DOCUMENT

DE TRAVAIL

N° 493

HETEROGENEITY, UNEMPLOYMENT BENEFITS AND VOLUNTARY LABOR FORCE PARTICIPATION

Antoine Devulder

June 2014

BANQUE DE FRANCE

EUROSYSTÈME

DIRECTION GÉNÉRALE DES ÉTUDES ET DES RELATIONS INTERNATIONALES

DIRECTION GÉNÉRALE DES ÉTUDES ET DES RELATIONS INTERNATIONALES

HETEROGENEITY, UNEMPLOYMENT BENEFITS AND VOLUNTARY LABOR FORCE PARTICIPATION

Antoine Devulder

June 2014

Heterogeneity, Unemployment Benefits and Voluntary Labor Force Participation

Antoine Devulder*

*Banque de France and Paris School of Economics. Email: antoine.devulder@gmail.com. I thank François Langot for his guidance, and Fabien Tripier for invaluable comments and suggestions.

Résumé

Ce papier développe un modèle DSGE néo-keynésien incluant des frictions de type recherche et appariement sur le marché du travail qui reproduit la faible volatilité du taux de participation dans la population active et sa corrélation modérée avec le PIB, tels qu'ils sont mesurés dans les données du cycle d'affaires américain. De ce fait, il est aussi en mesure de générer d'importantes fluctuations procycliques du ratio entre le nombre de postes vacants et le nombre de chômeurs. Deux explications plausibles à ce comportement du taux de participation sont proposées, à savoir l'hétérogénéité des préférences des ménages et l'indemnisation du chômage. Afin d'être cohérent avec un comportement rationnel des agents au niveau individuel, le modèle adopte, à la place d'une assurance parfaite, un système de répartition de la consommation qui motive la participation sur le marché du travail. Ainsi, les agents entrent volontairement dans la population active et acceptent volontairement les emplois qui leur sont éventuellement proposés.

Mots clés : population active, chômage involontaire, DSGE néo-keynésien, assurance chômage, cycle d'affaires, recherche d'emploi.

Codes JEL : E12, E24, E32, J21, J64, J65.

Abstract

In this paper, I propose a new Keynesian DSGE model with labor market search and matching frictions which replicates the low volatility and the moderate procyclicality of the labor force participation rate, that are observed in the United States at business cycle frequency. That being so, it can also generate large procyclical fluctuations in the vacancy-unemployment ratio. This results from two plausible explanations, namely heterogeneity in households preferences and unemployment benefits. Aggregate movements in the participation rate are also consistent with rational behavior of individual agents. In particular, heterogeneous workers cannot share perfectly their idiosyncratic risk and adopt a consumption allocation arrangement which motivates their participation in the labor market. As a result, both labor force participation and job acceptance are voluntary.

Keywords: labor force, involuntary unemployment, new Keynesian DSGE, unemployment insurance, business cycle, job search.

JEL classification: E12, E24, E32, J21, J64, J65.

Non-technical summary

Recent works have stressed the importance of accounting for the fluctuations in the size of the labor force during the business cycle. Yet, standard business cycle models with equilibrium unemployment, assuming search and matching frictions à la Mortensen-Pissarides, generally ignore the participation margin. When introduced in a natural way into these models, endogeneous participation strongly damages their empirical properties because they predict that fluctuations in the participation rate are much larger than they actually are in the US economy. Some recent papers nevertheless showed that it was possible to generate a low volatility of participation when assuming perfect risk-sharing with respect to leisure and well-suited preferences. But these approaches are not fully consistent with individual behaviors, since households do not explicitely decide to give up leisure time to search for jobs because they expect to be better-off if they are actually employed. More, the reasons why the inflows and outflows from the labor force are moderate over the business cycle do not include heterogeneity in individual preferences and unemployment benefits as common wisdom suggests. This paper incorporates these ingredients into a basic new Keynesian model with search and matching frictions and an imperfect insurance system which makes households voluntarily participate in the labor force. It successfully replicates the volatility and the correlation with output of the participation rate, while preserving the good empirical properties of the basic search and matching framework with respect to other labor market variables such as unemployment and vacancies. Both heterogeneity and unemployment benefits are needed to match these moments.

Introduction

Real business cycle models including search and matching frictions in the labor market and Nash-bargained wages along the lines of Mortensen and Pissarides [1994] and Pissarides [1985] have become the standard approach to describe economies with equilibrium unemployment. In contrast to models with Walrasian labor markets, they add an endogenous propagation mechanism, provide an intuitive and more realistic description of the way of functioning of the labor market (see Andolfatto [1996]), and are consistent with many key business cycle facts. A widespread assumption is that all households always participate in the labor market so the participation rate[1] is constant over time. Recently, however, a number of authors have stressed the importance of accounting for cyclical variations in the participation rate: Elsby et al. [2013] reveal that transitions at the participation margin contribute significantly to the cyclical fluctuations in the unemployment rate, and Campolmi and Gnocchi [2011] show that allowing for endogenous fluctuations in the labor force matters for monetary policy analysis. Erceg and Levin [2013] also argue that business cycle factors account for a significant part of the post-2007 decline in the participation rate.

One major obstacle to including endogenous participation in such models has been identified by Tripier [2003], Ravn [2008] and Veracierto [2008], who extend real business cycle models incorporating search frictions[2]: their models tend to predict excessive procyclical movements in the participation rate. The result of this "participation puzzle" is counterfactual labor market dynamics: unemployment tends to be procyclical, the Beveridge curve tends to be upward sloping and the fluctuations in labor market tightness, defined as the ratio of vacancies to unemployment, are too small. Consider an economy populated by identical households, including a very large number of identical members. Households members can be affected to one out of three exclusive discrete states: employment, unemployment, and non-participation, each of which being associated with a fixed utility value. With perfect risk-sharing, they all consume the same amount of market goods, while a lottery is used in order to choose those who supply labor, as in Rogerson [1988]. When time is indivisible, the equilibrium is then the same as in an economy with a single agent whose utility function is linear in labor and in search effort (or in leisure time). Therefore, when the labor market becomes more attractive, it is always advantageous to increase participation until the job finding rate is deteriorated, which means that participation reacts more than employment, so that unemployment moves procyclically. Formally, Ravn [2008] shows that

[1] The labor force is defined as the sum of employed and unemployed individuals; it includes people either having a job or actively searching for a job. The participation rate is the ratio of the labor force to the working age population.

[2] Tripier [2003] and Ravn [2008] use the Mortensen and Pissarides [1994] matching framework. Veracierto [2008] uses the Lucas and Prescott [1974] islands framework.

this situation implies a positive log-linear relationship between consumption and tightness; the model cannot replicate the high relative volatility of tightness observed in the data unless households are unrealistically risk-averse. Shimer [2013] answers by showing that rigid wages dampen fluctuations in the participation rate and therefore generate countercyclical unemployment in this framework. Another solution considered in the literature consists in assuming perfect-risk sharing with respect to home production. Individuals contribute to home production differently, depending on their status in the labor market, but then equally share the home-produced good within households. When compared with models where risk-sharing does not cover leisure time, the dynamic reponse of the participation rate is mitigated because preferences are convex with respect to home production. So Ebell [2011] proposes to calibrate the intertemporal elasticity of substitution over the home-produced good to match the relative volatility of the participation rate. This is also the strategy used by Den Haan and Kaltenbrunner [2009], while Christiano et al. [2014] also include a participation adjustment cost in the home production technology.

The microfoundations underlying these approaches are unrealistic along several dimensions. Households members do not decide voluntarily to give up leisure time to search for jobs because they expect to be better-off being employed than staying at home. Instead, households choose the desired size of the labor force and then pick up randomly participants among their members. Moreover, perfect insurance involving lotteries à la Rogerson [1988] generally implies that the employed workers are worse-off than the non-workers[3]. Besides, assuming rigid wages as put forward by Shimer [2013] contradicts empirical findings of Pissarides [2009] and Haefke et al. [2013][4]. Last, perfect risk-sharing with respect to both home production and market consumption is in itself questionable. But it is also doubtful that the response of the aggregate participation rate to cyclical changes in economic conditions is small only because individuals' marginal utility of home-production is decreasing, as suggested by the papers that use this assumption.

In actual economies, common wisdom suggests that the sluggishness of the participation rate results, at least to some extent, from heterogeneity in individual preferences: considering the variety of home tasks in which non-participants may be involved, or the differences in individual wealth, some never consider participating, others are very sensitive to the attractiveness of the labor market, while many workers never exit from the labor force. The dynamics of participation is also likely to be related to unemployment benefits: discouraged workers may decide to remain inside the labor force after loosing their jobs in order to benefit from insurance pay-

[3] Although Rogerson and Wright [1988] or Chéron and Langot [2004] use a specific form of non-separable preferences to have "involuntary" unemployment.

[4] They use worker-level data to show that the wages of newly hired workers are very sensitive to aggregate labor market conditions, when the dynamics of the aggregate wage rate reflects the sluggishness of the wages of ongoing matches.

ments, whereas they would have left it otherwise, and thenafter decide to stay inside the labor force because economic conditions are improving. In this paper, I propose a dynamic stochastic general equilibrium model with search and matching frictions which assumes that the low volatility and procyclicality of the participation rate result from these two explanations, and where the discrete choice to participate or not is made voluntarily by households members in order to maximize their individual welfare. For that purpose, the model adopts an imperfect insurance scheme as the one proposed by Christiano et al. [2010], where individual participation decisions are described by a principal-agent problem: the "head of a household" is unaware of the household members' idiosyncratic utilities associated with staying outside of the labor force, but she only observes whether each one is employed or not. Information asymmetry rules out the possibility of a perfect insurance against idiosyncratic labor market outcomes that would level consumption among individuals. Instead, they enter into a contractual agreement that provides incentives to participate in the labor market by endowing the employed workers with a higher level of consumption than the non-workers. After jobs are allocated randomly to participants, the employed workers are better-off than the unemployed ones. Furthermore, the only possible source of heterogeneity in individuals' equilibrium allocations is their consumption levels, which can take only two values at each date. Hence, the model remains tractable and can be solved with the usual methods for representative agent models.

The paper is organized as follows. Section 1 uses quarterly data of the US economy to establish some stylised facts regarding the joint business cycle dynamics of output, the participation rate, unemployment and vacancies. Section 2 uses the partial equilibrium labor market model of Pissarides [2000] in the steady state to analyse analytically how heterogeneity in preferences and unemployment benefits help in lessening the fluctuations of the participation rate. Section 3 develops the DSGE model with endogenous labor force participation. It includes sticky prices consistently with the new Keynesian approach, since this class of models has been widely adopted by central banks and policy institutions, especially for monetary policy analysis. In addition, Blanchard and Galí [2010] show that the search and matching and the new Keynesian frameworks can be successfully combined. Finally, section 4 proposes a calibration of the model parameters and discusses its empirical properties. The behavior of the participation rate, unemployment and vacancies is found to be very close to the data. The simulations also show that, in the model, heterogeneous preferences are not sufficient to replicate the moderate procyclicality of the participation rate in the absence of unemployment benefits.

