Job Uncertainty and Deep Recessions

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Abstract

We study a heterogeneous agents model which combines matching frictions in the labor market with incomplete asset markets and nominal rigidities. Workers can experience job terminations that send them into short term unemployment or more serious job terminations that require a more difficult search process, a state we call for mis-match. We show an increase in job uncertainty decreases aggregate demand which lowers hiring and therefore produces even more job uncertainty and potentially a deep recession. The amplification mechanism is small when asset markets are complete, prices are flexible or unemployment is predominantly short term. Quantitatively, with a moderate and empirically plausible amount of mis-match, the model can account for the amplitude of the increase in unemployment during the Great Recession, for the increase in unemployment duration, and for much of the shift and movement along the Beveridge curve.

Keywords: Job uncertainty, recessions, incomplete markets, heterogeneous agents, nominal rigidities, unemployment, mis-match

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1 Introduction

The Great Recession and its aftermath have witnessed unprecedented increases in the level and the duration of unemployment in the United States. The unemployment rate in September 2012 remains above 8 percent having surpassed 10 percent in late 2009 and the number of unemployed workers who have been out of work for 6 months or more now accounts for more than 40 percent of total unemployment, see Figure 1.[1] Much attention has already been devoted to examining these developments,[2] but relatively little work has explored the idea that the labor market crisis itself may have been an important *source* of the recession. In this paper we show that shocks that impact on future job prospects can be amplified significantly when a vicious circle of feedback arises between the labor market to the goods market. We demonstrate that such an amplification mechanism can arise when unemployment risk has a large impact on household savings, when aggregate demand has a strong impact on firms' hiring decisions, and when at least some fraction of the unemployed face significantly depressed labor market outcomes. We argue that all of these circumstances are relevant for the Great Recession and thus that the labor market amplification mechanism is key for understanding the depth of the Great Recession.

We examine a model where a menu of frictions interact. First, households face idiosyncratic unemployment risk and asset markets are incomplete. Specifically, we assume that households have access only to a nominal state-non-contingent bond and must observe a borrowing limit. Actual asset markets may be more sophisticated than this but the key assumption is that households cannot fully insure against idiosyncratic risks originating in the labor market. Mar-

[1] Elsby, Hobijn and Şahin (2010) provide a very insightful discussion of the labor market developments during the Great Recession.

[2] See Daly et al (2011) for a discussion of the change in the natural rate of unemployment during the Great Recession; Farber (2012) and Sterk (2011) examine the impact of the housing crisis on unemployment; Farber and Valletta (2011) examine the role of unemployment benefit duration; Atif and Sufi (2011) claim that much of the drop in employment can be accounted for by an adverse aggregate demand shock caused by a deterioration of household balance sheets.

ket incompleteness induces an incentive for households to engage in precautionary savings as a means of self-insurance. Secondly, firms are monopolistically competitive but there are nominal rigidities in price setting which we model using a state-contingent pricing set-up first suggested in Rotemberg (1982). The presence of nominal rigidities imply that changes in aggregate demand are more likely to be reflected in labor demand than when prices are fully flexible. Third, in the tradition of Diamond-Mortensen-Pissarides we assume that the labor market is characterized by matching frictions which prevent unemployed workers and firms with vacancies from being instantaneously and costlessly paired. We extend the standard matching model by allowing for two unemployment states which differ in the search efficiency. In particular, apart from normal frictional "short-term" unemployment, we assume that there is another more longer term "mis-match" unemployment state[3] which induces significantly more risk on the households.[4]

We investigate the impact on the economy of a temporary increase in job separations[5] and ask whether it may be amplified producing a full scale deep recession. In our model, an important aspect of this deterioration in the labor market is that currently employed workers face idiosyncratic risk about the identity of the matches will be resolved. Employed workers react to this risk by increasing their precautionary savings target and unemployed workers, realizing the future job finding opportunities have worsened, may likewise increase their desired savings rate. This mechanism is stronger the larger share of the job separations that are associated with mis-match because these workers face longer unemployment spells and may receive lower benefits. Consequently, the increase in job separations induces a decline in aggregate demand. In response to lower demand for their products, firms have an incentive to cut prices which partially offsets the fall in demand but nominal rigidities reduce this incentive. At the same

[3] Farber (2012) also highlights the role of the increase of unemployment duration during the Great Recession.

[4] Ravn (2008) and Hornstein (2011) model heterogeneity in search efficiency in a similar fashion.

[5] Elsby, Hobijn and Şahin (2010) document that the inflow rate into unemployment did increase quite substantially during the early parts of the Great Recession. They also show that most of this is due to a spike in the layoff rate. Hall (2010) also stress the role of job losses in the early parts of the Great Recession.

time, mis-match curbs the incentive of firms to exploit the labor market conditions to post more vacancies. Fewer vacancies, in turn, increase the expected income loss associated with unemployment because the job finding rate declines. Therefore, a vicious circle may appear in which deteriorating job prospects may trigger lower demand which worsens the labor market outlook even further. Under these circumstances, job uncertainty can trigger a deep recession.

We carefully calibrate parameters pertaining to preferences and technology including the extent of nominal rigidities. We calibrate the shock to the aggregate job separation rate by matching the experience of the U.S. economy during the early parts of the Great Recession. In particular, we feed into the model processes for job separations and for the share of job separations that send workers to the mis-match state which match the US time series for permanent layoffs and the share of unemployed workers who have been out of work for 6 months or more. The resulting calibration of the size of the mis-match shock is consistent with the estimates of Garlevy (2011) and Şahin et al (2012) regarding the importance of mis-match unemployment during the Great Recession.[6] The model is shown to produce a large recession in response to these shocks and we find an increase in the unemployment rate and a decrease in vacancies that closely resemble their empirical counterparts. This also means that the model produces the movement along and shift in the Beveridge curve observed in the US during the Great Recession.

We conduct an extensive robustness analysis of our results using a simplified model in which we impose a no-borrowing constraint on the households. Although this model features no wealth inequality in equilibrium, we find that it produces results that are quite similar to the benchmark model. Using this model, we demonstrate that the amplification mechanism is

[6]Barlevy (2011) estimates the extent mis-match from the shift in the Beveridge curve post-August 2008. Daly et al (2012) instead use the instability of the Beveridge curve during the Great Recession to derive an estimate of the change in the natural rate of unemployment. Şahin et al (2012) posit a model composed of many distinct labor markets and use this to measure mis-match unemployment. In an application to US data, they use dispersion in unemployment across industries, occupations, education and geography to estimate the extent of mis-match.

neutralized when either prices are flexible or asset markets are complete. In the latter case, an increase in job separations have limited impact on aggregate demand which reduces the adverse impact of the worsening labor market conditions. When prices are flexible, firms have a strong incentive to cut prices when aggregate demand declines which moderates very significantly the recessionary impact of the increase in job separations. We find that the model produces very similar results for the unemployment dynamics when either prices are flexible or asset markets are incomplete. In both cases, the model fails to reproduce the changes observed in unemployment and in vacancies observed during the Great Recession. In other words, it is the interaction between precautionary savings motives and nominal rigidities that produces the amplification mechanism. We also find that mis-match is crucial. When unemployment duration is short, an increase in job separations has limited impact on aggregate demand because there is little incentive on the part of employed workers to engage in precautionary savings against unemployment that have the mean duration observed in post-WWII U.S. data. Moreover, in such a labor market firms have a strong incentive to post vacancies when unemployment rises which reduces the adverse impact of an adverse shock to job separations.

We also examine the robustness of the results to key assumptions made in our analysis. First, we investigate the importance of wage setting. The benchmark model assumes that the real wage is fixed, an assumption that is not obviously contradicted by the data in the last recession at least, see also Shimer (2012). We replace this assumption with a Nash bargaining model and find that the results are sensitive to the assumptions made regarding workers' outside option should the partners disagree during the bargaining process. If a failed bargaining processes may send workers into mis-match unemployment, nominal wages may fall sufficiently that the amplification mechanism does not arise. Assuming alternatively that a failed bargaining process sends workers into the high search efficiency state only, the results under Nash bargaining are extremely similar to the benchmark model that assumes constant real wages. Another assumption in the benchmark model is that firms are owned by risk neutral entrepreneurs. These entrepreneurs thus pick up any impact that comes through changes in firms' profits. We report results for an alternative economy in which firms are owned by households and find these to be practically identical to the benchmark model.

The paper is closely related to the seminar contribution of Den Haan, Ramey and Watson (2000). In their analysis, matches are endogenously terminated and they examine how productivity shocks are propagated due to matching frictions and household savings decisions. Our analysis is also related to a number of other recent papers that have examined aggregate fluctuations in incomplete markets settings. Gomes, Greenwood and Rebelo (2002) and Krusell et al (2009) both study models that introduce frictional labor markets in a general equilibrium incomplete markets model with idiosyncratic risk. The former authors compute the welfare costs of business cycles while the latter authors examine how labor market uncertainty influences inequality and how imperfect insurance affects unemployment and other labor market outcomes. Krusell, Mukoyama and Şahin (2011) and Challe and Ragot (2012) instead investigate the role of precautionary savings for aggregate fluctuations in an incomplete markets setting with unemployment risk.[7] The latter of these authors show that precautionary savings may be important for understanding business cycle fluctuations. Caggese and Perez (2011) combine the heterogeneous agents model with a heterogeneous firm model where firm heterogeneity arises due to financial frictions and idiosyncratic "profit shocks". Consistently with the empirical results of Mian and Sufi (2011), they find that financial shocks can have important impact on unemployment and aggregate activity. Guerrieri and Lorenzoni (2011) and McKay and Reis (2012) instead introduce nominal rigidities into an incomplete markets setting but do not model frictions in the labor market. Our analysis combines nominal rigidities, heterogeneous agents, and frictional labor markets and illustrates how the combination of these frictions produces new insights regarding the aggregate and distributional effects of shocks that originate in the labor market.

