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# Sources and costs of labor market fluctuations and the role of stabilization policies

Antoine Lepetit

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UNIVERSITÉ PARIS 1 - PANTHÉON SORBONNE  
U.F.R. DE SCIENCES ÉCONOMIQUES

**Thèse pour le Doctorat de Sciences Economiques**

Antoine Lepetit

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**Sources and costs of labor market  
fluctuations and the role of stabilization  
policies**

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*Directeur de thèse:*

Florin Bilbiie - Professeur à l'Université Paris 1 Panthéon-Sorbonne

*Jury:*

Francesco Furlanetto - Chercheur à la Banque Centrale de Norvège

Jordi Galí - Professeur à l'Université Pompeu Fabra - Rapporteur

Jean-Olivier Hairault - Professeur à l'Université Paris 1  
Panthéon-Sorbonne

Federico Ravenna - Professeur à HEC Montréal - Rapporteur

*“L’université Paris I Panthéon-Sorbonne n’entend donner aucune approbation ni improbation aux opinions émises dans cette thèse. Ces opinions doivent être considérées comme propres à leur auteur.”*

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# Introduction Générale

La crise financière de 2008-2009 a provoqué un ralentissement de l'activité économique à l'échelle mondiale. En Europe, ses conséquences ont été aggravées par le début de la crise des dettes souveraines début 2010. Dans tous les pays, le ralentissement de l'activité économique s'est accompagné d'une détérioration des conditions sur le marché du travail. Aux États-Unis, le taux de chômage a doublé entre le début de l'année 2008 et la fin de l'année 2009. Dans la zone euro, il était de 7.2% début 2008 et a augmenté progressivement jusqu'à atteindre un pic de 12% à la mi-2013. Ces évolutions, quoique exceptionnelles de par leur taille, font partie intégrante de phases successives d'expansion économique et de récession, ce que les économistes appellent les « cycles économiques ». Les expansions se caractérisent par une augmentation simultanée de la croissance de la production et de l'emploi. Lors de récessions, au contraire, la croissance ralentit et les conditions sur le marché du travail se dégradent. En dépit de ces régularités, la relation entre les évolutions de l'activité économique et celles du marché du travail varie considérablement en fonction des pays et des périodes. Ces dernières années, alors que le taux de chômage a plus que doublé en Espagne, il n'a que très marginalement été affecté par le ralentissement de la croissance en Allemagne. Il est possible de

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rendre compte de cette hétérogénéité en calculant l'élasticité du taux de chômage à la production, c'est-à-dire la variation du taux du chômage divisée par la variation du taux de croissance de la production. Durant la période 2007-2011, cette élasticité était de 1.2 en Espagne, de 0.3 en France et de seulement 0.1 en Allemagne (ECB 2012). Cette hétérogénéité ne se limite cependant pas au taux de chômage. Elle concerne également d'autres indicateurs du marché du travail tels que le nombre d'heures travaillées ou le taux de participation à la population active. À titre d'exemple, alors que le taux de participation à la population active est resté inchangé en France durant la crise, il a chuté de trois points de pourcentage aux États-Unis.

Ces observations soulèvent un certain nombre de questions. Premièrement, quelles forces sous-tendent ces fluctuations du marché du travail ? Trouvent-elles leur origine sur le marché du travail ? Deuxièmement, le marché du travail a-t-il tendance à amplifier ou atténuer l'effet de ces « chocs » sur l'activité économique ? Finalement, quel est le coût de ces fluctuations et quel rôle doivent jouer les politiques de stabilisation économique, notamment la politique monétaire ?

Cette thèse a pour but de contribuer à la littérature académique qui s'est intéressée à ces questions. Une première partie de cette introduction présente les différentes approches adoptées dans la littérature. Une deuxième partie présente les chapitres de cette thèse et explique en quoi ils contribuent à la littérature existante.

## **Revue de littérature**

### **Chocs technologiques et cycles économiques**

Depuis la fin des années 1970 et la critique de Lucas (1976) de l'évaluation des politiques économiques à l'aide de modèles économétriques, l'accent a été mis sur le développement de modèles dans lesquels les mouvements de l'activité réelle découlent des comportements d'optimisation des agents économiques. L'analyse de la macroéconomie a donc basculé vers une approche basée sur fondements microéconomiques. L'émergence de la théorie des cycles réels, qui met le modèle de croissance néo-classique au centre de l'analyse des fluctuations économiques, s'inscrit dans la lignée de ce programme de recherche. Kydland et Prescott (1982) ont montré qu'un modèle de croissance soumis à des chocs de technologie pouvait reproduire la volatilité et les co-mouvements de la production intérieure brute, l'investissement et la consommation observés dans les données américaines d'après-guerre. Dans ce modèle, aucune imperfection de marché ne distord l'allocation des ressources et les fluctuations économiques sont efficaces. Toute intervention de politique économique est donc indésirable. De plus, le marché du travail étant parfaitement concurrentiel, le chômage involontaire est totalement absent de ce type de théorie. Les ménages effectuent un choix optimal entre emploi et inactivité en fonction de leurs préférences pour le loisir et la consommation.

Les années 1980 virent également l'émergence d'un nouveau cadre théorique pour l'analyse du marché du travail. Les travaux de Diamond, Mortensen et Pissarides (prix Nobel d'économie 2010) introduisirent l'idée qu'il est long et coûteux pour un chômeur de rechercher un emploi et pour une firme de pourvoir un em-

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ploi vacant. À une période donnée, du fait de ces frictions d'appariement, certains chômeurs ne peuvent pas trouver d'emploi et certains emplois vacants ne peuvent pas être pourvus. Le chômage apparaît alors naturellement comme phénomène d'équilibre. Ces modèles incluant des frictions d'appariement ont servi de cadre d'analyse pour étudier les effets de différentes politiques de l'emploi et du marché du travail. Ils ont également été utilisés pour expliquer les fluctuations cycliques du chômage et des emplois vacants. En général, ces études se sont placées dans un cadre où les fluctuations économiques sont essentiellement dues à des chocs de technologie. Shimer (2005) a montré que le modèle standard de frictions d'appariement ne peut pas expliquer la volatilité du marché du travail observée dans les données américaines. En effet, dans ce modèle, toute augmentation des revenus réels d'une firme due à un choc de technologie est compensée par une augmentation des salaires. Les firmes n'ont alors que très peu d'intérêt à augmenter l'emploi. De nombreuses extensions du modèle ont été proposées pour régler ce problème ; notamment l'introduction de rigidités salariales (Hall 2005, Hall and Milgrom 2008), l'introduction de coûts de formation en plus des coûts de recrutement (Pissarides 2009), l'introduction de frictions financières (Petrosky-Nadeau 2014) ou une autre calibration (Hagedorn and Manovskii 2008). Cependant, malgré cet intérêt pour les déterminants des fluctuations du chômage, seules quelques articles, notamment ceux de Hairault et al. (2010) et de Jung et Kuester (2011) ont proposé une analyse du coût de ces fluctuations. Ces auteurs ont montré que les frictions d'appariement génèrent une dynamique du chômage asymétrique qui peut s'avérer très coûteuse pour la société.

## **Quelle est l'importance des chocs trouvant leurs origines sur le marché du travail ?**

Les théories précédentes partent du principe que les chocs de technologie permettent d'expliquer la majeure partie des fluctuations économiques. Le rôle prédominant de ces chocs a été remis en cause par certains auteurs. Galí (1999) a identifié des chocs de technologie à l'aide de restrictions de long terme dans un modèle "Vector Auto Regressive" et trouvé qu'ils génèrent une corrélation négative entre les heures travaillées et la production. Les composantes cycliques de ces deux variables étant positivement et fortement corrélées dans la plus grande partie des pays de l'OCDE, ce résultat implique que les chocs de technologie ne peuvent pas être une des sources majeures des fluctuations économiques. Cette découverte a poussé les chercheurs à expliquer les fluctuations de l'activité économique à l'aide d'autres types de chocs. Récemment, suite à la crise financière de 2008-2009, les chocs trouvant leur origine dans le secteur financier ont fait l'objet d'une attention particulière (Justiniano et al. 2010, Christiano et al. 2015 par exemple).

Une des découvertes de ce programme de recherche est que les chocs trouvant leur origine sur le marché du travail sont de première importance. Hall (1997) a montré que les mouvements pro-cycliques de l'écart entre le taux marginal de substitution entre consommation et loisir et la productivité marginale du travail permettent d'expliquer la majeure partie des fluctuations de l'emploi. Ce résultat a été confirmé par Chari, Kehoe and McGrattan (2007). En pratique, deux chocs, un sur l'offre de travail et un sur le pouvoir de négociation des salariés, ont été utilisés pour expliquer les mouvements cycliques de ce "coin du travail". La distinction entre ces deux interprétations est d'une importance particulière pour évaluer les coûts en bien-être des fluctuations économiques. Dans un modèle de cycles réels

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d'affaire standard, l'économie s'ajuste de manière efficiente suite à un choc d'offre de travail. Cependant, un choc sur le pouvoir de négociation des salariés crée un écart entre les niveaux efficient et naturel de production. Par conséquent, expliquer les fluctuations du coin du travail avec l'un ou l'autre de ces chocs conduit à une évaluation très différente du coût en bien-être des fluctuations économiques. Galí et al. (2007) font l'hypothèse que les mouvements cycliques du coin du travail proviennent exclusivement de chocs sur le pouvoir de négociation des salariés et trouvent que les périodes de récession sont associées à des pertes de bien-être très importantes.

### **Quel est le rôle de la politique monétaire dans ces différentes théories des fluctuations ?**

Dans les modèles de cycles d'affaire réels, la politique monétaire n'a aucun impact sur l'activité réelle. Dans les modèles Keynésiens, au contraire, la viscosité des prix permet à la politique monétaire d'exercer un rôle stabilisateur sur les fluctuations de la production et du marché du travail à court terme. La nouvelle synthèse néo-classique réconcilie ces deux approches ; tout en mettant la viscosité des prix au centre de l'analyse des fluctuations économiques, elle conserve les principes d'optimisation inter-temporelle et d'anticipations rationnelles tirés de la révolution des cycles réels. Le modèle Nouveau Keynésien, qui est le produit de cette synthèse, est désormais le modèle de référence pour l'analyse de la politique monétaire. Dans ce modèle, l'activité économique est déterminée par le niveau de la demande à court terme. À long terme, néanmoins, la dynamique du modèle est celle d'un modèle de cycles d'affaire réels standard.

Dans ce modèle, il est optimal pour une banque centrale de se focaliser sur la stabilisation de l'inflation en réponse à des chocs de technologie ou de demande. Suivre une telle politique permet à l'autorité monétaire de refermer l'écart de production, soit l'écart entre le niveau de production et le niveau de production naturel. L'écart entre les niveaux de production naturel et efficient étant constant, une telle politique permet également de stabiliser l'écart entre le niveau de production et le niveau de production efficient. Cette propriété a été qualifiée de « coïncidence divine » par Blanchard et Galí (2007). Cependant, il convient de noter que stabiliser l'écart de production n'implique pas stabiliser la production elle-même. Dans une économie soumise à de nombreux chocs d'offre, le niveau de production naturel est très volatil et une politique de stabilité des prix génère d'importantes fluctuations de l'activité. Cette coïncidence divine n'est cependant valide que dans un cas particulier. De nombreuses études ont montré qu'une banque centrale fait face à un arbitrage entre la stabilisation de l'inflation et la stabilisation de la production en présence de certains chocs sur les coûts (notamment des chocs sur le pouvoir de négociation des salariés) ou de certaines frictions sur le marché du travail (Erceg Levin 2000, Blanchard et Galí 2007, Faia 2008) et dans le secteur financier (De Fiore et Tristani 2013). Cependant, dans l'écrasante majorité des cas, il reste optimal pour l'autorité monétaire de se consacrer quasi exclusivement à la stabilisation de l'inflation (Walsh 2014). L'arbitrage de politique monétaire existe mais il est très largement en faveur de la stabilisation de l'inflation.

Cette littérature utilise des modèles relativement simples et se propose d'isoler le rôle d'une ou plusieurs frictions pour la conduite optimale de la politique monétaire. D'autres études ont développé et estimé des modèles Nouveau Keynésiens

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incorporant un nombre conséquent de frictions nominales et réelles avec pour but de reproduire la dynamique observée de l'économie. Dans la plupart de ces modèles, les chocs trouvant leur origine sur le marché du travail jouent un rôle très important. Par exemple, dans le modèle de Smets et Wouters (2007), les chocs sur le pouvoir de négociation des salariés expliquent environ la moitié des fluctuations de la production et les deux-tiers des fluctuations de l'emploi à un horizon de quarante trimestres. Il a été montré que, dans ce type de modèle, l'arbitrage de politique monétaire entre stabilisation de l'inflation et stabilisation de la production dépend de l'importance relative des différents chocs trouvant leur origine sur le marché du travail. Debortoli et al. (2015) utilisent le modèle de Smets et Wouters (2007) et trouvent que la politique monétaire devrait mettre un poids important sur la stabilisation de l'activité réelle. À contrario, Justiniano et al. (2013) font l'hypothèse que les chocs d'offre de travail sont les déterminants principaux des fluctuations du coin du travail et trouvent qu'une politique de stabilité des prix est optimale.

### **Description des chapitres de thèse**

Cette thèse est composée de trois chapitres. Dans le premier chapitre, co-écrit avec Claudia Foroni et Francesco Furlanetto, nous nous intéressons aux sources des fluctuations sur le marché du travail. Notamment, nous isolons et nous quantifions le rôle joué par les chocs trouvant leur origine sur le marché du travail. Dans le second chapitre, co-écrit avec Vincent Boitier, nous montrons qu'une forme analytique simple pour le salaire peut être obtenue à partir d'un modèle de négociation des salaires très utilisé dans la littérature sur les frictions d'appariement. Dans le

dernier chapitre, je m'intéresse à la façon dont la conduite optimale de la politique monétaire dépend de la nature des fluctuations du chômage. Je montre qu'il est préférable pour l'autorité monétaire de mettre un poids important sur la stabilisation de l'activité réelle en présence de fluctuations du chômage asymétriques.

## **Chapitre 1**

Ce chapitre, co-écrit avec Claudia Forni et Francesco Furlanetto, tous deux chercheurs à la Banque Centrale de Norvège, tente d'apporter une réponse à la première question posée au début de cette introduction : quels chocs peuvent expliquer les fluctuations du marché du travail ? Les modèles macroéconomiques modernes expliquent les mouvements pro-cycliques du coin du travail à l'aide de chocs sur le comportement d'offre de travail des ménages ou sur le pouvoir de négociation des salariés. L'objectif de ce chapitre est d'identifier ces deux chocs dans un modèle « Vector Auto Regressive » (VAR) et de quantifier leurs contributions respectives aux fluctuations de la production, de l'inflation, des salaires, du chômage et de la population active.

Afin d'identifier ces deux chocs, nous proposons une nouvelle méthode basée sur des restrictions de signe. Celles-ci sont obtenues à partir d'un modèle Nouveau-Keynésien incorporant des frictions d'appariement sur le marché du travail et un choix de participation à la population active endogène. Il est vérifié que ces restrictions sont robustes à des changements de la calibration du modèle. Des intervalles réalistes sont définis pour chacun des paramètres du modèle et 10 000 calibrations différentes sont tirées de manière aléatoire à partir de ces intervalles. Les restrictions de signe que nous imposons sont vérifiées dans la quasi totalité de ces 10

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000 calibraitons. Notre contribution centrale est d'utiliser des données sur le taux de chômage et le taux de participation à la population active pour identifier les deux chocs. Dans le modèle théorique, le chômage et la population active sont pro-cycliques en réponse à des chocs sur l'offre de travail et contra-cycliques en réponse à des chocs sur le pouvoir de négociation des salariés. Ce comportement asymétrique du chômage et du taux de participation à la population active est utilisé pour identifier séparément les deux chocs dans le modèle VAR. Le tableau 0.1 donne un aperçu des restrictions de signe que nous utilisons pour identifier les différents chocs.

Table 0.1 : Restrictions de signe

	Demande	Technologie	Offre de travail	Pv. Négociation
PIB	+	+	+	+
Prix	+	-	-	-
Salaires réels	/	+	-	-
Chômage	-	/	+	-
Population active	/	/	+	-

Nous trouvons que les deux chocs trouvant leur origine sur le marché du travail contribuent de manière importante aux fluctuations de la production et du chômage. Le graphique 0.1 présente une décomposition de la variance des erreurs de prévision du modèle en fonction de l'horizon de prévision (en abscisse). On peut voir que les chocs d'offre de travail permettent d'expliquer une part conséquente des fluctuations économiques à long terme ; ils contribuent à 60% des fluctuations de la production et 50% des fluctuations du chômage à un horizon de trente trimestres. Les chocs sur le pouvoir de négociation des salariés jouent quant à eux un rôle plus important à court terme mais ont tout de même un impact non-négligeable à

long terme, notamment pour ce qui est des fluctuations du chômage. Ces résultats viennent compléter ceux d'une littérature qui s'est attachée à identifier des chocs d'offre de travail dans des modèles VAR. Shapiro et Watson (1988) trouvent que les chocs d'offre de travail expliquent une part importante des fluctuations de la production et des heures travaillées à long terme. Blanchard et Diamond (1989) et Chang et Schorfheide (2003) mettent également en évidence leur importance à plus court terme. Nous contribuons à cette littérature en affinant l'identification des chocs d'offre de travail. Les études précédentes ne permettaient pas une distinction entre chocs d'offre de travail et chocs sur le pouvoir de négociation des salariés. Ces résultats contribuent également à la littérature s'intéressant à l'identification de chocs trouvant leur origine sur le marché du travail dans le cadre de modèles DSGE. Dans un modèle DSGE standard, les chocs d'offre de travail et de pouvoir de négociation des salariés ne peuvent pas être séparément identifiés. Certains auteurs ont contourné ce problème en supposant que les chocs sur le pouvoir de négociation des salariés ne jouent aucun rôle à long terme (Justiniano et al. 2013) ou qu'ils sont les seuls déterminants du chômage à long terme (Galí et al. 2011). Au vu de nos résultats, aucune de ces deux hypothèses ne semble justifiée

Nous proposons également une analyse historique de l'évolution de la population active à l'aide de notre modèle VAR. Depuis 2008 et le début de la « Grande Récession », le taux de participation à la population active a chuté de trois points aux Etats-Unis. De nombreux travaux ont cherché à analyser les déterminants de cette baisse. Une partie de la littérature estime que celle-ci est essentiellement due à la faiblesse de la demande. D'autres auteurs, au contraire, estiment que la baisse du taux de participation à la population active est due à des facteurs structurels

