Uncertainty and labor force participation

Idriss Fontaine*

November 8, 2016

Abstract

Is an increase in uncertainty able to generate a fall in labor force participation? This paper provides some evidence indicating that the answer to this question is probably positive. Through a lens of a Bayesian VAR, I show that a surge in uncertainty leads to a decrease in participation which follows an u-shaped path. Then, I build a New Keynesian DSGE model with a frictional labor market, endogenous labor force and stochastic volatility. I show that the replication of the empirical comovements is not straightforward. A model with flexible prices gives counter-intuitive results. It gives rise to a strong precautionary saving motive inducing expansionary effects of uncertainty. In contrast, a model with price stickiness is able to reproduce the negative empirical comovements. As firms postpone their hiring investments, labor market tightness decreases and the household responds by reducing the labor force. I also show that monetary policy can have an important stabilizing role, while, wage rigidities greatly amplify the recessionary effects of uncertainty on output and participation.
Keywords: Uncertainty, labor force participation, New Keynesian model
JEL classifications: E32, E24, J21

*Université de La Réunion - CEMOI. email: idriss.fontaine@univ-reunion.fr. I am deeply grateful to Alexis Parmentier for his invaluable guidance and encouragement. I am also thankful for comments from François Langot and participants at the *CEMOI seminar*, *the October 2016 TEPP conference* in La Reunion. I am also indebted to Olivier Darné for providing me the CUI data. All errors are of my responsibility.

1 Introduction

In contrast to other post WW-II recessions, the Great Recession of 2008 and the subsequent slow recovery were accompanied by a persistent increase in uncertainty[1]. Policy designers or economic press have often argued that uncertainty is a key factor explaining the sluggish rebounds of the years 2009-2010. This unusual macroeconomic behavior is at the origin of a burgeoning academic attention for uncertainty. The pioneer contribution of Bloom (2009), prolonged by those of Fernández-Villaverde et al. (2011), Bachmann et al. (2013) or Basu and Bundick (2014) among others, indicates that heightened uncertainty impedes economic activity. A strand of this growing body of literature puts attention to the aftermaths of higher uncertainty on the labor market. Empirically, the work of Caggiano et al. (2014) suggests that uncertainty shock lead to a non-negligible increase in unemployment. Theoretically, the recent contribution of Leduc and Liu (2016) indicates that a surge in uncertainty pushes up the firm option value of "wait and see" for having more information about the future of the economy. As firms react by posting fewer vacancies unemployment unambiguously increases. However, to the best of my knowledge, all of these papers do not consider the participation margin. They are silent about a possible influence of uncertainty on the labor force participation (LFP, henceforth).

Macroeconomists often abstract from the participation margin since it is recognized that it is mainly acyclical over the business cycle. However, this conventional wisdom is challenged by, at least, two recent facts. First, Elsby et al. (2015) demonstrate that entries and exits from non-participation account for one third of cyclical fluctuations in unemployment. Second, the downward trend followed by the U.S. LFP rate accelerated during the depth recession following the Great Recession, a period characterized by unusual level of uncertainty[2]. The purpose of this paper is to make the connection between these two concepts. In other words, what the data tell us about the response of LFP consecutive to an uncertainty shock? To what extent uncertainty impacts the participation in the U.S.? What is transmission channel of uncertainty shocks when the economy explicitly include a participation margin?

To give answers to these questions, I investigate the empirical link between LFP and uncertainty. In particular, along the lines of Caggiano et al. (2014), Bachmann et al. (2013) and

[1]It is quite hard to provide a consensual definition of uncertainty. In general, it should be understood as the unpredictability about the future state of the economy. This unpredictability may have several sources, such as, bad anticipations about the future level of macroeconomic variables (for instance, GDP, inflation or exchange rates), the indecision about economic policy (for instance, fiscal policy), concerns over the evolution of financial markets (for instance, European debt crisis, bankruptcy of Lehman Brothers) or major events (for instance, terrorist attacks or the *Brexit*).

[2]BLS measures indicate that the participation rate has fallen about 2 percentage points during the first quarter of 2008 and the second quarter of 2011. Furthermore, Erceg and Levin (2014) find that the bulk of LFP variations during the Great Recession can be explained by cyclical factors

Leduc and Liu (2016), I estimate the joint dynamics of uncertainty, output and LFP within a Bayesian vector autoregression (VAR, henceforth) framework. As a proxy for uncertainty I use the Historical Economic Policy Index developed by Baker et al. (2015). I follow the bulk of the literature by isolating an uncertainty shock by using a Cholesky-type decomposition, the measure of uncertainty being ordered first in the VAR. The evidence is quite clear. An unexpected increase of uncertainty leads to a non-significant impact response of LFP. However, between 2 or 3 quarters after the shock, participation significantly decreases and follows an u-shaped path. This empirical evidence is robust to several alternative VAR estimations. Thus, changing the proxy for uncertainty, the participation variable and the Cholesky ordering do not alter the qualitative pattern followed by LFP in response to uncertainty surprise.

After the presentation of the empirical evidence, I adopt a theoretical point of view to rationalize the transmission channel of uncertainty. More specifically, I develop a New-Keynesian DSGE model embedding a frictional labor market and stochastic uncertainty volatility about the level of aggregate productivity. In contrast to previous works, the participation margin is explicitly modeled. Based on this framework, I operate step by step. First, I eliminate price stickiness in the model to put in light to what extent the option value of waiting operates. Under this scenario, the macroeconomic effect of uncertainty is expansionary since output and participation increase. This finding suggests that the non-abstraction from the participation margin induces a precautionary saving motive which undoes the "wait and see" channel. Hence, a model with flexible prices is unable to replicate the empirical comovements observed between uncertainty, output, and LFP.

Second, I activate the demand channel by adding sticky prices to the model. This framework allows me to have theoretical comovements which are in line with those observed in the data. Along the lines of Basu and Bundick (2014), I find that the demand channel helps to greatly amplify the transmission of uncertainty shock. Most prominently, heightened uncertainty prevents firms to reset prices and they must cut-off production to meet the depressed demand. Furthermore, driven by the "wait and see" behavior, firms become more cautious in their hiring decisions. Finally, observe that higher uncertainty leads to an increase in markups which is an additional channel for the propagation of the shock. These three mechanisms lead to a fall in future firm profits which react by opening fewer vacancies. As search activities have a lower probability to be successful, the value of participation of household decreases and the overall level of participation diminishes.

Finally, I test the sensitivity of the theoretical results to alternative parameterizations of the model. On the overall, the qualitative responses of the model economy are preserved, and a spike in uncertainty induces a fall in participation. I confirm the intuition of Cacciatore and Ravenna (2015). In addition to the demand channel, wage rigidities appear to be also an important factor for the magnification of an uncertainty shock. Furthermore, I also show that a specific monetary policy, which reacts to output gap and unemployment gap, may have an important stabilizing role.

The outline of the paper is structured as follows. Section 2 presents a brief survey of the literature. Section 3 investigates the empirical joint dynamics between uncertainty and participation. Section 4 describes the model economy. Section 5 presents simulations of the model and the main result. Finally, I conclude in section 6.

2 Related litterature

This paper combines two strands of literature. The first one aims at understanding LFP dynamics. The second one studies the macroeconomic impact of uncertainty.

2.1 Labor force participation

In contrast to the unemployment rate, the LFP rate is essentially acyclical. Based on this kind of evidence, the bulk of modern researches focuses on frameworks neglecting the participation margin. Nonetheless, current empirical evidence contradicts this view of labor market dynamics. In a recent article, Elsby et al. (2015) show that entries and exits from the labor force are at the origin of one third of unemployment variations. Furthermore, in recent years, the LFP rate displays an interesting feature. As indicated in figure 1, the LFP rate has begun to decline since the 2000's decade and this downward trend was not inverted. Is this fall in the LFP the consequence of demographic factors? Some elements suggest a negative answer to this question. First, it is noteworthy that the fall trend decelerated between 2004 and 2007, before reinforced its decline with the Great Recession and the deep recession accompanying it. Second, several works, as those of Erceg and Levin (2014), Aaronson et al. (2012) or Fujita (2014) (among other), demonstrate that more than three-quarter of fluctuations in participation can be attributable to cyclical factors. As a consequence of the recent cyclical properties of LFP it appears fundamental to investigate, both empirically and theoretically, the relationship between participation and the macroeconomic environment.

The introduction of a participation margin in an otherwise RBC-type model is not straightforward. Thus, the first papers dealing with this issue (see Ravn (2006), Tripier (2004) and Veracierto (2008)) faced difficulties to reproduce one key cyclical property of the labor market: the negative relation between unemployment and vacancies, i.e. the Beveridge curve. The drawback arises from the behavior of non-participation in response to aggregate shocks. For example, following a positive improvement in technology the representative household allocates more members into search activities. If the number of workers moving from non-participation to search unemployment is greater than those moving from search unemployment to employment, unemployment increases and exhibits a pro-cyclical behavior. The major problem is that these models do not match empirical moments of labor market participation. In the data, the participation is approximately 5 times less volatile than GDP, suggesting only a modest reaction of this margin to technology shocks.

Ebell (2011) is the first to formulate an answer to this puzzle, and she successfully replicates the low volatility of participation and the negative slope of the Beveridge curve. Her results rely on two choices in the calibration strategy. On the one hand, the elasticity of labor supply is chosen to match the low volatility of participation rather than GDP volatility. Thus, the value of this elasticity is relatively low and more in accordance with micro-econometric estimates. On the other hand, she adopts a calibration strategy close to the one proposed in Hagedorn and Manovskii (2008). In this respect, she introduces wage rigidity by imposing a low value of surplus share to the worker[3].

