}L_{t+k}\left(p_t^w\frac{P_{t+k-1}^w}{P_{t-1}^w}\right)\right]$$

using as the cost of labor the marginal rate of substitution, which is $MRS_{t+k} = \frac{\varpi L_{t+k}^{\delta}}{\mu_{t+k}}$ and is treated as constant in the maximization[12].

The wage in this economy is perfectly flexible thus workers and firms share the surplus created by a job match each period, regardless of whether this surplus is maximized. The wage equation for any intermediate firm in this model is the following:

$$w_{jt}L_{jt} = (1-\zeta)\left(\frac{G(L_{jt})}{\mu_t} - \frac{G^u(U_t)}{\mu_t} + b\right) + \zeta K_t \vartheta_t + \zeta \frac{p_{jt}^w}{P_t} x_{jt} \tag{18}$$

The details are left in Appendix B. The above expression is derived by combining equation (17) along with (12), (13) and (14). In an expansion, low unemployment increases tightness $\vartheta_t = V_t/U_t$, causing the wage to surge. On the other hand, due to the norm, low unemployment of relevant others raises the reputation loss $G^u(U_t)$ for the unemployed, forcing the wage to decline. The two effects ensure that outside opportunities do not allow the wage to be overly responsive to shocks.

New firms are price adjusters and thus the wage that is important for job creation is unique. However, to calculate the average wage in the economy, it must be taken into consideration whether the firm is adjusting its price or not, implying that the wages in the economy differ due to differences in the demand for labor. The average wage is:

$$\omega_t = w_t\left(p_t^{w^*}\right) + \gamma_w(1-\lambda)\frac{N_{t-1}}{N_t}\left(\omega_{t-1} - w_t\left(p_t^{w^*}\right)\right) + \frac{\gamma_w(1-\lambda)}{N_t}\int_{N_{t-1}} \nabla_{w,t,t-1} dj$$

where $\nabla_{w,t,t-1} = w_t\left(p_{jt-1}^w\right) - w_{t-1}\left(p_{jt-1}^w\right)$. The derivation is in Appendix C.

4.3 Retail firms

There is a continuum of retail firms that use as input the output of wholesale firms to produce the final good according to $y_{it} = X_{it}$, where X_{it} is the quantity of the composite intermediate good employed by the i^{th} retail firm. If c_{it}^h is the demand for consumption good i from the h^{th} household, then the aggregate consumption of the household is

$$C_t^h = \left[\int_0^1 c_{it}^{h\,\frac{\theta-1}{\theta}} di\right]^{\frac{\theta}{\theta-1}} \tag{19}$$

[12] This can be proved by substituting in the surplus, equation (16), the Bellman equations as presented in the previous sections. Trigari (2009) discusses the result extensively.

The underlying demand for consumption derived from the usual cost minimization problem is $c_{it}^h = \left(\frac{p_{it}}{P_t}\right)^{-\theta} C_t^h$ and the price of the composite good is the usual

$$P_t = \left[\int_0^1 p_{it}^{1-\theta} di\right]^{\frac{1}{1-\theta}} \tag{20}$$

A fraction γ of the firms is allowed to adjust their price each period and the ones failing to adjust simply index their price to the most recent inflation rate. A retail firm currently adjusting its price solves the following maximization problem:

$$\max_{p_t} \left\{ \sum_{k=0}^{\infty} \gamma^k E_t Q_{t,t+k} \left(\left(\frac{p_t}{P_{t+k}} \frac{P_{t+k-1}}{P_{t-1}} \right)^{1-\theta} - MC_{t+k} \left(\frac{p_t}{P_{t+k}} \frac{P_{t+k-1}}{P_{t-1}} \right)^{-\theta} \right) Y_{t+k} \right\} \tag{21}$$

where $MC = P_t^x$ is the retail firm's marginal cost. From the aggregate price index (20) follows:

$$P_t^{1-\theta} = (1-\gamma)\, p_t^{*^{1-\theta}} + \gamma P_{t-1}^{1-\theta} \left(\frac{P_{t-1}}{P_{t-2}} \right)^{1-\theta} \tag{22}$$

which combined with the first order condition of equation (21) gives the Phillips curve for the final goods.

4.4 Government and monetary authority

There is no government spending in this model and the government follows a Ricardian policy regime. I assume that the cost of vacancies is modeled as a tax cost, as in Kuester (2010), and thus $C_t = Y_t$. The monetary authority controls the nominal interest rate following the (log-linearized) Taylor rule:

$$\hat{R}_t = \rho_i \hat{R}_{t-1} + (1-\rho_i)\, \rho_\pi E_t \hat{\pi}_{t+1} + \hat{u}_t$$

The parameter ρ_π is the coefficient determining the response of the central bank to inflation. The coefficient ρ_i measures the degree of interest rate smoothing, while u_t represents the monetary policy shock. The central bank commits to keeping inflation expectations to around zero. Log-linearized Taylor rules of this type are a good characterization of monetary policy according to Clarida, Gali and Gertler (2000).

4.5 Equilibrium

Using the F.O.C of the intermediate firm's problem (Proposition 1) and the price of the aggregate service (8) in a log-linear form, the following expression for the intermediate good's inflation arises:

$$\pi_t^w = \frac{1}{1+\beta}\pi_{t-1}^w + \frac{\beta}{1+\beta}\pi_{t+1}^w + \kappa\left(m\hat{r}s_t - \hat{P}_t^x\right) - \kappa_n \hat{n}_t + \frac{1}{(\theta_w - 1)(1+\beta)}\left[\hat{n}_{t-1} + \beta\hat{n}_{t+1}\right] \quad (23)$$

where $\kappa = \frac{1}{1+\beta}\frac{1-\gamma_w(1-\lambda)}{1-\beta\gamma_w(1-\lambda)}\frac{\gamma_w(1-\lambda)}{1+\delta\theta_w}$, and $\kappa_n = \frac{1}{(\theta_w-1)(1+\beta)}\frac{1+\beta\gamma_w^2(1-\lambda)^2}{\gamma_w(1-\lambda)}$, $m\hat{r}s_t = \ell\hat{x}_t - \hat{\mu}_t$. All the steps for deriving the intermediate good Phillips curve are given in Appendix D.

I log-linearize the retail firm's first-order condition from (21) and combine it with a log-linear version of equation (22) I get the usual Phillips curve for the evolution of final good inflation:

$$\pi_t = \frac{1}{1+\beta}\pi_{t-1} + \frac{\beta}{1+\beta}E_t\pi_{t+1} + \frac{(1-\gamma)(1-\beta\gamma)}{\gamma(1+\beta)}\hat{P}_t^x \quad (24)$$

By definition, the relative price of the intermediate good firms is $P_t^x = \frac{P_t^w}{P_t}$. By log-linearizing this, I can express the price of the composite labor service, as a function of the intermediate and retail good inflation as follows:

$$\hat{P}_t^x = \hat{P}_{t-1}^x + \pi_t^w - \pi_{t-1} \quad (25)$$

5 Model Evaluation

The performance criterion on which the proposed model is evaluated is whether it can match the impulse responses to a monetary policy shock, identified in a structural vector autoregression (SVAR) on US data. For this empirical exercise a structural vector autoregression is estimated to an exogenous monetary policy shock using four lags for each variable. The policy instrument of the central bank used is the short-term nominal interest rate. The identification strategy is that the only variable contemporaneously correlated with the monetary shock is the nominal interest rate, while the remaining variables respond with a quarter lag[13].

An SVAR is estimated using quarterly US data from 1967:Q1 to 2012:Q1 for the following list of variables: the log of quarterly real GDP, the quarterly rate of change in the CPI, the log of Help-Wanted advertising, the civilian unemployment rate, the log of job creation for continuing establishments in manufacturing, the log of average hourly earnings in the business sector, the log of total hours in the business sector and the effective federal funds rate. Most of the data series come from the St. Louis economic database (Fred). The job creation variable comes from the job creation and destruction database by Davis, Haltiwanger and Shuh (1996) and the vacancy series comes from the Help-Wanted advertising. The job creation data-set includes series from three different data-sets which are spliced together.

[13] The timing of the model is adjusted accordingly to account for the identification strategy used in the empirical exercise.

Splicing methods similar to Faberman (2006) and Davis *et al.* (1996) are employed to extend the data series for job creation and vacancies up to 2012 using data series from the St. Louis database.