1 Facts

I use quarterly time series of gross domestic product, total population aged 15 to 64, employment of people aged 15 to 64, the number of participants in the labor force aged 15 to 64, and vacancies in the United States. The source is the OECD database and the sample covers 1977Q1 to 2012Q4, except for the time series for vacancies which includes the number of job openings in the non-farm sector provided by the Job Openings and Labor Turnover Survey of the Bureau of Labor Statistics, and starts in 2001Q1. All series are seasonally adjusted and detrended by the population aged 15 to 64, and unemployment is computed as the difference between participation and employment of people aged 15 to 64. Their cyclical components are obtained by applying a Hodrick-Prescott filter with smoothing parameter set to 1,600 to the logarithm of the per head series. The cyclical component of the labor market tightness ratio in logarithm is computed as the difference between the cyclical components of vacancies and unemployment. The time series used are shown in Figure 1.

Figure 1: U.S. detrended quarterly data

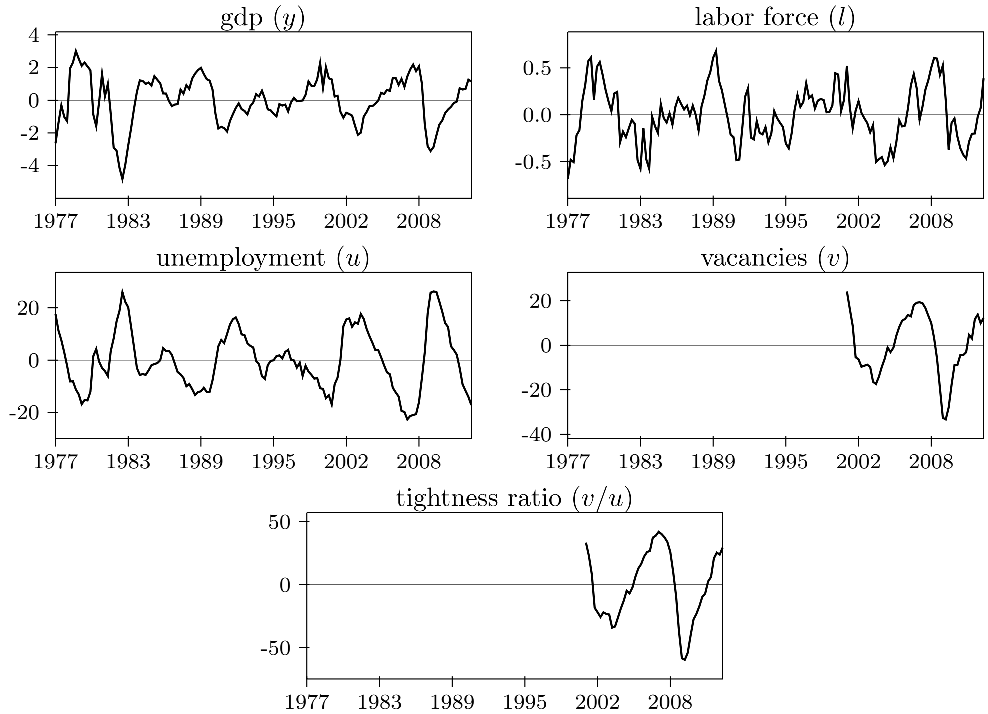


Table 1 reports their standard errors and correlation matrix. The following facts can be drawn from these statistics:

1. The participation rate is moderately procyclical (its correlation with output is around 0.5) and it varies five times less than output during the business cycle.

2. Unemployment and the number of vacant jobs are strongly negatively correlated, which

Table 1: Statistics for quarterly U.S. data

		y	l	u	v	v/u
standard deviation		0.014	0.003	0.113	0.140	0.280
correlation matrix	y	1.000	0.471	-0.866	0.883	0.922
	l	–	1.000	-0.488	0.263	0.311
	u	–	–	1.000	-0.935	-0.984
	v	–	–	–	1.000	0.983
	v/u	–	–	–	–	1.000

Notes: The table reports the standard errors and the correlation matrix of the cyclical components of the logarithm of gross domestic product per head (y), the employment rate (n), the participation rate (l), unemployment per head (u), the number of (non-farm) job openings per head (v) and the tightness ratio (v/u), over the period from 1977Q1 to 2012Q4 (2001Q1 to 2012Q4 for v and v/u).

materializes in a downward-sloping Beveridge curve.

3. Unemployment and vacancies vary approximately 10 times as much as output during the business cycle and are strongly correlated with output (negatively for unemployment and positively for vacancies); hence, the volatility of the tightness ratio is around 20 times higher than the one of output.

2 Analytical approach

This section uses a framework based on Pissarides [2000] to derive analytically the steady state elasticity of the participation rate with respect to productivity.

2.1 Workers and firms' behavior

There is a continuum of individuals of working age that is assumed to be of mass 1. Let u and v denote respectively the unemployment rate and the number of vacancies as a fraction of the labor force, and $\theta \equiv v/u$. The outcome of trade in the labor market is given by a matching function $m(u, v)$, increasing in both its arguments, concave and homogeneous of degree 1. It represents the ratio of the number of job matches taking place per unit of time to the size of the labor force. The vacancy filling rate can be written as a function of θ,

$$q(\theta) = \frac{m(u, v)}{v}.$$

With this notation, the job finding rate is

$$f(\theta) = \frac{m(u, v)}{u} = \theta q(\theta).$$

Job separation occurs at the constant Poisson rate λ. Agents have access to a perfect capital market with a continuously compounded return on assets denoted by r. Let p denote the value of a job's output, c the fixed cost per unit time of holding a vacancy and w the real cost of labor for a firm. The present discounted value of expected profits from an occupied job J satisfies

$$rJ = p - w - \lambda J, \tag{2.1}$$

while the present discounted value of expected profits from an occupied job V is

$$rV = -c + q(\theta)(J - V), \tag{2.2}$$

where c is a constant vacancy cost per unit of time. In addition, free creation of vacant jobs implies that $V = 0$.

Let z and h be the real non-market incomes received respectively by unemployed workers and by non-participants, which are assumed to be the same for all individuals. z is larger than h on the grounds that $z - h$ includes unemployment benefits. In addition to h, non-participants enjoy a real return from home production which is proportional to aggregate productivity p. Moreover, this return is assumed to vary across individuals, reflecting differences in individual productivities and preferences. I also make the simplifying assumption that unemployed workers spend all their time on job search and cannot take advantage of home production. The worth of being non-participant, denoted by l_0, can hence be written

$$l_0 = ap + h, \tag{2.3}$$

where the proportionality coefficient $a \geq 0$ is distributed with cumulative density $H(a)$. The present discounted value of the expected income flow of an unemployed worker and an employed worker, respectively U and W, satisfy

$$rU = z + f(\theta)(W - U), \tag{2.4}$$

$$rW = w + \lambda(U - W). \tag{2.5}$$

Individuals with leisure worth l_0 participate when

$$l_0 \leq rU. \tag{2.6}$$

The size of the labor force denoted by L is therefore $L = H(a_0)$, where

$$a_0 = \frac{rU - h}{p}$$

is the threshold value of a for which (2.6) holds with equality.

Next, the wage rate satisfies a Nash sharing rule of the economic rent associated with a job match, so the wage is

$$w = (1-\beta)z + \beta(p + c\theta), \tag{2.7}$$

with $0 \leq \beta \leq 1$.

2.2 Elasticity of the participation rate

The equilibrium conditions of the model summarized above yield the elasticity of the participation rate with respect to productivity in the steady state

$$\frac{dL}{dp}\frac{p}{L} = \frac{H'(a_0)}{H(a_0)}\left[\frac{\beta f(\theta)}{r+\lambda+\beta f(\theta)}\left(\frac{(r+\lambda)\eta}{(r+\lambda)(1-\eta)+\beta f(\theta)} + \frac{z}{p}\right) - \frac{z-h}{p}\right], \tag{2.8}$$

where η is the elasticity of the job finding rate $f(\theta)$ with respect to θ (details are provided in Appendix A).

The first positive term inside the brackets reflects the fact that productivity gains improve wages and the job finding rate, making participation in the labor market more attractive.

The difference between the revenues of the unemployed and the ones of the non-participants $z - h$, which includes unemployment benefits, has two contrasted effects on participation. On the one hand, it increases the steady state level of L, as is clear from equation (A.8) in Appendix A. On the other hand, it contributes negatively to the elasticity of participation with respect to productivity, as productivity gains raise the worth enjoyed by non-participants relatively to the extra revenue $z - h$ that is immediately earned by individuals who decide to participate in the labor market. Put differently, unemployment benefits, possibly amongst other revenues, provide an additional motivation to participate in the labor market but amplify countercyclical wealth effects on labor supply.

The effect of $z - h$ described above allows to draw a parallel with the preceeding works of Hagedorn and Manovskii [2008]: these authors have shown that reducing $p - z$ amplifies the response of labor demand, by making firms' profits smaller and hence more sensitive to job creation. The result is a high volatility of labor market tightness θ in their model. Conversely, the paper shows that increasing $z - h$ mitigates the response of households' labor supply, and hence dampens the volatility of the participation rate. A calibration strategy consistent with both findings is to set z close enough to p and h sufficiently lower than z.

The workers' bargaining power β has also an impact on the elasticity of participation with respect to productivity, because the expected gains from finding a job depend on the fraction of the rent associated with job creation that is taken by workers. However, it is easy to see that it is much smaller, as it is for the elasticity of tightness with respect to productivity.

The positive contribution of z/p in equation (2.8) can be interpreted as follows: z represents the worth of unemployment per se, i.e. for jobless workers with no job opportunity. When the job finding rate improves, the probability to remain jobless for a new participant decreases relatively to the one of finding a job. Therefore, the negative wealth effects on labor supply due to the presence of z described above are mitigated[5].

The other determinant of the elasticity of participation with respect to productivity is the degree of heterogeneity across individuals in the neighborhood of the marginal participant in the labor force[6], which is reflected by the term $H'(a_0)/H(a_0)$ in equation (2.8): when productivity p varies from p to $p + dp$, the threshold value of a such that $l_0 = rU$ varies from a_0 to $a_0 + da_0$. Then

$$\frac{H'(a_0)}{H(a_0)}|da_0|$$

represents the fraction of the labor force for which the difference between their leisure worth and the value of being unemployed changes sign, and thus who revise their participation decision. A small value of the density $H'(a_0)$ reflects that the number of individuals who have leisure worth close to the threshold is low, so that the response of the participation rate L to changes in productivity is weak. The opposite extreme assumption is no heterogeneity among households, which is implicitely used by Tripier [2003], Ravn [2008] and Veracierto [2008]. This case corresponds to a constant and given for all households in the model. If free entry in the labor market is possible, the coexistence of participants and non-participants in equilibrium implies that

$$ap + h = rU, \tag{2.9}$$

and the model does not determine the size of the labor force. When p changes, the equilibrium condition (2.9) above is disrupted and all participants either enter or leave simultaneously the labor force. If the model instead assumes that the equilibrium condition (2.9) always holds, as

[5]This mechanism involves z and not $z - h$ because the effect of loosing h for an individual who decides to participate remains unchanged.