Arseneau and Chugh (2012) depart from the RBC structure of the model economy and develop a New-Keynesian equilibrium model with labor market friction and a participation margin. In the spirit of Ebell (2011) they fix the elasticity of labor supply to a low value and they rely on an Hagedorn-Manovskii style calibration. In this framework, the volatility of labor force participation mimics the data fairly well. However differently from the RBC interpretation, though the level of participation decreases, unemployment increases after a productivity shock. In this setup, the demand channel acts, pushing up the unemployment.

Recently Campolmi and Gnocchi (2016) introduce a participation margin in an otherwise New-Keynesian model embedding labor market frictions. Without an Hagedorn-Manoskii style calibration, they are able to reproduce key moments of aggregate labor market variables. For instance, the low volatility of participation is reproduced and the negative relationship between vacancies and unemployment. They also show that the abstraction of the labor force may lead to misleading results about the dynamics of the model economy. In particular, with the presence of participation the unemployment is four time more volatile than in a model without participation. Moreover, in a model with constant participation the volatility of unemployment to inflation stabilization is too large.

[3] In is important to note that her fundamental results are not based on such extreme values of worker bargaining power and worker outside option as in Hagedorn and Manovskii (2008)

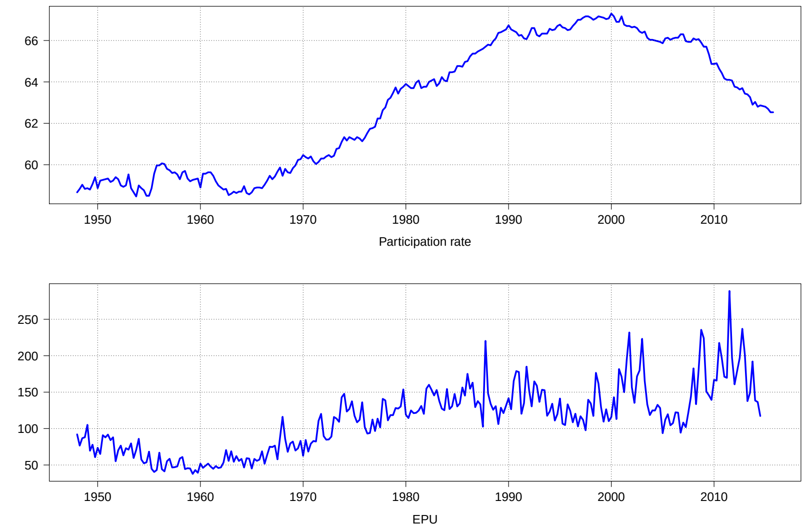

Figure 1: The participation rate and HEPU index over the period 1948-2015.
Sources: FRED database for the LFP, Baker et al. (2015) for uncertainty
Notes: The participation rate is expressed in percentage points.

2.2 Uncertainty and the macroeconomy

The macroeconomic effects of uncertainty attract a revived attention since the Great Recession and the subsequent low recovery[4]. As indicated in the bottom panel of figure 1, the Historical Economic Policy Uncertainty index sharply increased since the Great Recession. On the empirical side, the first purpose was to establish the sense of the effect and its importance in explaining macroeconomic fluctuations. Bachmann et al. (2013) analyze by means of structural vector autoregression (VAR, henceforth) the role of uncertainty in Germany and the U.S.. They find that heightened uncertainty induce, for both countries, a fall in manufacturing production, hours worker and employment. However, the negative effects of uncertainty are more persistent in the U.S. than in Germany. Also through the lens of VAR, the empirical findings of Basu and Bundick (2014), suggest that an uncertainty shock significantly pushes down output, consumption, investment and hours[5]. Finally, Alexopoulos and Cohen (2015) came to the conclusion that uncertainty explain an important share of variance of aggregate variables as output, production, consumption and investment[6].

[4]At this stage, it is important to have in head that uncertainty is not directly measurable since it has multiple origins. Researchers in this field use quite different assessments of uncertainty such as consumers' perceived uncertainty obtained from a survey, ex-ante forecast dispersion, stock market volatility, the variance of TFP growth rate obtained from a GARCH or Economic Policy Uncertainty (EPU). This is a non-exhaustive list of measure of uncertainty.

[5]Other researches document similar comovements between uncertainty and macroeconomic variables, for example Guglielminetti (2015), Leduc and Liu (2016), Charles et al. (2015)

[6]The paper of Cesa-Bianchi et al. (2014) is in stark contrast with the results mentioned above. Starting from a Global VAR and assuming that uncertainty and business cycles are driven by common factors, they

On the theoretical side of research, the interest for uncertainty is not new but it is renewed in recent times. In an "older" contribution, Bernanke (1983) argues that the presence of irreversible investments is key to understand uncertainty aftermaths. In such a framework, agents trade-off future returns of investments against the benefit of "wait and see" to have more information. Thus, in the event of a surge in uncertainty the option-value of waiting increases leading to a diminution in investment, and therefore in output. The paper of Bloom (2009) is at the origin of the renewed interest for uncertainty. In particular, he considers stochastic volatility uncertainty in a firm level model and he shows that the surprise shock diminishes output. The transmission channel is in line with Bernanke (1983). More specifically, Bloom (2009) shows that uncertainty expand an inner region, i.e. the degree of inaction of firms, by giving rise the real-option value of waiting. Thus, firms make a "pause" in their investment and hiring decisions because the value of waiting increases.

As for the participation margin, it is not straightforward to retrieve the comovements observed in the data with an equilibrium model. Basu and Bundick (2014) indicate that the introduction of price stickiness is a determinant factor in reproducing the effects of uncertainty. In a model with flexible prices and an elastic labor supply, a surge in uncertainty stimulates a precautionary motive leading the household to supply more labor. As flexible prices operate, markets clear and more inputs are used for production. Hence, heightened uncertainty implies a counter-intuitive result since it pushes down consumption but pushes up output. In contrast, when price adjustment is sluggish output is demand-determined. As firms are not freely able to adjust their own prices, they must reduce their production to meet demand. This mechanism induces a fall in consumption, investment, output and employment.

Finally, to my knowledge, three papers examine the impact of uncertainty in the context of DSGE model with frictional labor market. Leduc and Liu (2016) add a stochastic volatility uncertainty shock in a New-Keynesian model embedding a frictional labor market. They find that the presence of a non-Walrasian labor market is crucial for the transmission of uncertainty shocks. In this setup, an employment relationship can be assimilated to an irreversible investment as in Bernanke (1983). When uncertainty hits the economy the value of a job match decreases and firms are less likely to post vacancies leading ultimately to higher unemployment. Moreover, they also indicate that sticky prices amplify the negative effect of uncertainty on unemployment. In a more complex framework than Leduc and Liu (2016), Guglielminetti (2015) finds similar results. Finally, Cacciatore and Ravenna (2015) stress that wage rigidity deepen the negative effect of uncertainty on employment.

---

find that the former has no effect on the latter. Consequently, they favor the view that uncertainty should be seen as a symptom rather than the cause of economic fluctuations.

As in this paper, the aforementioned works add a frictional labor market in order to analyze the impact of uncertainty. However, they operate under the assumption that the participation margin is exogenous. I go one step further and I investigate to what extent uncertainty can affect the LFP dynamics.

3 The empirical evidence

This section presents the empirical evidence emerging from vector autoregression identified with a classical Cholesky decomposition. In a first part, the benchmark model is presented. In a second part, several sensitivity analyzes are conducted.

3.1 The baseline VAR

The baseline empirical model is a tri-variate VAR containing a measure of uncertainty, real GDP and a measure of participation. The uncertainty variable chosen is the Historical Economic Policy Uncertainty (HEPU, henceforth) index constructed by Baker et al. (2015). It has the advantage to cover a very long period starting in 1900[7]. The index is constructed by performing searches on influential U.S. newspapers[8]. In particular, three categories of term related to uncertainty, the economy and policy should be matched to include a newspaper article to the measure. The sensitivity of the results to the choice of uncertainty measure are evaluated in the next subsection. Output is measured by real GDP. The measure of participation is the civilian labor force participation rate[9]. The VAR is estimated on a quarterly basis and the sample covers the 1948Q2-2014Q3 period[10]. In order to interpret the effects of uncertainty shock as short-term dynamics relative to the stationary steady state, and to avoid any problem of long term relationship between variables, the cyclical components of the series are extracted with an HP-filter with a standard smoothing parameter (i.e. $\lambda = 1600$ for quarterly data)[11]. The VAR is estimated within a Bayesian framework by imposing the Minnesota prior. As suggested by the Akaike criterion, the VAR features 3 lags.

The isolation of a structural uncertainty shock is achieved by adopting the widely used Cholesky decomposition, and by ordering the measure of uncertainty first in the VAR. This

[7]The data are freely available on the economic policy uncertainty website by following the link: http://www.policyuncertainty.com/us_historical.html.

[8]From 1900 to 1985 6 newspapers were surveyed. Since 1985 from now 4 additional newspapers are added to the initial list (see the website quoted above or the paper of Baker et al. (2015) for more details on the data construction).

[9]The series is freely available on the FRED website with the following ID: CIVPART.

[10]Note that, monthly variables are converted into quarterly by simple arithmetic average.

[11]The KPSS test of stationarity indicates that all series are non-stationary because they are characterized by a trend. Once detrended all series are stationary and the VAR can be consistently estimated.