For the estimation of any model the parameters are partitioned into three sets: $\tau = \{\beta, \lambda, b, \delta\}$, τ_1 and τ_2. The first set τ is common for all estimated models while the other two may vary. Parameters in set τ are calibrated because: β is the discount factor and λ the separation rate which are important in matching key steady states[14]. The labor supply elasticity δ and the unemployment benefit b are calibrated because otherwise they let the algorithm replicate the small surplus calibration as in (Hagedorn and Manovskii 2008). The rest of the variables are left to be estimated within bounds enforced by theory and evidence[15]. After the estimation, the parameters of the benchmark model, are in turn partitioned into τ_1 and τ_2. In the benchmark estimation, $\tau_1 = \{\theta, \sigma, \theta_w, \gamma, \rho_y\}$ and $\tau_2 = \{\chi, \xi, \phi, \alpha, \zeta, \psi, \gamma_w, \rho_i, \rho_\pi\}$. The parameters in τ_1 are considered "ex-post" calibrated because they are those parameters that reached the upper or lower bound set by the theory or empirical evidence. They are estimated at a first stage but they are reported as calibrated due to their value or effect on estimation. Finally the parameters in τ_2 are considered estimated as they are the ones that are most important to the dynamics and also reach an interior solution.

The technique followed is introduced by Rotemberg and Woodford (1998) to bring the model to the data, an application of the minimum distance estimation. The parameters in the set τ_2 are estimated in order to minimize the distance between the model-implied impulse responses and the responses obtained from a structural VAR on US data, placing more weight on the most accurately estimated responses. The exact methodology is presented in detail below. $\Gamma_M(\Psi)$ is defined as the vector-valued function of the impulse responses from my model. It is a function of the parameter vector Ψ. I denote Γ_V as the vector of the impulse responses from the structural VAR on US data (1967:Q3 to 2012:Q1). The vector of estimated parameters is the vector $\hat{\Psi}$, the solution to the minimization problem

$$\Omega\left(\hat{\Psi}\right) = \min_{\Psi \in \Theta} \left[\Gamma_M(\Psi) - \Gamma_V\right]' \Sigma_V \left[\Gamma_M(\Psi) - \Gamma_V\right]$$

subject to the possible constraints imposed by the parameter space Θ obtained from theory. The diagonal matrix Σ_V is a matrix with diagonal elements as the inverses of the VAR impulse response variances. More details about this estimation procedure can be found in Trigari (2009), Christiano *et al.* (2005) and Amato and Laubach (2000).

[14] The results are unchanged for different values of the two parameters.

[15] For example γ must vary between 0 and 0.5 as evidence restricts the study to match the data using low degrees of price rigidity.

5.1 Calibration and Estimation

A summary of the calibrated parameters is presented in Table 1. The model is calibrated using values from independent studies. The steady state probability of a vacancy to be matched, q^v, is set to 0.7 as Cooley and Quadrini (1999) and den Haan, Ramey and Watson (2000). The probability of a worker to find a job, $\bar{q}^u$, is set to 0.6, as Cole and Rogerson (1999) implying an unemployment duration of 1.67 quarters. By picking those values for the two probabilities the value of the efficiency of the match, h, becomes 0.65[16]. The unemployment benefit b here is zero[17], the lowest possible value, to make sure it is not driving the result[18].

The separation rate, λ, is set to 0.035. This implies a 6% steady state unemployment level. Hall (1999) estimates a value of 0.08 and the values usually vary around 0.08 to 0.1. Here, the choice of separation rate is not important in achieving the target since the model can replicate the same results using a value for λ equal to 0.08 with minor differences. The discount rate, β, is 0.989, which implies a 1% real interest rate per quarter. The elasticity of substitution for the final goods, θ, is set to 11, which entails a markup of 1.1. The elasticity of substitution for the intermediate goods, θ_w, is set to 101 as in Altig, Christiano, Eichenbaum and Linde (2005). The risk aversion coefficient, σ, is set to 2 as commonly used. The inverse of labor supply elasticity, δ, is set to 10, which corresponds to a rather inelastic labor supply[19]. The value for the final good price rigidity, γ, is set to 0.5, along with evidence from Bils and Klenow (2004) suggesting that prices adjust, on average, every two quarters. For the social norm, ϕ takes the value of 1 when the norm is on and 0 when the norm is off.

The estimates associated with preferences, labor market, price rigidity and policy parameters appear in Table 2. Starting from the parameters related to household preferences, the habit persistence parameter χ is estimated to be 0.95. The estimate is close to the 0.97 value obtained by Kuester (2010) and the 0.91 value estimated by Boivin and Giannoni (2006). The estimate for the ROPE parameter, ξ, is around 1.81 and ϕ is estimated at 2.1.

For the labor market parameters, the elasticity of the matching function, α, is set to 0.41, which is close to the value of 0.4 estimated by Blanchard and Diamond (1989). Petrongolo and Pissarides (2001) estimate the elasticity of the matching function with respect to unemployment to be between $0.5 - 0.7$. The share of the surplus that goes to workers, ζ, is estimated in my model at 0.8. Although there is no microevidence for this parameter, it is

[16] The variable $h = \tilde{h}\phi^\alpha$ according to our definition of the matching function.

[17] Setting $b = 0.4$ as in Shimer (2005) has a very small impact on the responses and estimated parameter, as it is a critical goal of this paper, to create a model that is not too sensitive to unemployment benefit changes.

[18] A high value for the unemployment benefit increases the steady state value of the wage while decreasing the steady state of profits. This decreases the deviation of wage from its steady state thus increasing vacancy volatility. This mechanism creates amplification as set out by Hagedorn and Manovskii (2007).

[19] It implies a labor supply elasticity of $\frac{1}{\delta} = 0.1$. Trigari (2009) and Kuester (2010) use the same value. Card (1994) estimates that $\frac{1}{\delta} \in (0, 0.5)$.

close to the 0.77 value obtained by Braun (2006). Picking a low value for this parameter (0.05 as in Hagedorn and Manovskii 2008) and high unemployment benefit, the model can replicate the small surplus calibration. Trigari (2004) finds a similar estimate (0.81), while Kuester (2010) calculates it at around 0.21 and Shimer (2005a) calibrates it to 0.72. The vacancy adjustment cost, ψ, is estimated to be 2.39 which is close to Braun's estimate of 2.

The estimate of price rigidity, γ_w, is 0.55 which is close to the 0.5 value suggested by Bils and Klenow (2004). For the intermediate goods, Christiano et al. (2005) find an estimate for γ_w to be around 0.64. For the policy parameters, the policy inertia parameter, ρ_i, is 0.87 which is close to Kuester's 0.83 value and to Trigari's (2004) estimate[20] of 0.85. The monetary authority's response to inflation ρ_π is estimated to be 2.08.

5.2 The model's ability to match the data

Figure 1 presents the model-implied impulse responses along with the empirical impulse responses of the variables of interest after a unit monetary shock. The solid lines represent the responses obtained from running a VAR on quarterly US data from 1967:Q3 to 2012:Q1 after a federal funds rate shock. The solid lines with bullet marks represent the model-implied responses, and the gray areas indicate 90% confidence intervals. The model's responses are consistent with the persistence and cyclicality of various key macroeconomic variables in the data.

The model-predicted response of inflation is as low and inertial as its empirical counterpart. The model-implied responses of vacancies, unemployment and job creation can match the level of magnitude, as well as the persistence of the responses observed in the data. The job creation variable in the proposed model is the ratio of new matches to employment which coincides with the way the data series for job creation is extracted. The low and inertial response of the real wage is matched fairly well, despite the tendency of search and matching models augmented with monetary shocks to overshoot the responses of the real wage. The low and inertial wage response is obtained entirely due to nominal rigidities in the intermediate sector. Below I provide details as to how the various assumptions contribute to the picture in Figure 1.

The social norm: Figure 2 shows the optimal fit of the model without the social norm ($\phi = 0$). I do not present responses other than vacancies, unemployment, job creation and unemployment duration because the model performs fairly well in explaining those[21]. Clearly, the model cannot create the required amplification without the social norm specification. The estimates of the parameters of interest for this model are reported in the last two columns of table 2.

[20] The policy inertia parameter is important for the size and persistence of the responses. An extended discussion around this topic can be found in Walsh (2005).

[21] This is expected since the amplification puzzle affects primarily those four variables in this model.

During a downturn, the positive externality from unemployment does not reverse the strain experienced from income loss due to unemployment. In a recession, the unemployed are still in distress because of falling income and forgone opportunities. Under this framework, although they appear to be in less stress than what the standard search and matching model would predict, they are nonetheless in a very difficult situation. This psychological cost comes in addition to the standard cost of unemployment measured in falling income and not as a measure of the total cost of unemployment.

To further motivate the importance of the social norm, Figure 3 examines the effect on the model-implied responses using my benchmark calibration, for different values of ROPE. It is distinct that higher degrees of the ROPE parameter ξ, can significantly amplify the responses of vacancies, unemployment, job creation and unemployment duration in the model.