Also related to our analysis is a stream of recent papers that examine the impact of uncertainty shocks. In our model, asset market incompleteness implies that shocks to job termination

[7] The latter of these papers do not explicitly model labor market matching.

rates produce idiosyncratic uncertainty and we find that this is important for understanding the impact of labor market shocks on aggregate demand. Baker, Bloom and Davis (2012) suggest that policy uncertainty may have contributed significantly to the Great Recession. Closer to our analysis, Schalle (2012) investigates the impact of idiosyncratic productivity volatility shocks on unemployment in a directed search model with heterogeneous firms. He finds that the uncertainty effects induced by the volatility shocks can explain some of the rise in unemployment but not its persistence. Basu and Bundick (2012) analyze the effects of aggregate uncertainty shocks dynamic stochastic general equilibrium model with a representative consumer. Consistently with our analysis of the impact of idiosyncratic uncertainty, they find that nominal rigidities amplify the impact of uncertainty shocks. Basu and Bundick (2012) also demonstrate that a zero lower bound on the nominal interest rate may further amplify the impact of uncertainty shocks. Related to this, Rendahl (2012) shows how news shocks can generate severe recessions in a zero lower bound environment in a model with frictional labor markets. We will abstract from issues related to a lower bound on the nominal interest rate.

The remainder of the paper is organized as follows. Section 2 sets of the model economy. In Section 3 we study a version of the model in which there is no wealth inequality in equilibrium. Section 4 presents the results from the main model. Section 5 concludes and summarizes.

2 The Model Economy

The economy is inhabited by households, firms which are owned by entrepreneurs, and by a government which is in charge of monetary and fiscal policy. We introduce a number of frictions in goods, asset and labor market by combining three workhorse models in macroeconomics. First, the labor market is characterized by Diamond-Mortensen-Pissarides matching frictions which we extend by introducing differential matching prospects across unemployed workers. Secondly, as in Bewley (1977) and Aiyagari (1994), asset markets are incomplete. Specifically, following Krusell and Smith (1997), the model features idiosyncratic and aggregate risk in an incomplete markets set-up. Third, we assume that firms are monopolistically competitive and set prices in an environment with nominal rigidities in price setting. We adopt the set-up of Rotemberg (1982) where firms face quadratic costs of adjusting nominal prices. We examine the response of the economy to stochastic job separation shocks and shocks that affect the amount of labor market mis-match.

Households. There is a continuum of mass 1 of infinitely lived households indexed by $i \in (0, 1)$. Households have rational expectations and maximize the expected present value of their utility stream. A household is either working (matched with a firm) or unemployed and looking for a job. Unemployed workers differ in the efficiency of the matching technology that they face. This feature produces heterogeneity across unemployed workers in the expected duration of unemployment spells. Asset markets are assumed to be incomplete which produces an incentive for precautionary savings to insure against unemployment and other shocks. Differences in labor market histories and asset market incompleteness in combination produce wealth inequality across households.

Households consume a basket of consumption goods varieties:

$$\mathbf{c}_{i,t} = \left(\int_j \left(\mathbf{c}_{i,t}^j \right)^{1-1/\gamma} dj \right)^{1/(1-1/\gamma)} \tag{1}$$

where $\mathbf{c}_{i,t}^j$ denotes household i's consumption of goods of variety j and $\gamma > 1$ is the elasticity of substitution between consumption goods. Variety j is purchased at the nominal price $\mathbf{P}_{j,t}$. It follows that household i's demand for variety j is given as:

$$\mathbf{c}_{i,t}^j = \left(\frac{\mathbf{P}_{j,t}}{\mathbf{P}_t} \right)^{-\gamma} \mathbf{c}_{i,t} \tag{2}$$

where $\mathbf{P}_t$ is the price index associated with the consumption basket defined in (1):

$$\mathbf{P}_t = \left(\int_j \mathbf{P}_{j,t}^{1-\gamma} dj \right)^{1/(1-\gamma)} \tag{3}$$

A household that is employed in period t works full-time hours (normalized to one unit), receives a real wage $\mathbf{w}_t$, pays a lump-sum social security tax $\mathbf{T}_t^h$, and experiences a job termination with probability $\boldsymbol{\rho}_{x,t} \leq 1$. A fraction $\boldsymbol{\rho}_{r,t}$ of the workers that experience a job termination make a transition to unemployment state r, $r = s, l$, $\boldsymbol{\rho}_{s,t} + \boldsymbol{\rho}_{l,t} = 1$.

An unemployed household in state r receives (gross of taxes) unemployment benefits $\boldsymbol{\xi}_r \geq 0$ and finds a new job with probability $\boldsymbol{\eta}_{r,t}$. We assume that $\boldsymbol{\eta}_{l,t} < \boldsymbol{\eta}_{s,t}$ and will therefore, slightly imprecisely, refer to the two groups of unemployed workers as short- and long-term unemployed.[8] We will assume that $\boldsymbol{\xi}_s \geq \boldsymbol{\xi}_l$ so that the risk of a longer unemployment spell is not offset by higher benefits. An appealing interpretation of the two types of unemployed workers is that type l unemployed workers are mis-matched and face a more demanding job search process. We have in mind that mis-matched workers may need to move across professions, sectors or geographical areas to find a new job after a job termination.

Job terminations occur at the end of the period while new job matches are formed at the beginning of the period. Households are informed about the job loss probabilities at the beginning of the period and therefore have within-period perfect foresight about the share of currently employed workers who will lose their jobs and about the share of these that become short- and long-term unemployed. However, households face idiosyncratic uncertainty about both the identity of the workers who lose their jobs, about the unemployment state should they lose their job, and about future job separation rates.

Households have access to a state non-contingent bond which carries a (gross) nominal interest rate of $\mathbf{R}_t$. We impose a borrowing constraint by assuming that there is a utility cost of holding debt.[9] Let $\mathbf{b}^h_{i,t}$ denote household i's holding of bonds at the end of period t. We assume that there is a utility cost function, φ, and a debt limit $\overline{\mathbf{b}} \leq 0$ so that

$$\varphi\left(\mathbf{b}^h_{i,t}\right) = \begin{cases} 0 & \text{for } \mathbf{b}^h_{i,t} \geq \overline{\mathbf{b}} \\ \infty & \text{for } \mathbf{b}^h_{i,t} < \overline{\mathbf{b}} \end{cases} \tag{4}$$

This implies that no household chooses $\mathbf{b}^h_{i,t} < \overline{\mathbf{b}}$.

[8] In expectations, a type s unemployed worker will face shorter unemployment duration of an unemployment spell than type l individual. Ex-post, however, some "short-term" unemployed workers may face long unemployment spells and some "long-term" unemployed workers will find jobs fast.

[9] This assumption is computationally appealing.

Households face a sequence of budget constraints:

$$\mathbf{c}_{i,t} + \mathbf{b}_{i,t}^{h} = \mathbf{n}_{i,t}\mathbf{w}_t - \mathbf{T}_t^{h} + (1 - \mathbf{n}_{i,t})\,\mathbf{I}_{r,t}\boldsymbol{\xi}_r + \frac{\mathbf{R}_{t-1}}{1+\boldsymbol{\pi}_t}\mathbf{b}_{i,t-1}^{h},\ t \geq 0 \tag{5}$$

where $\mathbf{b}_{i,-1}^{h} > \overline{\mathbf{b}}$ is given and $\boldsymbol{\pi}_t$ denotes the net inflation rate in period t, $(1+\boldsymbol{\pi}_t) = \mathbf{P}_t/\mathbf{P}_{t-1}$. $\mathbf{n}_{i,t}$ indicates the employment status of household i at date t while $\mathbf{I}_{r,t}$ indicates the unemployment state status:

$$\mathbf{n}_{i,t} = \begin{cases} 0 & \text{if individual } i \text{ is unemployed in period t} \\ 1 & \text{if individual } i \text{ is employed in period t} \end{cases}$$

$$\mathbf{I}_{i,t} = \begin{cases} 1 & \text{if individual } i \text{ is unemployed in state } r \text{ in period t} \\ 0 & \text{otherwise} \end{cases}$$

Employed households solve the dynamic programming problem:

$$\begin{aligned} \mathbf{V}_i^{e}\left(\mathbf{b}_{i,t-1}^{h}, \mathbf{S}_t\right) &= \max_{\mathbf{c}_{i,t},\mathbf{b}_{i,t}} \{u\left(\mathbf{c}_{i,t}\right) - \varphi\left(\mathbf{b}_{i,t}^{h}\right) \\ &\quad + \boldsymbol{\beta}\mathbb{E}_t\left(1 - \sum_{r=s,l}\boldsymbol{\rho}_{x,t}\boldsymbol{\rho}_{r,t}\left(1 - \boldsymbol{\eta}_{r,t+1}\right)\right)\mathbf{V}_i^{e}\left(\mathbf{b}_{i,t}^{h}, \mathbf{S}_{t+1}\right) \\ &\quad + \boldsymbol{\beta}\sum_{r=s,l}\boldsymbol{\rho}_{x,t}\boldsymbol{\rho}_{r,t}\mathbb{E}_t\left(1 - \boldsymbol{\eta}_{r,t+1}\right)\mathbf{V}_i^{u,r}\left(\mathbf{b}_{i,t}^{h}, \mathbf{S}_{t+1}\right)\} \end{aligned} \tag{6}$$

subject to the budget constraint in equation (5) setting $\mathbf{n}_{i,t} = 1$. $u\left(\mathbf{c}_{i,t}\right)$ is a concave utility function. $\mathbf{V}_i^{e}\left(\mathbf{b}_{i,t-1}, \mathbf{S}_t\right)$ is the value for a household that is employed at the beginning of the period given her assets, $\mathbf{b}_{i,t-1}$, and given an aggregate state vector $\mathbf{S}_t$ which is specified below. $\mathbf{V}_i^{u,r}\left(\mathbf{b}_{i,t-1}, \mathbf{S}_t\right)$ is the value for an unemployed household who is faced with state $r = s, l$ unemployment. $\boldsymbol{\beta} \in (0,1)$ is the subjective discount factor, and $\mathbb{E}_t$ is the conditional expectations operator. $\boldsymbol{\rho}_{x,t}\boldsymbol{\rho}_{r,t}$ is the probability that a worker who is employed at the beginning of the period makes a transition to unemployment state r and $\sum_{r=s,l}\boldsymbol{\rho}_{x,t}\boldsymbol{\rho}_{r,t}\left(1 - \boldsymbol{\eta}_{r,t+1}\right)$ is the probability of not being employed at the beginning of period $t+1$.