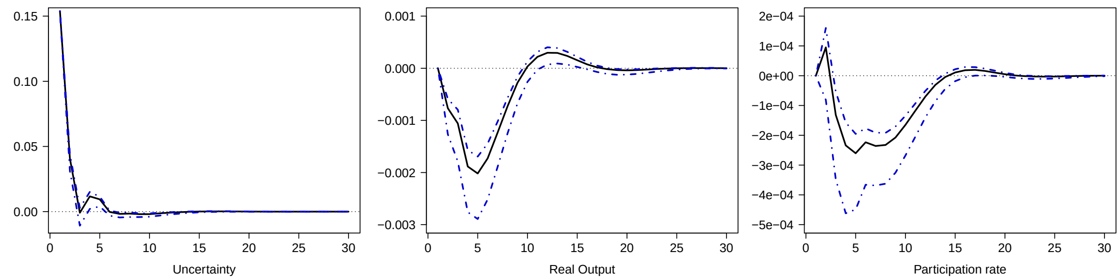

Figure 2: Impulse response functions to a one-standard deviation uncertainty shock.
Sources: Author's own calculations.
Notes: Black solid lines correspond to median response, blue error bands represent the 16th and 84th percentiles of the posterior distribution

identification scheme implies that the other shocks of the system have a contemporaneous zero effect on uncertainty. However, in subsequent periods, macroeconomic effects on uncertainty are allowed. Most importantly, another consequence of this strategy is that uncertainty shock has a non-zero contemporaneous impact on other variables of the system. Despite the fact that this identification assumption is very standard in the literature, it is possible to cast some doubt on the ordering of the variable. Once again, in a step of robustness check I re-estimate the VAR with an alternative ordering (see subsection 3.2.3)[12].

Figure 2 displays the estimated responses to a one-standard deviation uncertainty shock. In each panel, the black solid line represents the median response while the blue dashed lines report bands corresponding to 64th percent confidence interval. The one-standard uncertainty shock raises the level of HEPU of about 15% relative to its steady state. It takes about 3 quarters to regain its steady state. Output falls and follows an u-shaped path, with a maximum impact 5 quarters after the shock. The negative comovement between output and uncertainty is a striking feature for the U.S. (see for example Basu and Bundick (2014), Leduc and Liu (2016) or Charles et al. (2015)). Finally, a surprise increase in uncertainty leads to a non-significant response of particpation during the first 2 quarters following the shock. After this delay, the shock causes a significant decline in participation. On the overall and as output, the dynamic response of participation is u-shaped. However and in contrast to output, its response is more persistent since it goes back to the pre-shock level after 3 years (against 2 years for output).

[12] My paper is not the first to use a Choleski-type identification to recover a structural uncertainty shock, Leduc and Liu (2016), Basu and Bundick (2014), Bachmann et al. (2013) (among other) use a similar strategy.

3.2 Robustness

The benchmark VAR presented in the last subsection suggests that an uncertainty shock diminishes the participation rate. In this subsection, I examine whether the main result is robust to the choice of interest variables and to the order of the VAR.

3.2.1 Uncertainty indicator

By definition uncertainty is an unobservable concept with multidimensional origins such as financial markets, macroeconomics or economic policy. As a consequence of this inherent difficulty, it appears important to examine the sensitivity of the results to the choice of uncertainty proxy. In this subsection, I re-estimate the VAR by changing each time the measure of uncertainty. Specifically, I use three other proxies of uncertainty. The first one is the VIX index which measures the implied volatility of the S&P500 index options. The second one is the Composite Uncertainty Indicator (CUI, henceforth) constructed by Charles et al. (2015). In contrast to other measures of uncertainty, the CUI synthetizes distinct sources of uncertainty, namely macroeconomics, financial market and economic policy. The third one is the News Based Economic Policy Uncertainty index of Bloom et al. (2012)[13]. It combines three components: newspaper survey, temporary federal tax code provisions and disagreement among economic forecasters. The left panel of figure 3 traces out the impulse response of participation to uncertainty shock. The qualitative response of participation is similar whatever the measure of uncertainty, i.e. it follows an u-shaped pattern. However, the quantitative impacts are slightly different. For instance, the maximum decrease of participation is not reached in the same period, 5 quarters after the shock for the benchmark case against 9 quarters when the CUI index is used. When uncertainty is assessed by the VIX index the response of participation during the first three quarters is the highest, but remains indistinguishable from 0 (not shown in the figure). When the NEPU index is used, the fall in participation appears to be the highest. On the overall, my favorite measure of uncertainty displays an impulse path for participation which can be seen as a middle-point estimate.

3.2.2 Measures of LFP

Demographic factors, as the retirement wave due to baby-boomers, have been often invoked to explain the downward trend followed by the LFP rate. To prevent demographic factors to play any role, in this subsection I focus on the core of the labor market. Specifically, I

[13] The sample period covered by the NBEPU is shorter than the one for historical HEPU (it begins in 1985, while the HEPU begins in 1900). That is why I favor the HEPU index.

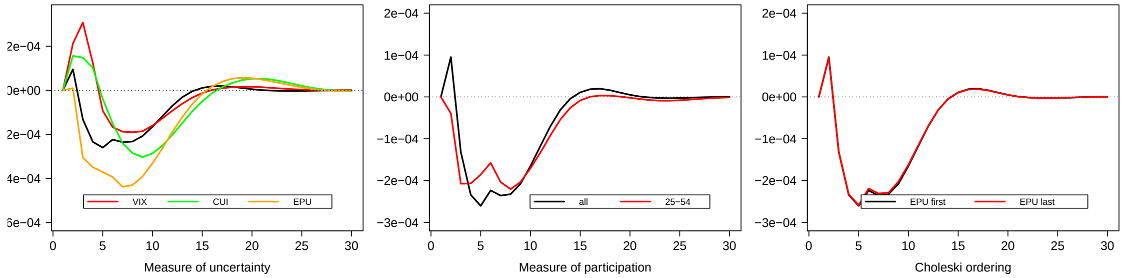

Figure 3: Robustness of VAR evidence.
Sources: Author's own calculations
Notes: Black solid lines correspond each time to the benchmark case. The left panel presents impulse responses of participation to uncertainty shock obtained from separetely estimating tri-variate VAR. The red line corresponds to the case of the uncertainty proxy is the VIX index, the green line corresponds to the case of the uncertainty proxy is the CUI index from Charles et al. (2015), the orange line corresponds to the case of the uncertainty proxy is the News EPU index of Baker et al. (2015). The middle panel presents the impulse response consecutive to uncertainty shock for different measures of participation. The red line refers to the case that the proxy of participation is the LFP of 25-54 years-old. The right panel presents impulse responses for different VAR ordering. The red line being the impulse response when uncertainty is ordered last.

estimate the same VAR as in subsection 3.1 but I replace the participation variable by the LFP rate of 25-54 years old. The impulse response of participation in such a model is shown in the middle panel of figure 3. The dynamic response of participation is remarkably similar to the benchmark case and its u-shaped pattern is entirely preserved. Since the recessionary evolution of participation is recovered when I focus on the 25-54 years old, demographic factors are not a noise for the main empirical results.

3.2.3 Cholesky ordering

Although, the identification scheme chosen here is quite standard in the literature, the Cholesky ordering of the VAR is quite questionable. In order to check if this assumption may affect the results, the VAR is re-estimated with the measure of uncertainty ordered last. This novel ordering of the VAR implies that all shocks of the system may have a contemporaneous impact on uncertainty. Alternatively, in this context the unexpected uncertainty shock does not affect contemporaneously output and participation. The right panel of figure 3 ,which presents the result, indicate that the qualitative and the quantitative are nearly the same, whatever the Cholesky ordering of variables.

3.2.4 More generous framework

The last step of robustness consists in the estimation of a more generous VAR. In particular, I add two variables to the baseline VAR: the Consumer Prices Index and the unemployment

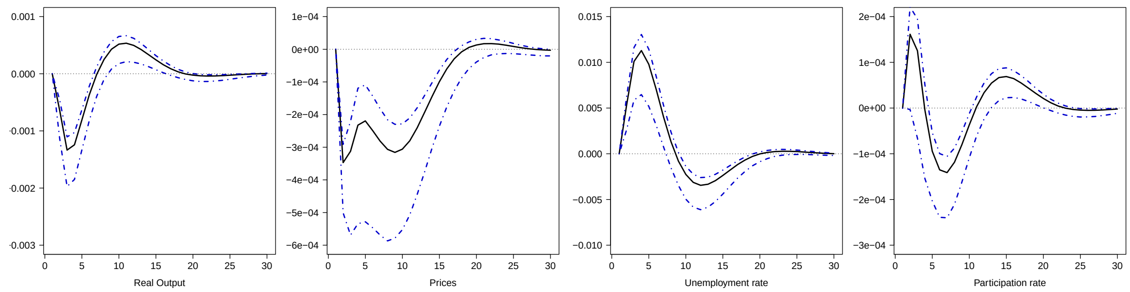

Figure 4: Impulse response functions to a one-standard deviation uncertainty shock - more generous framework.
Sources: Author's own calculations
Notes: Black solid lines correspond to median response, blue error bands represent the 16th and 84th percentiles of the posterior distribution

rate. I apply the same strategy to isolate the uncertainty shock, and I place the measure of uncertainty first in the VAR. This alternative VAR gives more insight about the macroeconomic effects of uncertainty. Figure 4 plots the estimated responses to a one-standard deviation uncertainty shock. An unexpected raise in uncertainty declines output and the price level. Unemployment increases significantly and follows a hump-shaped path with a maximum impact 5 quarters after the shock. Although, from a quantitative point of view the response of participation is slightly different, its qualitative response is similar compared to the baseline.