Price stickiness in the intermediate sector: The assumption of price stickiness in the form of Calvo contracts is very important in this model. The purpose of this assumption is twofold. First, it aims to enhance the model's persistence and second, to lower the volatility of the wage response after a monetary shock. The optimal fit of the model with flexible firms is presented in Figure 4, where the results are unsatisfactory.

The data used in this study include the Volcker disinflation period and thus the inflation response in figure 1 increases initially even though interest rates are increasing. This behavior is known as the price puzzle (Eichenbaum 1992). This study is not aiming in addressing this puzzle as it involves a large literature that tends to portray this puzzle as an empirical issue[22] (Hanson 2004 and Christiano 1998).

Many authors like Gertler and Trigari (2009), Hall (2005) and Shimer (2005b) have used wage rigidity for new firms to obtain amplification, an assumption that is rejected for its empirical validity by Pissarides (2009) and Haefke, Sonntag and van Rens (2009). Wage rigidity for new matches might be rejected by the evidence, but what about wage rigidity for continuing firms? Wage rigidity, at least for continuing firms, seems to be essential to guarantee the low and inertial response of the real wage observed in the data. Even disregarding the fact that it complicates the model further, according to Krause and Lubik (2007), the wage rigidity assumption could aid to matching the wage response, but does not contribute towards obtaining inflation inertia in the least.

Instead, the assumption of price rigidity for intermediate firms not only enables the model to match the real wage response, but also creates additional inflation inertia. Since an intermediate firm currently adjusting its price uses a single worker's labor hours in production, the firm takes into consideration how the labor price is directly affected by the firm's pricing decision. In an expansion, when a price-adjusting firm considers increasing its price, the demand for its product must fall. The fall in demand induces a fall in demand for labor hours, which implies a lower marginal cost for the firm, which in turn pressures the firm to

[22] For theoretically addressing the puzzle check Christiano *et al.* (2005)

decrease its initially set price. Treating each worker as a single firm adds the term $1+\delta\theta_w$ in the denominator of the parameter κ in the Phillips curve for the intermediate goods equation (23), which tends to decrease the volatility of intermediate good inflation and justifies the choice of a fairly inelastic labor supply (inverse of labor supply elasticity δ calibrated to 10). A discussion on the difference between firms employing a single worker against partly employing all workers in the economy can be found in chapter 3 of Woodford (2003). A similar assumption is made by Kuester (2010).

5.3 The model vs common criticism

Hagedorn and Manovskii (2008), (H&M hereafter) argue that tightness and unemployment can be amplified as long as steady state profits remain small while the wage is relatively large. Therefore, their model is calibrated such that the surplus of the worker is too small. Table 3 reports some important steady state values and parameters of the model and also includes the corresponding values from Shimer (2005) and H&M. In all three cases the steady state wage is relatively high compared to the output, but this attribute by itself cannot guarantee high amplification. Amplification can be boosted if the worker's value of unemployment is high compared to employment, or if the surplus of the worker is small enough. Table 3 indicates that the worker's surplus is calibrated to 0.01 in H&M, which is significantly lower than Shimer's 0.39 value and my model's 3.97 value. In this model, the value of being employed is much greater than that of being unemployed since the worker's outside option is negative (without unemployment benefits). In H&M, unemployed workers are nearly as well off as the employed (small surplus). In the proposed model there is a huge gap between the unemployment and employment state which brings it further in line with reality.

Moreover, when the social norm is removed ($\phi = 0$), then the surplus of the worker is 2.7 which implies that the unemployed are in distress not only because of the existence of the norm but also because of falling income. The norm is not a substitute for the strain caused from losses in income or opportunity, but an additional factor affecting the well-being of the unemployed. It is evident that the introduction of the norm improves the steady state welfare gap between the employed and the unemployed compared to similar work.

Another common critisism on search and matching models comes from Pissarides (2009) and Haefke et al. (2009) who claim that the correlation of wages of new matches and the productivity shock is equal to 1. The model-implied correlation between those two variables is estimated by simulating this model after a productivity shock, using the benchmark calibration. The implied correlation[23] between wages for new jobs and the productivity shock is 0.998.

[23] What contributes to the above is the assumption that wages are flexible in this economy and new firms are price adjusters, prohibiting price rigidity from affecting the wage for new matches.

5.4 Bringing the ROPE parameter to the data

The next task is to test the validity of the ROPE parameter ξ estimated in the previous section. The evidence presented up to this point relates the psychological cost of unemployment to the level of unemployment. However, all those estimates are cardinal measures and thus cannot be used to identify the parameters of the social norm in the model. This section presents the details to the estimation of the percentage of total consumption that should be given up to avoid fluctuations imposed by the social norm. Specifically, the certainty equivalent ce is estimated such that the expected welfare without the social norm equals the expected welfare with the norm included, which is

$$E_0 \sum_{t=0}^{\infty} U\left((1-ce)\,C_t, L_{jt}\right) = E_0 \sum_{t=0}^{\infty} U\left(C_t, L_{jt}, L_{jt}^u\right) \tag{26}$$

The left hand side of equation (26) is the welfare for an economy where there is no disutility from the norm, that is to say, where the consumer partially reduces consumption to insure against disutility from the norm. The right hand side corresponds to the benchmark utility function. This framework estimates the portion of consumption ce that is needed to eliminate welfare variations due to the social norm. A second order Taylor expansion of the utility functions in (26) is estimated to compute the second-order approximation to the solution to the model, using the techniques provided by Schmitt-Grohe and Uribe (2004). Then using Kim et.al (2008), I compute second order accurate solutions to equation (26) without the need of a simulation. The whole procedure is summarized in Appendix E.

Estimated under the benchmark calibration, equation (26), reveals that the compensation needed to eliminate the effects of the psychological cost of unemployment is 5% of the aggregate income. Households are willing to give up 5% of their income to be completely insured against the psychological effect imposed by the norm. Output and consumption is used interchangeably in this discussion because in every period all output is consumed ($C_t = Y_t$).

There are a few papers that quantify the psychological cost of unemployment for various countries reporting very similar findings. Clark and Oswald (2002) do the exercise with UK data, Winkelmann and Winkelmann (1998) with German data and Ravallion and Lokshin (2000) with Russian data. I am particularly interested in the findings of Blanchflower and Oswald (2004) since they apply the experiment to US data. The methodology[24] is identical

[24] They use the following regression equation: $u = A + \beta_1 S_1 + \beta_2 S_2 + ... + \gamma Y$ where u is a measure of psychological well-being, S_i comprises dummy variables and Y indicates a measure of household income. Let $S_1 = 1$ correspond to an unemployed person and $S_2 = 1$ correspond to an employed person, then $\Delta u = \Delta A + \beta_1 \Delta S_1 + \beta_2 \Delta S_2 + ... + \gamma \Delta Y$. When a person becomes unemployed ($\Delta S_1 = 1$ and $\Delta S_2 = -1$) and at the same time is compensated with some fixed income (ΔY) to maintain the same utility as before, (keep her on the same level curve $\Delta u = 0$), then that fixed income should be $\Delta Y = \frac{\beta_2 - \beta_1}{\gamma}$. This provides a measure that can be compared to the psychological cost of unemployment in the proposed model.

in all the above papers. The authors find that for the period from 1972 to 1998, the compensation for the effect of unemployment on happiness corresponds to a loss of annual income of around \$60,000. As average unemployment duration is around 15.7 weeks, or 1/3 of a year, then an average unemployment spell costs around \$20,000. During that period, the average income is around \$16,000[25] and the average unemployment rate is around 5.5%. Hence, the psychological cost of unemployment on the economy is of the magnitude of at least 6.9% of income.

Under the benchmark calibration my estimate is 4.8%, which is close to the value the above authors find empirically and therefore it can be considered a plausible value.It is evident that the psychological cost of unemployment is large and non-negligible for both the model and the data. It is therefore imperative that policy makers should take into consideration the evident psychological cost which, crucially, seems far greater than the cost of inflation, this latter being the element on which most authors tend to focus[26].

6 Conclusion

A model is proposed where the cost of unemployment to society considers an additional factor, the psychological cost of unemployment. This factor is shown by empirical findings to be highly significant, on a level comparable to effects of ill health to an individual's well-being. More empirical evidence suggests that this cost is higher the less unemployment there is around, indicating that the high volatility of unemployment also affects the volatility of this psychological cost throughout the business cycle. I incorporate those facts in a DSGE model with search unemployment and nominal rigidities in the form of a social norm and find that it improves the performance of the model significantly. A lower rate of unemployment within a household increases the support of the norm and puts greater pressure upon the individual unemployed. This extra psychological cost imposed by the norm counterbalances the bargaining power gained by decreasing unemployment duration during an expansion, preventing the wage from crowding out vacancy creation and boosting the model's amplification mechanism. The unemployment norm provides enough amplification to the model to match second moments in the data and can be used to provide amplification in any search and matching framework. The nominal rigidities (Calvo contracts), especially in the labor market, help account for other features of the data such as persistence. Price rigidity in the intermediate sector not only contributes in creating inflation inertia but also aids in keeping the wage response low and smooth. In a monetary model with no nominal rigidities in the labor market, the wage implied is too volatile.