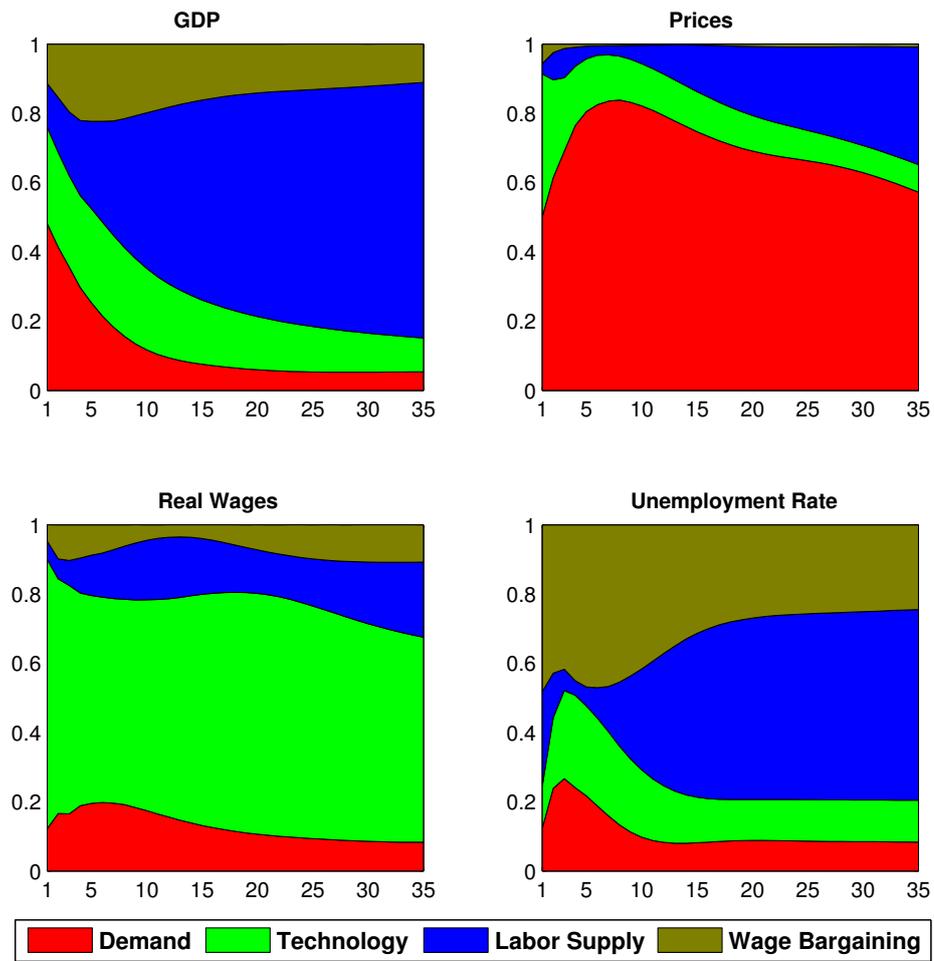


FIGURE 0.0.1 : Décomposition de la variance dans le modèle de base

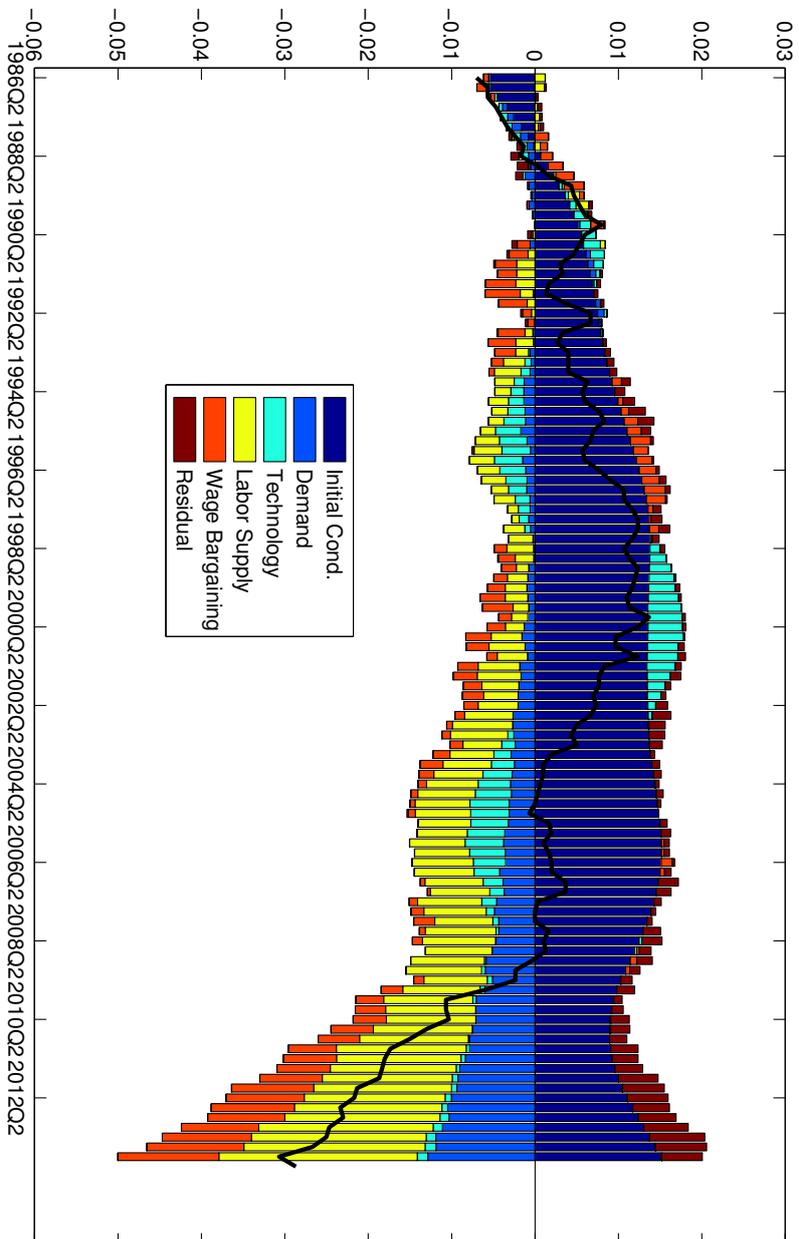
liés à des évolutions démographiques. Celles-ci devraient être en partie captées par notre choc d'offre de travail. Le graphique 0.0.2 présente une décomposition historique de la population active aux États-Unis. La ligne noire est la déviation de la population active de sa moyenne. Les barres de différentes couleurs représentent les contributions de chacun des chocs aux fluctuations de la population active. Historiquement, nous trouvons que les fluctuations de la population active sont principalement expliquées par des chocs sur l'offre de travail. Depuis 2008, ceux-ci ont contribué à environ 50% du déclin du taux de participation à la population active observé.

## **Chapitre 2**

Ce chapitre est co-écrit avec Vincent Boitier de l'Université Paris 1 Panthéon-Sorbonne. De nombreuses études ont montré que la prise en compte de rigidités salariales réelles permet d'expliquer les fluctuations cycliques du chômage et des emplois vacants. La plupart de ces études ont avancé l'idée que des normes sociales seraient à l'origine de ces rigidités de salaire (Hall 2005 ou Blanchard et Galí 2010). Hall et Milgrom (2008) ont quant à eux montré que les rigidités de salaire peuvent découler du processus de négociation salariale. En effet, lors de la négociation, il est optimal pour les employeurs et les chercheurs d'emploi de continuer à négocier jusqu'à ce qu'un accord soit trouvé. Toute menace de rompre la négociation de manière unilatérale n'est pas crédible. Ceci a pour conséquence d'isoler les salaires réels des conditions sur le marché du travail et de les rendre « rigides » de manière endogène.

Malgré l'intérêt qu'il a suscité, ce modèle de négociations salariales reste très peu

FIGURE 0.0.2 : Décomposition historique du taux de participation à la population active aux Etats-Unis



utilisé du fait de sa complexité. En effet, il est généralement impossible d'obtenir une expression simple pour le salaire réel. Dans ce chapitre, nous montrons qu'une telle expression simple et explicite pour le salaire peut être obtenue à partir d'un jeu à offres alternées à la Hall et Milgrom (2008) lorsqu'une restriction paramétrique plausible est imposée. Lors de la négociation, chacun des joueurs fait tour à tour une offre à l'autre. Si l'offre est acceptée, le jeu est terminé. Si l'offre est refusée, le jeu continue avec une certaine probabilité (inférieure à 1) et c'est à l'autre joueur de faire une offre. Lorsque l'hypothèse est faite que la probabilité exogène d'échec des négociations salariales est égale à la probabilité de sortie de l'emploi, une forme analytique simple pour le salaire peut être trouvée. Cette restriction est vérifiée dans le modèle estimé de Christiano et al. (2015).

Cette équation peut être utilisée dans des études qui ont recours à des rigidités sur les salaires pour générer des fluctuations réalistes du chômage et des emplois vacants. Elle présente l'avantage d'être simple et micro-fondée. Lorsqu'elle est utilisée dans des modèles avec frictions d'appariement à l'état stationnaire, les variables endogènes peuvent être exprimées en fonction des paramètres et des variables exogènes du modèle. Dans un modèle dynamique, elle présente l'avantage de générer une élasticité des salaires à la productivité du travail égale à celle estimée par Haefke et al. (2013).

### **Chapitre 3**

Ce chapitre cherche à évaluer le rôle de la nature des fluctuations du chômage pour la conduite optimale de la politique monétaire. Il contribue à la littérature sur les arbitrages de politique monétaire en montrant qu'il est préférable pour une banque

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centrale de mettre un poids important sur la stabilisation de l'activité réelle lorsque les fluctuations du chômage sont asymétriques. Dans beaucoup d'études, adopter une politique monétaire optimale plutôt qu'une politique de stabilité des prix génère des gains de bien-être négligeables. Lorsque les fluctuations du chômage sont asymétriques, les gains à adopter une politique monétaire qui réduit la volatilité macroéconomique s'avèrent importants.

Aux États-Unis, le taux de chômage augmente plus rapidement en période de récession qu'il ne décroît en période d'expansion économique (Ferraro 2015). Hairault et al. (2010) et Jung et Kuester (2011) ont montré qu'une telle dynamique asymétrique du chômage peut être obtenue dans un modèle du marché du travail standard avec des frictions d'appariement. Dans ce type de modèle, du fait de l'asymétrie des fluctuations du chômage, une plus grande volatilité du taux de chômage conduit à une augmentation du niveau moyen de celui-ci. La validité de ce mécanisme est confirmée par Benigno et al. (2015). Ces auteurs trouvent qu'une augmentation de la volatilité macroéconomique est associée à une augmentation du taux de chômage de long terme aux États-Unis.

Cette hausse du taux de chômage moyen est susceptible de conduire à une baisse de la consommation par tête et est donc potentiellement coûteuse du point de vue de la société. Ce chapitre cherche à comprendre comment la politique monétaire devrait être menée dans cet environnement. J'utilise un modèle Nouveau Keynésien avec des frictions d'appariement sur le marché du travail qui est calibré afin de reproduire des caractéristiques clés de l'économie américaine. Dans ce cadre, l'arbitrage entre la stabilisation de la volatilité de l'inflation et de la volatilité du chômage décrit par Taylor (1994) devient un arbitrage entre la stabilisation de

l'inflation et le taux chômage moyen. Dans la version de base du modèle, la différence entre le taux de chômage moyen et le taux de chômage d'état stationnaire est de 0.2 points de pourcentage. Lorsque la banque centrale suit une politique de stabilité des prix, cet écart atteint 0.44 points de pourcentage. De manière plus générale, pour une réponse à l'écart de production donnée, le taux de chômage moyen est une fonction croissante de la réponse systématique de la politique monétaire à l'inflation. Le graphique 0.0.2 représente graphiquement l'arbitrage qui est obtenu dans la calibration de base du modèle.

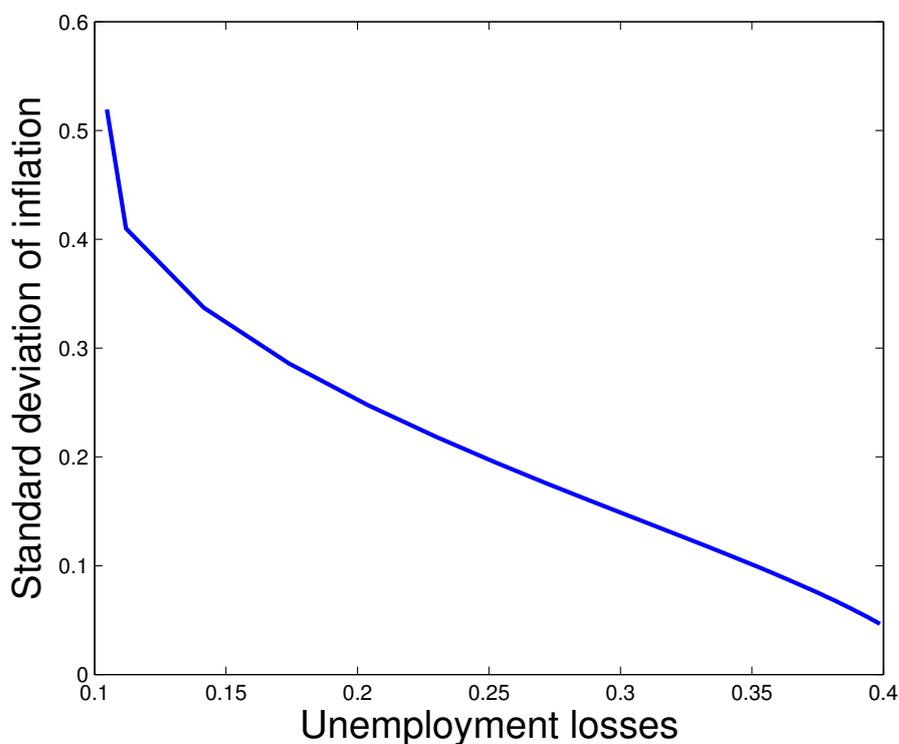


FIGURE 0.0.3 : Arbitrage entre la volatilité de l'inflation et le taux de chômage moyen dans un modèle Nouveau Keynésien avec des frictions d'appariement sur le marché du travail

La présence de cet arbitrage entre la stabilisation de l'inflation et le taux de

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chômage moyen implique qu'il est optimal pour une banque centrale d'adopter un mandat dual de stabilisation de l'activité réelle et de stabilisation de l'inflation. Comme on peut le voir dans le graphique 0.0.3, l'utilité du ménage représentatif dans la calibration de base du modèle est maximale lorsque la politique monétaire répond fortement aux fluctuations de l'emploi. Une telle politique monétaire permet de réduire la volatilité du chômage ainsi que le chômage moyen. Cette réduction du chômage moyen permet une augmentation de la consommation par tête et génère des gains de bien-être conséquents.

Valeur de la production domestique	Gains de bien-être
$b = 0$	0.43%
$b = 0.4$	0.18%
$b = 0.6$	0.09%
$b = 0.7$	0.05%

TABLE 0.2 : Gains de bien être en fonction de la valeur de la production domestique

Comme on peut le voir dans le tableau 0.2, la taille de ces gains dépend d'un paramètre clé, la valeur de la production domestique. Lorsque celle-ci est élevée, une augmentation donnée du chômage n'a qu'un impact faible sur la consommation et une politique de stabilité des prix est presque optimale. Cependant, lorsque cette valeur de la production domestique est faible, une augmentation similaire du chômage a un impact beaucoup plus marqué sur la consommation et il devient optimal de stabiliser les fluctuations de l'emploi.

Ce chapitre contribue à une littérature importante qui s'est intéressée à la conduite optimale de la politique monétaire en présence de frictions d'appariement sur le marché du travail. Faia (2008 et 2009) et Ravenna et Walsh (2012) ont mon-

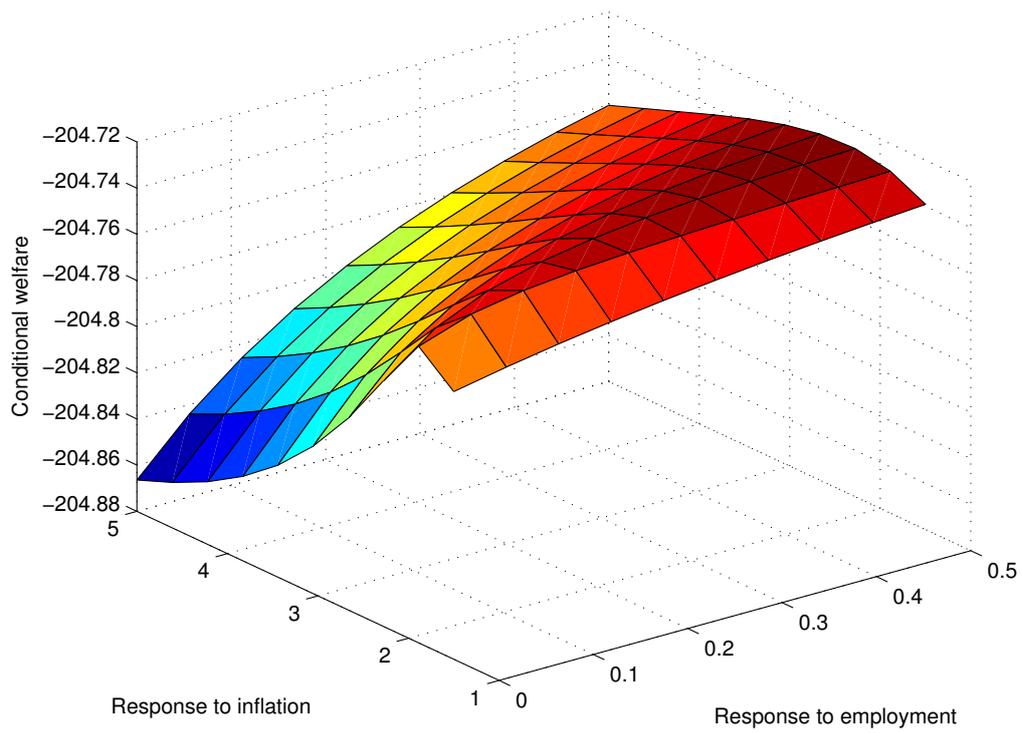


FIGURE 0.0.4 : Niveaux d'utilité en fonction de la réponse de l'autorité monétaire à l'inflation et à l'emploi

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tré qu'il existait un arbitrage entre la stabilisation de l'inflation et la stabilisation du chômage en présence de frictions d'appariement. Cependant, dans ces articles, la stabilisation quasi exclusive de l'inflation reste optimale. Thomas (2008) et Blanchard et Galí (2010) ont montré quant à eux qu'une politique de stabilité des prix peut conduire à des pertes importantes de bien être lorsque les salaires nominaux sont visqueux ou que les fluctuations de l'emploi ont un impact direct et négatif sur l'utilité des ménages. La contribution de ce chapitre est de montrer qu'une politique de stabilité des prix conduit également à des pertes de bien être importantes en présence de fluctuations du chômage asymétriques.

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The financial crisis of 2008-2009 triggered a global slowdown in economic activity. In Europe, its consequences were aggravated by the start of a debt crisis in early 2010. Across countries, the decline in economic activity was accompanied by rapidly deteriorating labor market conditions. In the United States, the unemployment rate rose from a rate of 5% in early 2008 to a peak of 10% at the end of 2009. In the Euro area, it rose continuously from a level of 7.2% in early 2008 to a peak of 12% by mid-2013. These developments, while exceptional in their magnitude, are part of a series of recurring phases of expansions and recessions, what economists call “business cycles”. Expansions are characterized by joint increases in output growth and employment while recessions are times when the growth rate of production wanes and labor market conditions progressively deteriorate. However, in spite of this observed regularity between output and employment, the relation between economic activity and labor market activity differs considerably across countries and across time. In the past years, while the unemployment rate was barely affected by the economic turmoil in Germany, it more than doubled in Spain. One way of capturing this heterogeneity in the reaction of the labor market to the crisis is to compute the elasticity of unemployment to output, that is, the change

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in unemployment divided by the change in the growth rate of output. During the 2007-2011 period, it varied from 1.2 in Spain to a mere 0.3 in France and 0.1 in Germany (ECB 2012). However, this heterogeneity is not limited to the behavior of the unemployment rate. It can also be observed when considering the cyclical behavior of other labor market indicators such as the labor force participation rate, or the number of hours worked.