4 Model economy

All in all, the empirical evidence conducted in the last section demonstrates that there is a robust negative relationship between the unpredictability of the future state of the economy and the participation margin. This section takes another route and aims at reproducing this negative comovement within a theoretical model. In order to examine the effects of uncertainty about the future state of the aggregate economy on the labor market and especially the participation margin, I consider a DSGE model which departs from the standard New-Keynesian in the extent to which it incorporates: i) time-varying standard deviation of the technology shock ii) a frictional labor market in the spirit of Mortensen and Pissarides (1994), iii) and an endogenous participation margin. Furthermore, in its baseline development the model feature external degree of habit persistence, risk adverse households maximizing their consumption levels, holding of bonds and labor supply. The production side is split in two sectors. In the first one, wholesale firms produce homogenous goods by using labor as their sole input. Wages are negotiated through the maximization of a Nash bargaining problem.

The possibility of rigidities on wages is also studied. In the second one, retailers purchase intermediate goods and sell them directly to households on a monopolistic competitive market. Prices stickiness operates at this level by assuming that each period only an exogenous fraction of retailers can charge their own prices. The monetary policy authority is assumed to follow a Taylor rule. The New-Keynesian nature of the model is very useful since it easily allows for counterfactual analyses.

4.1 The household

The representative household can be seen as a large family composed by a continuum of measure one of individuals. Each family member can be classified either as a non-participant or as a participant to the labor market. In the former case, individuals enjoy leisure. In the latter case, individuals are engaged either in working activities either in searching for a job. As it is common in this literature, each family member has the same level of consumption, since each of them pools its income to insure each other against fluctuations in consumption due to instability position on the labor market. This assumption follows Merz (1995). The household discounted expected utility has the following form:

$$\mathrm{E}_t \sum_{t=0}^{\infty} \beta^t \left\{ \frac{(c_t - hc_{t-1})^{1-\sigma}}{1-\sigma} - \chi \frac{l_t^{1+\varphi}}{1+\varphi} \right\} \quad (1)$$

where β is the discount factor, c_t the level of consumption, l_t the size of the labor force, h the degree of habit persistence, σ the degree of risk aversion, φ the inverse of labor force participation elasticity with respect to wage and χ a scale parameter. The household is confronted to the two following constraints:

$$c_t + \frac{B_{t+1}}{p_t r_t^n} = w_t e_t + b(l_t - e_t) + \frac{B_t}{p_t} + \Theta_t - T_t, \forall t \quad (2)$$

$$e_t = (1-\rho)e_{t-1} + f_t(l_t - (1-\rho)e_{t-1}), \forall t \quad (3)$$

The household can spend its revenue by consuming or by purchasing bonds which pay a nominal interest rate r_t^n. The revenue of the household consists in wages of employed family members, unemployment benefits b of unemployed, bonds B_t, firm profits Θ_t minus taxes T_t paid to government. Furthermore, the constraint (3) corresponds to the household perceived law of motion of employment. It indicates that the level of employment in period t is equal to the sum of non-separated job in period $t-1$ (ρ being the exogenous job separation rate) plus the current job finding (f_t being the job finding rate). Observe that $l_t - (1-\rho)e_{t-1}$ is an alternative way to denote unemployment.

The household chooses c_t, B_{t+1}, e_t and l_t in order to maximize (1) subject to constraints (2) and (3). By denoting the Lagrangian of the household problem Λ_1, the first order conditions (FOCs, henceforth) are:

$$\frac{\partial \Lambda_1(.)}{\partial c_t} = 0 \Leftrightarrow \lambda_t = (c_t - hc_{t-1})^{-\sigma} - \beta h \mathrm{E}_t (c_{t+1} - hc_t)^{-\sigma} \tag{4}$$

$$\frac{\partial \Lambda_1(.)}{\partial B_{t+1}} = 0 \Leftrightarrow 1 = \beta \mathrm{E}_t \frac{r_t}{\pi_{t+1}} \frac{\lambda_{t+1}}{\lambda_t} \tag{5}$$

$$\frac{\partial \Lambda_1(.)}{\partial l_t} = 0 \Leftrightarrow \Gamma_t = \frac{\chi l_t^{\varphi} - \lambda_t b}{f_t} \tag{6}$$

$$\frac{\partial \Lambda_1(.)}{\partial e_t} = 0 \Leftrightarrow \Gamma_t = \lambda_t (w_t - b) + \mathrm{E}_t \beta \Gamma_{t+1} \left((1-\rho)(1 - f_{t+1}) \right) \tag{7}$$

where λ_t is the Lagrange multiplier associated to constraint (2), Γ_t the one associated to (3) and $\pi_{t+1} = \frac{p_{t+1}}{p_t}$ the price inflation. The FOC (4) represents the utility marginal of consumption when the model features habit persistence in consumption. The FOC (5) is the conventional Euler equation for bonds. Finally, merging equations (6) and (7) gives the following participation condition

$$\chi l_t^{\varphi} \lambda_t^{-1} = b(1 - f_t) + f_t \left(w_t + \mathrm{E}_t \beta (1-\rho) \frac{1 - f_{t+1}}{f_{t+1}} \frac{\lambda_{t+1}}{\lambda_t} (\chi l_{t+1}^{\varphi} \lambda_{t+1}^{-1} - b) \right) \tag{8}$$

The LFP condition states that the marginal utility loss from allocating one additional family member into participation should equalize - at the optimum - the marginal expected return from having one additional member into the labor force. This expected payoff of participation is divided in two terms. On the one hand, if the job search fails at forming a match an unemployment benefit b is perceived. On the other hand, if the job search succeeds in forming a match, the payoff consists in a wage plus the continuation value. As indicated in Arseneau and Chugh (2012), the participation condition can be assimilated, from the household point of view, to a free-entry condition into search activities. Furthermore, it is noteworthy that in the event that matching frictions disappear, the above condition becomes identical to a standard labor/leisure condition[14]. In this model, instead, labor market frictions act and participation is increasing with the job finding rate. All else being equal, when the job finding rate is high, returns of search activities are also high, and the value of participation increases. In this event, the household has an incentive to allocate more family members into

[14]Matching frictions are erased when the job finding rate is equal to 1. In this case the LFP condition is simply: $\chi l_t^{\varphi} \lambda_t^{-1} = w_t$.

search activities.

4.2 The labor market

The labor market is subject to search frictions *à la* Mortensen and Pissarides (1994). Specifically, it is assumed that to form a matched pair both firms and workers must engage in a costly and time-consuming search process. The existence of labor market frictions formalizes the idea that unemployment is an equilibrium outcome. Each period t, the aggregate flows of hires m_t are characterized by a Cobb-Douglas matching technology of the form:

$$m_t = \omega s_t^{\alpha} v_t^{1-\alpha} \tag{9}$$

where s_t denotes unemployed searchers and v_t aggregate vacancies. The parameter $\omega > 0$ reflects the matching efficiency and $0 < \alpha < 1$ corresponds to the elasticity of the matching technology with respect to search unemployment. As the matching function exhibits constant returns to scale, it is convenient to define the labor market tightness as $\theta_t = \frac{v_t}{s_t}$. During a period the job finding probability is $f_t = \frac{m_t}{s_t} = \omega\theta_t^{1-\alpha}$. Analogously, the probability that an open vacancy is filled is $q_t = \frac{m_t}{v_t}$.

When a firm and a worker succeed in forming a job match, it is assumed that the newly created job becomes immediately productive. The timing of events can be summarized as follows. At the begining of each period, a fraction ρ of existing jobs in the previous period is severed for some exogenous reasons. Then, the representative family makes its optimal decisions for LFP. The individuals allocated into job search plus those who were separated constitute the pool of job seekers s_t. A fraction f_t of these individuals find a job. As a consequence of this timing, a measure $e_t = (1-\rho)e_{t-1} + f_t s_t$ of individuals is productive in period t and a measure $u_t = 1 - e_t$ of individuals remain unemployed and receives an unemployment benefit.

4.3 Intermediate good producers

The intermediate sector is composed by a continuum of firms. They produce an homogeneous good and they sell it to retailers in a competitive market. Firms in the intermediate sector use labor (which they hire in the frictional labor market) as their sole input. The aggregate production function is given by:

$$y_t = z_t e_t \tag{10}$$

where z_t denotes the aggregate level of technology. It follows the following stationary stochastic process:

$$\ln(z_t) = \rho_z \ln(z_{t-1}) + \sigma_t^z \varepsilon_t^z \tag{11}$$

where, $-1 < \rho_z < 1$ represents the degree of persistence of the technology shock, ε_t^z the i.i.d. innovation of the technology process. The variable σ_t^z is not common in the DSGE literature. It is the time-varying standard deviation of the technology shock used as the model proxy for the uncertainty shock. Note that, in this framework uncertainty shock is a second moment shock which follows the following autoregressive process :

$$\ln(\sigma_t^z) = (1 - \rho_\sigma) \ln(\sigma_z^*) + \rho_\sigma \ln(\sigma_{t-1}^z) + \sigma^\sigma \varepsilon_t^\sigma \tag{12}$$

In the latter equation, the parameter ρ_σ corresponds to the degree of persistence of the uncertainty shock, σ_z^* is the steady state standard deviation of the technology shock ε_t^z, ε_t^σ is an i.i.d. shock to the volatility of technology shock and σ^σ its standard deviation. Similar modeling of uncertainty shocks can be found in Fernández-Villaverde et al. (2011), Basu and Bundick (2014) and Leduc and Liu (2016) (among other). In my baseline model, I focus mainly on the understanding of the effects of unexpected innovations in the volatility of the technology shock process, i.e. the response to ε_t^σ.