A type r unemployed worker faces the problem:

$$\begin{aligned} \mathbf{V}_i^{u,r}\left(\mathbf{b}_{i,t-1}^{h}, \mathbf{S}_t\right) &= \max_{\mathbf{c}_{i,t},\mathbf{b}_{i,t}} \{u\left(\mathbf{c}_{i,t}\right) - \varphi\left(\mathbf{b}_{i,t}^{h}\right) + \boldsymbol{\kappa} + \boldsymbol{\beta}\mathbb{E}\boldsymbol{\eta}_{r,t+1}\mathbf{V}_i^{e}\left(\mathbf{b}_{i,t}, \mathbf{S}_{t+1}\right) \\ &\quad + \boldsymbol{\beta}\mathbb{E}_t\left(1 - \boldsymbol{\eta}_{r,t+1}\right)\mathbf{V}_i^{u,r}\left(\mathbf{b}_{i,t}, \mathbf{S}_{t+1}\right)\},\ h = s, l \end{aligned} \tag{7}$$

subject to the budget constraint in equation (5) setting $\mathbf{n}_{i,t} = 0$ and $\mathbf{I}_{r,t} = 1$. $\boldsymbol{\kappa} > 0$ denotes the utility of leisure enjoyed by an unemployed household (having normalized the utility of leisure of employed households to zero). As a matter of consistency, we will make the assumption that $\mathbf{V}_i^e\left(\mathbf{b}^h, \mathbf{S}\right) > \mathbf{V}_i^{u,s}\left(\mathbf{b}^h, \mathbf{S}\right)$ for all $\mathbf{b}^h$ and $\mathbf{S}$ so that no employed household has an incentive to voluntarily leave their current job. Under the condition that $\boldsymbol{\eta}_{s,t+1} > \boldsymbol{\eta}_{l,t+1}$ the condition that $\mathbf{V}_i^e\left(\mathbf{b}^h, \mathbf{S}\right) > \mathbf{V}_i^{u,s}\left(\mathbf{b}^h, \mathbf{S}\right)$ for all $\mathbf{b}^h$ and $\mathbf{S}$ automatically implies that $\mathbf{V}_i^e\left(\mathbf{b}^h, \mathbf{S}\right) > \mathbf{V}_i^{u,l}\left(\mathbf{b}^h, \mathbf{S}\right)$ for all $\mathbf{b}$ and $\mathbf{S}$.[10]

Entrepreneurs. Consumption goods are produced by a continuum of monopolistically competitive firms indexed by $j \in (0, 1)$ which are owned by risk neutral entrepreneurs. We let $\Psi < 1$ denote the measure of entrepreneurs. Entrepreneurs discount utility at the rate β and make decisions on the pricing of their good, on vacancy postings, and on their consumption and savings policies. In return for managing (and owning) the firm, they are the sole claimants to its profits (but will also have to stand ready to cover losses). We assume that entrepreneurs can save but face a no-borrowing constraint. This no-borrowing constraint implies that the entrepreneur finances hiring costs through retained earnings.[11]

Output is produced by according to a linear technology:

$$\mathbf{y}_{j,t} = \mathbf{A}\mathbf{n}_{j,t} \tag{8}$$

where $\mathbf{A} > \mathbf{0}$ and $\mathbf{n}_{j,t}$ denotes entrepreneur j's input of labor which is purchased from the households. Firms are assumed to be sufficiently large (i.e. the mass of entrepreneurs is small relative to the mass of households) that there are no indivisibility problems associated with the full-time hours assumption made earlier.

[10] The formulation of the unemployed workers problems in equations (7) assumes that there are no flows between the two unemployment states during unemployment. However, all workers face identical job prospects upon employment. The first of these assumptions is easily relaxed and immaterial for the results as long as the flow out of unemployment is sufficiently small for type l workers relative to type s workers.

[11] In the equilibrium, $\beta < 1/R$ so entrepreneurs will be borrowing constrained.

Following Rotemberg (1982) we assume that there are nominal rigidities in the form of quadratic costs of price adjustment which, together with frictional labor markets, implies that firms face a dynamic optimization problem. Given risk neutrality, entrepreneurs set prices to maximize the present discounted value of profits:

$$\mathbb{E}_t \sum_{s=0}^{\infty} \boldsymbol{\beta}^s \left(\left(\frac{\mathbf{P}_{j,t+s}}{\mathbf{P}_{t+s}} - \mathbf{mc}_{j,t+s} \right) \mathbf{y}_{j,t+s} - \frac{\phi}{2} \left(\frac{\mathbf{P}_{j,t+s} - \mathbf{P}_{j,t+s-1}}{\mathbf{P}_{j,t+s-1}} \right)^2 \mathbf{y}_{t+s} \right) \tag{9}$$

subject to:

$$\mathbf{y}_{jt} = \left(\frac{\mathbf{P}_{jt}}{\mathbf{P}_t} \right)^{-\gamma} \mathbf{y}_t \tag{10}$$

Equation (10) is the demand for goods variety j. $\mathbf{y}_t$, which is defined formally below, can be interpreted as aggregate real income. In equation (9) $\phi \geq 0$ indicates the size of costs of changing prices with $\phi = 0$ corresponding to flexible prices. $\mathbf{mc}_{j,t}$ denotes real marginal costs. The first-order condition for this problem is given as:

$$\begin{aligned} \left((1-\gamma) + \gamma \mathbf{mc}_{j,t} \frac{\mathbf{P}_t}{\mathbf{P}_{j,t}} \right) \mathbf{y}_{j,t} &= \phi \frac{\mathbf{P}_t}{\mathbf{P}_{j,t-1}} \left(\frac{\mathbf{P}_{j,t} - \mathbf{P}_{j,t-1}}{\mathbf{P}_{j,t-1}} \right) \mathbf{y}_t \\ &\quad + \phi \boldsymbol{\beta} \mathbb{E}_t \left[\left(\frac{\mathbf{P}_{j,t+1}}{\mathbf{P}_{j,t}^2} \right) \left(\frac{\mathbf{P}_{j,t+1} - \mathbf{P}_{j,t}}{\mathbf{P}_{j,t}} \right) \mathbf{P}_t \mathbf{y}_{t+1} \right] \end{aligned} \tag{11}$$

In a symmetric equilibrium, which will be the focus of our analysis, this simplifies to:

$$(1-\gamma) + \gamma \mathbf{mc}_t = \phi \boldsymbol{\pi}_t (1 + \boldsymbol{\pi}_t) - \phi \boldsymbol{\beta} \mathbb{E}_t \left[\boldsymbol{\pi}_{t+1} (1 + \boldsymbol{\pi}_{t+1}) \frac{\mathbf{y}_{t+1}}{\mathbf{y}_t} \right] \tag{12}$$

Firms hire labor in a frictional labor market. The law of motion for employment in firm j is given as:

$$\mathbf{n}_{j,t} = \left(1 - \boldsymbol{\rho}_{x,t}\right) \mathbf{n}_{j,t-1} + \mathbf{h}_{j,t}$$

where $\mathbf{h}_{j,t}$ denotes hires made by firm j in period t. The number of hires in turn is given as:

$$\mathbf{h}_{j,t} = \boldsymbol{\rho}_{f,t} \mathbf{v}_{j,t} \tag{13}$$

where $\mathbf{v}_{j,t}$ is the number of vacancies posted by the firm and $\boldsymbol{\rho}_{f,t}$ is the job filling probability. We assume that firms are sufficiently large that $\boldsymbol{\rho}_{f,t}$ can be interpreted as the fraction of vacancies that lead to a match.[12] The cost of posting a vacancy is given by $\boldsymbol{\mu} > 0$. Therefore, real marginal costs are given as:

$$\mathbf{mc}_{j,t} = \frac{\mathbf{w}_t}{\mathbf{A}} + \frac{\boldsymbol{\mu}}{\boldsymbol{\rho}_{f,t}} - \boldsymbol{\beta}\mathbb{E}_t\left[\left(1 - \boldsymbol{\rho}_{x,t+1}\right)\frac{\boldsymbol{\mu}}{\boldsymbol{\rho}_{f,t+1}}\right] \tag{14}$$

which incorporates the fact that hiring in period t impacts on future marginal costs through future hiring cost savings.

Finally, the budget constraint of entrepreneurs can be expressed as:

$$\mathbf{d}_{j,t} + \mathbf{b}^e_{j,t} + \mathbf{w}_t\mathbf{n}_{j,t} + \boldsymbol{\mu}\frac{\mathbf{h}_{j,t}}{\boldsymbol{\rho}_{f,t}} = \frac{\mathbf{P}_{j,t}}{\mathbf{P}_t}\mathbf{A}\mathbf{n}_{jt} - \mathbf{T}^e_t + \frac{\mathbf{R}_{t-1}}{1+\boldsymbol{\pi}_t}\mathbf{b}^e_{j,t-1} \tag{15}$$

$$\mathbf{b}^e_{j,t} \geq 0 \tag{16}$$

where $\mathbf{b}^e_{j,-1} \geq 0$ is given, $\mathbf{d}_{j,t}$ denotes entrepreneur j's consumption in period t and $\mathbf{b}^e_{j,t}$ their bond purchases in period t. Condition (16) imposes the no-borrowing constraint on entrepreneurs. $\mathbf{T}^e_t$ are employer contributions to social security.

Labor Market. We assume that the matching technology is given as:

$$\mathbf{m}_t = \psi\left(\mathbf{u}_{s,t} + \mathbf{q}\mathbf{u}_{l,t}\right)^{\alpha}\left(\mathbf{v}_t\right)^{1-\alpha} \tag{17}$$

where $\mathbf{m}_t$ denotes the measure of matches between firms (vacancies) and unemployed workers at date t, $\mathbf{u}_{r,t}$ is the measure of type r unemployed workers at date t and $\mathbf{v}_t$ is the measure of vacancies posted by the firms. $\psi > 0$, and $\alpha \in (0,1)$ are constant parameters. The parameter $\mathbf{q} \in (0,1]$ is the probability that a type l unemployed worker is searching for a job at date t. When $\mathbf{q} < 1$, type l workers are less likely to find a job than type s unemployed workers and face longer expected unemployment duration. We will think of this parameter as indicating the impact of mis-match unemployment on labor market prospects.