These observations raise a certain number of intertwined questions. First, which disturbances underlie these labor market fluctuations? Do they find their origin within or outside the labor market? Second, are there key characteristics of the labor market that tend to amplify or dampen the effects of these shocks on economic activity? Third, how costly are these fluctuations, and what does this imply for stabilization policies, especially monetary policy?

This thesis aims to contribute to a large body of literature that has attempted to shed some light on these issues. The first section of this introduction reviews the different approaches that have been taken to tackle these questions. It focuses on identifying the driving forces and on assessing the costs of labor market fluctuations implied by each of these competing theories. The second section details how the different chapters of this dissertation relate and contribute to this literature.

### **An overview of the literature**

#### **Technology-driven business cycles**

Since the end of the 1970s and the Lucas critique (1976) of econometric policy evaluation, a great emphasis has been placed on developing models in which movements in economic activity result from the optimizing decisions of individual

agents and in which the decision rules of these agents vary with changes in policy. That is, the focus has shifted towards an analysis of the macroeconomy based on micro-foundations. Following this research agenda, the real business cycles (RBC) revolution pioneered by Kydland and Prescott (1982) has established the neo-classical growth model as the main tool for the analysis of business-cycle fluctuations. These authors showed that a simple growth model buffeted by technology shocks can account reasonably well for the volatility and co-movements of gross domestic product, investment, and consumption in post-war US data. In the model, fluctuations are seen as the efficient response of the economy to technology shocks, and any policy intervention is thus welfare detrimental. Notably, labor markets are perfectly competitive and unemployment (or rather non-employment) can only result from an optimal choice of households between labor income and leisure time. In other words, this theory gives no room to involuntary unemployment.

In parallel, the seminal contributions of Diamond, Mortensen, and Pissarides, who were awarded the 2010 Nobel prize in economics for their work, established a new framework for the analysis of labor markets based on the idea that the mechanism through which unemployed workers and jobs are matched is costly and time consuming. Notably, it takes time and effort for job seekers to find a job and for firms to evaluate applications for job openings. These search frictions give rise to equilibrium unemployment as some workers are not able to find a job within a given period. While this search and matching theory of labor markets has been extensively used to study the effects of different labor market policies, an important literature has instead focused on the ability of the model to replicate the observed fluctuations in unemployment, vacancies, and labor market flows at business-cycle

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frequencies. These studies retain the idea of a world in which technology shocks account for the bulk of fluctuations in economic activity. Shimer (2005) showed that the canonical search and matching model is unable to account for the volatility of labor market variables observed in U.S. data. In the baseline case of Nash-bargained flexible wages, the wage is too sensitive to aggregate conditions and "eats" all the incentives of firms to adjust through the employment margin. Several modifications to the model including wage rigidity (Hall 2005, Hall and Milgrom 2008), an alternative calibration (Hagedorn and Manovskii 2008), the introduction of fixed matching costs (Pissarides 2009), or the introduction of financial frictions (Petrosky-Nadeau 2014) have been proposed to solve this issue. In most cases (although not all), the structure of the labor market has been shown to be a key factor for the propagation of shocks. In spite of this interest for the determinants of unemployment fluctuations, only a few studies have attempted to assess the cost of these fluctuations. Hairault et al. (2010) and Jung and Kuester (2011) are notable exceptions. They showed that the asymmetric unemployment dynamics brought about by matching frictions may lead to substantial business cycle costs.

### **Do labor market shocks matter ?**

The preceding theories relied on technology shocks as the driving forces of business-cycle fluctuations. This predominance of technology shocks was challenged by several authors. Galí (1999) identified technology shocks using long-run restrictions in a vector autoregressive (VAR) framework and found that these shocks generate a negative correlation between hours and output. Since those two variables are strongly positively correlated over the business-cycle in the data, this result im-

plied that technology shocks cannot be the sole source of fluctuations in economic activity, let alone a major one. This finding led researchers to rely on other disturbances to account for fluctuations in real activity. Recently, in light of the financial crisis, shocks originating in the financial sector (Justiniano et al. 2010, Christiano et al. 2015 for example) have received a great deal of attention.

This research agenda has found labor market shocks to be of particular importance. Hall (1997) showed that pro-cyclical movements in the gap between the marginal rate of substitution between consumption and leisure and the marginal product of labor could account for the most part of employment fluctuations. This result was confirmed by Chari, Kehoe and McGrattan (2007). In practice, movements in this “labor wedge” have been interpreted either as exogenous shifts in the disutility of supplying labor or as movements in wage mark-ups. The distinction between these two possible interpretations is of specific importance to evaluate the welfare costs of business cycles. In a prototypical real business cycle model, the adjustment of the economy to a labor supply shock is efficient. However wage mark-up shocks create an inefficient wedge between the efficient and the natural levels of output. Thus, accounting for movements in the labor wedge with one shock or the other will lead to markedly different views about the welfare costs of business cycles. Galí et al. (2007) interpret high-frequency shifts in the labor wedge as arising from movements in wage markups, and find that while business cycle costs are on average modest, recessions are associated with important welfare losses.

**What do these alternative theories of business cycles imply for the conduct of monetary policy ?**

In real business cycle models, monetary policy is essentially unimportant for real activity. In sticky-prices Keynesian models, however, monetary policy is viewed as a powerful tool to stabilize fluctuations in output and labor market activity. These two approaches were reconciled in a new neo-classical synthesis which combined the methodological insights of the RBC revolution, the application of inter-temporal optimization, and rational expectations, with the belief that short-run price stickiness is key to explaining economic fluctuations. The New Keynesian model that has emerged from this synthesis is now the workhorse model for the analysis of monetary policy. It essentially consists in a real business cycles model augmented with monopolistic competition in the product market and short-run price stickiness. In this framework, real activity is determined by aggregate demand in the short-run but follows the real business cycles dynamics in the long-run.

A central prediction of the baseline New Keynesian model is that, in the presence of technology shocks, a central bank should not try to stabilize fluctuations in output or labor market activity, but should only focus on stabilizing inflation. By doing so, it also closes the output gap, that is, the gap between the actual and the natural levels of output. Because the gap between the natural level of output and the first-best level of output is constant, this also implies that the monetary authority stabilizes the welfare-relevant output gap. This property, uncovered by Blanchard and Galí (2007), is referred to as the “divine coincidence”. However, it should be noted that stabilizing the output gap is not equivalent to stabilizing output. In a world with sizeable supply shocks (such as technology shocks), the

natural level of output is quite volatile and a policy of price stability is associated with large fluctuations in output. A large literature has shown that including other disturbances such as cost-push shocks (for example, wage mark-up shocks) or some frictions such as sticky nominal wages (Erceg et al. 2000), labor market frictions (Faia 2008) or financial frictions (De Fiore and Tristani 2013) can break this “divine coincidence” and create a trade-off between stabilizing inflation and the output gap for the policymaker. However, the terms of this trade-off are generally overwhelmingly in favor of inflation stabilization (Walsh 2014).

While the previous literature relied on rather simple models and tried to isolate the implications of the presence of certain frictions for the optimal conduct of monetary policy, large-scale New Keynesian models embedding many types of nominal and real frictions have also been developed and estimated, with the goal of describing the behavior of actual economies. In most of these models, labor market shocks play a conspicuous role. For example, in the estimated model of Smets and Wouters (2007), wage mark-up shocks account for about half of output fluctuations and two-thirds of employment fluctuations at a forty quarter horizon. Interestingly, in that type of model, the relative importance of the different labor market shocks has been shown to be critical to determine the terms of the trade-off between stabilizing inflation and real activity. Debortoli et al. (2015) use the model of Smets and Wouters (2007) and find that the monetary authority should optimally assign a large weight to the stabilization of real activity. Justiniano et al. (2013) use a similar model but assume that labor supply shocks are the main driver of the labor wedge. They find that, in that case, an exclusive focus on stabilizing inflation is optimal.

## **Description of the dissertation**

This dissertation is composed of three chapters. The first one tries to uncover the sources of labor market fluctuations. It places a special emphasis on analyzing the effects of different disturbances originating in the labor market. The second one addresses the inability of the canonical search and matching model to generate sizeable labor market fluctuations. It shows that a simple wage equation that generates sufficient propagation and is consistent with estimates of wage volatility can be derived from a popular wage-bargaining game. The last chapter studies how the nature of unemployment fluctuations affects the optimal design of monetary policy.

## **Chapter 1**

This chapter, co-authored with Claudia Foroni and Francesco Furlanetto from Norges Bank, addresses the first question mentioned at the beginning of this introduction : which disturbances underlie labor market fluctuations? As noted before, modern macroeconomic models rely on large labor market shocks to account for the pro-cyclical movements in the difference between the marginal rate of substitution and the marginal product of labor. In practice, these labor market shocks have been modeled either as exogenous shifts in the disutility of supplying labor or as movements in wage mark-ups. The objective of this chapter is to separately identify these two disturbances and quantify their importance for economic fluctuations in the context of a Vector Auto Regressive (VAR) model.

To achieve our goals, we propose a new identification scheme based on sign restrictions. The restrictions are derived from a New Keynesian model with search

and matching frictions in the labor market and endogenous labor force participation, and are shown to be robust to parameter uncertainty. Our key contribution is to use data on unemployment and labor force participation to disentangle the two shocks. In the theoretical model, unemployment and participation are pro-cyclical in response to labor supply shocks and countercyclical in response to wage bargaining shocks. This asymmetric behavior of unemployment and participation in response to the two shocks is used for identification purposes in the VAR.

The main result that emerges from our analysis is that both shocks originating in the labor market are important drivers of output and unemployment fluctuations. Labor supply shocks are particularly relevant to capture macroeconomic dynamics in the long run since they account for more than 60% of fluctuations in output and 50% in unemployment at a thirty quarter horizon. Wage bargaining shocks are more important at short horizons but also play a non-negligible role in the long run, especially for unemployment. In addition, we analyze the behavior of the labor force participation rate in the US through the lenses of our VAR model. We find that labor supply shocks are the main drivers of the participation rate and account for about half of its decline in the aftermath of the Great Recession.

These results are broadly in line with those of a literature that has investigated the role of labor supply shocks in VAR models. Shapiro and Watson (1988) find that labor supply shocks are important drivers of output and hours at low frequencies whereas Blanchard and Diamond (1989) and Chang and Schorfheide (2003) emphasize their relevance at business-cycle frequencies. We contribute to this literature by refining the identification of labor supply shocks. The previous VAR studies do not disentangle labor supply shocks from wage bargaining shocks.

## *Introduction*

In addition, this chapter is also related to previous studies in the dynamic stochastic general equilibrium (DSGE) literature dealing with shocks originating in the labor market. In a standard DSGE model, these two shocks cannot be separately identified. The literature has circumvented this problem by ruling out any role for wage markup shocks in the long run (Justiniano et al. 2013) or by assuming that they are the sole drivers of unemployment at low-frequencies (Galí et al. 2011). We do not find support for either of these assumptions. This has potentially important consequences for the policy recommendations that are drawn from these models. As explained before, accounting for movements in the labor wedge with one shock or the other leads to markedly different views about the costs of business cycles and about monetary policy trade-offs.

## **Chapter 2**

This chapter, co-authored with Vincent Boitier of Paris I Panthéon-Sorbonne University, is related to the literature that argues that real wage rigidity is key to explaining the size of labor market fluctuations. Most studies have relied on the idea that wage rigidities arise from norms or social consensus (Hall 2005 or Blanchard and Galí 2010). Hall and Milgrom (2008) proposed an alternative micro-founded way of introducing wage rigidities. These authors argued that, during bargaining, the threats points of both employers and job seekers are to delay bargaining than to terminate it. This tends to insulate wages from outside conditions in the labor market and make them endogenously rigid.

This model is getting increasingly popular in the literature but its complexity has limited its use. Indeed, in its baseline version, an analytical expression for wages

cannot be derived. In this chapter, we show that this problem can be circumvented and that a reduced-form wage equation can be derived from an alternating-offer bargaining game when a plausible parameter restriction is imposed. More precisely, we impose that the probability of breakdown during bargaining is equal to the separation rate. This restriction is supported by empirical evidence presented in Christiano et al. (2015).

This simple micro-founded wage equation can readily be used in studies that rely on wage rigidities to generate sizeable labor market fluctuations. Notably, it could of great use in papers using steady-state search and matching models and wishing to obtain analytical results. When our wage equation is used, the value of all endogenous variables can be expressed as a function of the parameters of the model and the laws of motion of exogenous variables. In its dynamic version, it also presents the distinct advantage of being consistent with estimates of the short-run elasticity of wages to labor productivity presented in Haefke et al. (2013).

### **Chapter 3**

The final chapter of this dissertation aims to understand how the nature of unemployment fluctuations shapes the optimal design of monetary policy. It contributes to the existing literature on monetary policy trade-offs by showing that the costs arising from asymmetric unemployment fluctuations provide a rationale for tolerating some inflation volatility in order to stabilize labor market activity. Unlike in most studies, the welfare gains of adopting a policy that reduces macroeconomic volatility rather than a policy of price stability are found to be positive and quite large.

## *Introduction*

In the United States, the unemployment rate rises more in recessions than it decreases in expansions (Ferraro 2015). As shown by Hairault et al. (2010) and Jung and Kuester (2011), such a feature of unemployment fluctuations arises naturally in the presence of search and matching frictions in the labor market. It implies that average unemployment will tend to increase with the mere succession of expansions and recessions. Benigno et al. (2015) provide some additional evidence in support of this conclusion. They show that increases in macroeconomic volatility lead to increases in long-run unemployment in the United States.

This rise in average unemployment may cause a significant decrease in consumption per capita and is thus potentially costly from the point of view of society. This chapter studies how monetary policy should react in light of these large costs. I use a standard New Keynesian model with search and matching frictions in the labor market that is calibrated to match key features of US data. I find that, in such an environment, the standard macroeconomic trade-off between inflation and unemployment volatility described in Taylor (1994) becomes a trade-off between inflation volatility and average unemployment. In the baseline version of the model, average unemployment is higher than steady-state unemployment by 0.2 percentage points when the monetary responds to both inflation and output. Under a policy of price stability, this gap doubles to 0.44 percentage points. More generally, holding the response to output constant, average unemployment is increasing in the central bank's response to inflation.

The presence of this trade-off between inflation volatility and average unemployment has some important implications for the conduct of monetary policy. I find that the central bank should optimally adopt a dual mandate, that is, a policy

that features a strong response to employment alongside inflation. By doing so, it reduces unemployment volatility as well as average unemployment. This reduction in unemployment and the ensuing increase in average consumption bring about potentially large welfare gains. The size of these gains depends on the value of home production. When it is high, a given increase in unemployment leads to a modest decrease in consumption and a policy of price stability is nearly optimal. However, when it is low, a similar increase in average unemployment leads to a much larger decline in average consumption and it becomes more beneficial to stabilize employment.

This chapter builds on a large body of literature that has endeavored to describe optimal monetary policy in the presence of labor market frictions. Faia (2008 and 2009) and Ravenna and Walsh (2012) show that a trade-off between inflation and unemployment stabilization arises in the presence of matching frictions but that the terms of this trade-off are overwhelmingly in favor of inflation stabilization. Thomas (2008) and Blanchard and Galí (2010) challenge this conclusion and show that an exclusive focus on inflation can lead to large welfare losses when nominal wages are staggered or when there is a direct utility cost of employment fluctuations. The contribution of this chapter is to show that such an exclusive focus on inflation stabilization is also welfare detrimental in the presence of large asymmetric unemployment fluctuations.



# Chapter 1

## Labor supply factors and economic fluctuations

This paper is co-authored with Claudia Foroni and Francesco Furlanetto from Norges Bank.

### 1.1 Introduction

What is the importance of disturbances originating in the labor market in driving economic fluctuations? Modern macroeconomic models rely on large labor market shocks to account for the procyclical movements in the difference between the marginal rate of substitution and the marginal product of labor (cf. Hall 1997, Smets and Wouters, 2003 and 2007, Galí, Gertler and López-Salido, 2007, Chari, Kehoe and McGrattan, 2009, Justiniano, Primiceri and Tambalotti, 2013, among many others). In practice these labor market shocks have been modeled either as exogenous shifts in the disutility of supplying labor or as movements in wage

mark-ups. Unfortunately, quantifying the relative importance of these two labor market shocks has proven to be challenging because they generate dynamics that are observationally equivalent. The objective of this paper is to separately identify the two disturbances, namely labor supply and wage bargaining shocks,<sup>1</sup> and quantify their importance for economic fluctuations in the context of a Vector Auto Regressive (VAR) model. To achieve our goals, we propose a new identification scheme based on sign-restrictions<sup>2</sup> that enables us to disentangle the two shocks.

The sign restrictions are derived from a New Keynesian model with search and matching frictions in the labor market and endogenous labor force participation and are shown to be robust to parameter uncertainty. Our key contribution is to use data on unemployment and labor force participation to disentangle the two shocks. In the theoretical model, unemployment and participation are procyclical in response to labor supply shocks and countercyclical in response to wage bargaining shocks. This asymmetric behavior of unemployment and participation in response to the two shocks is used for identification purposes in the VAR. Labor supply shocks and wage-markup shocks have been shown to be observationally equivalent in the standard New Keynesian model. In our theoretical framework, the presence of search frictions in the labor market and of the labor force partici-

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<sup>1</sup>Shocks to the wage equation assume different names in alternative set-ups. In New Keynesian models with monopolistically competitive labor markets, they are named wage mark-up shocks whereas in models with search and matching frictions in the labor market they are named wage bargaining shocks. Notice, however, that wage mark-up shocks are often interpreted as variations in the bargaining power of workers (cf. Chari, Kehoe and McGrattan, 2009). For consistency with the previous literature, we will name the wage shocks as wage mark-up or wage bargaining shocks according to the structure of the labor market.

<sup>2</sup>The use of sign restrictions in VAR models has been pioneered by Canova and De Nicolò (2002), Faust (1998), Peersman (2005) and Uhlig (2005). We follow Canova and Paustian (2011), Pappa (2009) and Peersman and Straub (2009) among others in deriving sign restrictions from a theoretical model. Earlier papers using sign restricted VAR models to investigate labor market dynamics are Fujita (2011) and Benati and Lubik (2014).

pation margin helps solve this issue.

The main result that emerges from our VAR analysis is that *both* shocks originating in the labor market are important drivers of output and unemployment fluctuations. Labor supply shocks are particularly relevant to capture macroeconomic dynamics in the long run since they account for more than 60% of fluctuations in output and 50% in unemployment at a 30-quarter horizon. Wage bargaining shocks are more important at short horizons but also play a non-negligible role in the long run, especially for unemployment. While the two shocks are of comparable importance across alternative specifications, their joint importance is magnified by the presence of the Great Recession in our sample period. Nevertheless, even when we extend or reduce the sample period, the role of labor market shocks remains substantial.