[6]That is the individual whose leisure worth as a non-participant is equal to the threshold value rU.

it is the case in the aforementioned papers, it constrains the dynamics of tightness according to

$$\theta = \frac{1-\beta}{\beta}\frac{ap-(z-h)}{c}. \tag{2.10}$$

When $z = h$, this equation is a formulation of Ravn [2008]'s consumption-tightness puzzle, except that wealth is measured by a linear function of productivity p rather than by the inverse of households' marginal utility of consumption as in a standard DSGE model. It implies that $\log\theta$ and $\log p$ have the same volatility. When h is not equal to z however, the tightness ratio may vary much more than p, since its elasticity with respect to productivity resulting from equation (2.10) is

$$\frac{d\theta}{dp}\frac{p}{\theta} = \frac{1}{1-\frac{z-h}{ap}}. \tag{2.11}$$

In sum, without heterogeneity in households preferences, the dynamics of the participation rate and of the tightness ratio are strongly constrained in the model. With heterogeneity, the magnitude of the participation rate's response to changes in productivity is very sensitive to the assumed distribution of preferences across households. Moreover, unemployment benefits add a countercyclical component to the dynamics of the participation rate. These properties are used in the general equilibrium model developed in what follows to replicate the facts identified in section 1.

3 DSGE Model

3.1 Labor market

The number of identical jobs n_t in period t includes the jobs of the previous period minus a constant fraction λ of them that are exogeneously destroyed, plus m_t new jobs. It is

$$n_t = (1-\lambda)n_{t-1} + m_t. \tag{3.1}$$

As in Pissarides [1985], job creation is assumed to be well-described by a Cobb-Douglas matching function depending on unemployment and on the number of vacancies v_t posted by the representative firm. Following Blanchard and Galí [2010], the variable that enters the matching function is unemployment "before job creation", that is $L_t-(1-\lambda)n_{t-1}$, where L_t denotes the participation rate, rather than actual unemployment $L_t - n_t$, so

$$m_t = \Upsilon v_t^{\kappa}(L_t-(1-\lambda)n_{t-1})^{1-\kappa}, \tag{3.2}$$

where Υ is a scale parameter of the matching technology. New matches of period t enter immediately in the production of period t, which helps temper the large fluctuations in firms' markup that would result from rigid prices and predetermined employment.

3.2 Households

The economy is populated by a large number, normalized to 1, of identical housholds, which can be represented by a representative household. Each household includes a continuum of members with a mass of 1, among which is the "head of the household", referred to as "the principal" or simply "the household" in what follows. Although jobs are likely to continue over time, all workers are hired at the beginning of each period only for one period of time. Alike, all households members may enter in or exit from the labor force at the beginning of each period. The assignment of participants in the labor market to available job positions involves a standard lottery, so they all have the same probability n_t/L_t to find a job in period t.

Housholds members derive utility from consumption of an homogeneous good and from home production, in which they can engage only when they are outside of the labor force[7]. The household members' utilities of home production are different, variable and memoryless over time. For that purpose, I assume that they are subject to an idiosyncratic shock denoted by i, drawn from a uniform distribution over $[0, 1]$ independantly across individuals and across time, that determines their instantaneous utility as follows:

$$U(i, C) = \begin{cases} \log C + \zeta i^{\sigma} & \text{if out of the labor force,} \\ \log C & \text{if in the labor force,} \end{cases}$$

where C denotes individual consumption, ζ is a scale parameter and σ characterizes the curvature of the utility of home production in the cross section of the household members[8].

As a starting point, the idiosyncratic shocks i is assumed to be privately observed by the household members. Free entry in the insurance market implies that individuals have access to a perfect insurance system: ex ante (that is before observing the results of the current period lotteries), they can decide to purchase a complete set of assets in order to insure against idiosyncratic labor market outcomes in the current period. With such a system, they all consume the same amount, so staying outside the labor force is always more desirable since it allows home production. Therefore, they use a lottery to choose the household members to supply labor. Yet, this allocation is dominated in terms of welfare by the one that consists in choosing the indi-

[7]As in section 2, the unemployed workers spend all their time searching for a job.

[8]By analogy with the partial equilibrium model of section 2, this corresponds to a distribution of the utility of home production across the household members with CDF $H(a) = (a/\zeta)^{1/\sigma}$ for $a \in [0, \zeta]$. Yet it does not depend on aggregate productivity in the general equilibrium model with convex preferences.

viduals who have drawn the lowest i instead. This motivates the use of a different arrangement to choose participants. Such an arrangement should incite the household members to voluntarily give up home production when their i is lower than any desired level of the participation rate. It should also be preferred ex ante by the household members to perfect insurance[9]. The arrangement assumed in the model is the following: the principal and the household members agree to allocate consumption in the current period only depending on whether they have a job or not ex post. Hence, two levels of consumption are possible, the one of the employed workers and the one of the others, respectively denoted by C^e ans C^u in real terms, with $C^e > C^u$ and $nC^e + (1-n)C^u = C$, C being aggregate real consumption of the household. Given values of C_t^e and C_t^u for a given period t, the household members decide to participate in the labor force when they draw a value of $i \in [0,1]$ such that their expected utility as participants exceeds their expected utility as non-participants, that is when

$$\frac{n_t}{L_t} \log C_t^e + \left(1 - \frac{n_t}{L_t}\right) \log C_t^u \geq \log C_t^u + \zeta i^\sigma.$$

Any individual who has drawn i lower than the threshold value for which this condition holds with equality is a participant, so this threshold value is the size of the labor force L_t. Hence, the principal can induce any desired value of L_t by setting C_t^e and C_t^u such that

$$n_t \log \frac{C_t^e}{C_t^u} = \zeta L_t^{1+\sigma}. \tag{3.3}$$

Of course, this arrangement requires that the household members pool all their revenues, which are described in what follows. Labor is remunerated at a unique real wage w_t per period and per employee. The household also receives a constant non-market revenue z (in real terms) per unemployed worker and a constant non-market revenue h (in real terms) per out-of-the-labor-force individual, which are both introduced as benefits paid by the government. She has access to financial markets to trade nominal assets b_t, remunerated at an interest factor r_t in period $t+1$. All households also own equal shares in monopolistic firms so they are all granted dividends for div_t in real terms. Last, the government pays them evenly a real lump-sum transfer T_t. The real budget constraint of the household is hence

$$C_t + \frac{b_t}{P_t} \leq b_{t-1}\frac{r_{t-1}}{P_t} + n_t w_t + (L_t - n_t)z + (1 - L_t)h + div_t + T_t,$$

where P_t is the price level of the final good in period t.

[9] This condition is satisfied for the proposed arrangement with the considered calibration, as shown in Appendix D.

The household does not internalize the job matching technology postulated in section (3.1). She rather takes as given the job finding probability, defined as the ratio of the new matches of the period to unemployment just before the matching process

$$f_t \equiv \frac{m_t}{L_t - (1-\lambda)n_{t-1}},$$

so the law of motion of employment that she observes is

$$n_t = (1-\lambda)n_{t-1} + f_t(L_t - (1-\lambda)n_{t-1}).$$

The objective function of the household is the sum of her members' utilities, which is equal (up to a constant) to:

$$U_t = \log C_t^u + \frac{\zeta\sigma}{1+\sigma} L_t^{1+\sigma}.$$

Appendix B provides a detailed derivation of the household's program. Her optimal behavior is described by

$$1 = \delta E_t \left[\frac{\Lambda_{t+1}}{\Lambda_t} \frac{r_t}{\pi_{t+1}} \right], \tag{3.4}$$

and

$$z - h + c\frac{\beta}{1-\beta}\frac{f_t}{q_t} = \left(\frac{1}{\Lambda_t} + (1+\sigma)(1-n_t)(C_t^e - C_t^u) \right) \zeta L_t^\sigma, \tag{3.5}$$

where δ is the discount factor that characterizes households' preference for the present, π_t is the aggregate inflation factor, $\Lambda_t = 1/C_t$ is the marginal utility of aggregate consumption and q_t is the vacancy filling rate defined in section 3.3. Equation (3.4) is a standard Euler condition, which determines the optimal intertemporal allocation of savings and consumption. Equation (3.5) determines the optimal size of the labor force, which is such that the marginal aggregate utility costs from higher participation compensate the marginal gains. The utility costs of higher participation result from the related decrease in home production but also from the reallocation of consumption in favor of the employed workers, aimed at increasing the incentives for the household members to enter in the labor market. This reallocation has a negative impact on aggregate utility because the non-employed have a higher marginal utility of consumption than the employed workers. Conversely, the marginal gains from increasing the participation rate are represented by the left side of equation (3.5). They result first from additional unemployment benefits, and, second, from the new jobs that are created thanks to a higher search effort – as measured by $L_t - (1-\lambda)n_{t-1}$ in the matching technology. At the bargained wage rate, this marginal gain is a function of the ratio of f_t to q_t.

Regarding the dynamics of the model, the presence of the positive constant $z-h$ to the left side and, when σ is high, of L_t^{σ} to the right side in equation (3.5) implies that the ratio of the job finding rate f_t to the vacancy filling rate q_t and hence the tightness ratio[10] may vary much more than the inverse of the marginal utility of aggregate consumption.

3.3 Firms

A representative firm uses labor input n_t to produce $p_t n_t$ of an homogeneous good, where p_t represents labor productivity and is exogenous. This good is sold at a relative price x_t to a continuum of monopolistic retailers. In order to post a vacancy, the firm has to expense a fixed cost c. As the family, she does not internalize the job matching technology, but takes as given the probability of filling a vacant position

$$q_t \equiv \frac{m_t}{v_t},$$

and observes the law of motion of employment

$$n_t = (1-\lambda)n_{t-1} + q_t v_t.$$

The firm chooses the number of vacancies v_t to post in order to maximize the expected flow of her discounted future profits subject to the law of motion of employment, as summarized by the definition of her value function

$$\begin{aligned} W_t(n_{t-1}) = \max_{v_t} & \left\{ x_t p_t n_t - w_t n_t - c v_t + \delta E_t \left[\frac{\Lambda_{t+1}}{\Lambda_t} W_{t+1}(n_t) \right] \right\} \\ & \text{s.t.} \\ & n_t \leq (1-\lambda)n_{t-1} + q_t v_t, \end{aligned}$$

where the presence of the family's marginal utility of aggregate consumption Λ_t reflects the fact that the firm values her profits in terms of welfare gains for shareholders. This program yields the optimality condition

$$\frac{c}{q_t} = x_t p_t - w_t + \delta(1-\lambda) E_t \left[\frac{\Lambda_{t+1}}{\Lambda_t} \frac{c}{q_{t+1}} \right]. \tag{3.6}$$

[10]With the "new Keynesian specification" of the matching technology (3.2), tightness is related to the ratio of f_t to q_t by

$$\theta_t = \frac{v_t}{L_t - n_t} = \frac{L_t - (1-\lambda)n_{t-1}}{L_t - n_t} \frac{f_t}{q_t}.$$