Given the matching technology, the job filling probability and the job finding probabilities

[12] This assumption can be relaxed which would produce ex-post heterogeneity across firms.

are given as:

$$\boldsymbol{\rho}_{f,t} = \psi\left(1-(1-\mathbf{q})\,\mathbf{u}_{l,t}/\mathbf{u}_t\right)^{\alpha}\boldsymbol{\theta}_t^{-\alpha} \tag{18}$$

$$\boldsymbol{\eta}_{s,t} = \psi\left(1-(1-q)\,\mathbf{u}_{l,t}/\mathbf{u}_t\right)^{\alpha-1}\boldsymbol{\theta}_t^{1-\alpha} \tag{19}$$

$$\boldsymbol{\eta}_{l,t} = \mathbf{q}\boldsymbol{\eta}_{s,t} \tag{20}$$

where $\boldsymbol{\theta}_t = \mathbf{v}_t/\mathbf{u}_t$ denotes labor market tightness, $\mathbf{u}_t$ is the measure of unemployed workers. Importantly, as long as $\mathbf{q} < 1$, the job filling rate depends negatively on the share of long term unemployed because these workers match less efficiently with vacancies than short term unemployed workers.[13] This externality means that it is costlier to fill jobs in periods with high long term unemployment which makes firm less likely to post vacancies.

The laws of motion of the stocks of employed and unemployed workers are given as:

$$\mathbf{n}_t = \left(1-\boldsymbol{\rho}_{x,t}\right)\mathbf{n}_{t-1} + \mathbf{m}_t \tag{21}$$

$$\mathbf{u}_{r,t} = \left(1-\boldsymbol{\eta}_{r,t}\right)\left(\mathbf{u}_{r,t-1} + \boldsymbol{\rho}_{r,t}\boldsymbol{\rho}_{x,t}\mathbf{n}_{t-1}\right) \tag{22}$$

Our candidates for stochastic shocks to the economy are exogenous changes in the job separation rate, $\boldsymbol{\rho}_{x,t}$, and in $\boldsymbol{\rho}_{s,t}$, which determines the share of workers affected job terminations that become short-term unemployed. We assume that:

$$\begin{aligned}
\boldsymbol{\rho}_{x,t} &= \overline{\boldsymbol{\rho}_x}\exp\left(\mathbf{z}_{x,t}\right) \\
\boldsymbol{\rho}_{s,t} &= \overline{\boldsymbol{\rho}_s}\exp\left(\mathbf{z}_{s,t}\right) \\
\mathbf{z}_{x,t} &= \boldsymbol{\lambda}_x\mathbf{z}_{x,t-1} + \boldsymbol{\varepsilon}_{x,t} \\
\mathbf{z}_{s,t} &= \boldsymbol{\lambda}_s\mathbf{z}_{s,t-1} + \boldsymbol{\varepsilon}_{s,t}
\end{aligned}$$

where $\overline{\boldsymbol{\rho}_x}, \overline{\boldsymbol{\rho}_s} \in (0,1)$ are the long-run levels of job termination and the share of short-term unemployed, respectively, while $\boldsymbol{\lambda}_x, \boldsymbol{\lambda}_s \in (-1,1)$ denote the persistence of shocks to the job termination rate and to the share of short-term unemployed. It is assumed that $\boldsymbol{\varepsilon}_t \sim N\left(0, \mathbf{V}_{\boldsymbol{\varepsilon}}\right)$ where $\boldsymbol{\varepsilon}_t = \left(\boldsymbol{\varepsilon}_{x,t}, \boldsymbol{\varepsilon}_{s,t}\right)'$.

[13] When $q = 1$, $1-(1-q)\,u_{l,t}/u_t = 1$ so this term drops out.

We experiment with alternative assumptions regarding wage setting. All schemes that we consider are required to be consistent with a non-negative surplus of any worker-firm matches so that none of the partners have an incentive to terminate an existing match voluntarily. In our benchmark model, we assume that real wages are constant, $\mathbf{w}_t = \overline{\mathbf{w}}$.[14] We examine whether the results are robust to assuming that wages are instead determined according to a Nash bargaining model. In the face of wealth heterogeneity, Nash bargaining introduces worker-specific wages which complicates the analysis very significantly.

Government. The government is in charge of monetary and fiscal policies. We assume that the government balances the budget period by period which means that:

$$\mathbf{u}_{s,t}\boldsymbol{\xi}_s + \mathbf{u}_{l,t}\boldsymbol{\xi}_l = \mathbf{T}_t^h + \Psi\mathbf{T}_t^e \tag{23}$$

which reflects the lump-sum nature of the social security taxes.

Monetary policy is specified by a rule for the short-term nominal interest rate. We assume that:

$$\mathbf{R}_t = \overline{\mathbf{R}}\left(\frac{1+\boldsymbol{\pi}_t}{1+\overline{\boldsymbol{\pi}}}\right)^{\delta} \tag{24}$$

where $\overline{\mathbf{R}}$ is the long-run nominal interest rate target, $\overline{\boldsymbol{\pi}}$ is the inflation target, and δ denotes the elasticity of the nominal interest rate to deviations of inflation from its target.

Equilibrium. We focus upon a recursive equilibrium in which households act competitively taking all prices for given while firms act as monopolistic competitors setting the price of their own variety taking all other prices for given. In equilibrium, firms are symmetric because there are no idiosyncratic productivity shocks, prices are set in a state-contingent manner, and because they assumed to be sufficiently large that they all hire the same number of workers.[15] We let $\mathbf{p}_{j,t} = \mathbf{P}_{j,t}/\mathbf{P}_t$ denote the relative price of firm j's product. Symmetry implies that this relative price equals 1 in equilibrium.

[14] We have checked that the match surplus is positive for all matches in all the results that we report.

[15] Firms are also assumed to be sufficiently big that there the full time hours assumption does not give rise to any indivisibility problems.

Households are instead heterogeneous and differ in their labor market status and in their wealth. In equilibrium, aggregate savings equal zero but, since wealth matters for savings choices, the wealth distribution is an aggregate state variable which impacts both on household and on entrepreneurial choices. We let $\mathbf{\Omega}_t = \Omega(\mathbf{b}_{t-1}, \mathbf{e}_t)$ denote the distribution of agents over asset levels and employment states, $\mathbf{b}_t = (\mathbf{b}_t^h, \mathbf{b}_t^e)$, $\mathbf{b}_t^h = (\mathbf{b}_{i,t}^h)_{i=0}^1$, $\mathbf{b}_t^e = \sum_j \mathbf{b}_{j,t}^e$ and $\mathbf{e}_t = (\mathbf{e}_{it})_{i=0}^1$ where e_{it} indicates the labor market status of household i (whether employed or unemployed in state $r = s, l$).[16] We let $\mathbf{d\Omega}_t$ denote the associated density of the joint distribution of assets and labor market status. The relevant state vector is then defined as $\mathbf{S}_t = (\mathbf{\Omega}_t, \boldsymbol{\rho}_{x,t}, \boldsymbol{\rho}_{s,t})$.

Definition 1 *A recursive monopolistic competition equilibrium is defined as a distribution of wealth* $\Omega(\mathbf{b}, \mathbf{e})$*, pricing kernels* $(\mathbf{w}(\mathbf{S}), \boldsymbol{\pi}(\mathbf{S}))$*, decision rules* $\left(\mathbf{c}_i^h(\mathbf{b}_i^h, \mathbf{S}_t), \mathbf{b}_i^{h\prime}(\mathbf{b}_i^h, \mathbf{S})\right)_{i=0}^1$ *and* $\left(\mathbf{p}_j(\mathbf{b}^e, \mathbf{S})_{j=0}^J, \mathbf{n}(\mathbf{b}^e, \mathbf{S}), \mathbf{h}(\mathbf{b}^e, \mathbf{S})\right)$*, value functions* $\left(\mathbf{V}_i^e(\mathbf{b}_i^h, \mathbf{S}), \mathbf{V}_i^{u,s}(\mathbf{b}_i^h, \mathbf{S}), \mathbf{V}_i^{u,l}(\mathbf{b}_i^h, \mathbf{S})\right)_{i=1}^1$ *and* $\mathbf{W}(\mathbf{b}^e)$*, and government policies* $(\mathbf{T}(\mathbf{S}), \mathbf{R}(\mathbf{S}))$ *such that*

(i) given the pricing kernel, the government policies, and the aggregate and individual states, the household decision rules solve the households problem;

(ii) given the pricing kernel, government policies, and the aggregate state, the entrepreneur decision rules solve the entrepreneurs' problem and $\mathbf{p}_j(\mathbf{b}^e, \mathbf{S})_{j=0}^J = 1$ *for all* j *and all* $(\mathbf{b}^e, \mathbf{S})$*;*

(iii) asset and goods market clear:

$$\begin{aligned} \int \mathbf{b}_i^{h\prime}(\mathbf{b}_i^h, \mathbf{S})\, d\mathbf{\Omega} + \Psi \mathbf{b}^e &= 0 \\ \int \mathbf{c}_i^h(\mathbf{b}_i^h, \mathbf{S})\, d\mathbf{\Omega} + \Psi \mathbf{c}^e &= \mathbf{y} \end{aligned}$$

(iv) the government budget constraint is satisfied and the nominal interest is given by the policy rule in equation (24)

Solution Method.

[16] The definition of $\mathbf{b}_t^e$ reflects the fact that entrepreneurs are symmetric in equilibrium.

3 Quantitative Results: No Wealth Inequality

Before turning to the general version of the model, we find it instructive to examine a special case where we impose that $\overline{\mathbf{b}} = 0$. The no-borrowing constraint implies that all households hold zero wealth in equilibrium so that the wealth distribution no longer is an aggregate state variable. We can therefore compute the equilibrium in a simple manner using a standard pertubation method. The relative simplicity of the numerical procedure also means that this version of the model lends itself to a rigorous robustness analysis. Although this model features no equilibrium wealth inequality, its key mechanisms are much the same as in the general version that allows for borrowing apart from the fact that there are no differential impact on agents according to their wealth.