Our results are related to a previous literature that investigates the role of labor supply shocks in VAR models. Shapiro and Watson (1988) consider demand, technology and labor supply shocks. They assume that the long-run level of output is only determined by technology and labor supply shocks. Moreover, they assume that, in the long-run, labor supply is not influenced by aggregate demand and the level of technology. They find that labor supply shocks are the most important driver of output and hours at low frequencies. More surprisingly, they also find that labor supply shocks are extremely important in the short run. While this result goes against the "conventional wisdom" that labor supply shocks should matter only in the long run, subsequent papers have confirmed the relevance of labor supply shocks at business cycle frequencies (cf. Blanchard and Diamond, 1989, and Chang and Schorfheide, 2003, on US data and Peersman and Straub, 2009,

on euro area data) in VAR models identified with impact or sign restrictions. We contribute to this literature by refining the identification of labor supply shocks: the previous VAR studies do not disentangle labor supply shocks from wage bargaining shocks. Nevertheless, as in the previous literature, we find that labor supply shocks play an important role at all horizons.

Our findings are also related to previous studies in the Dynamic Stochastic General Equilibrium (DSGE) literature dealing with shocks originating in the labor market. As previously mentioned, several studies identify the gap between the households' marginal rate of substitution and the marginal product of labor as an important driving force of business cycle fluctuations. Smets and Wouters (2003) and Chari, Kehoe and McGrattan (2009) observe that in a New Keynesian model this wedge could either be interpreted as an efficient shock to preferences or as an inefficient wage mark-up shock. Justiniano, Primiceri and Tambalotti (2013) and Smets and Wouters (2003) distinguish these two interpretations on the basis of the persistence in the exogenous processes: wage mark-up shocks are assumed to be independent and identically distributed whereas labor supply shocks are modeled as persistent processes. This identification strategy may solve the observational equivalence in the very short run but rules out any role for wage mark-up shocks at longer horizons. Galí, Smets and Wouters (2011) propose a reinterpretation of the standard New Keynesian model in which unemployment emerges because of the monopoly power of unions. This set-up allows them to disentangle labor supply shocks from wage-markup shocks. However, their modeling assumption implies that long-run movements in unemployment are restricted to be exclusively driven by wage-markup shocks. Therefore, our reading of the previous literature

is that only polar assumptions have been used to disentangle the two labor market shocks. According to our results, these polar assumptions do not find support in the data: *both* our identified wage bargaining shocks and labor supply shocks play a role in the short run *and* in the long run.

In addition, we analyze the behavior of the labor force participation rate in the US through the lenses of our VAR model. We find that labor supply shocks are the main drivers of the participation rate and account for about half of its decline in the aftermath of the Great Recession. The remaining share of the decline is mainly explained by demand shocks and wage bargaining shocks. Analyses of the recent decline in the participation rate in the US include Bullard (2014), Erceg and Levin (2013), Fujita (2014), Hornstein (2013) and Kudlyak (2013), among others. To the best of our knowledge, we are the first to provide a VAR perspective on this issue. Our work is also related to recent papers studying the dynamics of the participation rate. Barnichon and Figura (2014) use micro data on labor market flows to analyze the role of demographic and other labor supply factors in explaining the downward trends in participation and in unemployment. Elsy, Hobijn and Sahin (2015) show how a flows-based decomposition of the variation in labor market stocks reveals that transitions at the participation margin account for around one-third of the cyclical variation in the unemployment rate. Arseneau and Chugh (2012), Campolmi and Gnocchi (2014), Christiano, Eichenbaum and Trabandt (2014) and Galí, Smets and Wouters (2011), among others, model the participation decision in the context of DSGE models. Christiano, Trabandt and Walentin (2012) and Galí (2011) study the response of the participation rate to monetary, technology and investment-specific shocks in VAR models identified with short-run and long-run

restrictions. Unlike previous contributions, we provide evidence on the response of participation to different shocks using an identification scheme based on sign restrictions and we focus on the recent period.

The paper is structured as follows. Section 2 develops a New Keynesian model with labor market frictions and endogenous labor force participation. In Section 3 this model is used to derive robust sign restrictions to identify structural shocks in a VAR model estimated with Bayesian methods. Section 4 presents the results. Section 5 discusses the participation rate dynamics, while Section 6 further refines the interpretation of the wage bargaining shock and disentangles it into different components. Finally, Section 7 concludes.

## **1.2 Model**

This section develops a model that departs from the standard New Keynesian model in two ways. First, the labor market is not perfectly competitive but is characterized by search and matching frictions. Second, the labor force participation decision is modeled explicitly. Individual workers can be in three different labor-market states: employment, unemployment, and outside the labor force (which we also refer to as non-participation). Our contribution is not in the development of the model, which largely builds on Arseneau and Chugh (2012) and Galí (2011), but in showing that this set-up can break the observational equivalence between labor supply and wage bargaining shocks.

### 1.2.1 Labor market

The size of the population is normalized to unity. Workers and firms need to match in the labor market in order to become productive. The number of matches in period  $t$  is given by a Cobb-Douglas matching function  $m_t = \Gamma_t s_t^\alpha v_t^{1-\alpha}$ ,  $s_t$  being the number of job seekers and  $v_t$  the number of vacancies posted by firms. The parameter  $\Gamma_t$  reflects the efficiency of the matching process. It follows the autoregressive process  $\ln(\Gamma_t) = (1 - \zeta^\Gamma)\ln(\Gamma) + \zeta^\Gamma \ln(\Gamma_{t-1}) + \epsilon_t^\Gamma$ .  $\alpha \in [0, 1]$  is the elasticity of the matching function with respect to the number of job seekers. Define  $\theta_t = \frac{v_t}{s_t}$  as labor market tightness. The probability  $q_t$  for a firm of filling a vacancy and the probability  $p_t$  for a worker of finding a job are respectively  $q_t = \frac{m_t}{v_t} = \Gamma_t \theta_t^{-\alpha}$  and  $p_t = \frac{m_t}{s_t} = \Gamma_t \theta_t^{1-\alpha}$ .

At the end of each period, a fraction  $\rho$  of existing employment relationships is exogenously destroyed. We follow Christiano, Eichenbaum and Trabandt (2014) and assume that both those  $\rho N$  separated workers and the  $L - N$  unemployed workers face an exogenous probability of exiting the labor force  $1 - \omega$ ,  $\omega$  being the “staying rate”<sup>3</sup>,  $N$  the number of employed workers and  $L$  the size of the labor force. At the beginning of the following period, the representative household chooses the number of non-participants  $\tau$  it transfers to the labor force. The size of the labor force in period  $t$  is thus given by  $L_t = \omega(L_{t-1} - N_{t-1} - \rho N_{t-1}) + (1 - \rho)N_{t-1} + \tau_t$  and the number of job seekers by  $s_t = \omega(L_{t-1} - (1 - \rho)N_{t-1}) + \tau_t =$

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<sup>3</sup>As in Christiano, Eichenbaum and Trabandt (2014), we introduce this staying rate to account for the fact that workers move in both directions between unemployment, employment and participation. However, the introduction of  $\omega$  has no impact on the equilibrium conditions of the model. The household adjusts the number of non-participants that enter the labor force ( $\tau_t$ ) according to the value of  $\omega$  in order to reach its desired value of  $L_t$ . We check that  $\tau_t > -\omega(L_t - (1 - \rho)N_{t-1})$  holds in every period, that is, that the number of job seekers is always positive.

$L_t - (1 - \rho)N_{t-1}$ . Employment evolves according to the following law of motion

$$N_t = (1 - \rho)N_{t-1} + \Gamma_t s_t^\alpha v_t^{1-\alpha} \quad (1.2.1)$$

New hires become productive in the period and separated workers can find a job immediately with a probability given by the job finding rate, in keeping with the timing proposed by Ravenna and Walsh (2008). The unemployment rate in period  $t$  is  $u_t = \frac{L_t - N_t}{L_t}$ .

### 1.2.2 Households

The representative household consists of a continuum of measure one of infinitely lived members indexed by  $i \in [0, 1]$  who pool their consumption risk, following Merz (1995).  $i$  determines the disutility of participating of each individual. The latter is given by  $\chi_t i^\varphi$  if the individual participates in the labor force and zero otherwise.  $\chi_t$  is an exogenous preference shifter which evolves according to the stochastic process  $\ln(\chi_t) = (1 - \zeta^\chi)\ln(\chi) + \zeta^\chi \ln(\chi_{t-1}) + \epsilon_t^\chi$ .  $\varphi$  is a parameter determining the shape of the distribution of work disutilities across individuals. The intertemporal utility of each family member is given by

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[ \frac{C_{it}^{1-\sigma}}{1-\sigma} - \chi_t 1_{it} i^\varphi \right]$$

where  $1_{it}$  is an indicator function taking a value of 1 if individual  $i$  is employed in period  $t$  and 0 otherwise,  $\beta$  the rate of time preference,  $\sigma$  the coefficient of risk aversion and  $C_{it}$  individual's  $i$  consumption of the final good. Full risk sharing of consumption among household members implies  $C_{it} = C_t$  for all  $i$ . The household's

aggregate utility function is then given by

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[ \frac{C_t^{1-\sigma}}{1-\sigma} - \chi_t \frac{L_t^{1+\varphi}}{1+\varphi} \right] \quad (1.2.2)$$

These preferences are akin to those used by Arseneau and Chugh (2012) and Galí (2011) when the disutility of participating in the labor force is identical for employed and unemployed workers. The household chooses  $C_t, N_t, L_t$  and next period bond holdings  $B_{t+1}$  so as to maximize (1.2.2) subject to its budget constraint and its perceived law of motion of employment

$$P_t C_t + (1 + R_t)^{-1} \frac{B_{t+1}}{\varepsilon_t^p} = P_t [w_t N_t + b_t (L_t - N_t)] + B_t + P_t \Pi_t^r - P_t T_t \quad (1.2.3)$$

$$N_t = (1 - \rho) N_{t-1} + p_t [L_t - (1 - \rho) N_{t-1}] \quad (1.2.4)$$

Total labor income is given by  $w_t N_t$  and unemployed household members receive unemployment benefits  $b_t$ , which evolve according to the stochastic process  $\ln(b_t) = \zeta^b \ln(b_{t-1}) + (1 - \zeta^b) \ln(b) + \epsilon_t^b$ . Households receive profits  $\Pi_t^r$  from the monopolistic sector and invest in risk-free bonds that promise a unit of currency tomorrow and cost  $(1 + R_t)^{-1}$ . They also have to pay lump-sum taxes  $T_t$  in order to finance the unemployment insurance system. The final consumption good  $C_t \equiv \int_0^1 \left[ C_t(z) \frac{\varepsilon_t - 1}{\varepsilon_t} dz \right]^{\frac{\varepsilon_t}{\varepsilon_t - 1}}$  is a Dixit-Stiglitz aggregator of the different varieties of goods produced by the retail sector and  $\varepsilon_t$  is the elasticity of substitution between the different varieties. It follows the following exogenous stochastic process  $\ln(\varepsilon_t) = \zeta^\varepsilon \ln(\varepsilon_{t-1}) + (1 - \zeta^\varepsilon) \ln(\varepsilon) + \epsilon_t^\varepsilon$ . We refer to the innovations  $\epsilon_t^\varepsilon$  as price mark-up shocks since they influence the desired markup of price over marginal

cost for retail firms. The optimal allocation of income on each variety is given by  $C_t(z) = \left[\frac{P_t(z)}{P_t}\right]^{-\varepsilon_t} C_t$ , where  $P_t = \left[\int_0^1 P_t(z)^{\frac{\varepsilon_t-1}{\varepsilon_t}} dj\right]^{\varepsilon_t/(1-\varepsilon_t)}$  is the price index.  $\varepsilon_t^p$  is an exogenous premium in the return to bonds which follows the stochastic process  $\ln(\varepsilon_t^p) = \zeta^p \ln(\varepsilon_{t-1}^p) + (1 - \zeta^p) \ln(\varepsilon^p) + \varepsilon_t^p$ . We obtain two equations describing the household's optimal consumption path and its participation decision

$$\beta \varepsilon_t^p E_t \frac{1 + R_t}{\Pi_{t+1}} \left( \frac{\lambda_{t+1}}{\lambda_t} \right) = 1 \quad (1.2.5)$$

$$\chi_t L_t^\varphi C_t^\sigma = (1 - p_t) b_t + p_t \left[ w_t + E_t \beta_{t+1} (1 - \rho) \left( \frac{1 - p_{t+1}}{p_{t+1}} \right) (\chi_{t+1} L_{t+1}^\varphi C_{t+1}^\sigma - b_{t+1}) \right] \quad (1.2.6)$$

where  $\lambda_t = C_t^{-\sigma}$  is the marginal utility of consumption,  $\beta_{t+1} = \beta \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma}$  is the stochastic discount factor of the household and  $\Pi_{t+1} = \frac{P_{t+1}}{P_t}$  is price inflation in period  $t + 1$ . Equation (1.2.6) states that the marginal disutility of allocating an extra household member to participation, expressed in consumption units, has to be equal to the expected benefits of participating. The latter consist of unemployment benefits in the event that job search is unsuccessful and the wage plus the continuation value of being employed if job search is successful. This equation makes clear that participation decisions depend on the relative strength of two effects. According to a wealth effect, when consumption increases, leisure becomes relatively more attractive and the desired size of the labor force decreases. According to a substitution effect, when wages and the job finding rate increase, market activity becomes relatively more attractive and the desired size of the labor force increases.

### 1.2.3 Firms

The economy consists of two sectors of production as in Walsh (2005). Firms in the wholesale sector produce an intermediate homogeneous good in competitive markets using labor. Their output is sold to final good sector firms (retailers), which are monopolistically competitive and transform the homogeneous goods into differentiated goods at no extra cost and apply a mark-up. Firms in the retail sector are subject to nominal price staggering.

#### 1.2.3.1 Wholesale firms (intermediate goods sector)

Firms produce according to the following technology

$$Y_{jt}^w = Z_t N_{jt} \quad (1.2.7)$$

where  $Z_t$  is a common, aggregate productivity disturbance. Posting a vacancy comes at cost  $\kappa$ . Firm  $j$  chooses its level of employment  $N_{jt}$  and the number of vacancies  $v_{jt}$  in order to maximize the expected sum of its discounted profits

$$E_0 \sum_{t=0}^{\infty} \beta^t \frac{\lambda_t}{\lambda_0} \left[ \frac{P_t^w}{P_t} Y_{jt}^w - \kappa v_{jt} - w_t N_{jt} \right] \quad (1.2.8)$$

subject to its perceived law of motion of employment  $N_{jt} = (1 - \rho)N_{jt-1} + v_{jt}q(\theta_t)$  and taking the wage schedule as given. Wholesale firms sell their output in a competitive market at a price  $P_t^w$ . We define  $\mu_t = \frac{P_t}{P_t^w}$  as the mark-up of retail over wholesale prices. The second and third terms in equation (1.2.8) are, respectively, the cost of posting vacancies and the wage bill. In equilibrium all firms will post

the same number of vacancies and we can therefore drop individual firm subscripts  $j$ . We obtain the following job creation equation

$$\frac{\kappa}{q(\theta_t)} = \frac{Z_t}{\mu_t} - w_t + E_t \beta_{t+1} (1 - \rho) \frac{\kappa}{q(\theta_{t+1})} \quad (1.2.9)$$

This equation is an arbitrage condition for the posting of vacancies. It states that the cost of posting a vacancy, the deadweight cost  $\kappa$  multiplied by the time it takes to fill the vacancy, must be equal to the expected discounted benefit of a filled vacancy. These benefits consist of the revenues from output net of wages and future savings on vacancy posting costs.

### 1.2.3.2 Wages

In order to characterize the outcome of wage negotiations, we must first define the value of the marginal worker for the firm and the value of the marginal employed individual for the household. The value of the marginal worker for the firm is

$$J_t = \frac{Z_t}{\mu_t} - w_t + E_t \beta_{t+1} (1 - \rho) J_{t+1}$$

Consider the household's welfare criterion

$$H_t(N_t) = \text{Max}_{C_t, B_{t+1}, N_t, L_t} \left\{ \frac{C_t^{1-\sigma}}{1-\sigma} - \chi_t \frac{L_t^{1+\varphi}}{1+\varphi} + \beta E_t H_{t+1}(N_{t+1}) \right\}$$

It follows that

$$\frac{\partial H_t(N_t)}{\partial N_t} = C_t^{-\sigma} (w_t - b_t) + E_t \beta (1 - \rho) (1 - p_{t+1}) \frac{\partial H_{t+1}(N_{t+1})}{\partial N_{t+1}}$$

The value to the household of the marginal employed individual is  $W_t - U_t = \frac{\partial H_t(N_t)}{C_t^{-\sigma}}$

,

$$W_t - U_t = w_t - b_t + E_t \beta_{t+1} (1 - \rho) (1 - p_{t+1}) (W_{t+1} - U_{t+1})$$

If we compare this equation with equation (1.2.6), we can see that  $W_t - U_t = \frac{1}{p_t} \left( \frac{\chi_t L_t^\varphi}{C_t^{-\sigma}} - b_t \right)$ . Wages are then determined through a Nash bargaining scheme between workers and employers who maximize the joint surplus arising from the employment relationship by choosing real wages

$$\operatorname{argmax}_{\{w_t\}} \left[ (J_t)^{1-\eta_t} (W_t - U_t)^{\eta_t} \right] \quad (1.2.10)$$

where  $\eta_t$  is the worker's bargaining power. It evolves exogenously according to  $\eta_t = \eta \varepsilon_t^\eta$  where  $\varepsilon_t^\eta$  is a bargaining power shock that follows the stochastic process  $\ln(\varepsilon_t^\eta) = \zeta^\eta \ln(\varepsilon_{t-1}^\eta) + (1 - \zeta^\eta) \ln(\varepsilon^\eta) + \epsilon_t^\eta$ . We obtain the following sharing rule

$$(1 - \eta_t) (W_t - U_t) = \eta_t J_t \quad (1.2.11)$$

After some algebra, we find

$$w_t = b_t + \frac{\eta_t}{1 - \eta_t} \frac{\kappa}{q(\theta_t)} - E_t \beta_{t+1} (1 - \rho) (1 - p_{t+1}) \frac{\eta_{t+1}}{1 - \eta_{t+1}} \frac{\kappa}{q(\theta_{t+1})} \quad (1.2.12)$$

Note that labor supply shocks and wage bargaining shocks appear in different equations (equations 1.2.6 and 1.2.12, respectively) and can be separately identified without imposing additional assumptions. Thus, the introduction of search and matching frictions and of the participation margin in a New Keynesian model helps

solve the observational equivalence problem between these two shocks.