[25] As noted in Blanchflower and Oswald (2004) which is calculated in 1992 dollars.

[26] For example, Cooley and Hansen (1989) find the cost of inflation around 0.4% of output for 10% inflation rate.

The model can match the impulse responses implied by a structural VAR on quarterly US data from 1967:Q3 to 2012:Q1 and can be used for optimal monetary policy analysis. The goal is to match the data by assuming moderate degrees of price rigidity and without the aid of wage rigidity or unreasonable calibration, mechanisms which in any case have been heavily criticized. Among others, I address the Shimer puzzle by employing monetary shocks while avoiding stickiness in wages and high unemployment benefits. This paper attempts to create a monetary model that can be used for policy analysis, as the cost of unemployment incorporates also the associated psychological cost, which is extremely important to workers. This specification makes the trade-off between inflation and unemployment more challenging and should be important for any central bank conducting monetary policy.

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A Appendix

The job creation condition is derived in this appendix. Take the vacancy posting condition

$$\frac{K_t}{q_t^v} = E_t Q_{t,t+1} \left\{ F_{t+1}^J \left(p_{t+1}^{w^*} \right) \right\} \tag{27}$$

then substitute in the value of a job to the firm when it is adjusting it's price in the next period

$$F_{t+1}^J \left(p_{t+1}^{w^*} \right) = \Pi_{t+1}^w \left(p_{t+1}^{w^*} \right) + (1-\lambda) E_{t+1} Q_{t+1,t+2} \left\{ (1-\gamma_w) F_{t+2}^J \left(p_{t+2}^{w^*} \right) + \gamma_w F_{t+2}^J \left(p_{t+1}^{w^*} \frac{P_{t+1}^w}{P_t^w} \right) \right\}$$

It is clear from here that the relevant information for vacancy posting is the value of new firms and the new firms are always price adjusters next period. Manipulating the above expression, it becomes

$$\begin{aligned} F_{t+1}^J \left(p_{t+1}^{w^*} \right) = \Pi_{t+1}^w \left(p_{t+1}^{w^*} \right) + (1-\lambda) E_{t+1} Q_{t+1,t+2} \left\{ F_{t+2}^J \left(p_{t+2}^{w^*} \right) \right\} \\ + \gamma_w (1-\lambda) E_{t+1} Q_{t+1,t+2} \left(F_{t+2}^J \left(p_{t+1}^{w^*} \frac{P_{t+1}^w}{P_t^w} \right) - F_{t+2}^J \left(p_{t+2}^{w^*} \right) \right) \end{aligned}$$

and after using (27)

$$F_{t+1}^J \left(p_{t+1}^{w^*} \right) = \Pi_{t+1}^w \left(p_{t+1}^{w^*} \right) + (1-\lambda) \frac{K_{t+1}}{q_{t+1}^v} + \gamma_w (1-\lambda) E_{t+1} Q_{t+1,t+2} \Delta_{t+2}^w \left(p_{t+1}^{w^*}, p_{t+2}^{w^*} \right) \tag{28}$$

where $\Delta_{t+2}^w \left(p_{t+1}^{w^*}, p_{t+2}^{w^*} \right) = F_{t+2}^J \left(p_{t+1}^{w^*} \frac{P_{t+1}^w}{P_t^w} \right) - F_{t+2}^J \left(p_{t+2}^{w^*} \right)$

Plugging (28) back in (27) the job creation condition becomes

$$\frac{K_t}{q_t^v} = E_t Q_{t,t+1} \left\{ \Pi_{t+1}^w \left(p_{t+1}^{w^*} \right) + (1-\lambda) \frac{K_{t+1}}{q_{t+1}^v} + \gamma_w (1-\lambda) E_{t+1} Q_{t+1,t+2} \Delta_{t+2}^w \left(p_{t+1}^{w^*}, p_{t+2}^{w^*} \right) \right\}$$

The definition of $\Delta_{t+2}^w \left(p_{t+1}^{w^*}, p_{t+2}^{w^*} \right)$ is useful because, first, the steady state is zero and also it becomes zero when log-linearized. The model is not log-linearized in this instance, as the results remain the same regardless and therefore the delta term may be discarded.

B Appendix

In this section the wage equation for the j^{th} intermediate firm is derived. The subtraction of Bellman equations (13) and (14) is:

$$W_t^E\left(p_{jt}^w\right) - W_t^U = w_{jt}L_{jt} - DU_t + E_tQ_{t,t+1}\left\{\begin{array}{c}\left(1-\lambda-q_t^u\right)\left(W_{t+1}^E\left(p_{t+1}^{w*}\right) - W_{t+1}^U\right) \\ +\gamma_w\left(1-\lambda\right)\left(\begin{array}{c} W_{t+1}^E\left(p_{jt}^w\frac{P_t^w}{P_{t-1}^w}\right) - W_{t+1}^U \\ -\left(W_{t+1}^E\left(p_{t+1}^{w*}\right) - W_{t+1}^U\right)\end{array}\right)\end{array}\right\} \tag{29}$$

where $DU_t = \frac{G(L_{jt})}{\mu_t} + b - \frac{G^u\left(L_{jt}^u\right)}{\mu_t}$. Equation (17) holds for every period and for every firm, irrespective of price adjustment. This is because all intermediate firms negotiate their price every period (wage is flexible). This implies that the following equations hold:

$$(1-\zeta)\left(W_{t+1}^E\left(p_{t+1}^{*^w}\right) - W_{t+1}^U\right) = \zeta F_{t+1}^J\left(p_{t+1}^{*^w}\right)$$

and

$$(1-\zeta)\left(W_{t+1}^E\left(p_{jt}^w\frac{P_t^w}{P_{t-1}^w}\right) - W_{t+1}^U\right) = \zeta F_{t+1}^J\left(p_{jt}^w\frac{P_t^w}{P_{t-1}^w}\right)$$

Then after using the above facts equation (29) becomes:

$$W_t^E\left(p_{jt}^w\right) - W_t^U = w_{jt}L_{jt} - DU_t + E_tQ_{t,t+1}\left\{\begin{array}{c}\left(1-\lambda-q_t^u\right)\frac{\zeta}{1-\zeta}F_{t+1}^J\left(p_{t+1}^{w*}\right) \\ +\gamma_w\left(1-\lambda\right)\frac{\zeta}{1-\zeta}\left(\begin{array}{c} F_{t+1}^J\left(p_{jt}^w\frac{P_t^w}{P_{t-1}^w}\right) \\ -F_{t+1}^J\left(p_{t+1}^{w*}\right)\end{array}\right)\end{array}\right\}$$

then use the vacancy posting condition, equation (11) in to get

$$\begin{aligned} W_t^E\left(p_{jt}^w\right) - W_t^U &= w_{jt}L_{jt} - DU_t + \frac{\zeta}{1-\zeta}\left(1-\lambda-q_t^u\right)\frac{K_t}{q_t^v} \\ &+ \frac{\zeta}{1-\zeta}\gamma_w\left(1-\lambda\right)E_tQ_{t,t+1}\Delta_{t+1}^w\left(p_{jt}^w, p_{t+1}^{w*}\right)\end{aligned} \tag{30}$$

where $\Delta_{t+1}^w\left(p_{jt}^w, p_{t+1}^{w*}\right) = F_{t+1}^J\left(p_{jt}^w\frac{P_t^w}{P_{t-1}^w}\right) - F_{t+1}^J\left(p_{t+1}^{w*}\right)$.

The difference in the right hand sight of equation (11) is just the value of the job to the firm, where $F_t^V = 0$ in equilibrium. Use equation (12) along with the vacancy posting condition (11) to get

$$F_t^J\left(p_{jt}^w\right) = \Pi_t^w\left(p_{jt}^w\right) + (1-\lambda)\frac{K_t}{q_t^v} + \gamma_w\left(1-\lambda\right)E_tQ_{t,t+1}\Delta_{t+1}^w\left(p_{jt}^w, p_{t+1}^{*^w}\right) \tag{31}$$

Now plug equations (30) and (31) in (11) after using the following expression for the profit equation $\Pi_t^w\left(p_{jt}^w\right)=\frac{p_{jt}^w}{P_t}x_{jt}-w_{jt}L_{jt}$ and solve for the wage to get

$$w_{jt}L_{jt}=(1-\zeta)\frac{G\left(L_{jt}\right)}{\mu_t}-(1-\zeta)\frac{G^u\left(L_{jt}^u\right)}{\mu_t}+(1-\zeta)\,b_t+\zeta K_t\vartheta_t+\zeta\frac{p_{jt}^w}{P_t}x_{jt}$$

where $\frac{q_t^u}{q_t^v}=\vartheta_t$ (where ϑ_t is market tightness).