Intermediate good producers maximize their discounted profit by choosing the optimal level of employment e_t, the optimal number of vacancies v_t and by taking the wage as given

$$\mathrm{E}_t \sum_{t=0}^{\infty} \beta^t \frac{\lambda_t}{\lambda_0} \left(\frac{y_t}{\mu_t} - \kappa v_t - w_t e_t \right) \tag{13}$$

Subject to its perceived law of motion of employment

$$e_t = (1 - \rho) e_{t-1} + q_t v_t \tag{14}$$

where in (13) $\mu_t = \frac{p_t}{p_t^x}$ define the price markup of retailers over intermediate good producers, κ denotes the vacancy posting cost and w_t the wage. The FOCs of this problem are (with Λ_2 the Lagrangian associated to the firm problem):

$$\frac{\partial \Lambda_2}{\partial e_t} = 0 \Leftrightarrow J_t = \frac{z_t}{\mu_t} - w_t + \mathrm{E}_t \beta \frac{\lambda_{t+1}}{\lambda_t} (1 - \rho) J_{t+1} \tag{15}$$

$$\frac{\partial \Lambda_2}{\partial e_t} = 0 \Leftrightarrow \frac{\kappa}{q_t} = J_t \tag{16}$$

Equation (15) represents the expected value of a job match for a firm. Merging the last two equations leads to the job creation condition:

$$\frac{\kappa}{q_t} = \frac{z_t}{\mu_t} - w_t + \mathrm{E}_t\beta\frac{\lambda_{t+1}}{\lambda_t}(1-\rho)\frac{\kappa}{q_{t+1}} \tag{17}$$

The job creation condition states that at the equilibrium the expected cost of posting a vacancy equalizes the expected benefit of creating a new match. This benefit is composed of the current net surplus (real revenues minus the wage) plus the continuation value[15].

4.4 Wage setting

In equilibrium, when a matched pair is created its total surplus should be higher than the sum of outside options. As it is standard in this literature, I assume that the wage, which shares this rent, is established through the solution of a Nash bargaining problem. Before describing the outcome of the Nash bargaining, the surpluses induced by the match have to be identified. The value of a job from the firm point of view is already known since it is given by equation (15). For workers, the marginal surplus from being employed corresponds to the derivative of the household problem with respect to employment e_t divided by the marginal utility of consumption λ_t. Thus, based on (7), it is possible to write the worker surplus $W_t - U_t$ as follows:

$$W_t - U_t = w_t - b + E_t\beta(1-\rho)(1-f_{t+1})(W_{t+1} - U_{t+1}) \tag{18}$$

The wage w_t chosen by the two partners satisfies the following optimal condition:

$$W_t - U_t = \frac{\eta}{1-\eta}J_t \tag{19}$$

with η the exogenous bargaining power of firms. After substitution of the expressions of the two surpluses into (19), the following expression for the Nash bargained wage w_t^N is obtained:

$$w_t^N = (1-\eta)b + \eta\left(\frac{z_t}{\mu_t} + E_t\beta(1-\rho)\frac{\lambda_{t+1}}{\lambda_t}f_{t+1}\frac{\kappa}{q_{t+1}}\right) \tag{20}$$

The Nash bargained wage split the rent generated by the job relationship according to the bargaining weight η. Hence, the first term of the right hand side states that workers are compensated for a fraction $1-\eta$ of the foregone unemployment benefit. The second term on the right hand side indicates that workers are rewarded for a fraction η of firm revenues.

[15]Implicitly, it is assumed that firms have a nil return when a job destruction takes place.

In a recent paper Cacciatore and Ravenna (2015) study the importance of wage rigidity for the transmission of an uncertainty shock. They demonstrate that it greatly amplifies the response of the economy to surprise shock. Inspired by this kind of evidence, I introduce wage rigidity in the model. Following, Leduc and Liu (2016) I assume that wage evolution is given by:

$$w_t = w_{t-1}^{\varsigma}(w_t^N)^{1-\varsigma} \tag{21}$$

where $0 < \varsigma < 1$ captures the degree of wage rigidity. In other words, the logarithm of aggregate wages is the weighted sum of the wage prevailing in the previous period plus the wage Nash bargained in current period. The weights being the share of matched pairs which are able to renegotiate and those which are not. This framework breaks down the conventional assumption saying that wages are implicitly renegotiated each period.

4.5 Retailers and price adjustments

There is a measure one of retailers indexed by j operating in a monopolistic competitive market. Retailers purchase aggregate intermediate goods, transform each unit of these goods into retail goods before resell them directly to households. Let $y_t(j)$ be the quantity of output sold by retailer j. In this context, final output is produced according to the following constant return to scale technology:

$$y_t = \left(\int_0^1 y_t(j)^{\frac{\epsilon-1}{\epsilon}} dj\right)^{\frac{\epsilon}{\epsilon-1}} \tag{22}$$

where ϵ is the elasticity of demand for each intermediate good. The demand curve faced by each retailer can be written as:

$$y_t(j) = \left(\frac{p_t(j)}{p_t}\right)^{-\epsilon} y_t \tag{23}$$

with $p_t(j)$ the nominal price set by retailer j, while, p_t is the aggregate price index $p_t = \left(\int_0^1 p_t(j)^{1-\epsilon} dj\right)^{\frac{1}{1-\epsilon}}$. Price stickiness takes place at this level. Following Calvo (1983) it is assumed that retail firms are not able to choose their own prices. More specifically, each period a fraction $1-\xi$ of retail firms can choose a new price, whereas, the other fraction ξ is stuck and constrained to keeps the price prevailing in the previous period. The probability of a price change is constant overtime and independent of the time elapsed since the last adjustment. This assumption implies that a retail firm keep the same price on average during $\frac{1}{1-\xi}$ periods. Retailers integrate that they may be stuck with a price during s periods and maximize the following discounted profits:

$$\max E_t \sum_{s=0}^{\infty} \xi^s \beta^s \frac{\lambda_{t+s}}{\lambda_t} \left(\frac{p_t(j)}{p_{t+s}} - x_{t+s}\right) \left(\frac{p_t(j)}{p_{t+s}}\right)^{-\epsilon} y_{t+s} \tag{24}$$

Finally, the prices evolution are given by

$$p_t = \left[(1-\xi)(p_t^*)^{1-\epsilon} + \xi p_{t-1}^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}} \tag{25}$$

with p_t^* the optimal price.

4.6 Monetary authority and market clearing

The central bank controls the monetary policy by choosing the level of nominal interest rate according to a modified Taylor rule:

$$\left(\frac{r_t^n}{(r^n)^*}\right) = \left(\frac{\pi_t}{\pi^*}\right)^{\gamma_\pi} \left(\frac{u_t}{u^*}\right)^{\gamma_u} \tag{26}$$

with $(r^n)^*$, π^* and u^*[16] the steady state values of the nominal interest rate, the inflation rate, and the unemployment rate respectively. The coefficients γ_π and γ_u represent the degree of reaction of the central bank to deviation of inflation and unemployment rate from their steady states. As written in equation (26), the Taylor rule can be used to test different scenario of monetary policy.

Finally market clearing is achieved by imposing the following resource constraint:

$$y_t = c_t + \kappa v_t \tag{27}$$

The last equation states that output is either consumed or spent in vacancy posting.

4.7 Solution method

The purpose of the theoretical analysis is to assess the effects of a volatility increase (a positive shock to ε_t^σ) while keeping the level of productivity constant. To do so, I follow the bulk of the literature and I solve the model non-linearly by perturbation methods to obtain an approximation of the policy functions. Since the work of Aruoba et al. (2006), it is recognized that perturbation methods are accurate and able to deliver solution in a reasonable amount of time. As expressed in Fernández-Villaverde et al. (2011) traditional approximation methods, as log-linearization, do not work for the problem in hand. In particular, due to certainty equivalence a first-order approximation does not allow the examination of second moment shocks. In this case, the policy functions is varying only with level shocks and second

[16] Henceforth, the superscript * denotes the steady state of variables.

Parameter	Signification	Value/Target
β	Discount factor	0.99
σ	Degree of risk aversion	1.5
φ	Inv. of Frisch elasticity	5
h	Habit persistence	0.2
ξ	Prob. of price stickiness	0.75
μ^*	Price markup	1.2
e^*	S.s employment rate	0.94
l^*	S.s participation rate	0.63
ρ	Job separation rate	0.07
q^*	Job filling rate	0.7
θ^*	Tightness	0.7
f^*	Job finding rate	0.49
κ	Vacancy posting cost	$\frac{\kappa v^*}{y^*} = 0.7\%$
b	Unemployment benefits	$\frac{b}{w^*} = 40\%$
η	Bargaining power	0.9

Table 1: Baseline calibration

moment shocks do not appear at all in the policy functions[17]. Moreover, a second-order approximation of the policy functions is also inconsistent because it captures the effects of second moment shocks indirectly. In particular, in the latter case the second moment shocks enter the policy functions with a non-nil coefficients in their interaction with their respective level shocks. As a consequence, it is impossible to measure the effects of volatility shocks by maintaining constant the level shocks associated. The innovations to second moment shocks enter separately in the policy functions, and independently of the level shocks, only in a third-order approximation[18].