Monopolistic retailers indexed by $j \in [0,1]$ differentiate the fraction of the homogenous good that they purchase from the firm and set their prices under a lottery à la Calvo: they can only re-optimize their prices with a constant probability $1-\xi$ in every period. With probability ξ, their prices evolve automatically at a rate given by a convex combination of past aggregate inflation π_{t-1} (with weight ι) and long run inflation $\bar{\pi}$ (with weight $1-\iota$). Retailers sell their differentiated products $y_t(j)$, $j \in [0,1]$, to a competitive distributor who produces a quantity Y_t of the final good using a CES technology

$$Y_t = \left(\int_0^1 y_t(j)^{\frac{s-1}{s}} \, dj \right)^{\frac{s}{s-1}},$$

where the parameter s is the elasticity of substitution. The distributor chooses optimally the demand $y_t(j)$ addressed to any retailer $j \in [0,1]$. The inflation rate follows

$$1 = (1-\xi)\tilde{P}_t^{1-s} + \xi \left(\frac{\pi_{t-1}^{\iota}\bar{\pi}^{1-\iota}}{\pi_t} \right)^{1-s},$$

where $\tilde{P}_t$ is the relative price chosen by the $1-\xi$ retailers that are allowed to reoptimize in period t. Because retailers are all identical ex ante and the price setting problem is forward looking, they all choose the same optimal price. It is governed by

$$\tilde{P}_t = \frac{s}{s-1}\frac{H_{1t}}{H_{2t}} \quad \text{with} \quad \begin{aligned} H_{1t} &= x_t Y_t + \delta\xi \tfrac{\Lambda_{t+1}}{\Lambda_t} \left(\tfrac{\pi_{t+1}}{\pi_t^{\iota}\bar{\pi}^{1-\iota}} \right)^{s} H_{1t+1}, \\ H_{2t} &= Y_t + \delta\xi \tfrac{\Lambda_{t+1}}{\Lambda_t} \left(\tfrac{\pi_{t+1}}{\pi_t^{\iota}\bar{\pi}^{1-\iota}} \right)^{s-1} H_{2t+1}. \end{aligned}$$

3.4 Wage bargaining

The wage rate is flexible: in every period t, the representative household and the representative firm bargain over the current wage rate w_t in order to share the surplus created by successful matches. The negotiated wage is assumed to be the one that maximizes the convex combination of the marginal value of employment for the firm and for the household

$$\left(\frac{\partial W_t}{\partial n_{t-1}} \right)^{1-\beta} \left(\frac{1}{\Lambda_t}\frac{\partial V_t}{\partial n_{t-1}} \right)^{\beta},$$

where V_t denotes the value function of the household. The solution of this Nash bargaining problem is

$$(1-\beta)\frac{\partial V_t}{\partial n_{t-1}} = \beta\Lambda_t(1-f_t)\frac{\partial W_t}{\partial n_{t-1}},$$

which yields the wage equation (see Appendix C for details)

$$w_t = (1-\beta)\left(z + C_t^e - C_t^u - C_t^e \log \frac{C_t^e}{C_t^u}\right) + \beta\left(x_t p_t + c\delta(1-\lambda)E_t\left[\frac{\Lambda_{t+1}}{\Lambda_t}\frac{f_{t+1}}{q_{t+1}}\right]\right). \tag{3.7}$$

The bargained wage is a weighted average of, on the one hand, the contribution of an additional worker to the sales of the representative firm plus the vacancy posting expenses that are expected to be saved in the next period thanks to a new hire, and, on the other hand, the household's outside options. The latter term obviously includes the non-market revenue of the unemployed z, and the effects on the household's aggregate utility of the reallocation of consumption between her employed and non-employed members that follows job creation.

3.5 Monetary policy and general equilibrium

The interest rate is decided by the monetary authority according to the standard Taylor rule

$$r_t = r_{t-1}^{\rho}\left(\bar{r}\left(\frac{\pi_t}{\bar{\pi}}\right)^{r_\pi}\left(\frac{Y_t}{\bar{Y}}\right)^{r_y}\right)^{1-\rho}\varepsilon_{r,t}, \tag{3.8}$$

including an exogenous disturbance ε_r. In this equation, $\bar{Y}$ is the steady state level of output Y_t.

The final demand of goods is assumed to include an additional term, which stands for the residual demand items of the actual economy that are not described in the model (foreign trade, investment, government spending and changes in inventories). It is modelled as government spending and its counterpart includes transfers T_t and non-employment benefits $(L_t - n_t)z + (1 - L_t)h$ paid to households, ensuring a balanced budget in every period. Its real value is assumed to be constant over time and is denoted by G. Therefore market clearing implies

$$Y_t = C_t + G + cv_t. \tag{3.9}$$

4 Quantitative analysis

4.1 Calibration

The steady state levels of the employment rate and of the participation rate are respectively set to 0.70 and 0.75, which correspond to their observed averages over the period 1977-2012 in the United States, computed with the data described in section 1. The average share of private consumption in gross domestic product is 67.8% in the data, so $G/\bar{Y}$ is set to 0.319 considering that the real gross domestic product in the model includes production Y_t less recruiting expenses cv_t, and that the latter are assumed to represent 1% of production in the steady state (as in

Andolfatto [1996]). The monetary authority's inflation target is set to 2.5% a year (which is the average growth rate of the private consumption deflator over 1982-2012) and the discount factor δ is calibrated to 0.99 which implies a steady state real return on financial assets of 4.1% a year. Labor productivity is normalized to 1 in the steady state.

Usual parameters are taken from the search and matching and the new Keynesian literature. Following Andolfatto [1996], the steady state probability that a vacant position gets filled during a quarter is set to $\bar{q} = 0.90$. Regarding the job separation rate, the paper exploits more recent results reported by Shimer [2012]. Using a model which allows for the possibility that a worker exits the labor force, he finds that the sum of monthly employment-to-unemployment and employment-to-inactivity flows averages 5% of employment from 1967 to 2010. More precisely, on the basis of the corresponding time series, which are available online[11] from 1967Q2 to 2007Q2, the employment-to-unemployment transition rate averages 0.02 while the employment-to-inactivity transition rate averages 0.03. Consistently, the quarterly job separation rate λ is set to 0.15[12]. Given the considered calibration of the steady state employment and participation rates – which yields an average unemployment rate of 6.7% that is also consistent with the BLS time series used by Shimer [2012] – and the calibration of λ, the restriction that job destruction is equal to job creation in the long run implies that the steady state quarterly job finding rate $\bar{f}$ is 0.68. When the arrival of successful matches for unemployed workers in the steady state is modelled as a Poisson process, the corresponding monthly job finding rate is $1 - (1 - 0.68)^{1/3} = 0.32$, which matches the average monthly unemployment-to-employment transition rate computed with Shimer's time series from 1967Q2 to 2007Q2. Next, the elasticity of the matching function with respect to the number of vacancies κ and firms' bargaining power $1 - \beta$ are equal, so that the Hosios [1990] conditions are satisfied and the equilibrium is socially efficient. They are set to 0.5 as in Mortensen and Pissarides [1994]. The assumption that recruiting expenses represent 1% of output in the steady state implies that $c = 0.06$, and long run restrictions to the matching technology that $\Upsilon = 0.781$. The Calvo probability ξ is assumed to be 0.75, which implies that monopolist retailers can reoptimize their prices approximately once a year on average. The elasticity of substitution s is set to 6, which corresponds to a steady state markup on production prices of 20% for retailers. The degree of price indexation to past inflation ι is 0.5, and the parameters of the monetary policy rule are close to standard values: the reaction to inflation and to the output gap are $r_\pi = 1.5$ and $r_y = 0.125$ respectively. The coefficient on the lagged interest rate ρ is 0.7.

[11] At https://sites.google.com/site/robertshimer/research/flows. Time series are quarterly averages of monthly rates.

[12] The exact quarterly probability corresponding to a monthly job separation probability of 0.05 is $1 - (1 - 0.05)^3 = 0.143$.

The steady state consumption replacement ratio C^u/C^e and the scale parameter of non-participants' utility of home production ζ are chosen such that the optimal participation rate equation (3.5) and the individual participation condition (3.3) are both verified in the long run. The real income of the unemployed z comes from the wage equation (3.7) in the steady state. In a similar way to Hagedorn and Manovskii [2008], the revenues of the non-employed household members are not calibrated on the basis of actual insurance replacement rates or government benefits; here, z and h may include other non-market returns, such as family revenues, or pseudo-revenues reflecting the access to public infrastructure and services. Consistently, I do not calibrate the difference between z and h so that it represents 40% of the steady state wage rate, which is the value usually considered in the literature for unemployment benefits only. Instead, $z-h$ and the curvature of non-participants' utility of home production in the cross-section of households members σ are respectively set to 0.2038 (i.e. 24.8% of the steady state wage rate $\bar{w}$) and 7.8396 in order to match the observed volatility and correlation with output of the participation rate. The calibration of σ to replicate the dynamics of the participation rate is in line with the approach put forward by Ebell [2011] because the aggregate utility of non-participants with heterogeneity is formally similar to a representative agent's concave utility function of home goods consumption. With these values of $z-h$ and σ, I find $\zeta = 2.8301$, $z = 0.7975$ and $C^u/C^e = 0.7277$. The high value found for z (it represents 96.9% of the steady state real wage rate) directly results from vacancy costs – and therefore the firm's accounting profits – being small relatively to sales, and is consistent with the strategy used by Hagedorn and Manovskii [2008] to have large fluctuations in unemployment and vacancies. The steady state value of the consumption replacement ratio C^u/C^e is below empirical estimates of the drop in food consumption associated with becoming unemployed: according to Gruber [1997], this fall would range between 0 and a bit more than 20%, depending on the generosity of the unemployment insurance system; Chetty and Looney [2007] report a value of 10%. But as people consuming C^u in the model may also include long-term non-workers, it is sensible to use a value that is slightly lower than these estimates.

4.2 Exogenous processes

The model assumes two exogenous sources of fluctuations: labor productivity and monetary policy. The latter shock may include non conventional monetary policy decisions as well as all disturbances affecting the transmission of monetary policy decisions to private agents. The logarithm of labor productivity p_t is modelled as an AR(1) process with persistence 0.7 and standard deviation 0.0068. The monetary policy shock is a white noise with standard deviation 0.0062.

4.3 Dynamic properties

In order to assess the dynamic properties of the model, it is simulated assuming rational expectations and using a standard first-order perturbation method (see Judd [1998]). Table 2 reports its asymptotic properties. Since the model is very basic along several dimensions, including the absence of capital, the absence of real rigidities outside the labor market and the small number of exogenous shocks, matching quarterly autocorrelations is considered as outside the scope of this paper, and these moments are not reported[13].

Table 2: Second order moments in the model

		y	l	u	v	v/u
standard deviation		0.014	0.003	0.163	0.156	0.300
correlation matrix	y	1.000	0.471	-0.823	0.626	0.772
	l	–	1.000	-0.860	0.859	0.913
	u	–	–	1.000	-0.772	-0.944
	v	–	–	–	1.000	0.938
	v/u	–	–	–	–	1.000

Notes: The table reports the theoretical standard errors and correlation matrix of the deviations of $\log(Y_t - cv_t)$, $\log L_t$, $\log(L_t - n_t)$, $\log v_t$ and $\log(\frac{v_t}{L_t - n_t})$ from their steady state levels implied by the model.