3.1 Calibration

The calibration targets and parameter values are summarized in Tables 1 and 2. One model period corresponds to a calendar month. The household utility function is assumed to be given as:

$$u\left(\mathbf{c}_{it}\right) = \frac{\mathbf{c}_{it}^{1-\sigma} - 1}{1-\sigma},\ \sigma \geq 0$$

and we set $\sigma = 1.5$. This value is in the mid-range of empirical estimates of Attanasio and Weber (1995), Eichenbaum, Hansen, and Singleton (1988), and many others who have examined either household data or aggregate time series. σ determines the degree of risk aversion which matters for the household savings response to uncertainty and this is important in our model.

We assume an annual real interest rate of 3 percent and set the subjective discount factor equal to 0.99 for both households and entrepreneurs. This value is low relative to standard representative agent models but because of idiosyncratic risk and incomplete markets, agents have a strong incentive to engage in precautionary savings and a low real interest rate is required to induce zero savings in equilibrium.

We target an unemployment rate of 5 percent and a 15 percent share of long term unemployed (unemployed workers who have been out of work for 6 months or more) in the stationary equilibrium. These targets are close to the mean statistics for the United States in the post-1970 period. Following Rothstein (2011), we target a monthly hazard rate from unemployment to employment for a newly unemployed workers of 40 percent and a 30 percent monthly hazard rate for workers who have been unemployed for 26 weeks or more. These targets imply a steady-state job loss probability, $\overline{\boldsymbol{\rho}_x}$, of 2.95 percent per month, that $\overline{\boldsymbol{\rho}_s}$, the share of workers who experience a job loss that enter the pool of high search efficiency unemployment, equals 35 percent, and that the relative search efficiency of the mis-matched unemployed, $\mathbf{q}$, is 50.2 percent. We assume that the matching function elasticity to unemployment is equal to 50 percent ($\alpha = 0.5$), and normalize $\psi = 1$. $\boldsymbol{\mu}$, the vacancy cost parameter, is calibrated by targeting an average hiring cost of 4.5 percent of the quarterly wage bill. Given other parameters, this implies that $\boldsymbol{\mu} = 0.18$.

We calibrate the benefit levels, $\boldsymbol{\xi}_s$ and $\boldsymbol{\xi}_l$, by targeting estimates of the consumption loss during unemployment reported by Browning and Crossley (2001). Studying Canadian data, these authors find that consumption drops on average 14 percent upon a permanent job loss. They also document a lot of dispersion across workers with 25 percent suffering no loss while the worst hit 10 percent experience a consumption loss of 50 percent. In the the model, the borrowing limit implies that all households hold zero savings in equilibrium and therefore that consumption equals flow (after tax) income. Thus, in the stationary equilibrium, 35 percent (65 percent) of the population would suffer a consumption loss that would correspond to the difference between the real wage and $\boldsymbol{\xi}_s$ ($\boldsymbol{\xi}_l$). In order to moderate slightly the impact of the no-borrowing constraint, we assume that $\boldsymbol{\xi}_s = 0.925w$ and that $\boldsymbol{\xi}_l = 0.84w$ (where w is the real wage) which imply an average consumption loss upon unemployment of just below 14 percent as estimated by Browning and Crossley (2001) but has less variance across the unemployed agents.

We set the average mark-up is 20 percent which implies that γ, the elasticity of substitution between goods, is equal to 6. ϕ, the parameter that determines the importance of price adjustment costs, is calibrated to match price adjustment frequency of 5 months. This value is conservative but close to the value estimated by Bils and Klenow (2004).[17] This implies that $\phi = 142.86$. We assume that the government's inflation target $\overline{\pi} = 1$ so that it pursues price stability and we set $\delta = 1.5$, a conventional value in the new Keynesian literature.

Finally, we estimate the parameters of the stochastic processes that determine the persistence and volatility of the job separation rate and of the share of high search efficiency unemployed workers from time-series data for layoffs and the share of workers who have been unemployed for 6 months or more. We find estimates of $\lambda_x = 0.9774$ and $\lambda_s = 0.7926$. this implies a half-life of job separation shocks of 30 months while shocks to the share of regular vs. mis-matched unemployment die out very fast.

3.2 Results

The Impact of Shocks .Figures 2 and 3 illustrate the impact of a one standard error increase in job separations and in the share of mis-matched unemployed, respectively. We report the impact on the unemployment rate, on the share of unemployed workers who have been out of work for 6 months or more, on average unemployment duration, on the job finding rate, on vacancies, and, finally, on the real interest rate and the inflation rate.

An increase in the job separation rate puts upward pressure on the unemployment rate. At the same time, we find that there is a significant drop in the vacancy index which falls by 4 percent on impact and recovers only gradually over time. Thus, the increase in unemployment produced by the increase in layoffs is propagated though fewer vacancies which together imply a significant worsening of the labor market outlook and a large and very persistent decrease in the job finding rate. An important for why the increase in job separations spill over to vacancies derive from the impact on household savings. We notice that the real interest rate drops very significantly. This reflects mainly that a lower real interest rate is needed to clear

[17] To be precise, we calibrate ϕ by exploiting the equivalence between the Phillips curve implied by our model and the Phillips curve implied by the Calvo model.

the asset market because households increase their precautionary savings motive in response to the bleaker jobs prospects. In conjunction this produces a large and persistent in the level and duration of unemployment.

Figure 3 illustrates the impact of an (one standard deviation) increase in the share of job separations that send workers into mis-match unemployment holding constant the job separation rate. This shock has a large impact on the economy which is qualitatively similar to that of a layoff shock but quantitatively much larger. Mis-matched workers take on average longer to find a job than regular unemployed workers. This shock therefore stimulates the desire to savings which is reflected in a large drop in the real interest rate. This implies that firms face low demand for their goods and also realize that vacancies are hard to fill because of the preponderance of low search efficiency workers amongst the unemployed. Hence, vacancies fall very significantly which leads to a large drop in the job finding rate. The decrease in the job finding rate and the lower search efficiency of the stock of unemployed workers jointly imply that the unemployment rate and the average unemployment duration both increase very significantly.

We find it useful to compare the results of the benchmark economy to two alternative economies. In the first alternative economy we assume that prices are flexible, $\phi = 0$. In this economy, there is a much weaker transmission of shocks from households' demand for goods to firms' demand for labor since firms have a strong incentive to cut prices in response to weak goods demand. It is therefore useful to examine this alternative economy to understand how labor market frictions and idiosyncratic risk interact with goods market frictions.

In the second alternative economy we assume complete markets so that households can insure fully against idiosyncratic shocks. This is equivalent to assuming that households are organized in a single family which insures all idiosyncratic risk with the family's budget constraint being given by:

$$\mathbf{c}_t + \mathbf{b}_t^h = \mathbf{n}_t \mathbf{w}_t - \mathbf{T}_t + \mathbf{u}_{s,t} \boldsymbol{\xi}_s + \mathbf{u}_{l,t} \boldsymbol{\xi}_l + \frac{\mathbf{R}_{t-1}}{1 + \boldsymbol{\pi}_t} \mathbf{b}_{t-1}^h, \ t \geq 0 \tag{25}$$

where we use that intra-household insurance implies that consumption levels are equalized across households. This economy features no idiosyncratic risk and aggregate shocks in the labor market still impacts on the economy, the precautionary savings channel against idiosyncratic risk is neutralized.

Figure 4 demonstrates the impact of the job separation shock in the benchmark economy and in the economies where either prices are flexible but asset markets are incomplete or asset markets are complete but prices are sticky. The initial increase in unemployment in the complete markets model is almost the same as in the benchmark model but falls monotonically from the second month after the increase in layoffs and the peak increase is less than half of what is observed in the benchmark model. The reason from this is clear from the real interest rate path which shows that the demand channel is neutralized almost immediately when asset markets are incomplete. For that reason, apart from the first month, firms take advantage of the ease of hiring and post more vacancies. For that reason, the job finding rate is almost unaffected by the increase in job terminations and the amplification mechanism is almost totally neutralized. The flexible price model produces very similar results to the model with complete markets with the only difference being that the effects are somewhat more persistent in the flexible price economy than in the complete markets model. The amplification mechanism in the benchmark model is even stronger in response to the mis-match shock, see Figure 5. Here we find almost no impact on unemployment or any other variable when *either* prices are flexible or asset markets are complete.

We conclude from this that it is combination of incomplete markets and sticky prices that produce an amplification mechanism in which deteriorating labor market prospects produce low demand for goods which in turn leads to weak labor demand thereby creating a vicious circle. When asset markets are complete, there is little impact on goods demand while flexible prices neutralize the channel that goes from goods demand to labor demand.

A Great Recession Experiment. We now turn to a Great Recession experiment. We derive estimates of the sequences of innovations to job termination and to the fraction of workers that flow into high search efficiency unemployment, $(\varepsilon_{x,t}, \varepsilon_{s,t})_{t=2007:1}^{2012:1}$, by matching the observed US time-series on layoffs and the number of unemployed workers who have been out of work for 6 months or more (relative to the labor force). We back out these shocks for the sample period from January 2007 until January 2012. In order to avoid having too erratic shocks, we smooth both data series with a 4 months moving average filter. We then feed the resulting shock processes into the model economy and simulate the economy in response to this particular sequence of shocks.

The first two panels of Figure 6 show the path of layoffs and the fraction of long term unemployed that we target. The other two panels illustrate the time-series of unemployment and vacancies observed in US data together with the corresponding time-series implied by the benchmark model. We also show the corresponding time-series generated by the model when assuming either that there is no mis-match state, prices are flexible, or asset markets are complete. We initialize the unemployment rate at the steady-state and we report vacancies in terms of percentage deviations from steady-state.

The benchmark model reproduces almost exactly the observed unemployment rate. As in the actual data, unemployment starts increasing fast from early 2008 and peaks around 10 percent in late 2009 - early 2010. The model implies a slightly lower unemployment rate in the post-2011 sample than the actual value observed in the US but the difference is not large. One might think that this success in accounting for the increase in unemployment during the Great Recession derives from the fact that we are feeding the observed layoffs into the model but this intuition is not correct. In fact, when we assume either flexible prices or complete markets, we can account for a maximum 1.5 percentage point increase in unemployment, less than one third of the increase implied by the benchmark model. The complete markets model, in particular, fails miserably which indicates that precautionary savings play an important role for accounting for the benchmark model's ability to produce a deep recession in response to the labor market shocks. However, although the flexible prices cum incomplete markets model implies a larger increase in unemployment that the sticky prices cum complete markets, it still produces very little action in unemployment.