A consequence of the use of a third-order approximation is that it moves the ergodic distributions of the endogenous variables away from their deterministic steady state values. This is potentially a problem for the computation of the impulse response functions. Thus, to limit this pitfall I follow the same strategy than Basu and Bundick (2014). More specifically, starting from the steady state values, I simulate the model during 2000 periods by shutting-off all the shock of the system. This allows me to have that the literature calls the “stochastic steady state”, i.e. the set of value reached wherein no shock perturbs the system. Then, I compute the impulse response in percent deviation from the stochastic steady state of the

[17]As expressed in Fernández-Villaverde et al. (2011) the coefficients associated with these kind of variables are nil.

[18]Since the version 4.0, the pruning algorithm of Andreasen et al. (2013) is implemented in Dynare.

model[19].

4.8 Calibration

The model is calibrated in order to reproduce key stylized facts of the U.S. economy. Period length is measured in quarter. The discount factor β is fixed to 0.99 implying an annual interest rate of 4%. The degree of risk aversion σ if set to 1.5. Along the lines of Campolmi and Gnocchi (2016), the parameter φ reflecting the inverse of the elasticity of participation to real wages variations is set to 5. This implies a low reaction of participation to changes in the macroeconomic environment. There is no large consensus about the value governing habit persistence. By choosing a value of h equal to 0.2, I follow Guglielminetti (2015) and the baseline model features moderate degree of habit persistence in consumption.

From the production sector of the model economy, I follow the literature by fixing μ^*, the steady state markup of retailers on intermediate firms, to 1.2. I set the probability that retailers cannot reset their prices to 0.75.

On the labor market, some steady state and parameters are based on their observed average values. Thus, the steady state value of the employment rate is set to 94%[20]. Similarly, the steady state participation rate is set to 63%. Concerning the exogenous job separation rate, estimates range from 0.07 to 0.15. Consistently with Merz (1995) I retain the lower bound. The scalar parameter of efficiency ω of the matching function is chosen in order to pin down a quarterly job filling rate of 0,7. This set of values implies a steady state labor market tightness and a steady state job finding rate equal to 0.7 and 0.49, respectively. The cost induced by a vacancy posting κ is set in order to pin down a total vacancy expenditure which represents less than 1% of total output. This strategy is in line with Blanchard and Galí (2010). As in Campolmi and Gnocchi (2016), the value of unemployment benefit is fixed to target a steady state replacement ratio $\frac{b}{w^*}$ of 40%. The value of the firm bargaining power η is not imposed but deduced from the equilibrium condition. Thus, the implied firm bargaining power is equal to 0.9

As regard to the monetary policy rule, I follow standard practices. Hence, γ_π the coefficient of reaction to inflation deviations is set to 1.5. The one for unemployment gap is set to 0.125 as in Campolmi and Gnocchi (2016). Furthermore, a zero steady state inflation is targeted.

Finally, let me now turn to the calibration of the two shocks of the model. As standard,

[19] It is also possible to compute an alternative generalized impulse response using simulation procedure around the ergodic mean of the endogenous variable in the spirit of Koop et al. (1996). However, as demonstrated by Basu and Bundick (2014) the two methods of impulse response computations provide nearly identical results.

[20] More precisely, it corresponds to the employment rate within that active population.

the steady state level of aggregate technology is required to be equal to 1. For the persistence of the technology shock, I retain a value of 0.90. Its standard deviation σ_z^* is set to 0.1. Consensus is not reached about how to calibrate the second moment shock of uncertainty. Along the lines of Basu and Bundick (2014), I retain a value of 0.8 for its persistence degree. Concerning the standard deviation of the uncertainty shock, I follow Leduc and Liu (2016) and a value of 0.40 is chosen.

5 Results

This section presents the theoretical impulse response functions. In order to give more intuition about the transmission channel of uncertainty, the model is gradually modified. First, I consider the case of price flexibility. Second, price stickiness is introduced into the economy in order to activate the demand channel. Finally, under price stickiness, several alternative calibrations are considered. This last step allows me to check for the robustness of the overall results.

5.1 Model with price flexibility

As a starting point, I begin with the investigation of a model without prices stickiness. This framework is useful because it erases the demand channel. Two different mechanisms operate for the transmission of an uncertainty shock. First, higher uncertainty in the economy activates a precautionary saving motive. Specifically, an unexpected raise in uncertainty leads the household to supply more labor in order to work more and insure them against risk. In the model developed here, the household will be more likely to allocate more individuals into search activities. As suggested by equation (8), the benefit of participation depends on current return (an unemployment benefit if the worker does not find a job or a wage if she finds a job) plus a discounted continuation value. All else being equal, higher uncertainty decreases the interest rate implying an elevation of the continuation value. Second, as the labor market is characterized by search frictions, an increase in uncertainty may induce firms to post fewer vacancies. As highlighted by Leduc and Liu (2016), a job match is similar to an (partially) irreversible investment. In this spirit, uncertainty pushes up the real option value of "wait and see" to have more information about the future and firms make a pause in their hiring investments. This channel may be important for LFP. A decrease in vacancy posting lowers the job finding probability leading ultimately to a fall in the gain of search activities. In reaction to this channel, the household will allocate fewer individuals into participation.

To put in evidence the dominant effect governing in such a model, figure 5 plots the

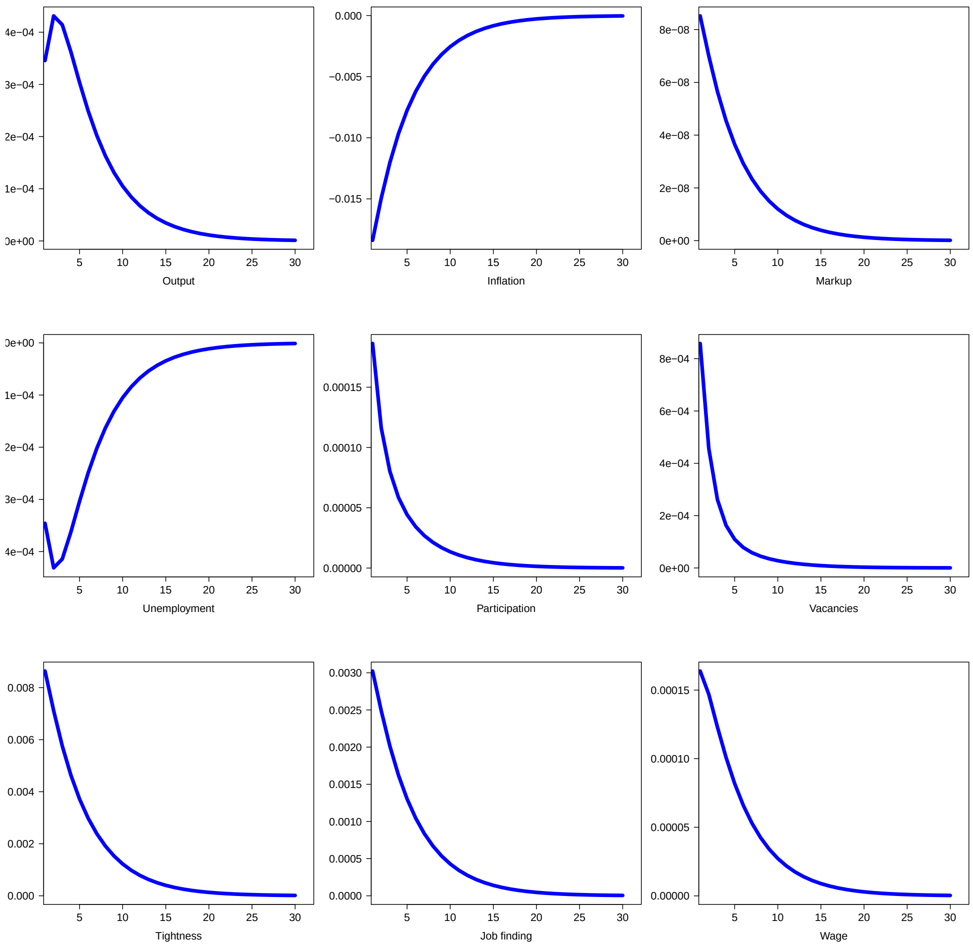

Figure 5: Impulse responses to an uncertainty shock under flexible prices.
Sources: Author's own calculations
Notes: Percentage deviations from trend are plotted.

impulse responses associated to this scenario. Unambiguously, the first effect prevails and an uncertainty shock gives rise to an important precautionary saving motive. Thus, after the surprise the participation value increases and the number of participants increases. As more individuals search for a job, it becomes easier to fill a vacancy and firms are more likely to post new vacancies. The job finding rate increases leading to a fall in unemployment (the job separation margin being exogenous). More inputs are used in production and retail firms will take advantage of this by lowering prices to meet demand. Ultimately, uncertainty is expansionary since output increases.