Not only the model is able to replicate exactly the volatility of the participation rate and its correlation coefficient with output, but it also performs remarkably well regarding the volatility of the tightness ratio. Consistently with the stylized facts presented in section 1, it also predicts volatilities of unemployment and vacancies that are around 10 times higher than output, strongly countercyclical unemployment (the correlation coefficient is -0.823 in the model versus -0.866 is the data) and a negatively sloped Beveridge curve. Yet, the model understates somewhat the correlation coefficients between unemployment and vacancies (with -0.772 versus -0.935 in the data) and between vacancies and output (with 0.626 versus 0.883 in the data). Appendix E shows the impulse response functions simulated with the model.

4.4 Alternative calibrations

In order to investigate the dynamic properties implied by the assumptions of heterogeneous preferences and of unemployment benefits, the model is simulated first with $\sigma = 0$, and then with $z = h$. The first case ($\sigma = 0$) amounts to assuming identical preferences. The household members are then perfectly insured since the consumption arrangement developed above requires that preferences are different; their program is detailed in Appendix F. With $\sigma = 0$, I consider different calibrations of $z - h$, aside from the baseline value $z - h = 0.2038$. First, it is chosen

[13] In RBC models with search and marching frictions as Shimer [2005], the persistence of exogenous technology is almost entirely passed to endogenous variables, whereas basic new Keynesian models generate lower persistence.

to minimize the volatility of the participation rate, and, second, to match the volatility of the tightness ratio in the data. Last, it is assumed to be the highest possible, that is $h = 0$.

The second case ($z = h$) is the absence of extra income for unemployed workers as compared to non-participants, or, in short, no unemployment benefits. I consider two alternative calibrations of σ, which are $\sigma = 7.8396$ as in the baseline and $\sigma = 34.7398$ to match the volatility of the participation rate in the data.

Finally, I set $h = z$ with $\sigma = 0$. This latter situation roughly corresponds to the models proposed by Tripier [2003], Ravn [2008] or Veracierto [2008], since both heterogeneity in preferences and unemployment benefits are cancelled. Table 3 reports a subset of the theoretical second order moments computed for all these cases (the full correlation matrix and standard deviations are provided in Tables 4 to 10 in Appendix G).

Table 3: Comparison with benchmark models

	std(l)	corr(l,y)	std(v/u)	corr(u,v)
data	0.003	0.471	0.280	-0.935
$\sigma = 7.840$ and $z - h = 0.204$	0.003	0.471	0.300	-0.772
no heterogeneity ($\sigma = 0$):				
$z - h = 0.204$	0.012	0.162	0.221	-0.313
$z - h = 0.248$ (minimizes std(l))	0.012	0.017	0.252	-0.420
$z - h = 0.290$ (matches std(v/u))	0.012	-0.113	0.280	-0.497
$z - h = 0.774$ ($h = 0$)	0.020	-0.795	0.553	-0.819
no unemployment benefits ($z - h = 0$):				
$\sigma = 7.840$	0.009	0.699	0.188	-0.436
$\sigma = 34.740$ (matches std(l))	0.003	0.678	0.294	-0.765
no heterogeneity nor u.b. ($\sigma = z - h = 0$)	0.017	0.735	0.051	0.854

Notes: The table reports the theoretical standard errors of the participation rate and the tightness ratio, and the theoretical correlation coefficients of participation and output on the one hand, unemployment and vacancies on the other hand. All variables are log-deviations from steady state levels.

With identical preferences, the model overestimates the volatility of the participation rate whatever the value of $z - h$. With h sufficiently lower than z however, it can replicate the volatility of the tightness ratio, consistently with the result found for the static model of section 2 when preferences are identical (see equation (2.11)). It can also generate a negative correlation between unemployment and vacancies. But it is at the expense of countercyclical movements in the participation rate. With heterogeneous preferences but no unemployment benefits, the model has good properties with respect to the volatility of both the participation rate and the tightness ratio when σ is increased to more than 30. However, it overestimates significantly the correlation of the participation rate with output, whatever the value of σ. When $h = z$ and $\sigma = 0$, as expected, the participation rate in the model is more procyclical than it is in the data, the volatility of the tightness ratio is strongly underestimated and the Beveridge curve is upward sloping (the correlation coefficient between u and v is 0.854). In sum, heterogeneity in preferences is needed to replicate the low volatility of the participation rate in the model. Yet, assuming that the unemployed receive a higher revenue than the non-participants is useful to match simultaneously the magnitude of the fluctuations in the participation rate and the moderate correlation between participation and output.

Concluding remarks

This paper contributes to the literature in several ways. First, it proposes credible foundations to business cycle models with endogenous labor force participation: the sluggishness of the participation rate results from intuitively plausible explanations, that are heterogeneity in households preferences and unemployment benefits, and individuals decide to participate voluntarily in the labor market because they expect to be better-off being employed. Heterogeneity in preferences introduces concavity in the aggregate utility of non-participation. In this respect, it is formally equivalent to assuming that identical households with convex preferences equally share home production. Regarding unemployment benefits, the paper transposes Hagedorn and Manovskii [2008]'s response to the "Shimer puzzle"[14], based on an adequate calibration of non-market revenues, into the "participation puzzle".

Next, the paper successfully incorporates these mechanisms into a new Keynesian framework: the proposed model has very promising dynamic properties. Moreover, with respect to previous business cycle models achieving the objective of small fluctuations in labor force participation, the paper shows that both a concave aggregate utility function of home production and unemployment benefits are needed to replicate simultaneously the volatility and the correlation with output of the participation rate.

Finally, the assumption of memoryless idiosyncratic shocks to preferences, based on previous works of Christiano et al. [2010], is a relatively simple modelling device to deal with heterogeneity without using the representative agent paradigm. Models such as the one proposed in this paper can be solved and simulated numerically using a standard perturbation method while keeping a limited degree of heterogeneity. In particular, this framework could be easily embedded into a larger DSGE model with many frictions and a higher number of shocks, which would be able to fit the data along more dimensions, including persistence.

[14] Shimer [2005] argues that labor demand tends to be insufficiently responsive in search and matching models.

References

David Andolfatto. Business cycles and labor market search. *American Economic Review*, 86: 112–132, 1996.

Olivier Blanchard and Jordi Galí. Labor markets and monetary policy: A new keynesian model with unemployment. *American Economic Journal: Macroeconomics*, 2(2):1–30, April 2010.

Alessia Campolmi and Stefano Gnocchi. Labor market participation, unemployment and monetary policy. Working Paper 2011/4, Magyar Nemzeti Bank, 2011.

Arnaud Chéron and François Langot. Labor market search and real business cycles: Reconciling nash bargaining with the real wage dynamics. *Review of Economic Dynamics*, 7(2):476–493, April 2004.

Raj Chetty and Adam Looney. Income risk and the benefits of social insurance: evidence from indonesia and the united states. In Takatoshi Ito and Andrew K. Rose, editors, *Fiscal policy and Management in East Asia*, volume 16, chapter 4, pages 99–121. University of Chicago Press, 2007.

Lawrence J. Christiano, Mathias Trabandt, and Karl Walentin. Involuntary unemployment and the business cycle. Working Papers 15801, NBER, 2010.

Lawrence J. Christiano, Martin S. Eichenbaum, and Mathias Trabandt. Understanding the great recession. Working Paper 20040, NBER, 2014.

Wouter J. Den Haan and Georg Kaltenbrunner. Anticipated growth and business cycle in matching models. *Journal of Monetary Economics*, 56:309–327, 2009.

Monique Ebell. On the cyclicality of unemployment: resurrecting the participation margin. *Labour Economics*, 18:822–836, 2011.

Michael W. L. Elsby, Bart Hobijn, and Ayşegül Şahin. On the importance of the participation margin for labor market fluctuations. Working Paper 2013-05, Federal Reserve Bank of San Francisco, 2013.

Christopher J. Erceg and Andrew T. Levin. Labor force participation and monetary policy in the wake of the great recession. Working Paper 13/245, International Monetary Fund, 2013.

Jonathan Gruber. The consumption smoothing benefits of unemployment insurance. *Amercian Economic Review*, 87(1):192–205, March 1997.

Christian Haefke, Marcus Sonntag, and Thijs van Rens. Wage rigidity and job creation. *Journal of Monetary Economics*, forthcoming, 2013.

Marcus Hagedorn and Iourii Manovskii. The cyclical behavior of equilibrium unemployment and vacancies revisited. *American Economic Review*, 98(4):1692–1706, 2008.

Arthur J. Hosios. On the efficiency of matching and related models of search and unemployment. *Review of Economic Studies*, 57(3):279–298, 1990.

Kenneth L. Judd. *Numerical methods in Economics*. MIT Press, 1998.

Robert E. Lucas and Edward C. Prescott. Equilibrium search and unemployment. *Journal of Economic Theory*, (106):514–550, 1974.

Dale T. Mortensen and Christopher A. Pissarides. Job creation and job destruction in the theory of unemployment. *Review of Economic Studies*, 61:397–415, 1994.

Christopher A. Pissarides. Short-run equilibrium dynamics of unemployment, vacancies, and real wages. *American Economic Review*, 75(4):676–690, September 1985.

Christopher A. Pissarides. *Equilibrium unemployment theory*. MIT Press, 2nd edition, 2000.

Christopher A. Pissarides. The unemployment volatility puzzle: is wage stickiness an answer? *Econometrica*, 77(5):1339–1369, September 2009.

Morten O. Ravn. The consumption-tightness puzzle. In Lucrezia Reichlin and Kenneth West, editors, *NBER International Seminar on Macroeconomics 2006*, chapter 1, pages 9–63. University of Chicago Press, 2008.

Richard Rogerson. Indivisible labor, lotteries and equilibrium. *Journal of Monetary Economics*, 21:3–16, 1988.

Richard Rogerson and Randall Wright. Involuntary unemployment in economies with efficient risk-sharing. *Journal of Monetary Economics*, 22:501–515, 1988.

Robert Shimer. The cyclical behavior of equilibrium unemployment and vacancies. *American Economic Review*, 95(1):25–49, March 2005.

Robert Shimer. Reassessing the ins and outs of unemployment. *Review of Economics Dynamics*, 15(2):127–148, April 2012.

Robert Shimer. Job search, labor force participation and wage rigidities. In Acemoglu, Arellano, and Dekel, editors, *Advances in Economics and Econometrics: Tenth World Congress*, volume 2, chapter 3, pages 197–235. Cambridge University Press, 2013.

Fabien Tripier. Can the labor market search model explain the allocations of time? *Economic Modelling*, (21):131–146, 2003.

Marcelo Veracierto. On the cyclical behavior of employment, unemployment and the labor force participation. *Journal of Monetary Economics*, 55:1143–1157, September 2008.