### 1.2.3.3 Retail firms

A measure one of monopolistic retailers produces differentiated goods with identical technology transforming one unit of intermediate good into one unit of differentiated retail good. The demand function for the retailer's products is

$$Y_t(z) = (P_t(z)/P_t)^{-\epsilon_t} Y_t^d \quad (1.2.13)$$

where  $P_t = \left[ \int_0^1 P_t(z)^{1-\epsilon_t} \right]^{1/(1-\epsilon_t)}$  and  $Y_t^d$  is aggregate demand for the final consumption good. As in Calvo (1983), we assume that each retailer can reset its price with a fixed probability  $1 - \delta$  that is independent of the time elapsed since the last price adjustment. This assumption implies that prices are fixed on average for  $\frac{1}{1-\delta}$  periods. Retailers optimally choose their price  $P_t^o(z)$  to maximize expected future discounted profits given the demand for the good they produce and under the hypothesis that the price they set at date  $t$  applies at date  $t + s$  with probability  $\delta^s$ .

$$\text{Max} E_t \sum_{s=0}^{\infty} (\delta^s \beta_{t,t+s}) \left[ \frac{P_t^o(z) - P_{t,t+s}^w}{P_{t,t+s}} \right] Y_{t,t+s}(z)$$

All firms resetting prices in any given period choose the same price. The aggregate price dynamics are then given by

$$P_t = \left[ \delta P_{t-1}^{\epsilon_t} + (1 - \delta) (P_t^o)^{1-\epsilon_t} \right]^{\frac{1}{1-\epsilon_t}}$$

### 1.2.4 Resource constraint and monetary policy

The government runs a balanced budget. Lump-sum taxation is used to finance the unemployment insurance system  $b_t(1 - p_t)s_t = T_t$ . Aggregating equation (13) across firms, we obtain

$$Y_t = Z_t N_t = \int_0^1 \left( \frac{P_t(z)}{P_t} \right)^{-\varepsilon_t} [C_t + \kappa v_t] dz \quad (1.2.14)$$

where  $\int_0^1 \left( \frac{P_t(z)}{P_t} \right)^{-\varepsilon_t}$  measures relative price dispersion across retail firms. Monetary policy is assumed to be conducted according to an interest rate reaction function of the form

$$\log \left( \frac{1 + R_t}{1 + R} \right) = \phi_r \log \left( \frac{1 + R_{t-1}}{1 + R} \right) + (1 - \phi_r) \left( \phi_\pi \log \left( \frac{\Pi_t}{\Pi} \right) + \phi_y \log \left( \frac{Y_t}{Y} \right) \right) \quad (1.2.15)$$

The log-linear equations characterizing the decentralized equilibrium are presented in Appendix A.1.

## 1.3 Robust sign restrictions

### 1.3.1 Methodology

We parameterize the model to study the effects of four different shocks. Two labor market shocks, a labor supply shock and a wage bargaining shock, are considered alongside standard demand and neutral technology shocks. In Section 6 we extend our analysis and study the effects of matching efficiency and unemployment bene-

fits shocks, while price mark-up shocks are considered in the appendix. The labor supply shock is captured by the preference shifter  $\chi_t$  in equation (1.2.6). A decrease in  $\chi_t$  lowers the disutility of allocating an extra household member to labor force participation and, all other things being equal, leads to an increase in the desired size of the labor force. The wage bargaining and the neutral technology shocks show up respectively as variations in the share of the surplus associated with an employment relationship that accrues to the household,  $\eta_t$  in equation (1.2.12), and as movements in  $Z_t$  in equation (1.2.7). The demand shock is modelled through a “risk-premium” shock  $\varepsilon_t^p$ , which drives a wedge between the interest rate controlled by the central bank and the return on assets held by the households. As explained in Fisher (2014), this term can be interpreted as a structural shock to the demand for safe and liquid assets such as short-term US Treasury securities. A positive shock to  $\varepsilon_t^p$  increases households’ incentives to save and reduces current consumption. However, our identified demand shock should not only be interpreted in this narrow sense since the restrictions that we impose in Section 1.3.3 are also consistent with other demand disturbances such as monetary policy, government spending and discount factor shocks.

We use the theoretical model to derive sign restrictions that are robust to parameter uncertainty. In order to do so, we assume that the values of key parameters are uniformly and independently distributed over a selected range. This range for each structural parameter is chosen by conducting a survey of the empirical literature. While the interval for each parameter is independently and subjectively selected, one could make the ranges correlated and data-based using the approach of Del Negro and Schorfheide (2008). Here we follow Canova and Paustian (2009)

who argue that the former approach is preferable since it provides information about the range of possible outcomes the model can produce, prior to the use of any data. We then draw a random value for each parameter, obtain a full set of parameters, and compute the distribution of impact responses to a given shock for each variable of interest. This exercise is repeated for 10,000 simulations. Note that it is common practice in the literature to only show percentiles of the distribution of theoretical impulse response functions. We choose to follow a stricter criterion by reporting the entire distribution in order to ensure the robustness of our sign restrictions. We focus on impact responses since only assumptions on the impact responses are used for identification in the VAR. Only in a few cases where the impact response is uncertain, we impose restrictions on the responses in the second period.

#### 1.3.2 Parameter ranges

The model period is one quarter. Some parameters are fixed to a particular value. The discount factor is set to 0.99, so that the annual interest rate equals 4%. The steady-state labor force participation rate is set to 0.66, its pre-crisis level. We set the steady state levels of tightness and unemployment to their mean values over the period 1985-2014. We use the seasonally adjusted monthly unemployment rate constructed by the Bureau of Labor Statistics (BLS) from the Current Population Survey (CPS). Labor market tightness is computed as the ratio of a measure of the vacancy level to the seasonally adjusted monthly unemployment level constructed by the BLS from the CPS. The measure of the vacancy level is constructed by using the Conference Board help-wanted advertisement index for 1985-1994, the

composite help-wanted index of Barnichon (2010) for 1995-2014 and the seasonally-adjusted monthly vacancy level constructed by the BLS from JOLTS for 2001-2014. Over these periods, the mean of the unemployment rate is 6.1% and the mean of labor market tightness is 0.5. For practical purposes, our targets will be 6% and 0.5 respectively. We follow Blanchard and Galí (2010) and assume that the steady state job finding rate is equal to 0.7. These targets imply, through the Beveridge Curve, a job destruction rate of approximately 0.15. The staying rate  $\omega$  is set to 0.22, its mean in the data over the period 1990-2013 (cf. Hornstein, 2013).

The intervals for the other parameters are chosen according to the results of empirical studies and to the posterior distribution of structural parameters reported in estimated medium-scale DSGE models (cf. Galí, Smets and Wouters, 2011, Gertler, Sala and Trigari, 2008, and Furlanetto and Groshenny, 2014). The coefficient of risk-aversion  $\sigma$  is allowed to vary in the interval  $[1, 3]$ , the preference parameter  $\varphi$  driving the disutility of labor supply in the interval  $[1, 5]$ , and the degree of price stickiness  $\delta$  in the interval  $[0.5, 0.8]$ . The elasticity of substitution between goods  $\varepsilon$  is assumed to vary in the interval  $[6, 11]$ , which corresponds to a steady-state mark-up between 10 and 20 percent. The elasticity of matches with respect to the number of job seekers  $\alpha$  is allowed to vary in the interval  $[0.5, 0.7]$ , following evidence in Petrongolo and Pissarides (2001). The replacement ratio  $b/w$  is assumed to lie in the interval  $[0.2, 0.6]$ , which is centered around the value used by Shimer (2005) and comprises the ratio of benefits paid to previous earnings of 0.25 used by Hall and Milgrom (2008). Following evidence in Silva and Toledo (2009), the vacancy posting cost  $\kappa$  is fixed such that hiring costs are comprised between 4 and 14 percent of quarterly compensation. The steady state values of

### 1.3 Robust sign restrictions

the matching efficiency parameter  $\Gamma$ , the bargaining power  $\eta$  and the parameter scaling the disutility of participating  $\chi$  are then determined through steady-state relationships.

For the monetary policy rule, we choose ranges that include parameter values generally discussed in the literature. We restrict the inflation response to the range  $[1.5, 3]$ , the output response to the range  $[0, 1]$ , and the degree of interest rate smoothing to the range  $[0, 1]$ . The intervals for the persistence of the different shocks are chosen according to the posterior distributions of parameters reported in the estimated DSGE models of Galí, Smets and Wouters (2011), Gertler, Sala and Trigari (2008) and Furlanetto and Goshenny (2014). Table 1.1 gives the ranges for all the parameters.

Table 1.1 : Parameter ranges

Parameter	Description	Range
$\sigma$	Coefficient of risk aversion	$[1, 3]$
$\varphi$	Inverse of the Frisch labor supply elasticity	$[1, 5]$
$\delta$	Degree of price stickiness	$[0.5, 0.8]$
$\varepsilon$	Elasticity of substitution between goods	$[6, 11]$
$\alpha$	Elasticity of matches with respect to $s$	$[0.5, 0.7]$
$\frac{b}{w}$	Replacement ratio	$[0.2, 0.6]$
$\frac{\kappa}{q}$	Hiring costs (as a % of quarterly wages)	$[4, 14]$
$\phi_r$	Interest rate inertia	$[0, 0.9]$
$\phi_\pi$	Interest rate reaction to inflation	$[1.5, 3]$
$\phi_y$	Interest rate reaction to output	$[0, 1]$
$\zeta^p$	Autoregressive coefficient, risk-premium shock	$[0.1, 0.8]$
$\zeta^z$	Autoregressive coefficient, neutral technology shock	$[0.5, 0.99]$
$\zeta^x$	Autoregressive coefficient, labor supply shock	$[0.5, 0.99]$
$\zeta^\eta$	Autoregressive coefficient, wage bargaining shock	$[0, 0.5]$
$\zeta^\gamma$	Autoregressive coefficient, matching efficiency shock	$[0.5, 0.99]$
$\zeta^b$	Autoregressive coefficient, unemployment benefits shock	$[0.5, 0.99]$

### **1.3.3 Impact responses to shocks and sign restrictions**

We now proceed to the simulation exercise. All the shocks we consider increase output contemporaneously. Figure 1.9.1 shows that a negative risk-premium shock triggers a positive response of output and prices. As the premium on safe assets decreases, it is of less interest for households to save and aggregate demand increases. Firms would like to increase prices but most are unable to do so and need to respond to higher demand by producing more. As a consequence, they recruit more workers and unemployment decreases. These positive responses of output and prices and the negative response of unemployment will be used as sign restrictions in the VAR to identify demand shocks. The restriction on prices is especially important as it enables us to disentangle demand shocks from other shocks.

The distribution of impact responses to technology shocks is presented in Figure 1.9.2. Positive technology shocks lead to a decrease in marginal costs and prices. The reactions of unemployment and vacancies depend on the degree of price stickiness and on the response of monetary policy. Firms can now produce more with the same number of employees and they would like to decrease prices and increase production. However, most of them are unable to do so and may contract employment by reducing the number of vacancies. This effect is stronger the higher the degree of price stickiness and the weaker the response of monetary policy following the shock (cf. Galí, 1999). When the central bank responds vigorously to inflation, the large decrease in the real interest rate counteracts this effect. Importantly, in the event of a strong drop in vacancies and of a rise in unemployment (which happens when prices are very rigid and monetary policy is

very inertial), the decrease in hiring costs may lead to a decrease in real wages on impact. However, real wages overshoot their steady-state value under almost all parameter configurations from period two onwards. We use the positive response of output and real wages and the negative response of prices to identify technology shocks.<sup>4</sup>

The distribution of impact responses to labor supply shocks is presented in Figure 1.9.3. Positive labor supply shocks take the form of a decrease in the disutility of allocating an extra household member to participation. It becomes beneficial for households to allocate more of their members to job search and labor force participation increases. This increase in the number of job seekers makes it easier for firms to fill vacancies and hiring costs decrease, thereby leading to a decrease in wages and prices and to an increase in output and employment. However, all new participants do not find a job immediately and unemployment increases in the first periods after the shock. We use the positive responses of output and unemployment and the negative responses of wages and prices to identify labor supply shocks. As in Peersman and Straub (2009), who derive a set of sign restrictions from a standard New Keynesian model, the asymmetric behavior of wages in response to labor supply shocks and technology shocks is key in identifying these two forces.

The distribution of impact responses to a wage bargaining shock is presented in Figure 1.9.4. This shock has a direct negative effect on wages. This contributes to lower marginal costs and prices. Because firms now capture a larger share of

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<sup>4</sup>In the baseline exercise, the restrictions on wages are imposed on impact. In Section 4.2 we check that imposing the restrictions in period two (rather than on impact) does not alter the results.

the surplus associated with employment relationships, they post more vacancies and increase employment. In spite of the higher job finding rate, the increase in consumption and the decrease in wages tend to lower participation. Unemployment clearly decreases. We use the positive response of output and the negative responses of wages, prices and unemployment to identify wage bargaining shocks. Note that the sign restrictions we use to identify this shock are also consistent with two other labor market shocks, a matching efficiency shock and an unemployment benefits shock. To account for this issue, we further disentangle the wage bargaining shock in Section 6. Table 1.2 provides a summary of the sign restrictions.

Table 1.2 : Sign restrictions

	Demand	Technology	Labor Supply	Wage Bargaining
GDP	+	+	+	+
Prices	+	-	-	-
Real wages	/	+	-	-
Unemployment	-	/	+	-

The main contribution of this paper is to use unemployment data to separately identify labor supply shocks from other labor market shocks within the context of a VAR model. It is the restriction on unemployment that enables us to separately identify the labor supply shock and the wage bargaining shock. Nonetheless, the participation response (procyclical to labor supply and countercyclical to wage bargaining) can help refine the identification.<sup>5</sup> We will explore this avenue in an extension in Section 5. We view our approach as being "agnostic" as we only

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<sup>5</sup>Note that all our restrictions are also satisfied when we introduce wage stickiness. We assume flexible wages in the baseline set-up to maintain the model as simple as possible. The restrictions are also satisfied when we increase the persistence of wage bargaining shocks to higher values (usually not considered in the literature). All results are available upon request.

### 1.3 Robust sign restrictions

need to use a minimal set of robust and arguably uncontroversial restrictions to identify the different structural shocks. Our results can then be used to evaluate the potential sources of misspecifications in DSGE models.

Importantly, our restrictions are not only robust to parameter uncertainty but also, to some extent, to model uncertainty. Shocks to the labor force also increase unemployment in the seminal paper by Blanchard and Diamond (1989). Furthermore, all the restrictions we impose are also satisfied in the estimated model by Galí, Smets and Wouters (2011) in which unemployment arises from the monopoly power of unions and preferences feature a very low wealth effect. In that model, labor force participation and unemployment are also procyclical in response to labor supply shocks and countercyclical in response to wage mark-up shocks. A positive labor supply shock leads to an increase in the size of the labor force and, because wages do not adjust immediately to keep wage mark-ups constant, to an increase in unemployment. A negative wage mark-up shock leads to a decrease in wages and unemployment. As a result, labor force participation, which is directly linked to the level of wages, also decreases.

Our VAR identification scheme is also related to earlier attempts to identify labor supply disturbances in the sign restrictions literature. Peersman and Straub (2009) identify demand and technology shocks alongside labor supply shocks by using a sign-restricted VAR. We go one step further in that we manage to identify labor supply shocks separately from other labor market shocks. Chang and Schorfheide (2003) assume that an increase in hours due to a labor supply shock leads to a fall in labor productivity as the productive capacity of the economy is fixed in the short run. As they note, their identified labor supply shock might also correspond to a

demand shock. In the presence of sticky prices, an exogenous increase in demand might also generate a negative co-movement between hours and labor productivity. We are able to circumvent this problem with our identification scheme.

In addition to our main contribution, which is to provide a way of separately identifying labor supply and wage bargaining shocks in VAR setup, we are also able to disentangle wage bargaining shocks from other shocks. In the model of Galí, Smets and Wouters (2011), unemployment is solely due to the monopoly power of unions. Our model is more general in that unemployment is not only driven by the bargaining power of workers being too high but also by reallocation shocks or unemployment benefits shocks. In section 6, we show that it provides a useful laboratory to disentangle these shocks from wage bargaining shocks.

## **1.4 Empirical results**

In this section, we present the results derived from our baseline model that is estimated with Bayesian methods with quarterly data in levels from 1985Q1 to 2014Q1 for the US. The VAR includes five lags and four endogenous variables, i.e. GDP, the GDP deflator as a measure of prices, real wages and the unemployment rate. All variables with the exception of the unemployment rate are expressed in terms of natural logs. The data series and the details of the econometric model and its estimation are presented in the appendix. The baseline model includes four shocks: one demand shock and three supply shocks (a technology shock, a labor supply shock and a wage bargaining shock).

### 1.4.1 The baseline VAR model

Figure 1.9.5 plots the variance decomposition derived from our model. The horizontal axis represents the horizon (from 1 to 35 quarters) and the vertical axis represents the share of the variance of a given variable explained by each of the four shocks. The variance decomposition is based at each horizon on the median draw that satisfies our sign restrictions.<sup>6</sup>

The main result that emerges from our analysis is that both our identified labor market shocks play a significant role in explaining economic fluctuations. These shocks account for 20 percent of output fluctuations on impact and almost 80 percent in the long run. Moreover, they explain around 50 percent of unemployment fluctuations at short horizons and 80 percent at long horizons. The wage bargaining shock is more important at short horizons (especially for unemployment) whereas the labor supply shock is crucial to capture macroeconomic dynamics in the long run (both for output and unemployment). In Figures 1.9.6 and 1.9.7 we present the impulse response functions for these two labor market shocks. The labor supply shock has large and persistent effects on GDP. The decline in real wages is protracted despite the fact that we impose the restriction only on impact. This is key to separately identifying labor supply and technology shocks. The median response of unemployment is positive for the first three quarters before turning negative. Thus, the adverse unemployment effects of a positive labor sup-

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<sup>6</sup>As discussed in Fry and Pagan (2011), a variance decomposition based on the median of the impulse responses combines information stemming from several models so that it does not necessarily sum to one across all shocks. As in Furlanetto, Ravazzolo and Sarferaz (2014), our variance decomposition measure is rescaled such that the variance is exhaustively accounted for by our four shocks. In Section 4.2 we consider an alternative measure of central tendency in which the variance decomposition does not require any normalization.

ply disturbance are rather short-lived. An expansionary wage bargaining shock has a large and persistent effect on the unemployment rate, which declines for several quarters, and to some extent also on output. Notice that at this stage the only source of identification between the labor market shocks is the behavior of unemployment in the very short run. Nevertheless, this restriction turns out to be sufficiently informative so that the model assigns a larger explanatory power to labor supply shocks in the long run, a feature that, we believe, is realistic, at least as long as labor supply shocks capture the large changes over time in demographics, family structure, and female labor force participation, as discussed in Rogerson (2012).

An important role for shocks originating in the labor market in driving economic fluctuations is in keeping with results from previous VAR studies that include labor supply shocks (without, however, disentangling wage bargaining shocks). In Shapiro and Watson (1988) the labor market shock explains on average 40 percent of output fluctuations at different horizons and 60 percent of short-term fluctuations in hours (80 percent in the long run). In Blanchard and Diamond (1989) shocks to the labor force explain 33 percent of unemployment volatility in the very short run and around 15 percent in the long run. In Chang and Schorfheide (2003) labor-supply shifts account for about 30 percent of the variation in hours and about 15 percent of output fluctuations at business cycle frequencies. Peersman and Straub (2009) do not report the full variance decomposition in their VAR but the limited role of technology shocks in their model let us conjecture an important role for the two remaining shocks, i.e. demand and labor supply. We conclude that the available VAR evidence is reinforced by our results. While

the structural interpretation of our identified labor supply and wage bargaining shocks remains an open question, our model suggests that supply shocks that move output and real wages in opposite directions (and with different impact effects on unemployment) play a significant role in macroeconomic dynamics.