The dynamic behavior of the model economy contradicts empirical evidence. It is also at odds with theoretical illustrations of Leduc and Liu (2016)[21] and Guglielminetti (2015) [22]. In

[21]For more details, see subsection IV.2.1 and figure 6 of their paper
[22]For more details, see subsection 6.2 and figures 8 and 9 of her paper

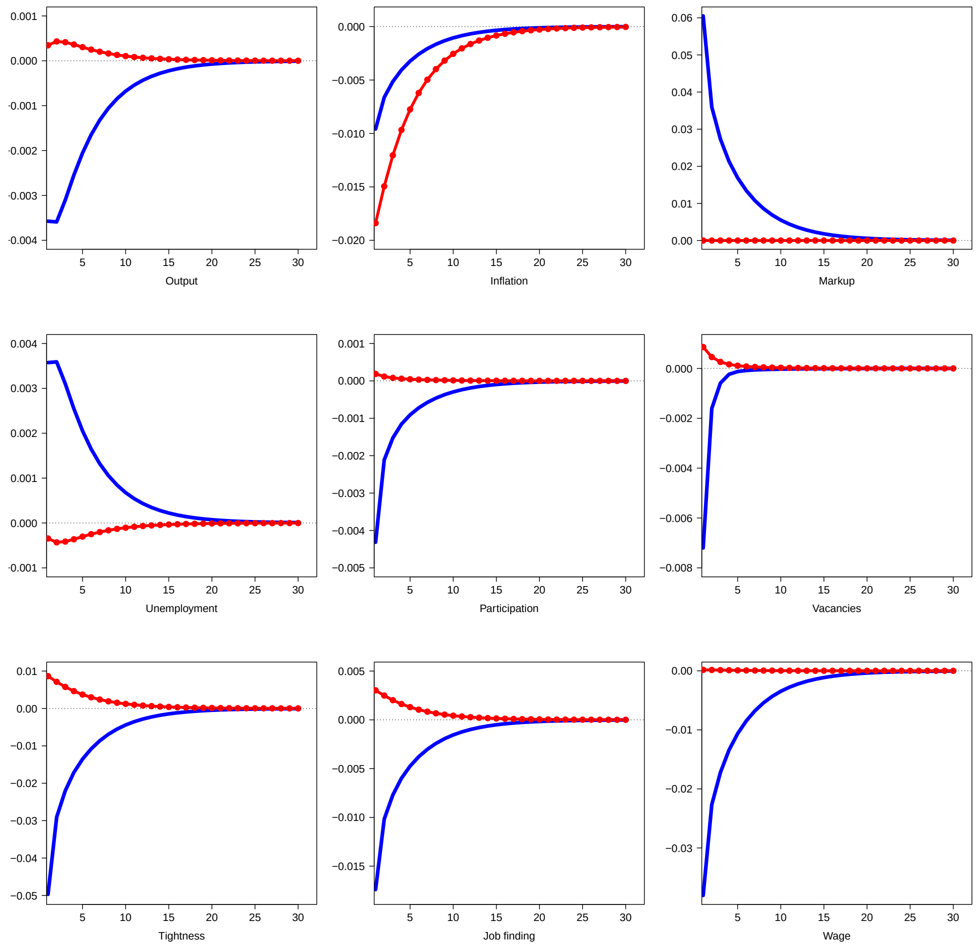

Figure 6: Impulse responses to an uncertainty shock under price stickiness.
Sources: Author's own calculations
Notes: Percentage deviations from trend are plotted. Blue lines correspond to IRFs for a model with sticky prices. Red lines correspond to ird for a model with flexible prices.

those models, close to the one developed here, but with an inelastic labor supply, they both find that uncertainty is recessionary since it declines output and increases unemployment. The surge in unemployment being explained by the raise in the value option of "wait and see". The non-abstraction from the participation margin explains these divergent results. As indicated previously, the participation condition is close to a traditional labor/leisure condition (the difference being frictions on the labor market) which induces a higher precautionary motive. In the context of the model developed here, this is translated to an important "flow" of non-participant members into the participation pool.

5.2 Introduction of price stickiness

In this subsection, I activate the demand channel by adding price stickiness to the model economy. Since the work of Basu and Bundick (2014) it is recognized that price rigidities greatly magnify the theoretical responses to an uncertainty surprise. Figure 6 depicts the dynamic responses of several key macroeconomic variables to a volatility uncertainty shock. First of all, in quantitative terms, the impulse responses confirm that price stickiness is an important channel for the transmission of uncertainty shocks. For instance, the impact response of output is multiplied by 10, while the impact response of participation is multiplied by 23 (in absolute term for both). Second, the message delivered by the model economy is in stark contrast with findings of the previous subsection since now an uncertainty shock leads to a decline in output, labor market tightness, job finding rate and participation. Conversely, in this setup the price markup and the measure of unemployment both increase.

The general mechanism may be summarized as follow. When an uncertainty shock hits the economy, household behavior is driven again by a precautionary motive. Thus, all else being equal, the household chooses to consume less and to supply more labor. Under sticky prices, retailers cannot take full advantage of this increase of the labor supply, which ultimately translates into higher markup. As suggested in equation (17), an increase in markup leads to a fall in the value of a match. On the overall, the decrease in inflation is less important than in the model featuring flexible prices. Furthermore, as price rigidities prevent firms to meet the new depressed demand, their profits fall. This mechanism also leads to a diminution in the value of a job match. Finally, observe that the "wait and see" channel acts. Facing to higher uncertainty about the future level of productivity, firms prefer to postpone their hiring investments. As a consequence of these three mechanisms, fewer vacancies are opened and the job finding probability decreases implying higher unemployment. The decrease in the LFP results from this fall in job finding opportunities. As illustrated in equation (8), if the labor market is tightened from worker point of view, the participation value decreases and the household optimally allocates fewer members into participation.

The analysis of this subsection confirms that the demand channel is crucial to reproduce comovements observed in the data. Thus, price stickiness completely reversed the expansionary effects of uncertainty observed under flexible prices. The introduction of price stickiness is also of first interest for the behavior of labor market variables. Hence, in this framework, the model is able to replicate the surge of the unemployment rate and the drop of participation observed in the empirical study of this paper. From a theoretical point of view, it seems that the decrease in firm opportunities, which alter the efficiency of the match process, is key to understand the decrease in participation. The next subsection will test the sensitivity of these results to different model specifications.

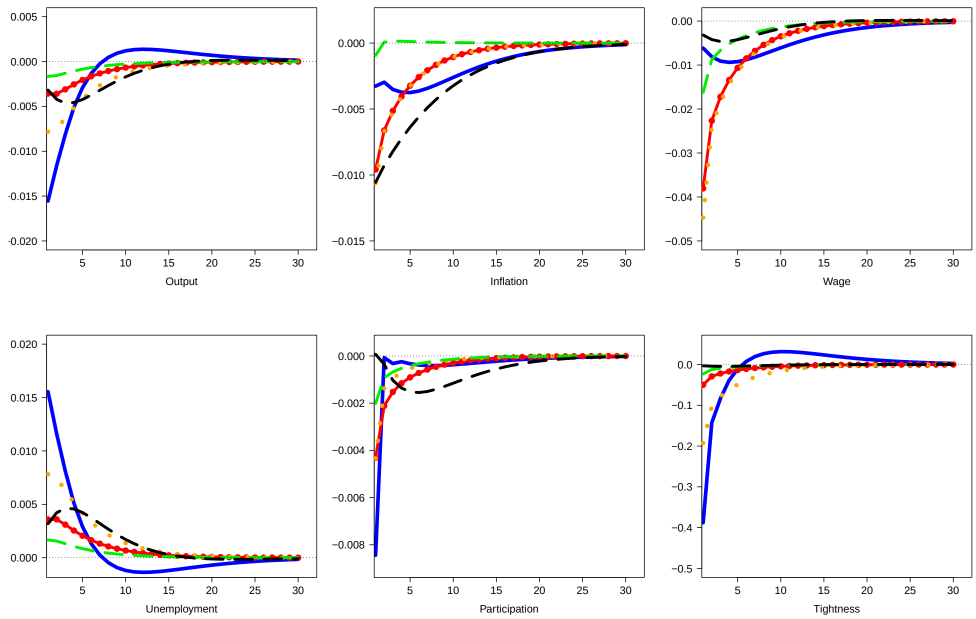

Figure 7: Impulse responses to uncertainty shock - alternative calibrations.
Sources: Author's own calculations
Notes: Percentage deviations from trend are plotted. Blue lines correspond to IRFs for a model with sticky prices and wage rigidity. Red lines correspond to IRFs for a model with sticky prices. Green lines correspond to IRFs for a model with sticky prices and an alternative formulation of the Taylor rule. Orange dotted lines correspond to IRFs for a model with sticky prices and high unemployment benefits (80% of real wages). Black dashed lines correspond to IRFs for a model with sticky prices wage rigidity and high level of habit persistence.

5.3 Sensitivity analysis

Figure 7 compares the response of the model economy under different parameterizations. All models presented in the figure feature price stickiness. Blue solid lines correspond to the specification including wage rigidity. Red lines refer to the model presented in the last subsection. Green and orange lines trace out the impulse responses for a model with an alternative formulation of the Taylor interest rule, and with high unemployment benefits respectively. Finally, the black-dashed lines correspond to a model with both wage rigidity and high level of habit persistence. In qualitative term, all impulse responses deliver the same message. Heightened uncertainty unambiguously increases unemployment, while, it has a negative effect on output, inflation, wage, labor market tightness and participation. Nonetheless, it should be noted that the purely quantitative effects are varying.

The introduction of wage rigidity is an additional transmission channel of the uncertainty shock. In this framework, an unexpected rise in uncertainty leads to the highest response of output, labor market tightness, unemployment and LFP. Unsurprisingly, the wage decrease is weak. Specifically, exposed to more uncertainty firms are not able to adjust wage downwards.

This mechanism amplifies the decrease in the match value leading to a fall in labor market tightness and job finding (not shown on figure 7). From the household point of view, the value of allocating an additional member into participation decreases. At the optimum, fewer members move from non-participation to participation. The results presented here confirm the conclusion of Cacciatore and Ravenna (2015) about the important role of wage sluggishness.

When the replacement ratio is high (80% of real wage), the surge in unemployment is also important. Indeed, in this setup an unemployment spell has a higher value, leading workers to be more reluctant for accepting low wage.