A Derivation of the elasticity of the participation rate

Equations (2.1) can be written as

$$J = \frac{p-w}{r+\lambda}, \tag{A.1}$$

and free creation of vacant jobs yields

$$J = \frac{c}{q(\theta)}, \tag{A.2}$$

so

$$p - w - \frac{(r+\lambda)c}{q(\theta)} = 0. \tag{A.3}$$

Equations (2.4), (2.5) and (2.7) imply

$$\left(r+\lambda+\theta q(\theta)\right)(W-U) = w - z = \beta(p-z) + \beta c\theta.$$

Then

$$\begin{aligned}\left(r+\lambda+\beta\theta q(\theta)\right)(W-U) &= \left(r+\lambda+\theta q(\theta)\right)(W-U) - (1-\beta)\theta q(\theta)(W-U)\\ &= \beta(p-z) + \beta c\theta - (1-\beta)\theta q(\theta)(W-U).\end{aligned}$$

Using the Nash bargaining condition and (A.2),

$$W - U = \frac{\beta}{1-\beta}J = \frac{\beta}{1-\beta}\frac{c}{q(\theta)}, \tag{A.4}$$

this equation becomes

$$\left(r+\lambda+\beta\theta q(\theta)\right)(W-U) = \beta(p-z) + \beta c\theta - \beta c\theta = \beta(p-z). \tag{A.5}$$

Substituting into equation (2.4)

$$rU = z + \frac{\beta\theta q(\theta)(p-z)}{r+\lambda+\beta\theta q(\theta)} = \omega(\theta)p + (1-\omega(\theta))z, \tag{A.6}$$

with

$$\omega(\theta) = \frac{\beta\theta q(\theta)}{r+\lambda+\beta\theta q(\theta)}. \tag{A.7}$$

Hence, the participation rate is

$$L = H(a_0) = H\left(\frac{rU-h}{p}\right) = H\left(\omega(\theta)\frac{p-z}{p} + \frac{z-h}{p}\right). \tag{A.8}$$

Differentiating this equation yields

$$dL = \frac{1}{p} H'(a_0) \left(\omega'(\theta)(p-z)\, d\theta - \frac{(1-\omega(\theta))z - h}{p} dp \right),$$

$$\frac{dL}{dp} = \frac{1}{p} H'(a_0) \left(\omega'(\theta)(p-z) \frac{d\theta}{dp} + \omega(\theta)\frac{z}{p} - \frac{z-h}{p} \right), \tag{A.9}$$

with

$$\omega'(\theta) = \frac{(r+\lambda)\beta(\theta q'(\theta) + q(\theta))}{(r+\lambda+\beta\theta q(\theta))^2}.$$

Let

$$\eta \equiv \frac{\partial \log \theta q(\theta)}{\partial \log \theta} = 1 + \theta \frac{q'(\theta)}{q(\theta)}$$

be the elasticity of the job finding rate with respect to tightness. Then

$$\omega'(\theta) = \frac{(r+\lambda)\eta\beta q(\theta)}{(r+\lambda+\beta\theta q(\theta))^2}.$$

Deriving the elasticity of participation with respect to productivity from (A.9) requires calculating the elasticity of tightness with respect to productivity, as in Hagedorn and Manovskii [2008]: equations (A.3) and (2.7) imply that

$$(1-\beta)(p-z) - \beta c\theta = \frac{(r+\lambda)c}{q(\theta)}. \tag{A.10}$$

Differentiating this equation gives

$$\begin{aligned}
(1-\beta)\, dp - \beta c d\theta &= -\frac{(r+\lambda)cq'(\theta)}{q(\theta)^2} d\theta \\
(1-\beta)\, dp - \beta c d\theta &= \frac{(r+\lambda)c(1-\eta)}{\theta q(\theta)} d\theta \\
(1-\beta)\, dp &= \left(\beta c + \frac{(r+\lambda)c(1-\eta)}{\theta q(\theta)} \right) d\theta.
\end{aligned}$$

Equation (A.10) can be written as

$$1 - \beta = \frac{1}{p-z} \left(\frac{(r+\lambda)c}{q(\theta)} + \beta c\theta \right),$$

which implies

$$\begin{aligned}
\frac{1}{p-z} \left(\frac{(r+\lambda)c}{q(\theta)} + \beta c\theta \right) dp &= \left(\beta c + \frac{(r+\lambda)c(1-\eta)}{\theta q(\theta)} \right) d\theta \\
\frac{\theta}{p-z} (r+\lambda+\beta\theta q(\theta))\, dp &= (\beta\theta q(\theta) + (r+\lambda)(1-\eta))\, d\theta
\end{aligned}$$

$$\frac{d\theta}{dp} = \frac{\theta}{p-z}\frac{r+\lambda+\beta\theta q(\theta)}{(r+\lambda)(1-\eta)+\beta\theta q(\theta)} \tag{A.11}$$

Substituting (A.11) into (A.9) gives

$$\begin{aligned}
\frac{dL}{dp} &= \frac{1}{p}H'\left(a_0\right)\left(\omega'(\theta)\theta\frac{r+\lambda+\beta\theta q(\theta)}{(r+\lambda)(1-\eta)+\beta\theta q(\theta)} + \omega(\theta)\frac{z}{p} - \frac{z-h}{p}\right) \\
&= \frac{1}{p}H'\left(a_0\right)\left(\frac{(r+\lambda)\eta\beta\theta q(\theta)}{(r+\lambda+\beta\theta q(\theta))^2}\frac{r+\lambda+\beta\theta q(\theta)}{(r+\lambda)(1-\eta)+\beta\theta q(\theta)} + \frac{\beta\theta q(\theta)}{r+\lambda+\beta\theta q(\theta)}\frac{z}{p} - \frac{z-h}{p}\right) \\
&= \frac{1}{p}H'\left(a_0\right)\left[\frac{\beta\theta q(\theta)}{r+\lambda+\beta\theta q(\theta)}\left(\frac{(r+\lambda)\eta}{(r+\lambda)(1-\eta)+\beta\theta q(\theta)} + \frac{z}{p}\right) - \frac{z-h}{p}\right],
\end{aligned}$$

and

$$\frac{dL}{dp}\frac{p}{L} = \frac{H'\left(a_0\right)}{H(a_0)}\left[\frac{\beta\theta q(\theta)}{r+\lambda+\beta\theta q(\theta)}\left(\frac{(r+\lambda)\eta}{(r+\lambda)(1-\eta)+\beta\theta q(\theta)} + \frac{z}{p}\right) - \frac{z-h}{p}\right].$$

B Households' decisions

Let $\Gamma \equiv C^e/C^u > 1$ denote the inverse of the consumption replacement ratio. The participation condition is:

$$n_t \log \Gamma_t = \zeta L_t^{1+\sigma}$$

Aggregate utility is:

$$\begin{aligned}
U_t &= \int_0^{L_t}\left(\frac{n_t}{L_t}\log C_t^e + \left(1-\frac{n_t}{L_t}\right)\log C_t^u\right)di + \int_{L_t}^1\left(\log C_t^u + \zeta i^\sigma\right)di \\
&= n_t \log C_t^e + (L_t - n_t)\log C_t^u + (1-L_t)\log C_t^u + \frac{\zeta}{1+\sigma}(1-L_t^{1+\sigma}) \\
&= n_t \log \Gamma_t + \log C_t^u + \frac{\zeta}{1+\sigma} - \frac{\zeta}{1+\sigma}L_t^{1+\sigma} \\
&= \zeta L_t^{1+\sigma} + \log C_t^u + \frac{\zeta}{1+\sigma} - \frac{\zeta}{1+\sigma}L_t^{1+\sigma} \\
&= \log C_t^u + \zeta\left(1-\frac{1}{1+\sigma}\right)L_t^{1+\sigma} + \frac{\zeta}{1+\sigma} \\
&= \log C_t^u + \frac{\zeta\sigma}{1+\sigma}L_t^{1+\sigma} + \frac{\zeta}{1+\sigma}
\end{aligned}$$

The sum of individual consumptions equals aggregate consumption C_t so:

$$\log C_t = \log\left(n_t C_t^e + (1-n_t)C_t^u\right) = \log\left(n_t\frac{C_t^e}{C_t^u}C_t^u + (1-n_t)C_t^u\right) = \log\left(n_t\Gamma_t + 1 - n_t\right) + \log C_t^u$$

Therefore aggregate utility is:

$$U_t = \log C_t - \log\left(n_t\Gamma_t + 1 - n_t\right) + \frac{\zeta\sigma}{1+\sigma}L_t^{1+\sigma} + \frac{\zeta}{1+\sigma}$$

The program of the family is (the constant in utility is omitted):

$$
\begin{aligned}
V_t(b_{t-1}, n_{t-1}) = \max_{C_t, L_t, \Gamma_t, n_t, b_t} \Bigg\{ & \log C_t - \log(n_t \Gamma_t + 1 - n_t) + \frac{\zeta\sigma}{1+\sigma} L_t^{1+\sigma} + \delta E_t \left[V_{t+1}(b_t, n_t) \right] \\
& + \Lambda_t \left(b_{t-1} \frac{r_{t-1}}{P_t} + n_t w_t + (L_t - n_t) z + (1 - L_t) h - C_t - \frac{b_t}{P_t} + t_t + div_t \right) \\
& + \mu_t \left((1-\lambda)(1-f_t) n_{t-1} + f_t L_t - n_t \right) \\
& + \nu_t \left(n_t \log \Gamma_t - \zeta L_t^{1+\sigma} \right) \Bigg\}
\end{aligned}
$$

where the three constraints (budget constraint, law of motion of employment and participation condition) are directly written using a Lagrangian form. The first order conditions yield:

- w.r.t. C_t:

$$\frac{1}{C_t} = \Lambda_t$$

- w.r.t. Γ_t:

$$\nu_t = \frac{\Gamma_t}{n_t \Gamma_t + 1 - n_t}$$

- w.r.t. L_t:

$$\zeta\sigma L_t^{\sigma} + \Lambda_t(z - h) + \mu_t f_t = \nu_t \zeta (1+\sigma) L_t^{\sigma}$$

- w.r.t. n_t:

$$-\frac{\Gamma_t - 1}{n_t \Gamma_t + 1 - n_t} + \delta E_t \left[\frac{\partial V_{t+1}}{\partial n_t} \right] + \Lambda_t (w_t - z) - \mu_t + \nu_t \log \Gamma_t = 0$$

- w.r.t. b_t:

$$\delta E_t \left[\frac{\partial V_{t+1}}{\partial b_t} \right] = \frac{\Lambda_t}{P_t}$$

And the envelope conditions:

- w.r.t. b_{t-1}:

$$\frac{\partial V_t}{\partial b_{t-1}} = r_{t-1} \frac{\Lambda_t}{P_t}$$

- w.r.t. n_{t-1}:

$$\frac{\partial V_t}{\partial n_{t-1}} = \mu_t (1-\lambda)(1-f_t)$$

From the definition of aggregate consumption

$$\nu_t = \frac{\Gamma_t}{n_t \Gamma_t + 1 - n_t} = \frac{C_t^e}{C_t} = 1 + \frac{C_t^e - C_t}{C_t} = 1 + (1-n_t) \frac{C_t^e - C_t^u}{C_t} = 1 + (1-n_t) \Lambda_t (C_t^e - C_t^u)$$

and

$$\frac{\Gamma_t - 1}{n_t\Gamma_t + 1 - n_t} = \frac{C_t^e - C_t^u}{C_t} = \Lambda_t(C_t^e - C_t^u)$$

From the Nash bargaining condition:

$$(1-\beta)\frac{\partial V_t}{\partial n_{t-1}} = \beta\Lambda_t(1-f_t)\frac{\partial W_t}{\partial n_{t-1}}$$

And the optimal decision of the representative firm yields:

$$\frac{\partial W_t}{\partial n_{t-1}} = (1-\lambda)\frac{c}{q_t}$$

Therefore:

$$\frac{\partial V_t}{\partial n_{t-1}} = \frac{\beta}{1-\beta}\Lambda_t(1-f_t)(1-\lambda)\frac{c}{q_t}$$

and

$$\mu_t = \frac{\beta}{1-\beta}\Lambda_t\frac{c}{q_t}$$

Finally, the optimal participation condition becomes:

$$\Lambda_t(z-h) + c\frac{\beta}{1-\beta}\Lambda_t\frac{f_t}{q_t} = \left(1 + (1+\sigma)(1-n_t)\Lambda_t(C_t^e - C_t^u)\right)\zeta L_t^\sigma$$

The marginal utility cost of higher participation represented by the right side of this expression can be interpreted as follows: ζL_t^σ corresponds to the decrease in home production, while $(1+\sigma)(1-n_t)\Lambda_t(C_t^e - C_t^u)\zeta L_t^\sigma$ is the effect of the reallocation of consumption in favor of the employed workers.