Our results are also related to previous theoretical studies in the business cycle literature dealing with the importance of shocks originating in the labor market. Hall (1997) identified preference shifts as the most important driving force of changes in total working hours. In the DSGE literature, this preference shift has been interpreted either as an efficient shock to preferences or as an inefficient wage mark-up shock (cf. Smets and Wouters, 2007). Since these two shocks are observationally equivalent in a standard New Keynesian model, several authors have attempted to disentangle them by imposing additional assumptions. In Justiniano, Primiceri and Tambalotti (2013), wage mark-up shocks are assumed to be white noise and their explanatory power is concentrated in the very short run, whereas labor supply shocks are key drivers of macroeconomic fluctuations.<sup>7</sup> Galí, Smets and Wouters (2011) are able to disentangle the two shocks but in their model unemployment is solely due to the monopoly power of households or unions in labor markets. Thus, long-run movements in unemployment can only be driven by wage mark-up shocks. Not surprisingly, they find that wage mark-up shocks account for 80 to 90 percent of unemployment fluctuations at a 40-quarter horizon. Our findings suggest that shocks generating the type of co-movements between variables that are typically associated with wage mark-up shocks are important

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<sup>7</sup>The role of wage mark-up shocks is reduced further by the introduction of a measurement error in wages that makes these shocks irrelevant for business cycle fluctuations. The presence of this measurement error differentiates Justiniano, Primiceri and Tambalotti (2013) from Smets and Wouters (2003).

*both* in the short run *and* in the long run. Moreover, they are not the only driving force of unemployment in the long run. Thus, we do not find support for the popular assumptions on the role of wage mark-up shocks made in the aforementioned papers. As noted in Section 2, we do, however, provide an alternative way of solving the observational equivalence problem between wage bargaining and labor supply shocks within the context of a New Keynesian model. In our theoretical framework, labor supply shocks and wage bargaining shocks appear in different equations (equations 1.2.6 and 1.2.12, respectively) and can be separately identified without imposing additional assumptions. In addition, unlike Galí, Smets and Wouters (2011) who report that wage markup shocks are the main drivers of inflation at all horizons, we find that labor market shocks play a minor role in driving prices. When considering the 1985-2008 period, both labor market shocks have a very limited influence on prices. When considering the 1985-2014 and the 1964-2014 periods, labor supply shocks account for a small part of fluctuations in prices at long horizons while the role of wage bargaining shocks remains negligible.

While we concentrate our interest on labor market shocks, our baseline VAR model also includes demand shocks and technology shocks whose impulse responses are presented in Figures 1.2.8 and 1.2.9. We find that demand shocks are the main drivers of fluctuations in prices both in the short and in the long run, as in Furlanetto, Ravazzolo and Sarferaz (2014). They also play a substantial role for output and unemployment fluctuations at short horizons. Technology shocks are the dominant drivers of real wages, thus suggesting a tight link between real wages and productivity. The fact that productivity shocks have a large effect on real wages and a limited effect on unemployment is consistent with most models

with search and matching frictions driven by productivity shocks. According to our results, those models should not be dismissed simply because they generate limited unemployment volatility in response to technology shocks. The bulk of unemployment volatility may be explained by other shocks, as it is the case in our VAR model.

The responses of real wages to demand shocks and of unemployment to technology shocks are left unrestricted in our identification scheme. Therefore, the VAR may provide some new empirical evidence on these conditional responses of variables that have received some attention in the literature (cf. Galí, 1999 and 2013). In our model real wages tend to decrease in response to an expansionary demand shock. This is consistent with the predictions of a New Keynesian model with a moderate degree of price rigidity and an important degree of wage stickiness (cf. Galí, 2013). Additionally, we find that unemployment decreases in response to a positive technology shock. This is consistent with New Keynesian models with a limited degree of price stickiness and a not too inertial monetary policy rule and with previous evidence in the sign restrictions literature (cf. Peersman and Straub, 2009), but it is in contrast with the evidence presented in most VAR models identified with long-run restrictions (cf. Galí, 1999).

### 1.4.2 Sensitivity analysis

We now test the robustness of our results with respect to the choice of the sample period, the wage series included in the estimation and the measure of central tendency used to compute the variance decomposition. In Figure 1.9.10 we present the variance decomposition for output and unemployment in each experiment.

In the first row we expand the sample by using data over the period 1965Q1-2014Q1. As in the baseline model, wage bargaining shocks are more important for unemployment, whereas labor supply shocks matter more for output. Nonetheless, once again, polar assumptions on the role of the two labor market shocks are not supported by the VAR. More generally, the joint importance of the two labor market shocks is lower than in the baseline model.

In the second row we restrict our attention to the Great Moderation period (1985Q1-2008Q1), thus excluding the Great Recession from the sample period. We see that the relative importance of labor supply and wage bargaining shocks is confirmed (in particular for unemployment dynamics), whereas their joint importance for business cycle fluctuations is reduced. This indicates that the model sees the Great Recession as a period of unusually large labor market shocks.

We then estimate the model over the baseline sample period including a different wage series in the set of observable variables (cf. third row in Figure 1.9.10). Following Justiniano, Primiceri and Tambalotti (2013) we use data on nominal compensation per hour in the nonfarm business sector, from NIPA. This series is more volatile than the BLS series that we use in our baseline analysis. In this case the importance of wage bargaining shocks increases substantially.

In our baseline model we follow the early sign restriction literature and show variance decompositions that are based at each horizon on the median draw that satisfies our restrictions. We now also present results based on a different measure of central tendency such as the median target proposed by Fry and Pagan (2011).<sup>8</sup>

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<sup>8</sup>Fry and Pagan (2011) show that it is problematic to interpret structurally the median of sign-restricted impulse responses. In fact, taking the median across all possible draws at each horizon implies mixing impulse responses that emanate from different structural models. They suggest choosing impulse responses from the closest model to the median response

### 1.5 Introducing data on the participation rate

In this experiment (cf. fourth row in Figure 1.9.10), the importance of labor supply shocks for GDP is slightly larger than in our baseline model, whereas results for unemployment are largely confirmed.

Finally, in the last row of Figure 1.9.10 we reconsider the restriction imposed on the response of real wages to technology shocks. In our theoretical model the impact response can be negative for parameterizations characterized by a high degree of price stickiness and interest rate smoothing. However, the response of real wages is almost always positive at horizon two. In our last sensitivity check we take the model at face value and we impose the restrictions on real wages at quarter two rather than on impact. The results are basically unaffected.

To sum up, we conclude that the *joint* importance of the labor market shocks is somewhat lower (although still far from being negligible) when we extend or reduce the sample period. However, the two shocks remain of comparable importance across the different experiments (with a larger role for wage bargaining shocks in the short term and a larger role for labor supply shocks at low frequencies).

## 1.5 Introducing data on the participation rate

In the previous section we identified labor supply and wage bargaining shocks on the basis of the different sign of the unemployment response. In this section we further disentangle the two shocks by using data on the labor force participation rate. A robust feature of our theoretical model is that the participation rate is procyclical in response to labor supply shocks and countercyclical in response to

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instead.

wage bargaining shocks. A decrease in the bargaining power of workers triggers a decrease in wages and an increase in consumption, which tend to make participation relatively less attractive, and an increase in the job-finding rate, which tends to make participation relatively more attractive. The first two effects dominate in almost all the parameterizations of the model we consider (cf. Figure 1.9.4). This restriction is also satisfied in the estimated model of Galí, Smets and Wouters (2011) which features preferences with a low wealth effect on labor supply and sticky wages.

We introduce the participation rate in the VAR to take advantage of the additional restrictions. We also include a fifth shock with no specific economic interpretation that is defined as a residual shock that does not satisfy the restrictions imposed on the other four identified shocks. In that way we match the number of shocks and the number of variables in the system.<sup>9</sup> The restrictions are summarized in Table 1.3.

Table 1.3 : Sign restrictions

	Demand	Technology	Labor Supply	Wage Bargaining
GDP	+	+	+	+
Prices	+	-	-	-
Real wages	/	+	-	-
Unemployment	-	/	+	-
Participation	/	/	+	-

In Figure 1.9.11 we plot the variance decomposition for the extended model with five shocks. We remark that the previous results for output and unemployment are broadly confirmed: if anything, we see a slightly larger role for wage bargaining

<sup>9</sup>An alternative set-up that includes a fifth shock with economic interpretation is considered in the appendix. There we consider price mark-up shocks by introducing additional restrictions on the behavior of the participation rate.

### 1.5 Introducing data on the participation rate

shocks in the decomposition of GDP, thus making the contribution of the two labor market shocks more balanced. The residual shock plays a minor role except for prices and, to some extent, real wages. It is confirmed that demand and technology shocks are the dominant drivers of prices and real wages respectively.

The participation rate is mainly driven by labor supply shocks, both in the short run and in the long run. The contribution of wage bargaining shocks is relevant in the short run whereas demand and technology shocks have a limited effect. In Figure 1.9.12 we plot the impulse responses of the participation rate to the four identified shocks.<sup>10</sup> An expansionary labor supply shock has a very persistent effect on the participation rate, whereas the impact of a wage bargaining shock is more short-lived (negative over the first three quarters and positive afterwards). The participation rate does not respond to demand shocks, whereas it tends to increase in response to technology shocks (although the impact response is uncertain).<sup>11</sup>

Our model can also be used to investigate the historical evolution of the participation rate, with a special focus on recent years. It is well known that the participation rate has been steadily increasing over time until the very end of the 1990s. Since then, it has been gently declining with an acceleration from 2008 onwards (cf. the solid line in Figure 1.9.13 where the participation rate is plotted in deviation from its mean over the sample period). In the absence of shocks the model would forecast the participation rate at the end of the sample to be 1 per-

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<sup>10</sup>The impulse responses for the other variables are very similar to the ones derived in the baseline model.

<sup>11</sup>The evidence on the response of participation to technology shocks is mixed: it is countercyclical in Galí (2011) unlike in Christiano, Trabandt and Walentin (2012) where it is procyclical. Both papers identify technology shocks using long-run restrictions, but the exact specification of the models differ. Christiano, Trabandt and Walentin (2012) include more variables in their analysis and identify more shocks. Our results weakly support a procyclical response. Further discussion on this point is provided in the appendix.

cent above its sample mean rather than 3 percent below (cf. the dark blue area in Figure 1.9.13).<sup>12</sup> The model interprets the recent decline in the participation rate as driven mainly by contractionary labor supply shocks, which explain around half of the recent decline. Wage bargaining and demand shocks each account for roughly one fourth of the decline, whereas technology shocks are almost irrelevant in driving participation dynamics in recent years.

Our results complement a recent and rich literature on the decline in participation that is summarized in Bullard (2014). One strand of the literature interprets the decline in participation as a response to the protracted weak state of the economy (cf. Erceg and Levin, 2013, among others). Under this view ("the bad omen view" in the words of Bullard, 2014) the decline of the unemployment rate over the latest period does not really reflect an improvement in the labor market because it coexists with a stubbornly low employment-to-population ratio. In contrast, a second strand of the literature argues that the decline in the participation rate simply reflects changing demographics in the US economy, and that the different demographic groups have different propensities to participate (cf. Fujita, 2013; Kudlyak, 2013; among others). Under this view (the "demographics view" in the words of Bullard, 2014), the unemployment rate remains a good indicator of labor market health. Our labor supply shock explains slightly more than 50 percent of the participation decline and may capture, at least to some extent, "the de-

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<sup>12</sup>This reflects the influence of the initial conditions. For stationary processes, the contribution of the initial state becomes negligible as the sample period increases. However, for very persistent and non-stationary processes, these initial values play a role even in the presence of a relatively long sample (cf. Luetkepohl, 2011). It is common practice in the literature to present historical decompositions in deviation from the long run unconditional forecast, which is driven by the initial conditions. For the sake of transparency, we plot the original series and display the role of the initial conditions.

### *1.5 Introducing data on the participation rate*

mographics view". Our results are then in the same ballpark as BLS projections (according to which more than 70 percent of the decline is due to purely demographic factors) and of Fujita (2014) who finds that about 65 percent of the decline in participation is due to retirements and disability.

However, labor supply shocks are also likely to capture a declining desire to work in addition to the demographic factors. Supporting evidence is provided in a recent paper by Barnichon and Figura (2014), who use CPS micro data and a stock-flow accounting framework to explain the downward trends in unemployment (between the early 1980s and the early 2000s) and in participation (since the beginning of the 2000s). Barnichon and Figura (2014) identify a secular decline in the share of non-participants who want a job and, importantly, this decline is broad-based across demographic groups. Non-participants interested in a job enter the labor force only rarely and mainly directly through employment. Therefore, a decline in their share may lower both the unemployment rate and the participation rate. Barnichon and Figura (2014) find that this labor supply shift can account for 1.75 percentage points of the decline in participation, whereas the demographic factors account for an additional 1.5 percentage points. They suggest three possible interpretations for this negative labor supply shift: i) a reduction in the added-worker effect driven by the strong wage growth of the second half of the 1990s, ii) a higher emphasis on education, perhaps in part in response to a rising high school and college wage premium, iii) a change in preferences. All these factors are likely to be captured by our labor supply shock together with the demographic factors.

## 1.6 Disentangling wage bargaining shocks

In the previous sections we showed that labor supply and wage bargaining shocks can be separately identified on the basis of the unemployment and participation rate responses to shocks. As we saw in the previous section, the use of data on participation is particularly useful to refine the interpretation of labor supply shocks. The objective of this section is to further disentangle the wage bargaining shock. In particular, we rely again on our theoretical model presented in Section 2 to show that the dynamics generated by wage bargaining shocks are similar to the ones derived from shocks to unemployment benefits and matching efficiency.

In Figure 1.9.14 we plot the distribution of impact responses to an unemployment benefit shock, i.e a variation in  $b_t$  in equation (1.2.12). We see that the impact effects on all the variables are the same as the ones generated by wage bargaining shocks. Therefore, exogenous variations in unemployment benefits are captured by wage bargaining shocks in the VAR. In Figure 1.9.15 we plot the distribution of impact responses to a matching efficiency shock that shows up as a variation in the parameter  $\Gamma$  in the matching function. The sign of the responses of output, prices, unemployment, real wages and participation rate are the same in response to both matching efficiency shocks and wage bargaining shocks. Therefore, we can conclude that the wage bargaining shock identified in the VAR should not be interpreted narrowly as just reflecting fluctuations in the bargaining power of workers. It also captures fluctuations in unemployment benefits and variations in matching efficiency.

While in the baseline VAR model matching efficiency shocks are grouped to-

## 1.6 Disentangling wage bargaining shocks

gether with wage bargaining shocks, the use of data on vacancies may allow us to separately identify the two shocks. An improvement in matching technology lowers hiring costs and wages. As vacancies are filled more easily, firms expand employment and output increases. The sign of the response of vacancies depends crucially on the degree of price stickiness (cf. Furlanetto and Goshenny, 2014, and Justiniano and Michelacci, 2011). When the degree of price rigidity is high, firms can not decrease prices as much as they would like to: the expansion in aggregate demand is less pronounced and firms do not need necessarily to post more vacancies to produce the quantities demanded. Thus, the impact response of vacancies can be either positive or negative in our model, as shown in Figure 1.9.15. However, the response of vacancies is unambiguously negative in period two, even for moderate degrees of price stickiness.<sup>13</sup> In contrast, wage bargaining shocks move unemployment and vacancies in opposite directions both on impact and in period two, as shown in Figure 1.9.4. Therefore, we can go one step further in the analysis by introducing data on vacancies in our VAR and by using the asymmetric response of this variable in response to wage bargaining and matching efficiency shocks to disentangle these two forces. The restrictions on vacancies are imposed in the second period in keeping with the prediction of the theoretical model, as detailed in Table 1.4.

In Figure 1.9.16, we plot the variance decomposition of this extended model. While the contributions of demand and technology shocks to economic volatility

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<sup>13</sup>Benati and Lubik (2014) show that separation rate shocks also move unemployment and vacancies in the same direction. Both matching efficiency and separation shocks have been considered as examples of reallocation shocks in the literature and both shocks are consistent with our identification assumptions under general conditions. Balakrishnan and Michelacci (2001) identify reallocation shocks using data on flows into and out of the unemployment pool.

Table 1.4 : Sign restrictions

	Demand	Technology	Labor Supply	Wage Bargaining	M. efficiency
GDP	+	+	+	+	+
Prices	+	-	-	-	-
Real wages	/	+	-	-	-
Unemployment	-	/	+	-	-
Vacancies	/	/	/	+	-

are mostly unchanged, labor supply and wage bargaining shocks now account for a more modest share of fluctuations in output and unemployment. The contribution of matching efficiency shocks to the variance of the different variables is substantial. Notice that it is crucial to rely on a model with search and matching frictions to disentangle wage bargaining shocks from reallocation shocks. There is usually great skepticism on what wage bargaining shocks are in structural models. Our analysis here suggests that they may capture the effects of reallocation shocks (and perhaps shocks to the unemployment benefits) more than variations in unions' bargaining power.

In Figure 1.9.17 we see that two shocks can be interpreted as shifters of the Beveridge curve insofar as they move unemployment and vacancies in the same direction for a few quarters. This is imposed as an identification assumption for matching efficiency shocks but not for labor supply shocks, whose effect on vacancies is ambiguous in the context of the theoretical model. A contractionary labor supply shock lowers both unemployment and vacancies on impact (thus shifting the Beveridge curve inward) but the effect on vacancies is quickly reversed. Therefore, our analysis adds one additional element to the debate on the outward shift of the Beveridge curve observed in the immediate aftermath of the Great Reces-

sion: while a negative matching efficiency shock triggers an outward shift of the Beveridge curve, a negative labor supply shock generates an inward shift on impact and then generate dynamics along the curve in the south-east direction (cf. impulse responses in Figure 1.9.17). These results lead us to two considerations. First, negative matching efficiency shocks are a promising explanation to rationalize the outward shift in the Beveridge curve observed in the aftermath of the Great Recession. Second, negative labor supply shocks cannot explain the outward shift of the Beveridge curve (in fact they imply a short-lived inward shift) but can explain why the recovery has been so sluggish through movements along the Beveridge curve leading to lower vacancy posting and higher unemployment. As far as we know, these dimensions have so far been neglected in the debate.

## 1.7 Conclusion

The objective of this paper is to identify labor supply shocks separately from other shocks originating in the labor market in the context of a sign restricted VAR. To achieve our goal we impose theory-based sign restrictions on the responses of the unemployment rate and the participation rate to shocks. We find that the importance of wage bargaining shocks is larger in the short run, while labor supply shocks are crucial to capture macroeconomic dynamics in the long run. However, both shocks have a quantitatively relevant impact both in the short run and the long run. Therefore, disentangling these shocks is important. Our results suggest that polar assumptions on the role of labor market shocks (i.e. assuming that one of the shocks is irrelevant in the long run, in the short run or at any horizon) often

made in the DSGE literature may be misguided.