The key reason for these differences derive from how the shocks impact on vacancies. In the US, the number of vacancies fell dramatically during the Great Recession and have only recovered mildly since the middle of 2009. The benchmark model captures very well the size of the drop in vacancies (but perhaps not quite so well the dynamics since it implies a much later recovery in the number of vacancies than the US experience). Under the assumptions of either flexible prices or complete markets, we find instead that the model implies little change in vacancies during the early parts of the recession and an *increase* above 2007 levels from 2009 onwards. The lack of a drop in vacancies under these circumstances means that job prospects deteriorate only little beyond the change in job separations and this is the reason why the model fails to produce a strong increase in unemployment when assuming either flexible prices or complete markets. This reflects the fact that the increase in unemployment makes it attractive for firms to hire workers because of the ease of transforming vacancies into hires. This is also the case in the benchmark model but here low demand for goods hold back firms' hiring efforts. Said otherwise, while the benchmark model features a strong feedback from households to firms which is reflected in low labor demand, there is little such feedback when either prices are flexible or asset markets are complete.

In order to evaluate the importance of the mis-match unemployment state we also report the outcome for unemployment and vacancies when we set $(\varepsilon_{s,t})_{t=2007:1}^{2012:1} = 0$ so that the economy is hit by job separation shocks only. In this case, we find a moderate increase in unemployment and a path of vacancies that are very similar to what the outcome under flexible prices. Thus, the increased risk for a low income state with long duration that is key for generating the amplification mechanism.

Much discussion surrounding the Great Recession as focused on the relationship between unemployment and vacancies and the outward shift in the Beveridge curve that seems to have occurred since 2007. We illustrate this in Figure 7. During the early parts of the recession, there was a marked decline in both vacancies and in the unemployment rate but later on the crisis, the recovery in vacancies has been associated with only a minor decline in unemployment consistent with the view that the Beveridge curve has shifted out. In Figure 7 we also report the joint trends in unemployment and vacancies implied by our model by combining the last two panels of Figure 6. The versions of the model that assume either flexible prices, complete markets, or changes only in job separation rates fail to reproduce the joint decrease in unemployment and vacancies during the early parts of the recession and the implied relationship between unemployment and vacancies bear little resemblance if any to its empirical counterpart. The benchmark model instead performs extremely well at least until the later part of the recession where there is a more significant rise in vacancies and drop in unemployment in the US data than predicted by the model. Nonetheless, the model is remarkably successful in accounting for the Beveridge curve.

One important lesson from this is that the success of the model in accounting for the rise in the level and unemployment during the Great Recession does not hinge on an unrealistic increase in mis-match unemployment. Instead, the key is the strong amplification mechanism embedded in the model.

3.3 Robustness

Nash Bargaining.

4 Quantitative Results

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5 Appendices

Table 1: Targets and Parameter Values

Targets	
0.05	unemployment rate
0.4	average job finding rate among newly unemployed
0.3	average job finding rate among unemployed > 6m
0.045	hiring cost as a fraction of the quarterly wage
0.15	fraction of long-term unemployed
0	inflation rate
Parameters	
0.03	s.s. job termination rate ($\overline{\rho}_x$)
0.65	s.s. fraction into mismatch ($\overline{\eta}$)
0.19	$\frac{\theta}{\mu}$ ratio of vacancy cost over matching efficiency parameter
0.50	prob. of search mismatched (γ)
0.84	real wage ($\overline{w}$)
0.0024	s.s.nominalinterestrate($\overline{r}$)

Table 2: Stationary State Values

Parameter	Value	Meaning
c_e	0.829	consumption employed
$c_{u,s}$	0.767	consumption regular unemployed
$c_{u,l}$	0.696	consumption mismatch unemployed
r	0.00246	nominal interest rate (monthly)
ρ_x	0.0295	job termination rate
ρ_s	0.350	fraction of terminations that flow to regular unemployment
ρ_f	0.592	job finding rate regular unemployed
q	0.502	probability that mismatched can search
u_s	0.00677	mass of regular unemployed
u_l	0.04322	mass of mismatch unemployed

c_e :	0.829264	consumption employed
$c_{u,r}$:	0.766769	consumption regular unemployed
$c_{u,m}$:	0.69631	consumption mismatch unemployed
w :	0.829264	wage
r :	0.00246197	nominal interest rate
ρ_x :	0.0295529	job termination rate
η :	0.650383	fraction terminations into mismatch
ρ_f :	0.591644	job finding rate regular unemployed
γ :	0.5019	probability that mismatch can search
$-$	2.78	average unemployment duration
u_r	0.00677477	mass of regular unemployed
u_m	0.0432259	mass of mismatch unemployed
ρ_f^{av}	0.359589	average job finding rate