As the model is demand driven, I investigate the effect of a change in the monetary policy conducted by the central bank. Thus, I run the model with an alternative Taylor rule. In particular, it is assumed that the monetary policy reacts to deviations of inflation, output gap and the unemployment gap. Under this scenario the response of the economy is significantly different. As shown in figure 7, the responses of output and inflation are sharply lower. For instance, the fall in output is 10 times less important with this specification. On the labor market, the new monetary policy has an important stabilizing role. As monetary policy reacts to unemployment gap, the fall in unemployment is the lowest. Furthermore, the labor market tightness is almost constant following the shock, leading ultimately to a moderate decline in participation.

Finally, note that the empirical behaviors of unemployment, output and participation are retrieved when the model features a high degree of habit persistent and rigid wages. Thus, in this particular setup, the responses of output and participation are u-shaped. The peak response is reached approximately one year after the shock (the peak being achieved with a slight lag for participation). Furthermore, the hump-shaped pattern of unemployment is also reproduced.

6 Conclusion

This paper is the first to investigate the potential link between uncertainty and participation from empirical and theoretical points of view. Using a tri-variate Bayesian vector autoregression, I show that an unexpected increase in uncertainty leads to an u-shaped dynamic response of participation. Although the impact response is not significant, it is statistically significant 2 quarters after the impact and relatively persistent thereafter. The negative comovement between uncertainty and LFP is robust to several VAR alternatives. Hence, when I change the measure of uncertainty the qualitative response is entirely preserved and my favorite measure of uncertainty (the HEPU) appears to be a midpoint estimate. Furthermore, the main result is insensitive to the choice of participation variable and to the Cholesky ordering.

I then incorporate search frictions, endogenous participation decisions and a time-varying uncertainty shock into an otherwise New Keynesian DSGE model. I show that the replication of the empirical comovement is not straightforward. Thus, if the model features flexible prices, uncertainty is expansionary, increases output and participation but decreases unemployment. In this context, the precautionary saving motive dominates over the value option of "wait and see" of firms. Adding price stickiness greatly magnifies the response of the economy to uncertainty surprise. Furthermore, it is a key factor to reproduce observed comovements. In such a framework, firms cannot change their prices to meet the depressed demand. Hence, in addition to the wait and see channel, the demand channel pushes down future profits of firms. This mechanism totally undoes the precautionary behavior of household which responds to the fall in labor market tightness by moving fewer members from non-participation to participation. In addition, I also indicate that monetary policy can greatly stabilize the detrimental effect of uncertainty. Finally, along the lines of Cacciatore and Ravenna (2015), I demonstrate that, as sticky prices, wage rigidities is an important mechanism for the transmission of uncertainty shock on participation. As firms cannot freely renegotiate future wages, future profits of firms further reduce, leading to an even more decrease in LFP.

The findings outlined in this paper are complementary to previous works. It emphasizes that the abstraction from the participation margin may be misleading, even if it seems to be acyclical in the data. It supports the view that rigidities on prices and wages are important keys for reproducing the negative relationship between uncertainty, output and participation. Furthermore, I think that the theoretical relationship between uncertainty and participation should be studied in more depth and in a more complex framework than the one proposed here. For instance, adding capital accumulation or specific labor market institutions in a theoretical model will be probably informative. In this sense, this paper should be seen as a starting point in the investigation of the relationship between the participation to the labor market and economic uncertainty.

References

Aaronson, D., J. H. Davis, and L. Hu (2012). "Explaining the Decline in the U.S. Labor Force Participation Rate". Chicago Fed Letter 296, Federal Reserve Bank of Chicago.

Alexopoulos, M. and J. Cohen (2015). "Uncertain Times, Uncertain Measures". 2009 Meeting Papers 1211, Society for Economic Dynamics.

Andreasen, M. M., J. Fernández-Villaverde, and J. Rubio-Ramírez (2013, April). "The Pruned State-Space System for Non-Linear DSGE Models: Theory and Empirical Applications". Working Paper 18983, National Bureau of Economic Research.

Arseneau, D. M. and S. K. Chugh (2012). "Tax Smoothing in Frictional Labor Markets". *Journal of Political Economy 120*(5), 926–985.

Aruoba, S. B., J. Fernández-Villaverde, and J. F. Rubio-Ramírez (2006). "Comparing solution methods for dynamic equilibrium economies". *Journal of Economic Dynamics and Control 30*(12), 2477 – 2508.

Bachmann, R., S. Elstner, and E. R. Sims (2013). "Uncertainty and Economic Activity: Evidence from Business Survey Data". *American Economic Journal: Macroeconomics 5*(2), 217–249.

Baker, S., R., N. Bloom, and F. Steven, J. (2015). "Measuring economic policy uncertainty". NBER Working Paper Series 21633, National Bureau of Economic Research.

Basu, S. and B. Bundick (2014). "Uncertainty Shocks in a Model of Effective Demand". Working Paper RWP 14-15, Federal Reserve Bank of Kansas City.

Bekaert, G., M. Hoerova, and M. L. Duca (2013). "Risk, uncertainty and monetary policy". *Journal of Monetary Economics 60*(7), 771 – 788.

Bernanke, B. (1983). "Irreversibility, Uncertainty and Cyclical Investment". *Journal of Monetary Economics 98 (1)*, 85–107.

Blanchard, O. and J. Galí (2010). "Labor Markets and Monetary Policy: A New Keynesian Model with Unemployment". *American Economic Journal: Macroeconomics 2*(2), 1–30.

Bloom, N. (2009). "The Impact of Uncertainty Shocks". *Econometrica 77*(3), 623–685.

Bloom, N., M. Floetotto, I. Saporta-Eksten, and S. J. Terry (2012). "Really Uncertain Business Cycles". NBER Working Paper 18245, National Bureau of Economic Research.

Born, B. and J. Pfeifer (2014). "Policy risk and the business cycle". *Journal of Monetary Economics 68*, 68 – 85.

Cacciatore, M. and F. Ravenna (2015). "Uncertainty and the Business Cycle". Mimeo.

Caggiano, G., E. Castelnuovo, and N. Groshenny (2014). "Uncertainty shocks and unemployment dynamics in U.S. recessions". *Journal of Monetary Economics 67*, 78–92.

Calvo, G. A. (1983). "Staggered prices in a utility-maximizing framework. *Journal of Monetary Economics 12*(3), 383–398.

Campolmi, A. and S. Gnocchi (2016). "Labor market participation, unemployment and monetary policy". *Journal of Monetary Economics 79*, 17–29.

Cesa-Bianchi, A., M. H. Pesaran, and A. Rebucci (2014). "Uncertainty and Economic Activity: A Global Perspective". Working Paper CESifo 4736, Center for Economic Studies & Ifo Institute.

Charles, A., O. Darné, and F. Tripier (2015). "Uncertainty and the Macroeconomy: Evidence from a composite uncertainty indicator". Working Paper.

Ebell, M. (2011). "On the cyclicality of unemployment: Resurrecting the participation margin". *Labour Economics 18*(6), 822–836.

Elsby, M. W. L., B. Hobijn, and A. Şahin (2015). "On the importance of the participation margin for labor market fluctuations". *Journal of Monetary Economics 72*, 64–82.

Erceg, C. J. and A. T. Levin (2014). "Labor Force Participation and Monetary Policy in the Wake of the Great Recession". *Journal of Money, Credit and Banking 46*(S2), 3–49.

Fernández-Villaverde, J., P. Guerrón-Quintana, K. Kuester, and J. Rubio-Ramírez (2015, November). "Fiscal Volatility Shocks and Economic Activity". *American Economic Review 105*(11), 3352–84.

Fernández-Villaverde, J., P. Guerrón-Quintana, J. F. Rubio-Ramírez, and M. Uribe (2011). "Risk Matters: The Real Effects of Volatility Shocks". *The American Economic Review 101*(6), 2530–2561.

Foroni, C., F. Furlanetto, and A. Lepetit (2015). "Labour supply factors and economic fluctuations". Working Paper, Norges Bank Research.

Fujita, S. (2014). "On the Causes of Declines in the Labor Force Participation Rate". Research Rap, Federal Reserve Bank of Philadelphia.

Gertler, M. and A. Trigari (2009). "Unemployment Fluctuations with Staggered Nash Wage Bargaining". *Journal of Political Economy 117*(1), 38–86.

Guglielminetti, E. (2015). "The Effects of Uncertainty Shocks on the Labor Market: A Search Approach". Working Paper.

Hagedorn, M. and I. Manovskii (2008). "The Cyclical Behavior of Equilibrium Unemployment and Vacancies Revisited". *American Economic Review 98*(4), 1692–1706.

Hall, R. E. (2005). "Employment Fluctuations with Equilibrium Wage Stickiness". *The American Economic Review 95*(1), 50–65.

Koop, G., M. Pesaran, and S. M. Potter (1996). "Impulse response analysis in nonlinear multivariate models". *Journal of Econometrics 74*(1), 119 – 147.

Leduc, S. and Z. Liu (2016). "Uncertainty shocks are aggregate demand shocks". *Journal of Monetary Economics 82*, 20–35.

Merz, M. (1995). "Search in the labor market and the real business cycle". *Journal of Monetary Economics 36*(2), 269–300.

Mortensen, D. T. and C. A. Pissarides (1994). "Job Creation and Job Destruction in the Theory of Unemployment". *The Review of Economic Studies 61*(3), 397–415.

Ravn, M. O. (2006). "The Consumption-Tightness Puzzle". Working Paper 12421, National Bureau of Economic Research.

Tripier, F. (2004). "Can the labor market search model explain the fluctuations of allocations of time?". *Economic Modelling 21*(1), 131–146.

Veracierto, M. (2008). "On the cyclical behavior of employment, unemployment and labor force participation". *Journal of Monetary Economics 55*(6), 1143–1157.