C Appendix

Here an expression for aggregate wage is derived. Some firms are price adjusting and some hold the price fixed, therefore the average wage is not trivial. Start by defining the aggregate wage as the weighted sum of the N_t firms operating each period

$$\omega_t=\frac{1}{N_t}\int\limits_{N_t}w_t\left(p_{jt}^w\right)dj$$

Break the firms into old and new ones

$$\omega_t=\frac{1}{N_t}\int\limits_{(1-\lambda)N_{t-1}}w_t\left(p_{jt}^w\right)+\frac{1}{N_t}\int\limits_{N_t-(1-\lambda)N_{t-1}}w_t\left(p_{jt}^w\right)dj$$

Old firms are then broken down further to price adjusters and non adjusters followed by adding and subtracting $\frac{\gamma_w(1-\lambda)}{N_t}\int\limits_{N_{t-1}}w_{t-1}\left(p_{jt-1}^w\right)$ to get

$$\begin{aligned}\omega_t=&\frac{\left(1-\gamma_w\right)(1-\lambda)}{N_t}\int\limits_{N_{t-1}}w_t\left(p_t^{w^*}\right)dj\\&+\frac{\gamma_w\,(1-\lambda)}{N_t}\int\limits_{N_{t-1}}w_{t-1}\left(p_{jt-1}^w\right)\\&+\frac{1}{N_t}\int\limits_{N_t-(1-\lambda)N_{t-1}}w_t\left(p_t^{w^*}\right)dj\\&+\frac{\gamma_w\,(1-\lambda)}{N_t}\int\limits_{N_{t-1}}\left[w_t\left(p_{jt-1}^w\right)-w_{t-1}\left(p_{jt-1}^w\right)\right]\end{aligned}$$

Finally the average wage is

$$\omega_t=w_t\left(p_t^{w^*}\right)+\gamma_w\,(1-\lambda)\,\frac{N_{t-1}}{N_t}\left(\omega_{t-1}-w_t\left(p_t^{w^*}\right)\right)+\frac{\gamma_w\,(1-\lambda)}{N_t}\int\limits_{N_{t-1}}\nabla_{w,t,t-1}dj$$

where $\nabla_{w,t,t-1} = w_t\left(p^w_{jt-1}\right) - w_{t-1}\left(p^w_{jt-1}\right)$ which is another delta (inverted delta) variable. The integral in the last term of the expression is impossible to compute. However when log-linearized it can be computed easily.

Log-linearizing the average wage equation I get the equation for the average economy-wide wage

$$\begin{aligned}\hat{\omega}_t &= (1-\lambda)\left(\hat{n}_{t-1} - \hat{n}_t + \hat{w}^*_t\right) - \gamma_w (1-\lambda)\left(\hat{n}_{t-1} - \hat{n}_t + \hat{w}^*_t\right)\\ &+ \gamma_w (1-\lambda)\left(\hat{n}_{t-1} - \hat{n}_t + \hat{\omega}_{t-1}\right)\\ &+ \hat{w}^*_t - (1-\lambda)\left(\hat{n}_{t-1} - \hat{n}_t + \hat{w}^*_t\right)\\ &+ \frac{\gamma_w (1-\lambda)}{\bar{w}}\hat{\nabla}_{w,t,t-1}\end{aligned}$$

The only thing which remains to be defined is $\nabla_{w,t,t-1}$. The wage equation for a firm charging a price p^w_{jt-1} on period $t-1$ is repeated below

$$w_{t-1}\left(p^w_{jt-1}\right) = \frac{1}{L_{t-1}\left(p^w_{jt-1}\right)}\begin{bmatrix}(1-\zeta)\, DU_{t-1}\left(p^w_{jt-1}\right) + (1-\zeta)\, b\\ +\zeta K_{t-1}\vartheta_{t-1} + \zeta\frac{p^w_{jt-1}}{P_{t-1}}x_{t-1}\left(p^w_{jt-1}\right)\end{bmatrix}$$

and the wage this same firm would pay if it failed to adjust its price next period is (There is still inflation indexation in this case)

$$w_t\left(p^w_{jt-1}\frac{P^w_{t-1}}{P^w_{t-2}}\right) = \frac{1}{L_t\left(p^w_{jt-1}\frac{P^w_{t-1}}{P^w_{t-2}}\right)}\begin{bmatrix}(1-\zeta)\, DU_t\left(p^w_{jt-1}\frac{P^w_{t-1}}{P^w_{t-2}}\right) + (1-\zeta)\, b\\ +\zeta K_t\vartheta_t + \zeta\frac{p^w_{jt-1}}{P_t}\frac{P^w_{t-1}}{P^w_{t-2}}x_t\left(p^w_{jt-1}\frac{P^w_{t-1}}{P^w_{t-2}}\right)\end{bmatrix}$$

where in both equations $DU_t = \frac{G(L_t)}{\mu_t} - \frac{G^u(L^u_t)}{\mu_t}$ is the disutility from labor and the social norm. Log-linearize both expressions to get

$$\begin{aligned}\hat{\nabla}_{w,t,t-1} &= -\bar{w}\left[\theta_w\left(\pi^w_t - \pi^w_{t-1}\right) + \left(\hat{X}_t - \hat{X}_{t-1}\right)\right]\\ &+\frac{1}{\bar{L}}\begin{bmatrix}(1-\zeta)\frac{\bar{L}^{1+\delta}}{\bar{\mu}}\left[\theta_w\left(\pi^w_t - \pi^w_{t-1}\right) + \left(\hat{X}_t - \hat{X}_{t-1}\right) - \frac{1}{1+\delta}\left(\hat{\mu}_t - \hat{\mu}_{t-1}\right)\right]\\ -(1-\zeta)\frac{\bar{G}^u}{\bar{\mu}}\left(-\xi\left(\hat{u}_t - \hat{u}_t\right) - \left(\hat{\mu}_t - \hat{\mu}_{t-1}\right)\right) + \zeta\bar{K}\bar{\vartheta}\left(\hat{K}_t - \hat{K}_{t-1} + \hat{\vartheta}_t - \hat{\vartheta}_{t-1}\right)\\ +\zeta\bar{P}^x\frac{\bar{X}}{\bar{N}}\left[P^x_t - P^x_{t-1} + (\theta_w - 1)\left(\pi^w_t - \pi^w_{t-1}\right) + \hat{X}_t - \hat{X}_{t-1}\right]\end{bmatrix}\end{aligned}$$

D Appendix

In this appendix, the Phillips curve for the evolution of the price index of the intermediate firms is derived. The intermediate firm's problem is:

$$\max_{p^w_t}\sum_{k=0}^{\infty}\gamma^k_w (1-\lambda)^k E_t Q_{t,t+k}\left[\frac{p^w_t}{P_{t+k}}\frac{P^w_{t+k-1}}{P^w_{t-1}}x_{t+k}\left(p^w_t\frac{P^w_{t+k-1}}{P^w_{t-1}}\right) - MRS_{t+k}L_{t+k}\left(p^w_t\frac{P^w_{t+k-1}}{P^w_{t-1}}\right)\right]$$

where the cost of labor is the marginal rate of substitution, which is $MRS_{t+k} = \frac{\varpi L_{t+k}^{\delta}}{\mu_{t+k}}$. The FOC of the intermediate firm's problem is:

$$\left(1-\theta_w\right) E_t \sum_{k=0}^{\infty} \gamma_w^k \left(1-\lambda\right)^k Q_{t,t+k} \frac{p_t^w}{P_{t+k}} \left(\frac{p_t^w}{P_{t+k}^w}\right)^{-\theta_w} \left(\frac{P_{t+k-1}^w}{P_{t-1}^w}\right)^{1-\theta_w} X_{t+k}$$
$$= \theta_w E_t \sum_{k=0}^{\infty} \gamma_w^k \left(1-\lambda\right)^k Q_{t,t+k} \frac{MRS_{t+k}}{Z_{t+k}} \left(\frac{p_t^{w^*}}{P_{t+k}^w}\right)^{-\theta_w} \left(\frac{P_{t+k-1}^w}{P_{t-1}^w}\right)^{-\theta_w} X_{t+k}$$