While the two shocks are of comparable importance across all specifications, their joint importance is magnified by the presence of the Great Recession in our sample period. Nevertheless, even when we extend or reduce the sample period, the role of labor market shocks remains substantial, in keeping with previous contributions starting with Shapiro and Watson (1988) and Blanchard and Diamond (1989). While the structural interpretation of these shocks is still debatable, our paper suggests that they should not be dismissed as potential drivers of business cycle fluctuations. In that sense, the fact that labor market shocks prove to be important in estimated New Keynesian models (as in Smets and Wouters, 2007) is not necessarily problematic. Nevertheless, our results suggest that it is important to disentangle the different shocks, and we provide a theoretical set-up where this is feasible. Modeling search and matching frictions and the participation decision is crucial to allow both shocks to play a role both in the short run and in the long run, unlike in Galí, Smets and Wouters (2011).

More generally, we think that these two labor market shocks capture a broad series of factors. We have made some progress in the interpretation of wage bargaining shocks by showing that they are also likely to capture variations in unemployment benefits and shifts in matching efficiency. These shocks have also been considered as indicators of structural reforms in the labor market (cf. Blanchard and Giavazzi, 2003, and Fiori, Nicoletti, Scarpetta and Schiantarelli, 2012) and investigating this interpretation in the context of our model might be an interesting avenue for future research. Similarly, different interpretations may be attached to labor supply shocks: disentangling the demographic explanation from the declining

## *1.7 Conclusion*

desire to work among non-participants, in particular by investigating the possible explanations proposed by Barnichon and Figura (2014), might be worthwhile to refine the interpretation of these shocks.

## 1.8 Appendix

### 1.8.1 Log-linear equations characterizing the decentralized equilibrium

- $c_t = E_t c_{t+1} - \frac{1}{\sigma}(r_t - E_t \pi_{t+1} + \varepsilon_t^p)$
- $\frac{\kappa}{\Gamma} \theta^\alpha (\alpha \theta_t - \gamma_t) = \frac{Z}{\mu} (z_t - \mu_t) - w w_t + \beta(1-\rho) \frac{\kappa}{\Gamma} \theta^\alpha (\sigma c_t - \sigma E_t c_{t+1} + \alpha E_t \theta_{t+1} - E_t \gamma_{t+1})$
- $w w_t = b b_t + \frac{\eta}{1-\eta} \frac{\kappa}{\Gamma} \theta^\alpha \left[ \frac{\varepsilon_t^\eta}{1-\eta} - \gamma_t + \alpha \theta_t \right] - \beta(1-\rho) \frac{\eta}{1-\eta} \frac{\kappa}{\Gamma} \theta^\alpha (1-p) * \left( \sigma c_t - \sigma E_t c_{t+1} + \frac{\varepsilon_{t+1}^\eta}{1-\eta} - E_t \gamma_{t+1} + \alpha E_t \theta_{t+1} \right) \beta(1-\rho) \frac{\eta}{1-\eta} \frac{\kappa}{\Gamma} \theta^\alpha p E_t p_{t+1}$
- $\pi_t = \beta E_t \pi_{t+1} - \frac{(1-\beta\delta)(1-\delta)}{\delta} \mu_t - \frac{(1-\beta\delta)(1-\delta)}{\delta} \frac{1}{\varepsilon-1} \varepsilon_t$
- $\chi L^\varphi C^\sigma (\varphi l_t + \sigma c_t + \chi_t) = p(w-b)p_t + (1-p)b b_t + p w w_t + \beta(1-\rho)(1-p)(\chi L^\varphi C^\sigma - b) * (p_t + \sigma c_t) + \beta(1-\rho) \chi L^\varphi C^\sigma (1-p) E_t (\chi_{t+1} + \varphi l_{t+1}) - \beta(1-\rho)(\chi L^\varphi C^\sigma - b) E_t p_{t+1} + \beta(1-\rho)(1-p) b E_t (\sigma c_{t+1} - b_{t+1})$
- $c c_t + \kappa \theta (L - (1-\rho)N) \theta_t + \kappa \theta L l_t - \kappa (1-\rho) N \theta n_{t-1} = Z N (z_t + n_t)$
- $n_t = (1-\rho)(1-p)n_{t-1} + \frac{pL}{N} l_t + p \left( \frac{L}{N} - 1 + \rho \right) p_t$
- $r_t = \phi_r r_{t-1} + (1-\phi_r) (\phi_\pi \pi_t + \phi_y y_t)$
- $p_t = (1-\alpha) \theta_t + \gamma_t$
- $\eta_t = \varepsilon_t^\eta$
- $z_t = \zeta^Z z_{t-1} + \varepsilon_t^Z$
- $\varepsilon_t^p = \zeta^p \varepsilon_{t-1}^p + \varepsilon_t^p$

- $\varepsilon_t^\eta = \zeta^\eta \varepsilon_{t-1}^\eta + \epsilon_t^\eta$
- $\varepsilon_t^\varepsilon = \zeta^\varepsilon \varepsilon_{t-1}^\varepsilon + \epsilon_t^\varepsilon$
- $\gamma_t^\Gamma = \zeta^\Gamma \gamma_{t-1}^\Gamma + \epsilon_t^\Gamma$
- $b_t^b = \zeta^b b_{t-1}^b + \epsilon_t^b$
- $\chi_t^X = \zeta^X \chi_{t-1}^X + \epsilon_t^X$

## 1.8.2 Data sources

This subsection lists the sources of the data series used in the estimation of the VAR

- **Unemployment rate:** taken from the website of the Bureau of Labor Statistics “Labor Force Statistics from the Current Population Survey”, series ID LNS14000000, seasonally adjusted, aged 16 years and over
- **Civilian labor force participation rate:** taken from the website of the Bureau of Labor Statistics, series ID LNS11300000, seasonally adjusted, aged 16 years and over
- **Vacancies:** We use the Help Wanted Index of the Conference Board from 1951m1 to 1994m12 and Barnichon’s (2010) index from 1995m1 to 2013m6. We also have JOLTS data for job openings from 2000m12 to 2014m3. In order to construct a series for vacancy levels, we apply the following formula  $V_t = \frac{HWI_t * \bar{V}_{2000m12-2013m6}}{HWI_{2000m12-2013m6}}$  where  $\bar{V}_{2000m12-2013m6}$  is the average of job openings in JOLTS and  $H\bar{W}I_{2000m12-2013m6}$  is the average of the help wanted index

over the period 2000m12 to 2013m6. For the period 2013m6 to 2014m3, we use JOLTS data directly.

- **Prices:** taken from the FRED. Gross Domestic Product: Implicit Price Deflator, Index 2009=100, Quarterly, Seasonally Adjusted, GDPDEF
- **Output:** Quarterly real output in the nonfarm sector constructed by the BLS MSPC program, ID SERIES PRS85006043, base year 2009.
- **Nominal wages 1:** taken from the website of the Bureau of Labor Statistics. Average Hourly Earnings of Production and Nonsupervisory Employees, ID series CES0500000008, seasonally adjusted. Available only from 1964 onwards.
- **Nominal wages 2:** taken from the Fred. Nonfarm Business Sector: Compensation Per Hour, Index 2009=100, Quarterly, Seasonally Adjusted, COMP-NFB.

When the original data is at a monthly frequency, we take quarterly averages of monthly data. Nominal wages are deflated using the implicit price deflator of GDP to obtain real wages.

### **1.8.3 Bayesian estimation of the VAR**

We illustrate in this Appendix the econometric procedure we use for the estimation of the different VAR models presented in the paper. We start from the standard

reduced-form VAR representation:

$$y_t = C_B + \sum_{i=1}^P B_i y_{t-i} + u_t, \quad (1.8.1)$$

where  $y_t$  is a  $N \times 1$  vector containing our  $N$  endogenous variables,  $C_B$  is a  $N \times 1$  vector of constants,  $B_i$  for  $i = 1, \dots, P$  are  $N \times N$  parameter matrices, with  $P$  the maximum number of lags we include in the model (5 in our specific case), and  $u_t$  is the  $N \times 1$  one-step ahead prediction error with  $u_t \sim N(0, \Sigma)$ , where  $\Sigma$  is the  $N \times N$  variance-covariance matrix. Given the large number of parameters to be estimated, we prefer to use Bayesian methods. Moreover, the models are specified and estimated with variables in levels. This is a nice feature of the Bayesian approach, which can be applied regardless of the presence of nonstationarity (cf. Sims, Stock, and Watson, 1990, and Sims and Uhlig, 1991, for more details on this point).

### Estimation procedure

The VAR model described in (1.8.1) can be rewritten in a compact way as:

$$\mathbf{Y} = \mathbf{X}\mathbf{B} + \mathbf{U}, \quad (1.8.2)$$

where  $\mathbf{Y} = [y_1 \dots y_T]'$ ,  $\mathbf{B} = [C_B \ B_1 \ \dots \ B_p]'$ ,  $\mathbf{U} = [u_1 \dots u_T]'$ , and

$$\mathbf{X} = \begin{bmatrix} 1 & y'_0 & \dots & y'_{-p} \\ \vdots & \vdots & \vdots & \vdots \\ 1 & y'_{T-1} & \dots & y'_{T-p} \end{bmatrix}.$$

Finally, for convenience, we rewrite (1.8.2) into its vectorized form:

$$\mathbf{y} = (I_n \otimes \mathbf{X})\beta + \mathbf{u}, \quad (1.8.3)$$

where  $\mathbf{y} = \text{vec}(\mathbf{Y})$ ,  $\beta = \text{vec}(\mathbf{B})$ ,  $\mathbf{u} = \text{vec}(\mathbf{U})$ , and with  $\text{vec}()$  denoting columnwise vectorization. The error term  $\mathbf{u}$  follows a normal distribution with a zero mean and variance-covariance matrix  $\Sigma \otimes I_T$ . The likelihood function in  $\mathbf{B}$  and  $\Sigma$  is defined as:

$$L(B, \Sigma) \propto |\Sigma|^{-\frac{T}{2}} \exp \left\{ -\frac{1}{2}(\beta - \hat{\beta})'^{-1} \otimes \mathbf{X}'\mathbf{X}(\beta - \hat{\beta}) \right\} \exp \left\{ -\frac{1}{2}\text{tr}(\Sigma^{-1}S) \right\},$$

where  $S = ((\mathbf{Y} - \mathbf{X}\hat{\mathbf{B}})'(\mathbf{Y} - \mathbf{X}\hat{\mathbf{B}}))$  and  $\hat{\beta} = \text{vec}(\hat{\mathbf{B}})$  with  $\hat{\mathbf{B}} = (\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'\mathbf{Y}$ . We specify diffuse priors so that the information in the likelihood is dominant and these priors lead to a Normal-Wishart posterior. In more detail, we a diffuse prior for  $\beta$  and  $\Sigma$  that is proportional to  $|\Sigma|^{-(n+1)/2}$ . The posterior becomes:

$$p(B, \Sigma|y) \propto |\Sigma|^{-\frac{T+n+1}{2}} \exp \left\{ -\frac{1}{2}(\beta - \hat{\beta})'^{-1} \otimes \mathbf{X}'\mathbf{X}(\beta - \hat{\beta}) \right\} \exp \left\{ -\frac{1}{2}\text{tr}(\Sigma^{-1}S) \right\}, \quad (1.8.4)$$

where  $y$  denotes all available data. The posterior in (1.8.4) is the product of a normal distribution for  $\beta$  conditional on  $\Sigma$  and an inverted Wishart distribution for  $\Sigma$  (see, e.g. Kadiyala and Karlsson, 1997 for the proof). We then draw  $\beta$  conditional on  $\Sigma$  from

$$\beta|\Sigma, y \sim N(\hat{\beta}, \Sigma \otimes (\mathbf{X}'\mathbf{X})^{-1})$$

and  $\Sigma$  from

$$\Sigma|y \sim IW(S, \nu),$$

where  $\nu = (T - n) * (p - 1)$  and  $N$  representing the normal distribution and  $IW$  the inverted Wishart distribution.

### Identification procedure

In order to map the economically meaningful structural shocks from the reduced form estimated shocks, we need to impose restrictions on the variance covariance matrix we estimated. In detail, the prediction error  $u_t$  can be written as a linear combination of structural innovations  $\epsilon_t$

$$u_t = A\epsilon_t$$

with  $\epsilon_t \sim N(0, I_N)$ , where  $I_N$  is an  $(N \times N)$  identity matrix and where  $A$  is a non-singular parameter matrix. The variance-covariance matrix has thus the following structure  $\Sigma = AA'$ . Our goal is to identify  $A$  from the symmetric matrix  $\Sigma$ , and to do that we need to impose restrictions. To obtain identification via sign restrictions, we follow the procedure described in Rubio-Ramirez, Waggoner and Zha (2010). The algorithm has the following steps. First, we compute  $A$  as the Cholesky decomposition of our estimated variance covariance matrix. We then compute rotations of this matrix, computing first a matrix  $Q$  with a QR decomposition of  $X = QR$ , where  $X$  is drawn from  $X \sim N(0, I_N)$ . Then, we generate candidate impulse responses from  $AQ$  and  $B_i$  for  $i = 1, \dots, P$  and check if the generated impulse responses satisfy the sign restrictions. If the sign restrictions

are satisfied, we store our impulse response, if not we draw a new  $X$ . We iterate over the same procedure again until we obtain 1000 impulse responses which satisfy our sign restrictions.

### **1.8.4 Introducing price-markup shocks**

This subsection provides an extension to the analysis carried out in Section 5. The residual shock is replaced by a shock with an economic interpretation, a price mark-up shock. This shock is introduced in the theoretical framework by assuming that the elasticity of substitution between goods  $\varepsilon$  is stochastic. In the model, the market power of firms comes from the imperfect substitutability between goods. Thus, an increase in  $\varepsilon$  leads to a decrease in firms' mark-ups. The distribution of impact responses to a price mark-up shock is presented in Figure 1.9.18. An increase in the elasticity of substitution between goods leads to a decrease in prices and an increase in aggregate demand. In order to produce more, firms recruit more workers and unemployment decreases. The decrease in unemployment puts upward pressure on wages. The increase in the job-finding rate and in wages tend to make labor force participation relatively more interesting, whereas the increase in consumption tends to make labor force participation relatively less interesting. The first effect dominates under all parameterizations. Notice that the price mark-up shock implies the same dynamics for output, prices and wages as the technology shock. However, the behavior of participation is markedly different in response to the two shocks. Participation decreases following a technology shock, whereas it increases following a price mark-up shock. Notice that the existence of price mark-up shocks can reconcile the response of participation to technology shocks

in the New Keynesian model presented in Section 2 (where it is countercyclical) and in the VAR estimated in Section 5 (where it is mildly procyclical). The VAR result is not necessarily inconsistent with the theoretical model because in that specification technology shocks and price mark-up shocks are not separately identified. The procyclicality in the VAR, in fact, can just reflect the importance of price mark-up shocks. To further investigate this point we use the asymmetric response of participation in order to disentangle price mark-up shocks and technology shocks in the VAR. The restrictions used in this exercise are summarized in Table 1.5. Figure 1.9.19 presents the variance decomposition for the extended

Table 1.5 : Sign restrictions

	Demand	Technology	Labor Supply	W. Bargaining	Price-markup
GDP	+	+	+	+	+
Prices	+	-	-	-	-
Real wages	/	+	-	-	+
Unemployment	-	/	+	-	/
Participation	/	/	+	-	+

model with price mark-up shocks. Our main result on the absolute and relative importance of the two labor market shocks is confirmed. The price markup shock accounts for a small but significant share of unemployment and labor force participation fluctuations in the short run. It also accounts for a fairly large share of movements in real wages at all horizons and for around 10 percent of output fluctuations on average over different horizons, thus absorbing some explanatory power from technology shocks. More generally, this exercise can be used to quantify the joint importance of price mark-up and wage bargaining shocks, i.e. the so called "inefficient shocks" in the DSGE literature. Inefficient shocks received

a special attention in the literature since they generate large trade-offs between output gap stabilization and inflation stabilization in standard New Keynesian models. Moreover, they are particularly important in the definition of output gap measures. Here we provide a new perspective on the importance of these shocks in the context of a VAR model. According to our results, the two shocks explain on average around 20 percent of output fluctuations, whereas they are more important for the labor market variables and they are relevant for inflation only in the short-run.