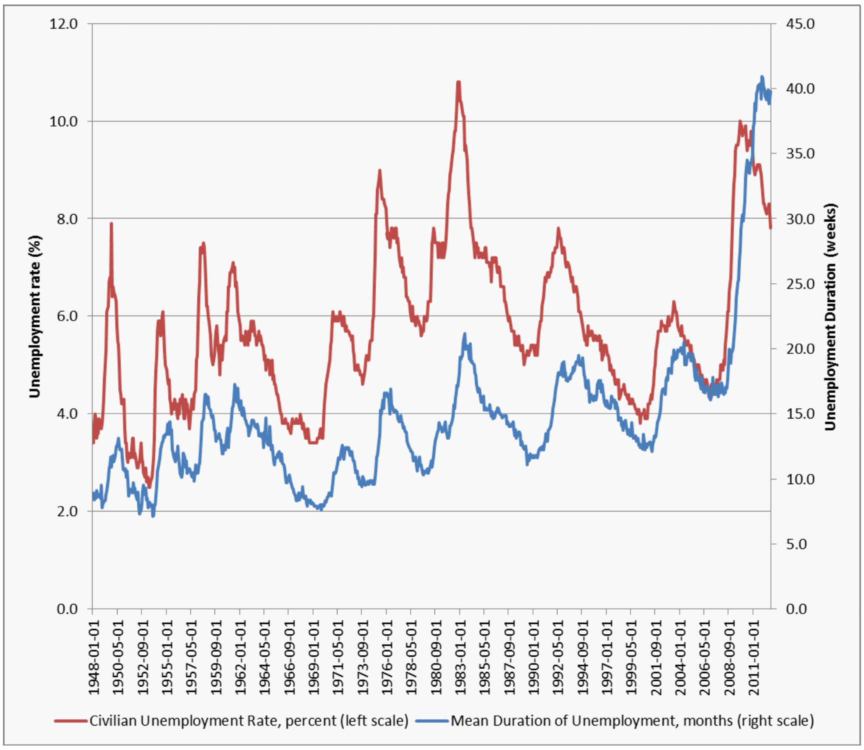

Figure 1. US Labor Market Conditions

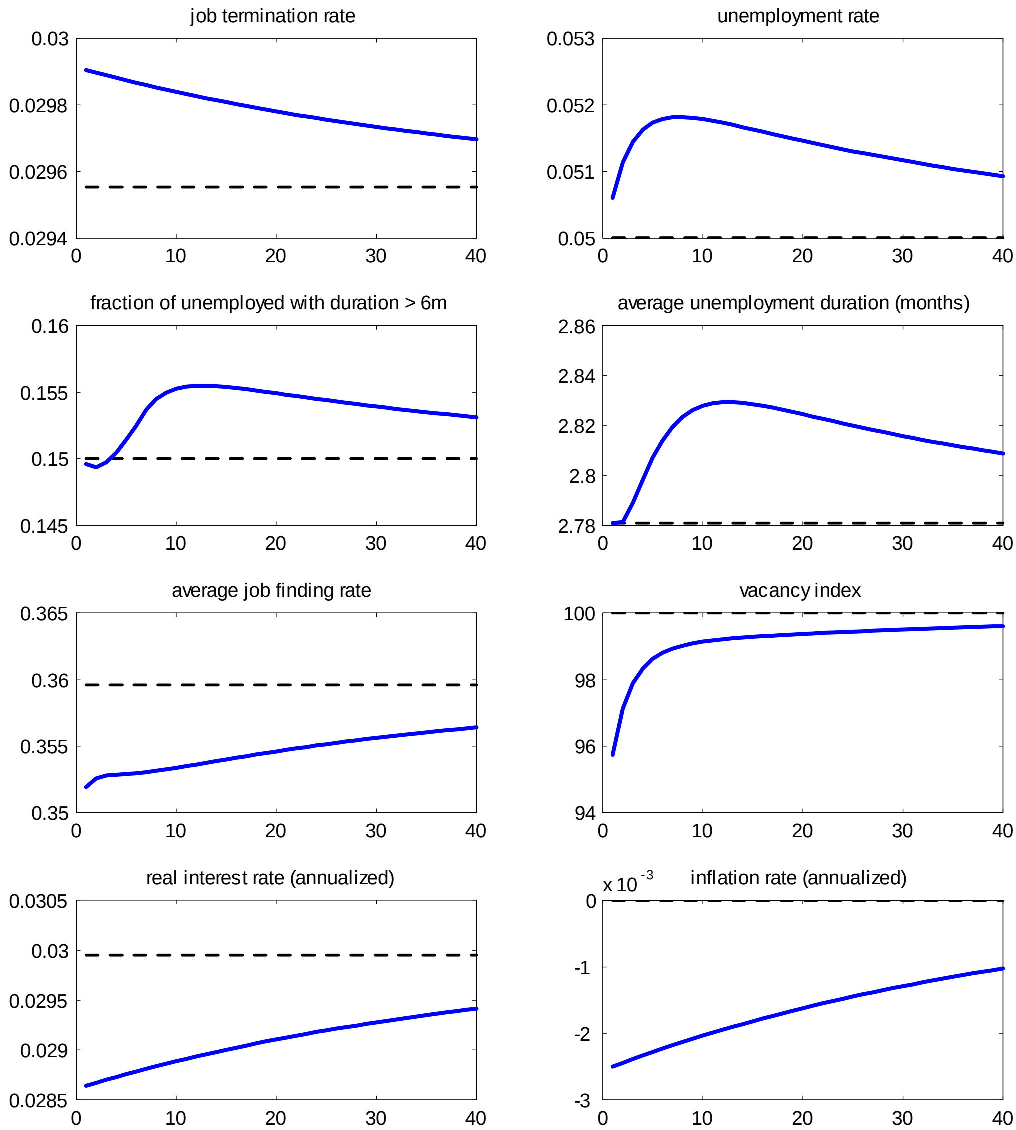

Figure 2. Benchmark Model: Impact of Job Separation Shock

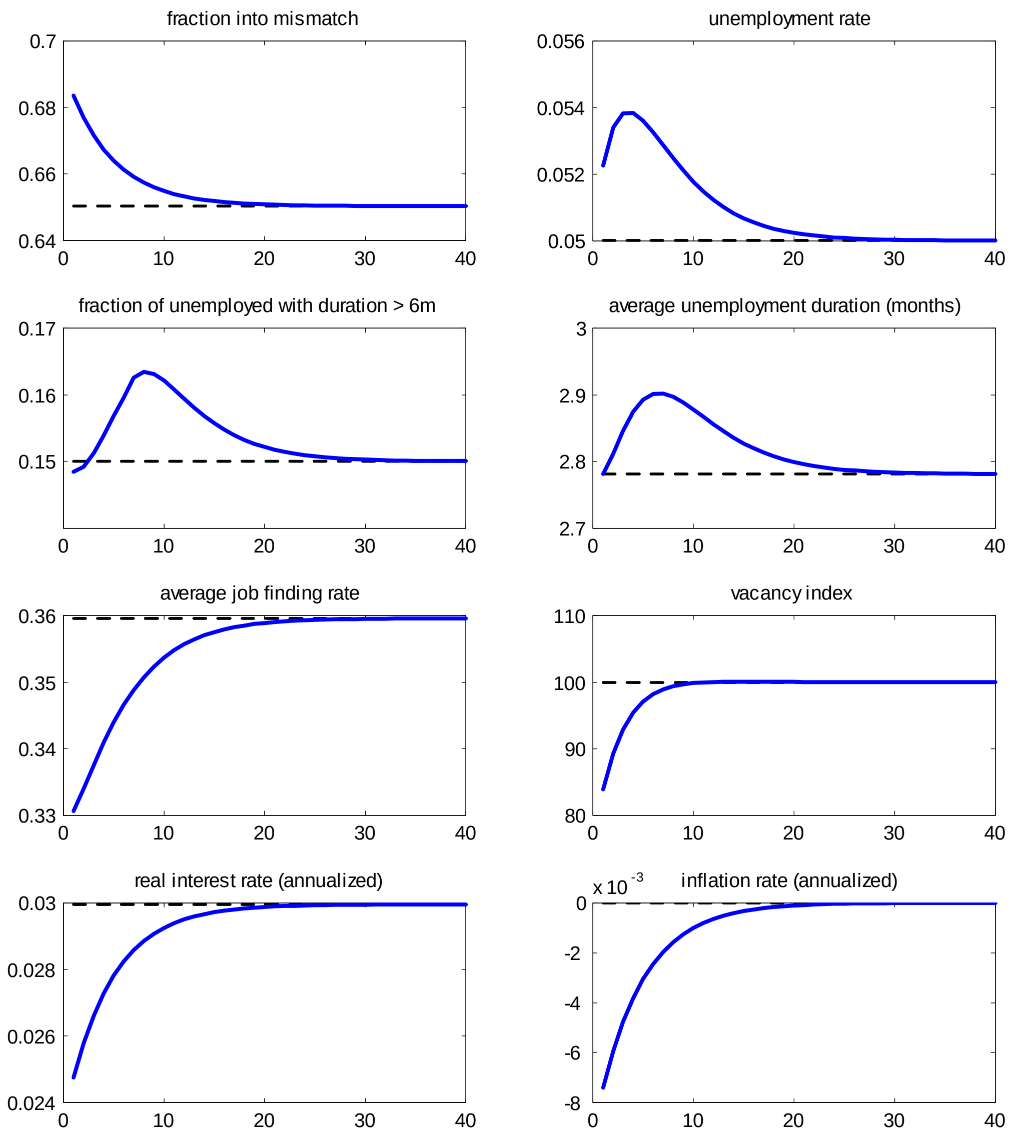

Figure 3. Benchmark Model: Impact of Mis-Match Shock

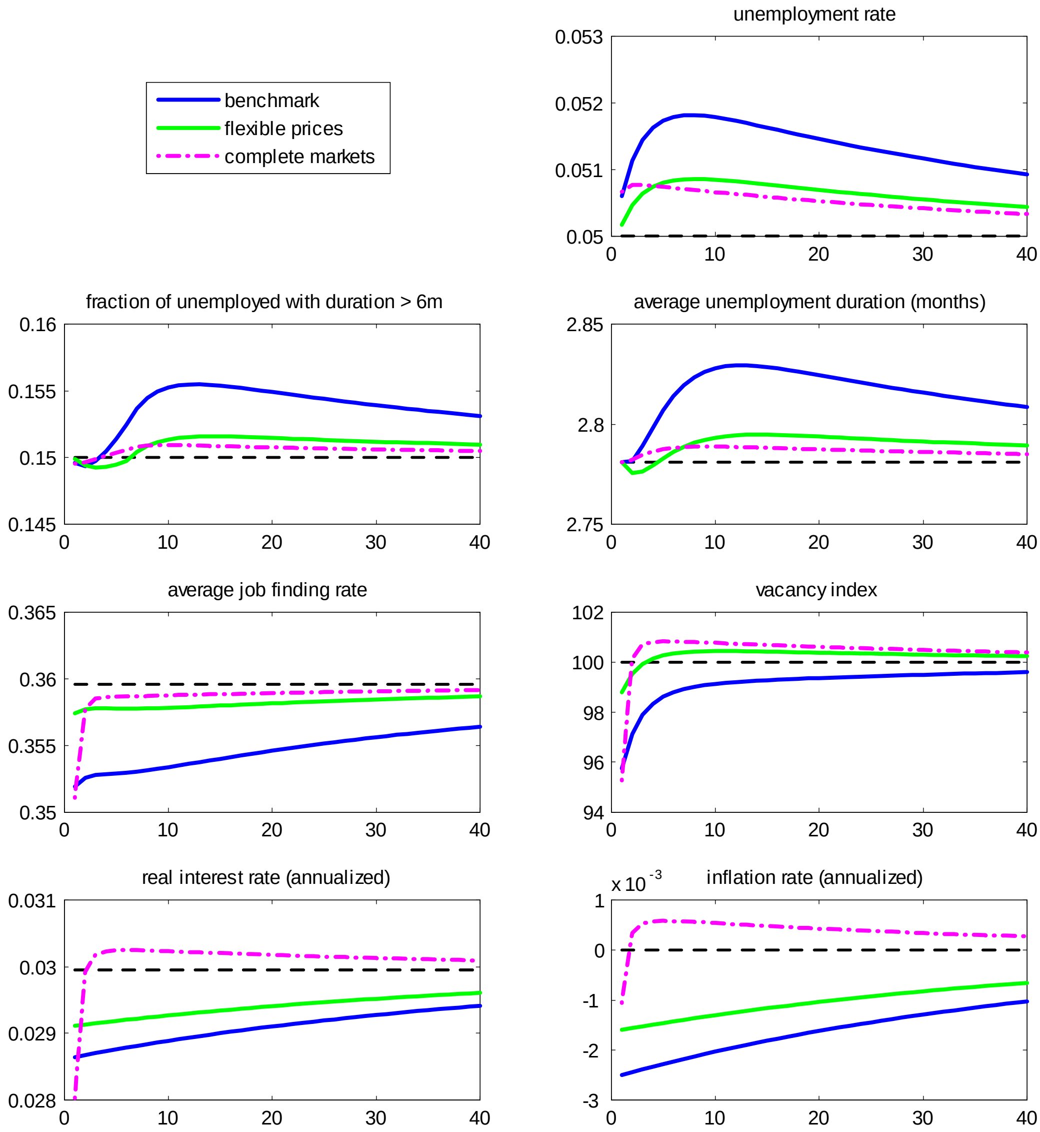

Figure 4. Impact of Job Separation Shock under Alternative Assumptions