The first-order condition can be rewritten as:

$$\left(1-\theta_w\right) E_t \sum_{k=0}^{\infty} \gamma_w^k \left(1-\lambda\right)^k Q_{t,t+k} P_{t+k}^x \left(\frac{p_t^{w^*}}{P_t^w}\frac{P_t^w}{P_{t+k}^w}\right)^{1-\theta_w} \left(\frac{P_{t+k-1}^w}{P_{t-1}^w}\right)^{1-\theta_w} X_{t+k}$$
$$= \theta_w E_t \sum_{k=0}^{\infty} \gamma_w^k \left(1-\lambda\right)^k Q_{t,t+k} X_{t+k} \frac{MRS_{t+k}}{Z_{t+k}} \left(\frac{p_t^{w^*}}{P_t^w}\frac{P_t^w}{P_{t+k}^w}\right)^{-\theta_w} \left(\frac{P_{t+k-1}^w}{P_{t-1}^w}\right)^{-\theta_w}$$

where $P_t^x = \frac{P_t^w}{P_t}$

Define $G_t^w = \frac{p_t^{w^*}}{P_t^w}$. Log-linearize the above

$$\left(1-\theta_w\right) \bar{P}^x \bar{G}^w = \theta_w \bar{\Phi} \tag{32}$$

Therefore

$$E_t \sum_{k=0}^{\infty} \beta^k \gamma_w^k \left(1-\lambda\right)^k \begin{pmatrix} \hat{P}_{t+k}^x + \left(1-\theta_w\right) g_t^w \\ +\left(1-\theta_w+\theta_w\right)\left(\hat{P}_t^w - \hat{P}_{t-1}^w\right) \\ +\left(1-\theta_w\right)\left(\hat{P}_{t+k-1}^w - \hat{P}_{t+k}\right) \end{pmatrix} \tag{33}$$
$$= E_t \sum_{k=0}^{\infty} \beta^k \gamma_w^k \left(1-\lambda\right)^k \left(m\check{r}s_{t+k} - \hat{z}_{t+k} - \theta_w g_t^w - \theta_w \left(\hat{P}_{t+k-1}^w - \hat{P}_{t+k}\right)\right)$$

Hat variables are deviations from steady state. Please note that the real marginal cost is: $MRS_{t+k} = \frac{\varpi L_{t+k}^{\delta}}{\mu_{t+k}}$, $L_{t+k} = \frac{x_{t+k}\left(p_t^w \frac{P_{t+k-1}^w}{P_{t-1}^w}\right)}{Z_{t+k}}$, $x_{t+k}\left(p_t^w \frac{P_{t+k-1}^w}{P_{t-1}^w}\right) = \left(\frac{p_t^{w^*}}{P_t^w}\frac{P_t^w}{P_{t+k}^w}\frac{P_{t+k-1}^w}{P_{t-1}^w}\right)^{-\theta_w} X_{t+k}$.

Log-linearizing the above expressions one by one yields:

$$m\check{r}s_{t+k} = \ell \hat{l}_{t+k} - \mu_{t+k}$$

$$\hat{l}_{t+k} = \hat{x}_{t+k} - \hat{z}_{t+k}$$

$$\hat{x}_{t+k} = X_{t+k} - \theta_w \left(g_t^w + \hat{P}_t^w - \hat{P}_{t+k}^w + \hat{P}_{t+k-1}^w - \hat{P}_{t-1}^w\right)$$

Combine the above four equations to get

$$m\check{r}s_{t+k} - \hat{z}_{t+k} = -\theta_w \left(g_t^w + \hat{P}_t^w - \hat{P}_{t+k}^w + \hat{P}_{t+k-1}^w - \hat{P}_{t-1}^w \right) + X_{t+k} - \mu_{t+k} - z_{t+k}$$

Define $m\hat{r}s_{t+k} = X_{t+k} - \mu_{t+k} - \hat{z}_{t+k}$ as the marginal rate of substitution if the prices are at the steady state full employment level.

$$m\check{r}s_{t+k} - \hat{z}_{t+k} = m\hat{r}s_{t+k} - \theta_w \left(\hat{g}_t^w + \hat{P}_t^w - \hat{P}_{t+k}^w + \hat{P}_{t+k-1}^w - \hat{P}_{t-1}^w \right)$$

Substitute this into equation (33),

$$\begin{aligned} & g_t^w + \pi_t^w \\ & = \frac{1 - \beta\gamma_w (1-\lambda)}{(1+\theta_w)} E_t \sum_{k=0}^{\infty} \beta^k \gamma_w^k (1-\lambda)^k \left(m\hat{r}s_{t+k} - \hat{P}_{t+k}^x + (1+\theta_w)\, \pi_{t+k}^w \right) \end{aligned}$$

Write the above in recursive form and rearrange,

$$g_t^w = \frac{1 - \beta\gamma_w (1-\lambda)}{(1+\theta_w)} \left(m\hat{r}s_t - \hat{P}_t^x \right) + \beta\gamma_w (1-\lambda)\, E_t \left(\hat{g}_{t+1}^w + \pi_{t+1}^w - \pi_t^w \right) \qquad (34)$$

where $m\hat{r}s_t = X_t - \mu_t - \hat{z}_t$

After some algebraic calculations the price of the aggregate intermediate good (8) is:

$$\begin{aligned} P_t^{w^{1-\theta_w}} &= (1-\gamma_w)(1-\lambda) \int\limits_{N_{t-1}} \left(p_t^{w^*} \right)^{1-\theta_w} dj \\ &+ \gamma_w (1-\lambda) \int\limits_{N_{t-1}} \left(p_{jt-1}^w \frac{P_{t-1}^w}{P_{t-2}^w} \right)^{1-\theta_w} dj \\ &+ \int\limits_{N_t - (1-\lambda) N_{t-1}} \left(p_t^{w^*} \right)^{1-\theta_w} dj \end{aligned}$$

where $p_t^{w^*}$ is the optimal price. Log-linearizing the above and using the steady state condition $\bar{N}\bar{G}^{w^{1-\theta_w}} = 1$ and $\hat{g}_t^w \equiv p_t^{w^*}/P_t^w$

$$\hat{g}_t^w = \frac{\xi}{1-\gamma_w (1-\lambda)} \left(\hat{n}_t - \gamma_w (1-\lambda)\, \hat{n}_{t-1} \right) + \frac{\gamma_w (1-\lambda)}{1-\gamma_w (1-\lambda)} \left(\pi_t^w - \pi_{t-1}^w \right)$$

Combining this last equation with equation (34), I get the Phillips curve for intermediate good inflation:

$$\begin{aligned}\pi_t^w &= \frac{1}{1+\beta}\pi_{t-1}^w + \frac{\beta}{1+\beta}\pi_{t+1}^w \\ &+ \frac{1}{1+\beta}\frac{1-\gamma_w(1-\lambda)}{1-\beta\gamma_w(1-\lambda)}\frac{\gamma_w(1-\lambda)}{(1+\delta\theta_w)}\left(m\hat{r}s_t - \hat{P}_t^x\right) \\ &+ \frac{1}{(\theta_w-1)(1+\beta)}\hat{n}_{t-1} - \frac{1}{(\theta_w-1)(1+\beta)}\frac{1+\beta\gamma_w^2(1-\lambda)^2}{\gamma_w(1-\lambda)}\hat{n}_t + \frac{1}{(\theta_w-1)}\frac{\beta}{1+\beta}\hat{n}_{t+1}\end{aligned}$$

E Appendix

Following Nakata (2012) who summarizes the procedure of Kim et al. (2008), first find the second order approximation to the solution of the model using the techniques in Schmitt-Grohe and Uribe (2004) which leads to

$$\begin{aligned}y_t &= G_{ss} + G_x x_t + \frac{1}{2}G_{xx}[x_t \otimes x_t] \\ x_{t+1} &= H_{ss} + H_x x_t + \frac{1}{2}H_{xx}[x_t \otimes x_t] + Qe_{t+1}\end{aligned}$$

where x_t are the predetermined variables and y_t indicates the rest of the variables in the model. According to Kim et al. (2008), to find second-order accurate solutions one needs only first-order accurate solutions. The variable $y_t^{(i)}$ or $x_t^{(i)}$corresponds to the i^{th} accurate solution to the model and therefore,

$$\begin{pmatrix} y_t^{(2)} \\ y_t^{(1)} \otimes y_t^{(1)} \end{pmatrix} = \begin{pmatrix} G_x & \frac{1}{2}G_{xx} \\ 0 & G_x \otimes G_x \end{pmatrix} \begin{pmatrix} x_t^{(2)} \\ x_t^{(1)} \otimes x_t^{(1)} \end{pmatrix} + \varepsilon_{t+1}^y$$

$$\begin{pmatrix} x_{t+1}^{(2)} \\ x_{t+1}^{(1)} \otimes x_{t+1}^{(1)} \end{pmatrix} = \begin{pmatrix} H_x & \frac{1}{2}H_{xx} \\ 0 & H_x \otimes H_x \end{pmatrix} \begin{pmatrix} x_t^{(2)} \\ x_t^{(1)} \otimes x_t^{(1)} \end{pmatrix} + \varepsilon_{t+1}^x$$

where $E_0\varepsilon_{t+1}^y = \begin{bmatrix} G_{ss} & 0 \end{bmatrix}^T$, $E_0\varepsilon_{t+1}^x = \begin{bmatrix} H_{ss} & Q \otimes Qvec(I_{n_e}) \end{bmatrix}^T$ and I_{n_e} an identity matrix. Make the necessary transformation to the above system to get

$$\begin{aligned}Y_t &= A_y X_t + \varepsilon_{t+1}^y \\ X_{t+1} &= A_x X_t + \varepsilon_{t+1}^x\end{aligned} \tag{35}$$