C Wage bargaining

The marginal value of employment for the household is:

$$\frac{\partial V_t}{\partial n_{t-1}} = (1-\lambda)(1-f_t)\left(\Lambda_t(w_t - z) - \Lambda_t(C_t^e - C_t^u) + \delta E_t\left[\frac{\partial V_{t+1}}{\partial n_t}\right] + \Lambda_t C_t^e(\log C_t^e - \log C_t^u)\right)$$

The term $-\Lambda_t(C_t^e - C_t^u)$ reflects the fact that increasing the number of employed workers (with high consumption) implies that individual consumptions are diminished when aggregate consumption and the replacement ratio are unchanged. The term $\Lambda_t C_t^e(\log C_t^e - \log C_t^u)$ stands for the fact that job creation relaxes somewhat the individual participation constraint (3.3): since it improves the job finding rate, it makes the participant state more attractive, which allows a reallocation of consumption in favor of the non-employed household members.

The marginal value of employment for the firm is:

$$\frac{\partial W_t}{\partial n_{t-1}} = (1-\lambda)\left(x_t p_t - w_t + \delta E_t\left[\frac{\Lambda_{t+1}}{\Lambda_t}\frac{\partial W_{t+1}}{\partial n_t}\right]\right)$$

Substituting into the Nash bargaining condition yields:

$$\begin{aligned}(1-\beta)&\left((w_t - z) - (C_t^e - C_t^u) + \delta E_t\left[\frac{1}{\Lambda_t}\frac{\partial V_{t+1}}{\partial n_t}\right] + C_t^e(\log C_t^e - \log C_t^u)\right)\\ &= \beta\left(x_t p_t - w_t + \delta E_t\left[\frac{\Lambda_{t+1}}{\Lambda_t}\frac{\partial W_{t+1}}{\partial n_t}\right]\right)\end{aligned}$$

$$\begin{aligned}w_t = &\ \beta x_t p_t + (1-\beta)\left(z + C_t^e - C_t^u - C_t^e(\log C_t^e - \log C_t^u)\right)\\ &+ \beta\delta E_t\left[\frac{\Lambda_{t+1}}{\Lambda_t}\frac{\partial W_{t+1}}{\partial n_t}\right] - \beta\delta E_t\left[\frac{\Lambda_{t+1}}{\Lambda_t}(1-f_{t+1})\frac{\partial W_{t+1}}{\partial n_t}\right]\end{aligned}$$

$$\begin{aligned}w_t = &\ (1-\beta)\left(z + C_t^e - C_t^u - C_t^e(\log C_t^e - \log C_t^u)\right)\\ &+ \beta\left(x_t p_t + \delta E_t\left[\frac{\Lambda_{t+1}}{\Lambda_t}f_{t+1}\frac{\partial W_{t+1}}{\partial n_t}\right]\right)\end{aligned}$$

$$\begin{aligned}w_t = &\ (1-\beta)\left(z + C_t^e - C_t^u - C_t^e(\log C_t^e - \log C_t^u)\right)\\ &+ \beta\left(x_t p_t + c\delta(1-\lambda)E_t\left[\frac{\Lambda_{t+1}}{\Lambda_t}\frac{f_{t+1}}{q_{t+1}}\right]\right)\end{aligned}$$

D Welfare comparison between perfect and imperfect insurance with information asymmetry

If the household members adopt a perfect insurance system, then participants in the labor market are chosen using a lottery. All individuals consume and save the same amount, so the instantaneous utility of the household who consumes C when the participation rate is L is given by:

$$U^{pi} = \log C + (1-L)\int_0^1 (\zeta i^\sigma)\, di = \log C + \frac{\zeta}{1+\sigma}(1-L)$$

whereas it is:

$$U^{ii} = \log C - \log\left(n\frac{C^e}{C^u} + 1 - n\right) + \frac{\zeta\sigma}{1+\sigma}L^{1+\sigma} + \frac{\zeta}{1+\sigma}$$

under the imperfect insurance assumption. Set out below is the difference in steady state aggregate utility levels between the imperfect insurance and the perfect insurance cases for given C, n and L, and assuming a degree of generosity of the imperfect insurance scheme summarized by $\frac{C^u}{C^e}$:

$$U^{ii} - U^{pi} = \frac{\zeta}{1+\sigma}\left(\sigma L^{1+\sigma} + L\right) - \log\left(n\frac{C^e}{C^u} + 1 - n\right)$$

With the proposed calibration, this difference is approximately 0.2048 in the steady state, so the imperfect insurance scheme yields an instantaneous utility that is 22.7% higher on average (in terms of consumption units) than the perfect insurance. It will thus be preferred by households. This is because some household members with the highest utilities of home production are likely to be chosen as participants when the selection involves a the lottery.

E Impulse response functions

Impulse responses are plotted in log-deviations from steady state levels.

Figure 2: Impulse responses to a 1% technology shock

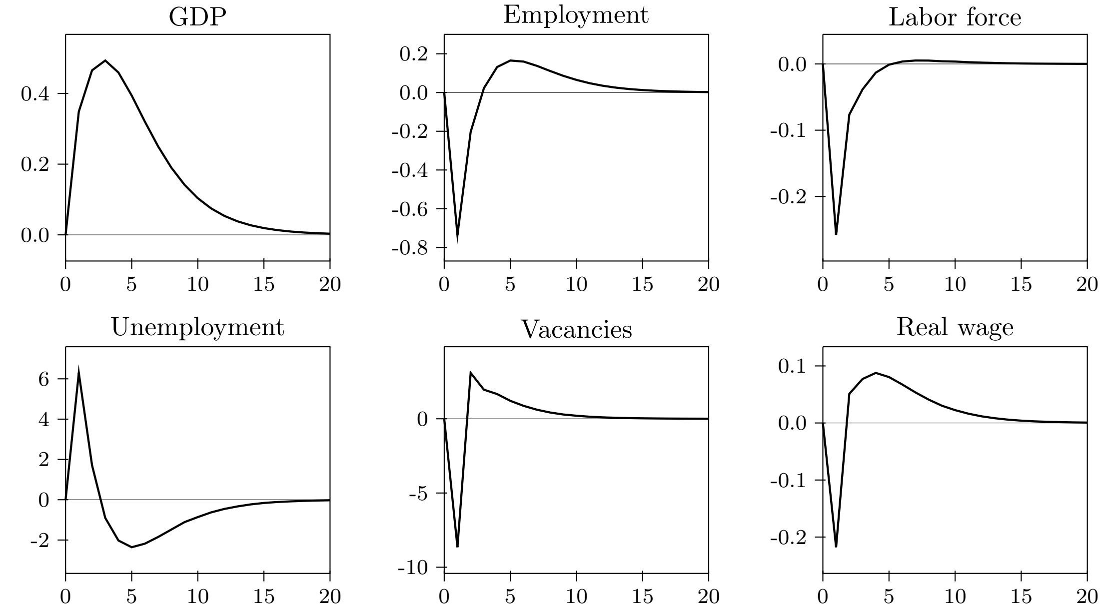
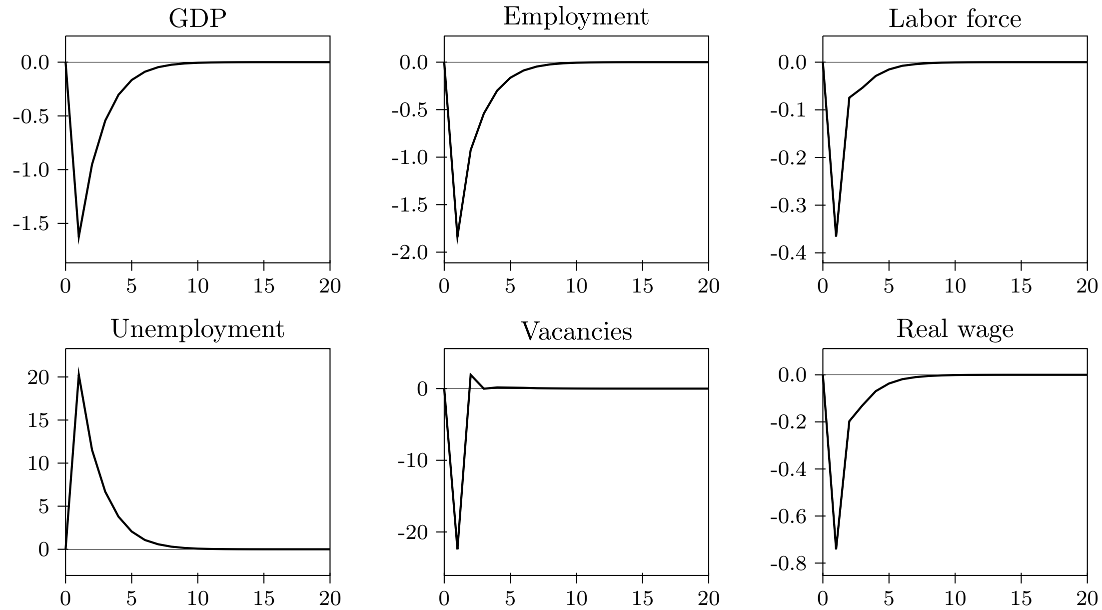