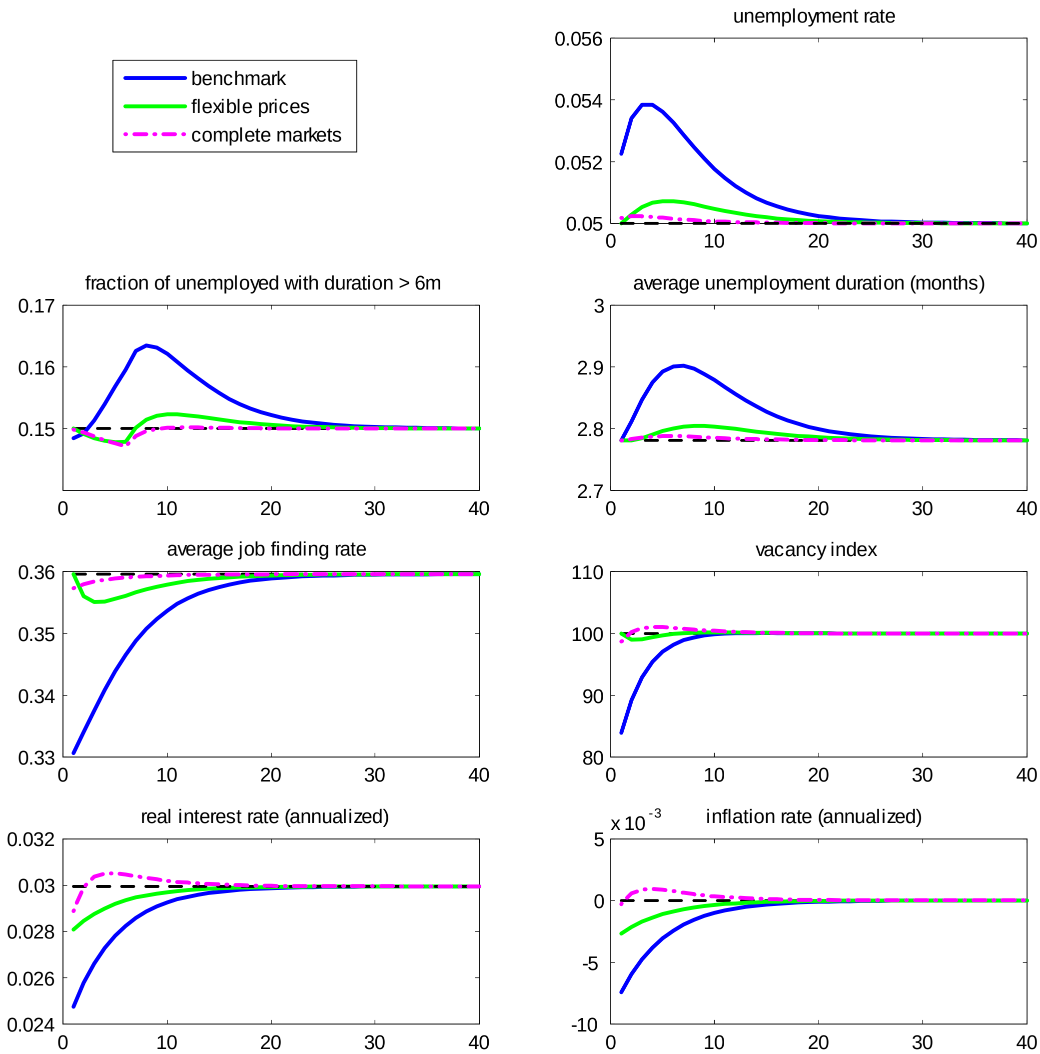

Figure 5. Impact of Mis-Match Shock under Alternative Assumptions

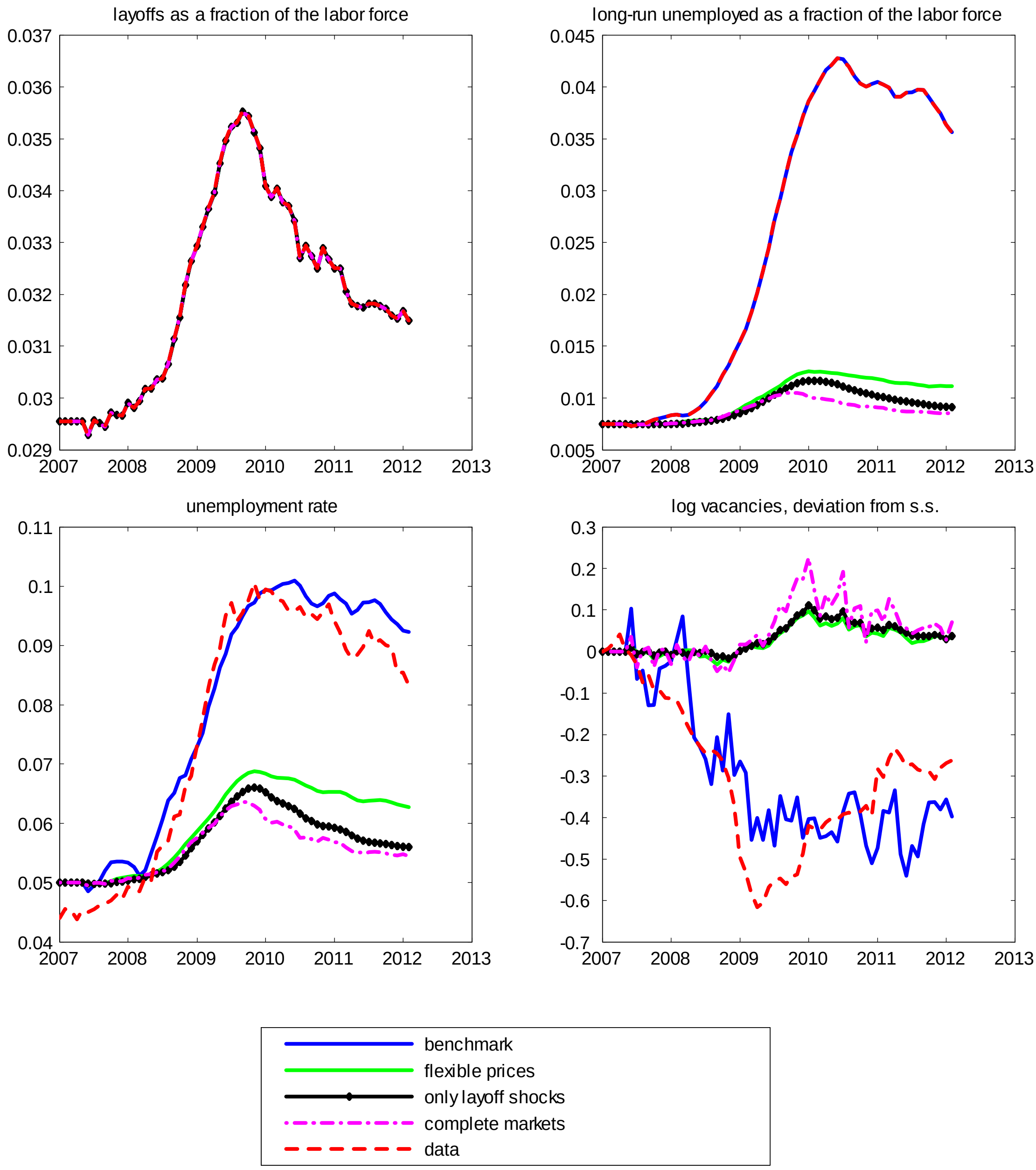

Figure 6. Great Recession Experiment

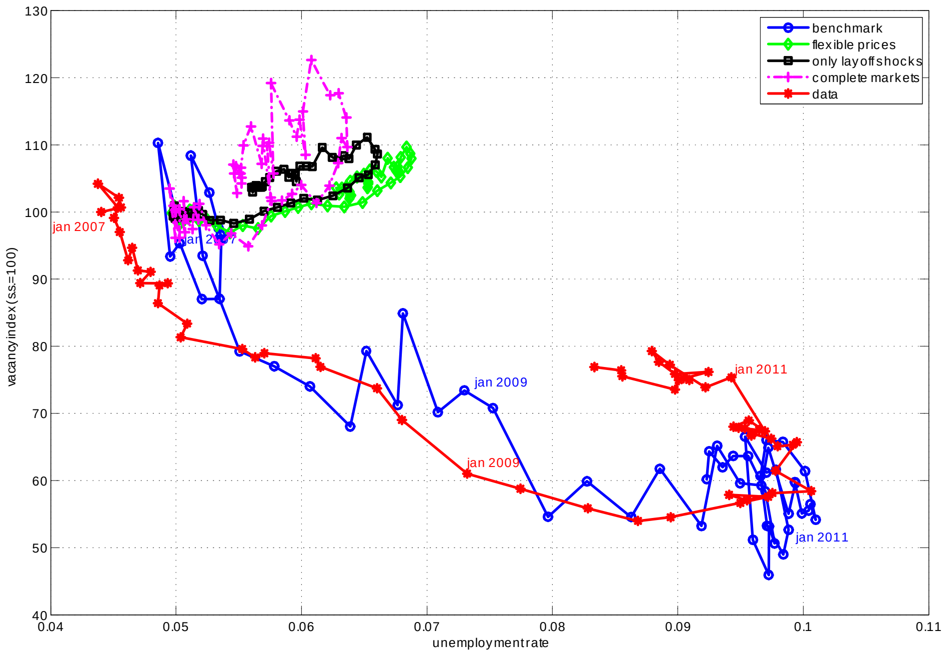

Figure 7. The Beveridge Curve

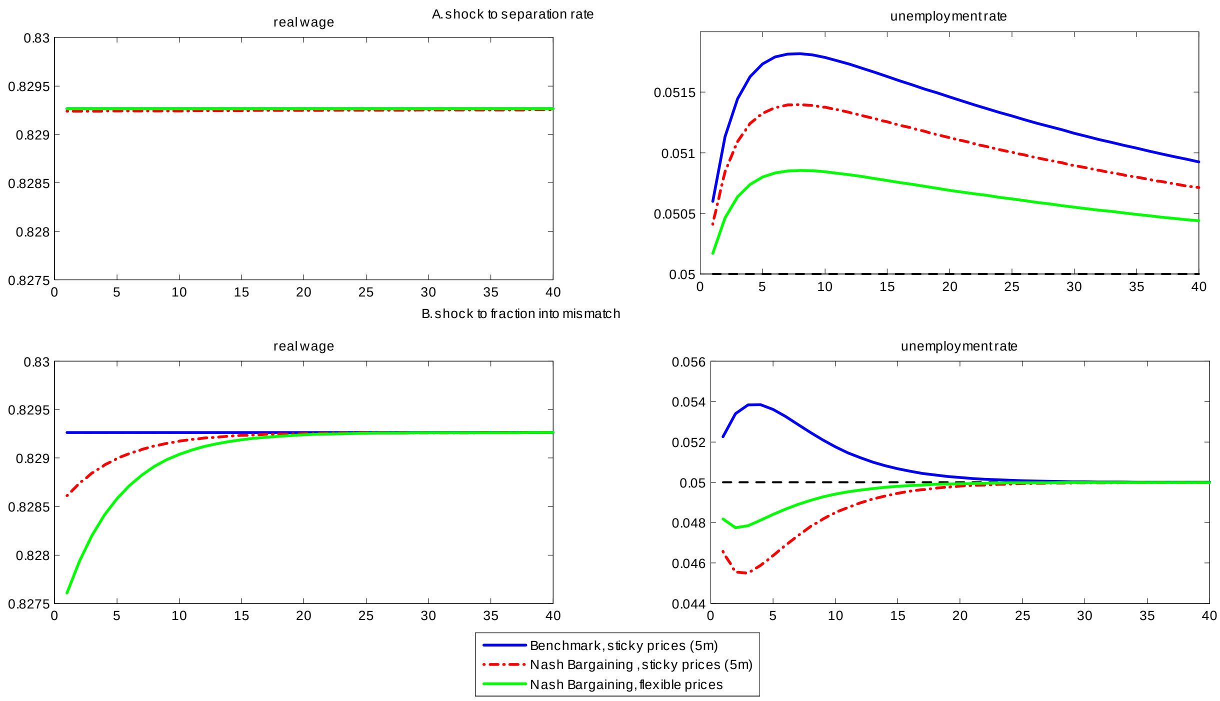

Figure 8.Nash Bargaining