Taking the second-order Taylor expansion to the utility function

$$\begin{aligned}
&E_0 \sum_{t=0}^{\infty} \beta^t u\left(y_t, x_{t,}\right) \\
&\simeq \frac{u\left(\bar{y}, \bar{x}\right)}{1-\beta} + E_0 \sum_{t=0}^{\infty} \beta^t \left[\nabla u_y\left(\bar{y}, \bar{x}\right) y_t^{(2)} + \frac{1}{2} \nabla u_{yy}\left(\bar{y}, \bar{x}\right) y_t^{(1)} \otimes y_t^{(1)}\right] \\
&+ E_0 \sum_{t=0}^{\infty} \beta^t \left[\nabla u_x\left(\bar{y}, \bar{x}\right) x_t^{(2)} + \frac{1}{2} \nabla u_{xx}\left(\bar{y}, \bar{x}\right) x_t^{(1)} \otimes x_t^{(1)}\right]
\end{aligned}$$

Apply equation (35) to the second-order welfare expansion to get the second-order accurate solution to the utility function without a need to simulate the model, which is expressed as follows:

$$\begin{aligned}
E_0 \sum_{t=0}^{\infty} \beta^t u\left(y_t, x_{t,}\right) \simeq \frac{u\left(\bar{y}, \bar{x}\right)}{1-\beta} + \begin{bmatrix} \nabla u_y\left(\bar{y}, \bar{x}\right) \\ \frac{1}{2} \nabla u_{yy}\left(\bar{y}, \bar{x}\right) \end{bmatrix}^T \left[A_y\left(I - \beta A_x\right)^{-1} \frac{\beta}{1-\beta} E_0 \varepsilon_{t+1}^x + \frac{\beta}{1-\beta} E_0 \varepsilon_{t+1}^y\right] \\
+ \begin{bmatrix} \nabla u_x\left(\bar{y}, \bar{x}\right) \\ \frac{1}{2} \nabla u_{xx}\left(\bar{y}, \bar{x}\right) \end{bmatrix}^T \left(I - \beta A_x\right)^{-1} \frac{\beta}{1-\beta} E_0 \varepsilon_{t+1}^x
\end{aligned}$$

Parameter	*Name/Explanation*	*Value*	*Source*
β	time discount factor	0.989	real rate 1% per quarter
σ	risk aversion coefficient	2	most commonly used value
δ	inverse of labor supply elast.	10	$\frac{1}{\delta} \in$ (0,0.5) Card (1994)
q^u	s.s unemployment probability	0.6	matches un. duration of 1.67
λ	separation rate	0.035	Implies 5.5% s.s. unemployment
b	unemployment benefit	0	match data with lowest un. benefit
q^v	steady state vacancy probability	0.7	den Haan et al (2000)
γ	final good price rigidity	0.5	Bils & Klenow (2004)
θ_w	elast of substitution int goods	101	as in Christiano et al. (2005)
θ	elasticity of subs final goods	11	corresponds to 1.1 markup

Table 1: A Summary of the baseline calibration. Nearly all those variables are estimated at a first stage but they have either been deemed as unimportant for dynamics or they have reached their upper or lower bound set by theory or empirical evidence.

Parameter	*Name/explanation*	*Norm on*		*Norm off*	
		Value	*st.dev.*	*Value*	*st.dev.*
χ	habit persistence	0.95	(0.001)	(0.95)	(0.001)
ξ	ROPE coefficient	1.81	(0.011)	–	–
ϕ	determines level of norm	2.09	(0.09)	–	–
α	elast. matching function	0.41	(0.001)	(0.2)	(0.008)
ζ	workers bargaining power	0.80	(0.005)	(0.76)	(0.005)
ψ	vac adjustment cost parameter	2.39	(0.15)	(1.96)	(0.14)
γ_w	intermediate good price rigidity	0.55	(0.021)	(0.56)	(0.020)
ρ_i	policy inertia	0.87	(0.002)	(0.89)	(0.003)
ρ_π	policy response to inflation	2.08	(0.11)	(3.1)	(0.14)

Table 2: Estimated parameters from the minimum distance procedure matching the model-implied impulse responses with the empirical. The numbers in parentheses indicate standard deviations. Estimates are provided for the benchmark model with the norm (Norm on in table) and the estimates of the model without the norm (Norm off).

Name/Explanation	*Symbol in model*	*No Norm*	*Model*	*Shimer*	*H&M*
Worker bargaining par.	ζ	0.81	0.81	0.72	0.05
Worker outside option	$\left[\frac{G(L_{jt})}{\mu_t} - \frac{G^u(U_{ht})}{\mu_t}\right]/\bar{Y}$	0.42	-0.31	0.41	0.95
Share of wage to gdp	$\bar{w}\bar{L}/\bar{Y}$	0.2	0.91	0.98	0.97
Outside option to wage	$\left[\frac{G(L_{jt})}{\mu_t} - \frac{G^u(U_{ht})}{\mu_t}\right]/\bar{w}\bar{L}$	0.02	-0.34	0.42	0.98
Surplus of worker	$\left(\bar{W}^E - \bar{W}^U\right)/\bar{Y}$	2.7	3.97	0.39	0.01
Value of firms	$\bar{F}^J/\bar{Y}$	1.03	0.96	0.15	0.26

Table 3: A comparison of different calibrations between the proposed model and those of other authors in the literature, e.g., Shimer and Hagedorn and Manovskii. All values include parameters and steady state values.

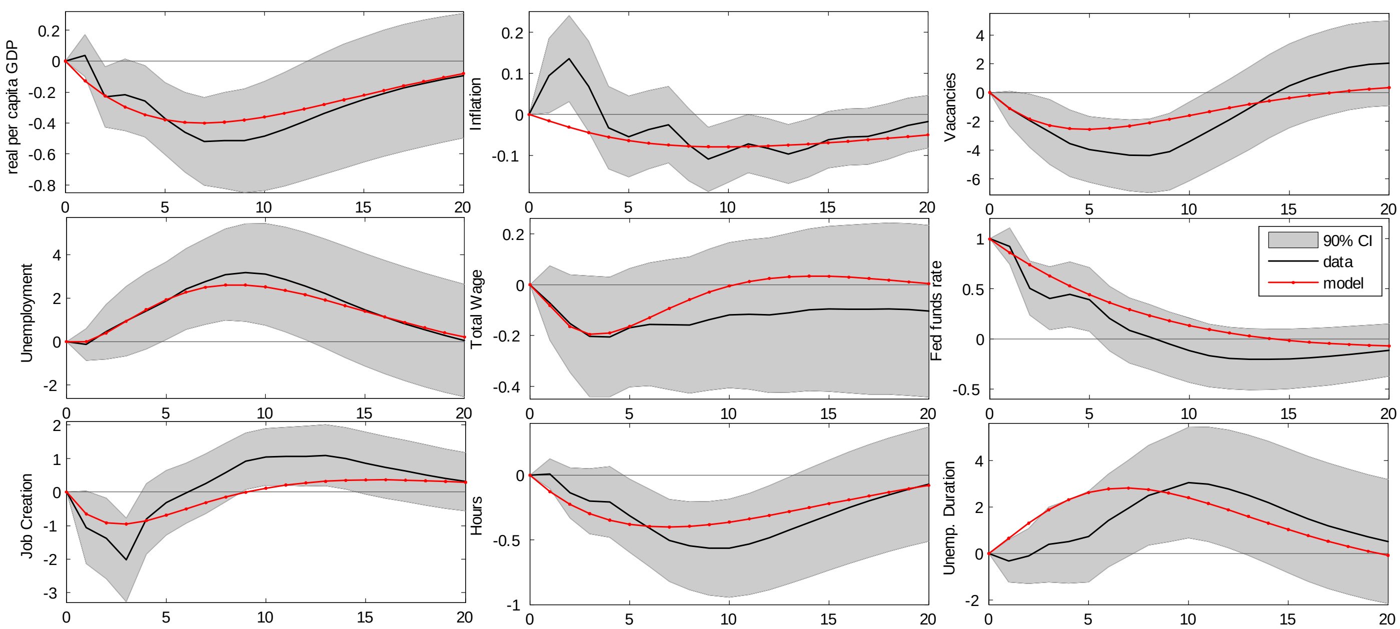

Figure 1: Solid lines indicate the empirical responses after a unit monetary shock (shock to the federal funds rate), while the red solid lines with bullet marks indicate the model-implied impulse responses. The gray areas are 90% confidence intervals.