Figure 3: Impulse responses to a 1% monetary policy shock



F Identical preferences

There is a large number, normalized to 1, of identical housholds. Each household includes a continuum of members with a mass of 1. The instantaneous utility of a household member who consumes C in the current period is

$$U(i,C) = \begin{cases} \log C + \zeta & \text{if out of the labor force,} \\ \log C & \text{if in the labor force,} \end{cases},$$

where ζ is the common utility of home production. The model assumes a lottery to choose among individuals those who participate in the labor market and among participants those who are actually employed. Households members insure themselves against idiosyncratic risks that arise from these lotteries: at the beginning of period t, each individual decides to buy $\tilde{b}_t$ units of participation insurance at price $\tilde{\tau}_t$ that pay $\tilde{b}_t$ in real terms whenever he is not selected to participate in the labor market during period t, and $\breve{b}_t$ units of unemployment insurance at price $\breve{\tau}_t$ that pay $\breve{b}_t$ in real terms whenever he is selected to participate but is not appointed to a job. The ex ante (i.e. before being selected or not for participation and a fortiori being hired or not) value function of an individual holding nominal assets for b_{t-1} and when employment was n_{t-1} during the previous period is:

$$\begin{aligned} V_t(b_{t-1}, n_{t-1}) = \max_{\mathcal{C}_t} \Big\{ & n_t \left(\log C_t^e + \delta E_t V_{t+1}(b_t^e, n_t)\right) \\ & + (L_t - n_t)\left(\log C_t^u + \delta E_t V_{t+1}(b_t^u, n_t)\right) + (1 - L_t)\left(\log C_t^o + \zeta + \delta E_t V_{t+1}(b_t^o, n_t)\right) \Big\} \\ & \text{s.t.} \\ & C_t^e + \frac{b_t^e}{P_t} + \tilde{\tau}_t \tilde{b}_t + \breve{\tau}_t \breve{b}_t \leq b_{t-1}\frac{r_{t-1}}{P_t} + w_t + T_t + div_t \\ & C_t^u + \frac{b_t^u}{P_t} + \tilde{\tau}_t \tilde{b}_t + \breve{\tau}_t \breve{b}_t \leq b_{t-1}\frac{r_{t-1}}{P_t} + z + \breve{b}_t + T_t + div_t \\ & C_t^o + \frac{b_t^o}{P_t} + \tilde{\tau}_t \tilde{b}_t + \breve{\tau}_t \breve{b}_t \leq b_{t-1}\frac{r_{t-1}}{P_t} + h + \tilde{b}_t + T_t + div_t \\ & n_t \leq (1-\lambda)(1-\phi_t)n_{t-1} + f_t L_t \end{aligned}$$

Where

$$\mathcal{C}_t \equiv \left\{ C_t^e, C_t^u, C_t^o, b_t^e, b_t^u, b_t^o, \tilde{b}_t, \breve{b}_t, L_t, n_t \right\}$$

is the vector of variables that are decided by each individual in period t. Let Λ_t^e, Λ_t^u and Λ_t^o be the Lagrange multipliers associated with these budget constraints. The first order conditions yield:

$$\Lambda_t^e = \frac{1}{C_t^e}\ ,\quad \Lambda_t^u = \frac{1}{C_t^u}\ ,\quad \Lambda_t^o = \frac{1}{C_t^o}$$

$$\Lambda_t^e n_t \tilde{\tau}_t + \Lambda_t^u (L_t - n_t)\tilde{\tau}_t + \Lambda_t^o (1-L_t)(\tilde{\tau}_t - 1) = 0$$

$$\Lambda_t^e n_t \breve{\tau}_t + \Lambda_t^u (L_t - n_t)(\breve{\tau}_t - 1) + \Lambda_t^o (1-L_t)\breve{\tau}_t = 0$$

$$\delta E_t \frac{\partial V_{t+1}}{\partial b_t^e} = \frac{\Lambda_t^e}{P_t}$$

$$\delta E_t \frac{\partial V_{t+1}}{\partial b_t^u} = \frac{\Lambda_t^u}{P_t}$$

$$\delta E_t \frac{\partial V_{t+1}}{\partial b_t^o} = \frac{\Lambda_t^o}{P_t}$$

Free entry in the insurance market implies:

$$\tilde{\tau}_t = 1 - L_t$$

$$\breve{\tau}_t = L_t - n_t$$

Therefore:

$$\Lambda_t^e = \Lambda_t^u = \Lambda_t^o \quad \Leftrightarrow \quad C_t^e = C_t^u = C_t^o \equiv C_t$$

As the objective function V_{t+1} is a bijection, we get:

$$b_t^e = b_t^u = b_t^o \equiv b_t$$

From the budget constraints, we have immediately:

$$\tilde{b}_t = w_t - h$$

$$\breve{b}_t = w_t - z$$

The problem can be written with a representative household formulation. The latter has the following objective function:

$$V_t(b_{t-1}, n_{t-1}) = \max_{C_t, L_t, n_t, b_t} \left\{ \log C_t + (1-L_t)\zeta + \delta E_t V_{t+1}(b_t, n_t) \right\}$$

s.t.

$$C_t + \frac{b_t}{P_t} \leq b_{t-1}\frac{r_{t-1}}{P_t} + n_t w_t + (L_t - n_t)z + (1-L_t)h + T_t + div_t$$

$$n_t \leq (1-\lambda)(1-f_t)n_{t-1} + f_t L_t$$

This program yields the first order condition with respect to the participation rate

$$\zeta = c\frac{\beta}{1-\beta}\Lambda_t\frac{f_t}{q_t} + \Lambda_t(z-h),$$

and the wage equation becomes

$$w_t = (1-\beta)z + \beta\left(x_t p_t + \delta(1-\lambda)cE_t\left[\frac{\Lambda_{t+1}}{\Lambda_t}\frac{f_{t+1}}{q_{t+1}}\right]\right).$$

G Dynamic properties under alternative calibrations

The dynamic properties of the model for the different calibrations considered in the paper are reported in the following tables:

Table 4: Second order moments with $\sigma = 0$ and $z - h = 0.2038$

		y	l	u	v	v/u
standard deviation		0.013	0.012	0.147	0.124	0.221
correlation matrix	y	1.000	0.162	-0.844	0.773	1.000
	l	–	1.000	0.266	0.601	0.162
	u	–	–	1.000	-0.313	-0.844
	v	–	–	–	1.000	0.773
	v/u	–	–	–	–	1.000

Notes: The table reports the theoretical standard errors and correlation matrix of the deviations of $\log(Y_t - cv_t)$, $\log n_t$, $\log L_t$, $\log(L_t - n_t)$, $\log v_t$ and $\log(\frac{v_t}{L_t - n_t})$ from their steady state levels.

Table 5: Second order moments with $\sigma = 0$ and $z - h = 0.2481$

		y	l	u	v	v/u
standard deviation		0.013	0.012	0.167	0.130	0.252
correlation matrix	y	1.000	0.017	-0.883	0.797	1.000
	l	–	1.000	0.343	0.472	0.017
	u	–	–	1.000	-0.420	-0.883
	v	–	–	–	1.000	0.797
	v/u	–	–	–	–	1.000

Table 6: Second order moments with $\sigma = 0$ and $z - h = 0.2899$

		y	l	u	v	v/u
standard deviation		0.012	0.012	0.186	0.136	0.280
correlation matrix	y	1.000	-0.113	-0.907	0.816	1.000
	l	–	1.000	0.421	0.344	-0.113
	u	–	–	1.000	-0.497	-0.907
	v	–	–	–	1.000	0.816
	v/u	–	–	–	–	1.000

Table 7: Second order moments with $\sigma = 0$ and $z - h = 0.7742$

		y	l	u	v	v/u
standard deviation		0.010	0.020	0.382	0.195	0.553
correlation matrix	y	1.000	-0.795	-0.979	0.918	1.000
	l	–	1.000	0.871	-0.548	-0.795
	u	–	–	1.000	-0.819	-0.979
	v	–	–	–	1.000	0.918
	v/u	–	–	–	–	1.000

Table 8: Second order moments with $\sigma = 7.8396$ and $z - h = 0$

		y	l	u	v	v/u
standard deviation		0.015	0.009	0.091	0.129	0.188
correlation matrix	y	1.000	0.699	-0.801	0.604	0.804
	l	–	1.000	-0.745	0.909	0.987
	u	–	–	1.000	-0.436	-0.785
	v	–	–	–	1.000	0.900
	v/u	–	–	–	–	1.000

Table 9: Second order moments with $\sigma = 34.7398$ and $z - h = 0$

		y	l	u	v	v/u
standard deviation		0.014	0.003	0.159	0.154	0.294
correlation matrix	y	1.000	0.678	-0.779	0.609	0.740
	l	–	1.000	-0.937	0.933	0.996
	u	–	–	1.000	-0.765	-0.941
	v	–	–	–	1.000	0.937
	v/u	–	–	–	–	1.000

Table 10: Second order moments with $\sigma = 0$ and $z - h = 0$

		y	l	u	v	v/u
standard deviation		0.017	0.017	0.081	0.098	0.051
correlation matrix	y	1.000	0.735	0.047	0.560	1.000
	l	–	1.000	0.547	0.837	0.735
	u	–	–	1.000	0.854	0.047
	v	–	–	–	1.000	0.560
	v/u	–	–	–	–	1.000

Documents de Travail

480. E. Mengus, “Honoring Sovereign Debt or Bailing Out Domestic Residents: A Theory of Internal Costs of Default,” March 2014

481. C. Labonne and G. Lamé, “Credit Growth and Bank Capital Requirements: Binding or Not?,” March 2014

482. S. Gilchrist and B. Mojon, “Credit Risk in the Euro area,” April 2014

483. G. Vuillemey and R. Breton, “Endogenous Derivative Networks,” April 2014

484. G. Cette, R. Lecat and A-O-A. Jiddou, “How do firms adjust production factors to the cycle?,” April 2014

485. M. Bussière, B. Camara, F.-D. Castellani, V. Potier and J. Schmidt, “ Shock Transmission Through International Banks - Evidence From France,” May 2014

486. A. Monfort, J-P. Renne and G. Roussellet, “A Quadratic Kalman Filter,” May 2014

487. P. Benczúr, G. Kátay, Á. Kiss and O. M. Rácz, “Income Taxation, Transfers and Labour Supply at the Extensive Margin,” June 2014

488. R. Jimborean and A. Kelber, “Foreign direct investment drivers and growth in Central and Eastern Europe in the aftermath of the 2007 global financial crisis,” June 2014

489. F. Pegoraro, A. F. Siegel and L. Tiozzo ‘Pezzoli, “International Yield Curves and Principal Components Selection Techniques: An Empirical Assessment,” June 2014

490. F. Pegoraro, A. F. Siegel and L. Tiozzo ‘Pezzoli, “Specification Analysis of International Treasury Yield Curve Factors,” June 2014

491. J-S. Mésonnier and A. Monks, “Did the EBA Capital Exercise Cause a Credit Crunch in the Euro Area?,” June 2014

492. F. Alvarez , H. Le Bihan and F. Lippi, “Small and large price changes and the propagation of monetary shocks,” June 2014

493. A. Devulder, “Heterogeneity, Unemployment Benefits and Voluntary Labor Force Participation,” June 2014

Pour accéder à la liste complète des Documents de Travail publiés par la Banque de France veuillez consulter le site : www.banque-france.fr

For a complete list of Working Papers published by the Banque de France, please visit the website: www.banque-france.fr

Pour tous commentaires ou demandes sur les Documents de Travail, contacter la bibliothèque de la Direction Générale des Études et des Relations Internationales à l'adresse suivante :

For any comment or enquiries on the Working Papers, contact the library of the Directorate General Economics and International Relations at the following address :

BANQUE DE FRANCE
49- 1404 Labolog
75049 Paris Cedex 01
tél : 0033 (0)1 42 97 77 24 ou 01 42 92 63 40 ou 48 90 ou 69 81
email : 1404-ut@banque-france.fr