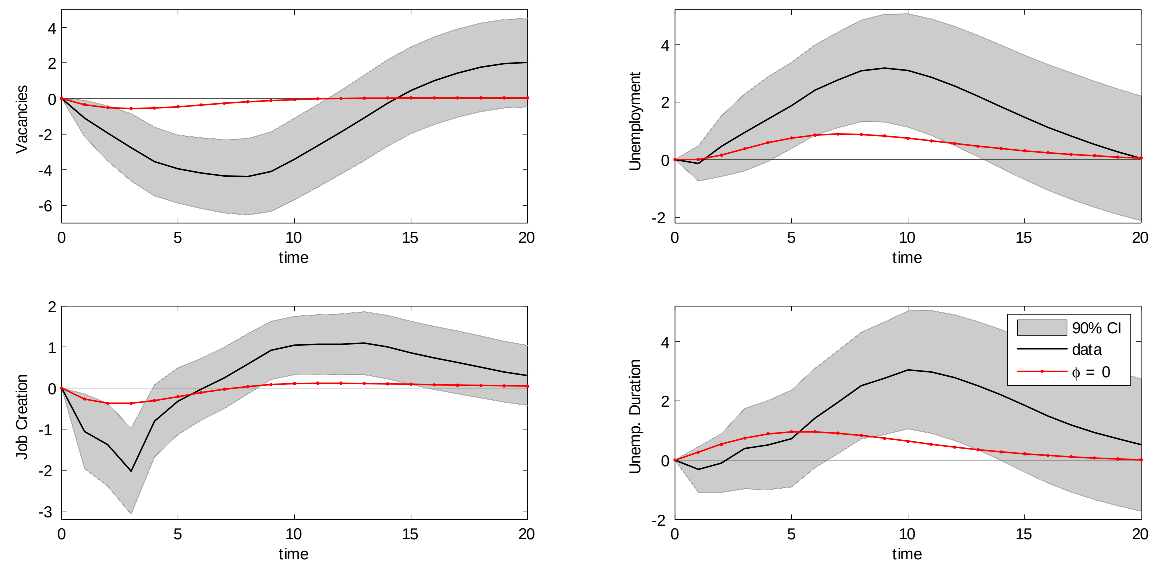

Figure 2: Optimal fit of the model without the social norm ($\phi = 1$). The red dotted lines are the model implied responses and the black are the responses from a VAR on US data. The shaded regions are 90% confidence intervals. The only focus is on the four variables because the performance of such a model for the rest of the variables is acceptable.

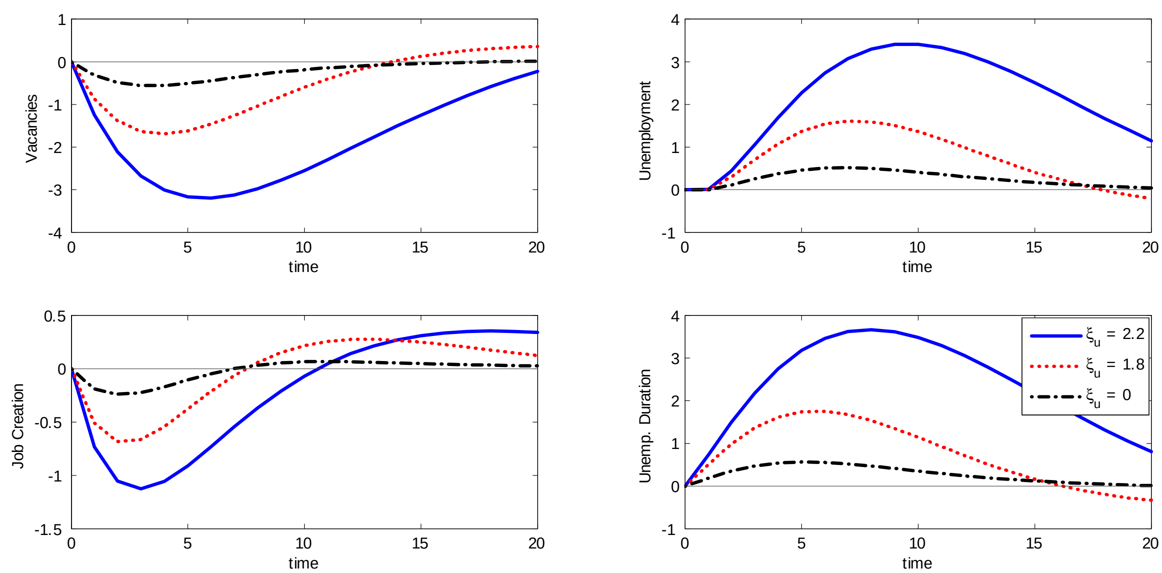

Figure 3: Impulse responses after a monetary shock for different values of the ROPE parameter ξ_u using the benchmark calibration for the rest of the parameters. Varying ξ_u can boost amplification significantly.

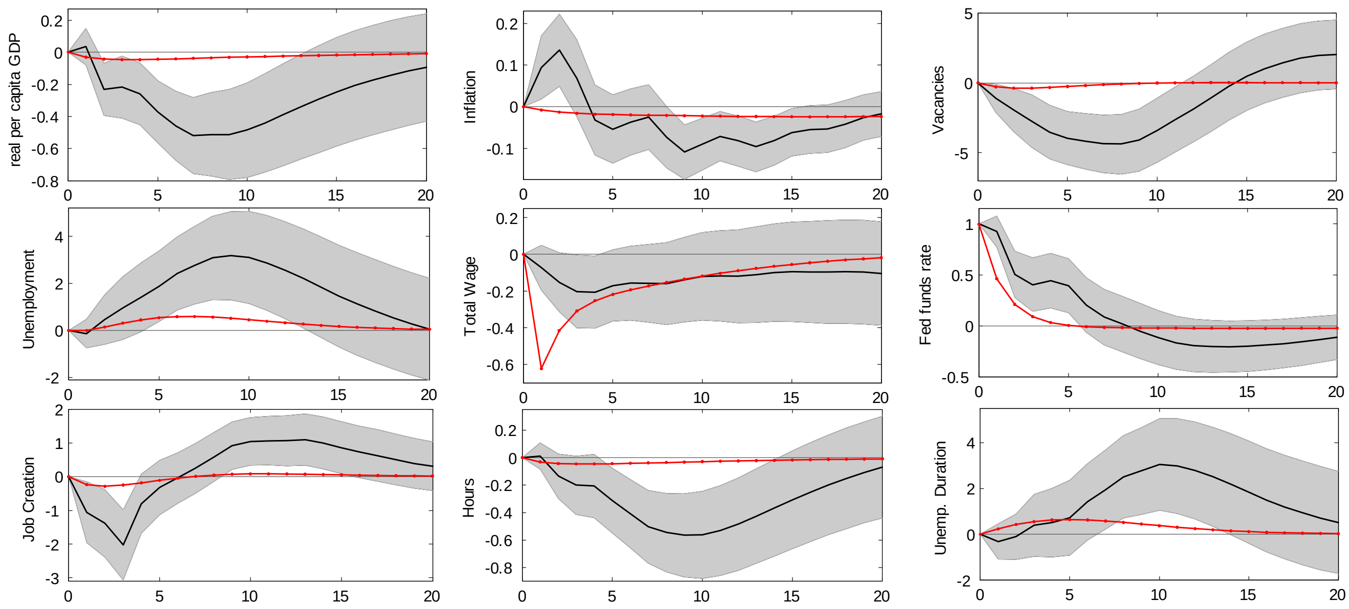

Figure 4: The Optimal fit of the model with flexible intermediate firms. Red lines with dots are model-implied impulse responses and the black solid lines are the responses from a VAR on US data. Shaded regions are 90% confidence intervals. The model is unable to match the responses in the data, without overshooting the wage.