## **1.9 Figures**

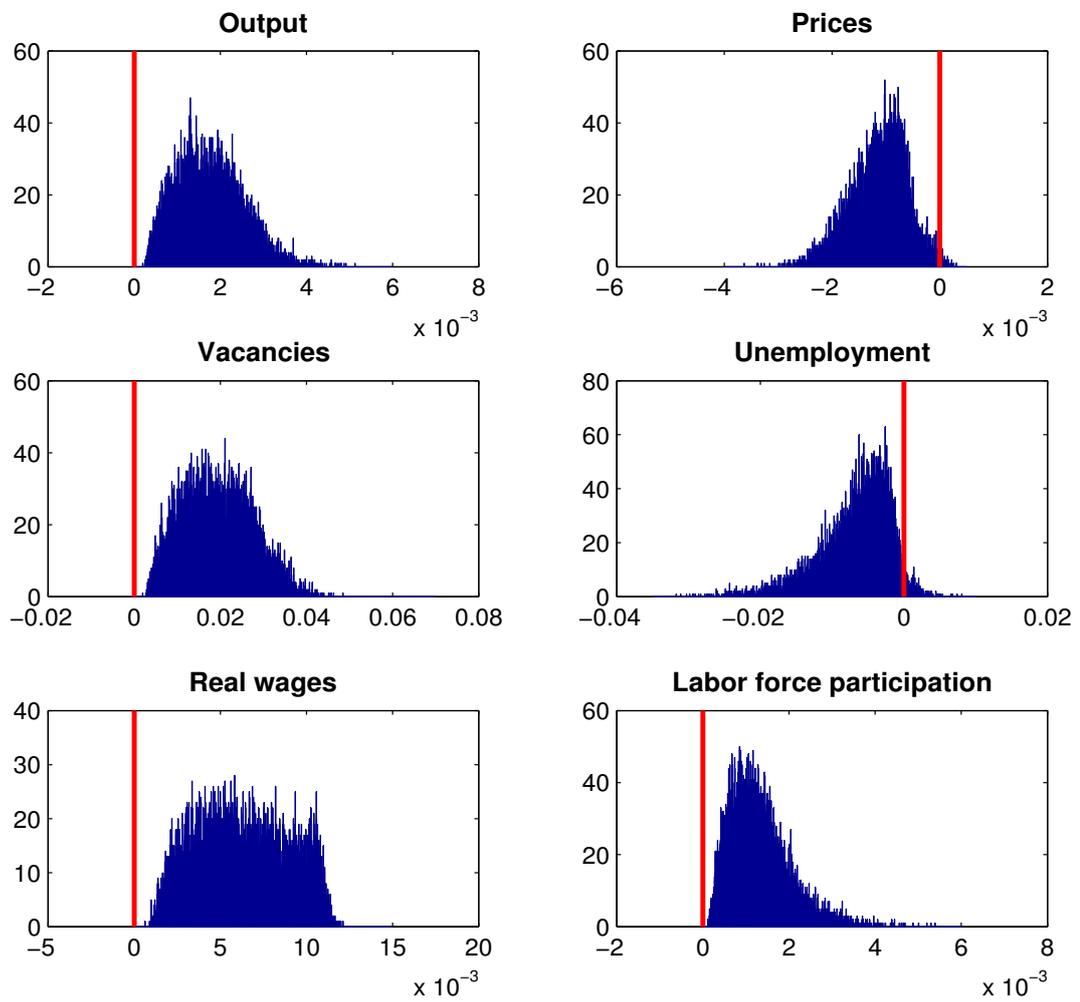


Figure 1.9.1 : Distribution of impact responses to a 1% risk premium shock

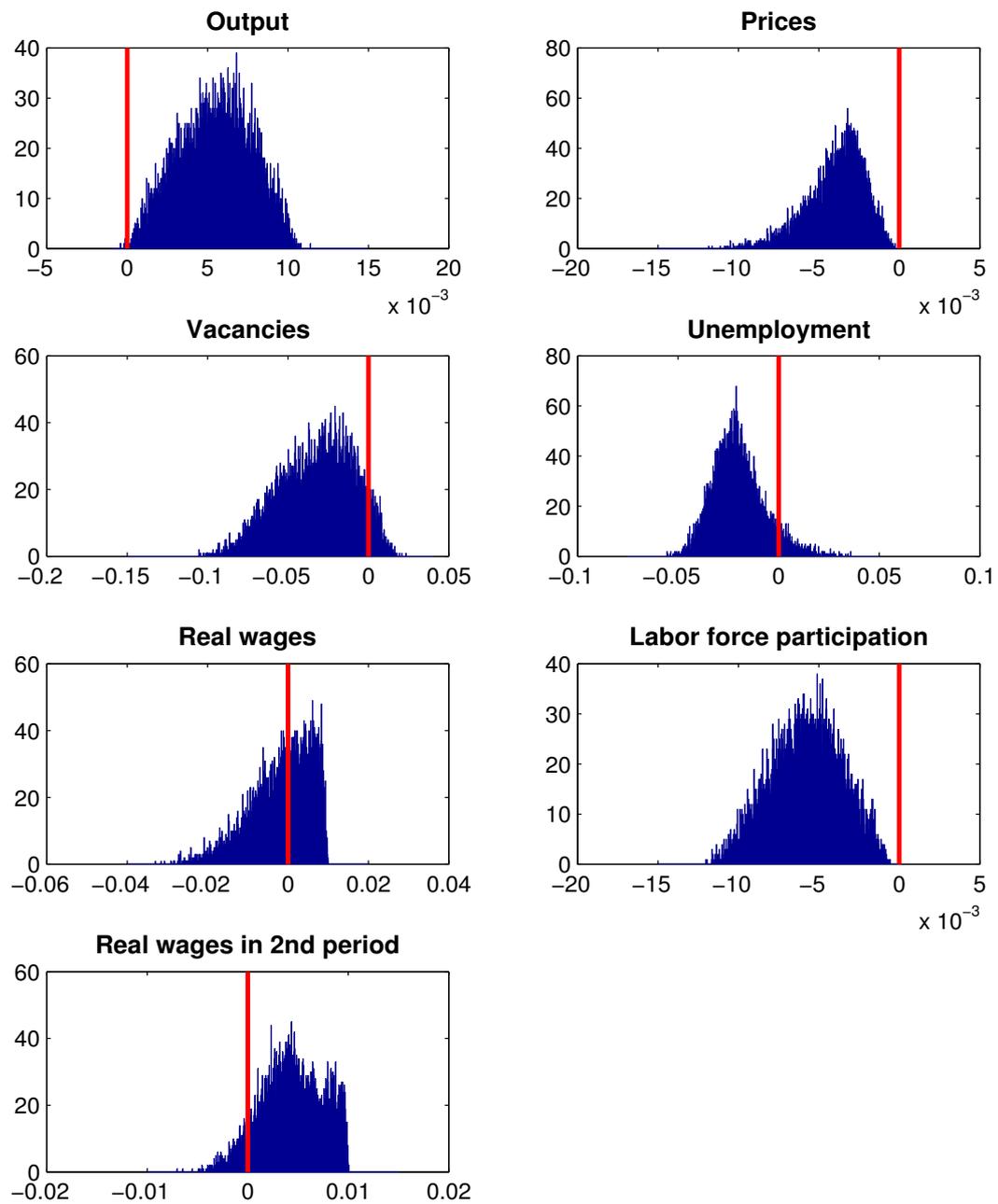


Figure 1.9.2 : Distribution of impact responses to a 1% technology shock

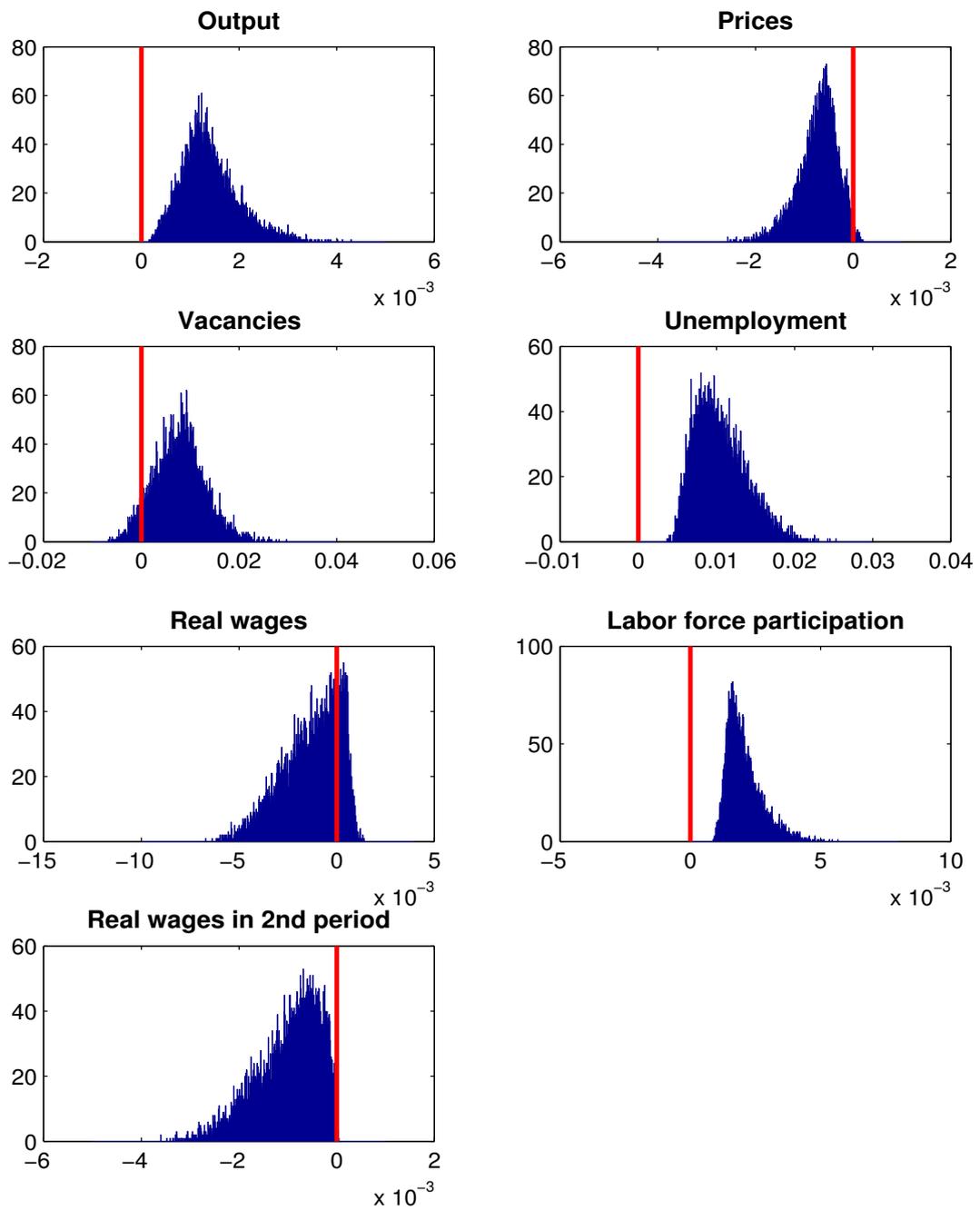


Figure 1.9.3 : Distribution of impact responses to a 1% labor supply shock

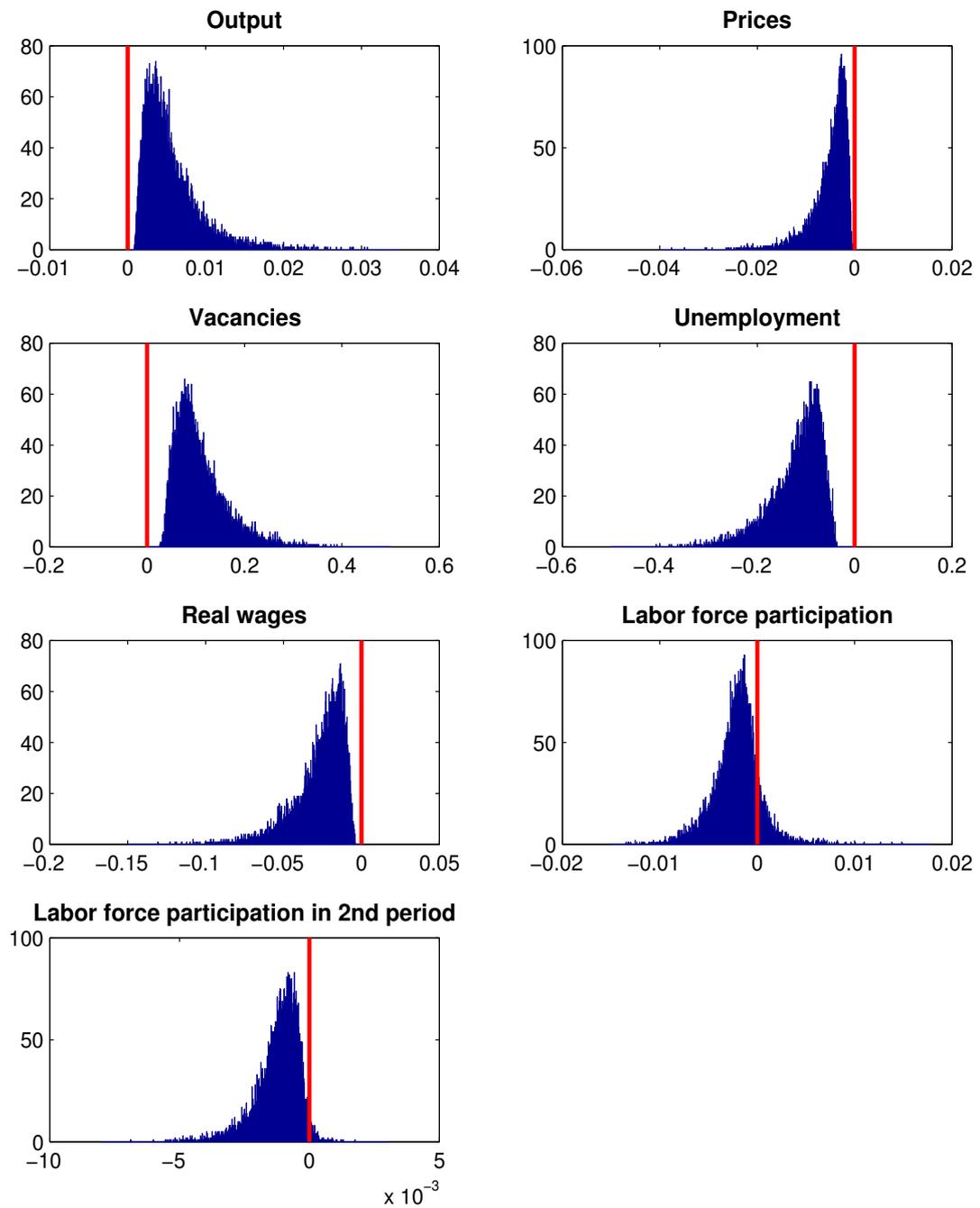


Figure 1.9.4 : Distribution of impact responses to a 1% wage bargaining shock

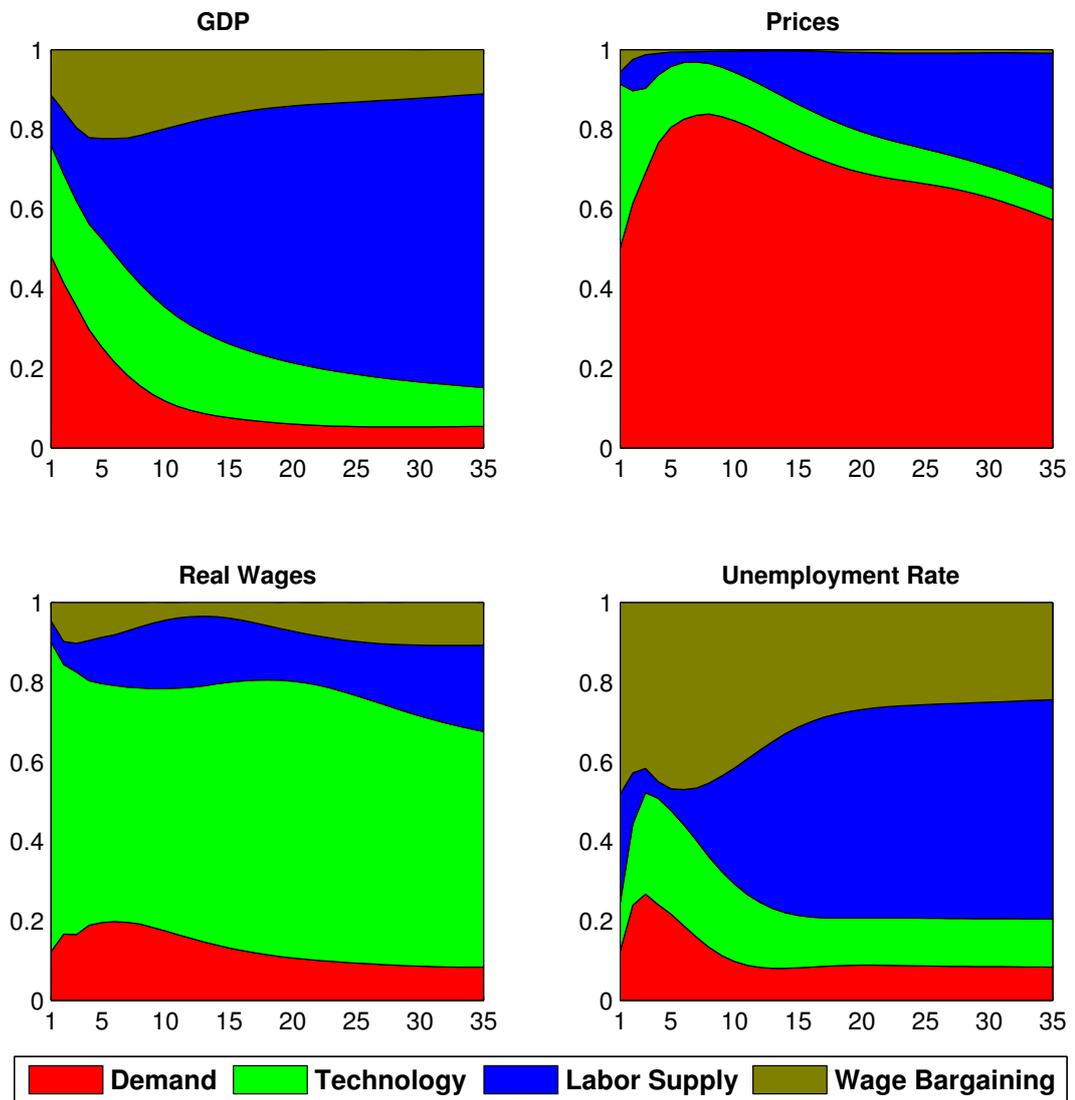


Figure 1.9.5 : Variance decomposition for the baseline VAR model

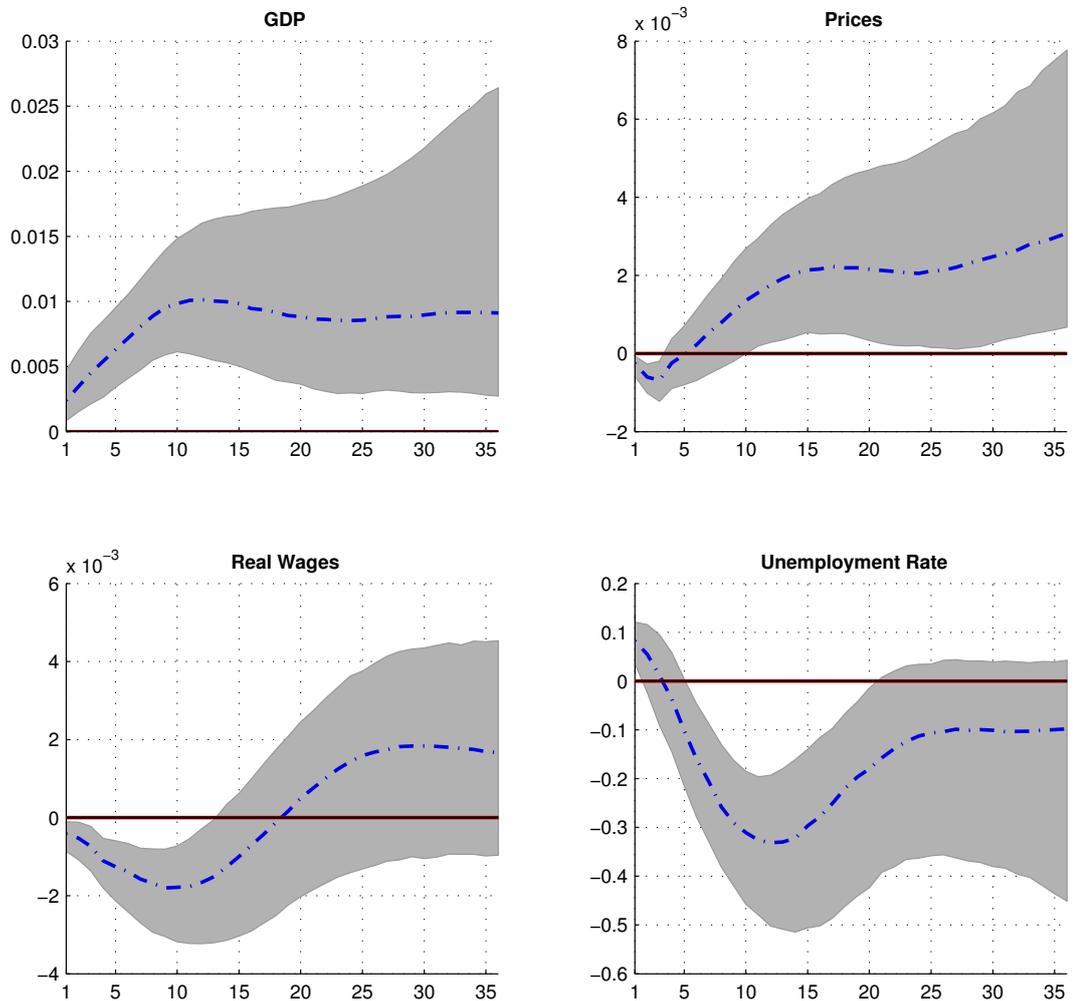


Figure 1.9.6 : Impulse responses to a labor supply shock in the baseline VAR model. The dashed-dotted line represents the posterior median at each horizon and the shaded area indicates the 16th and 84th percentiles of the impulse responses.

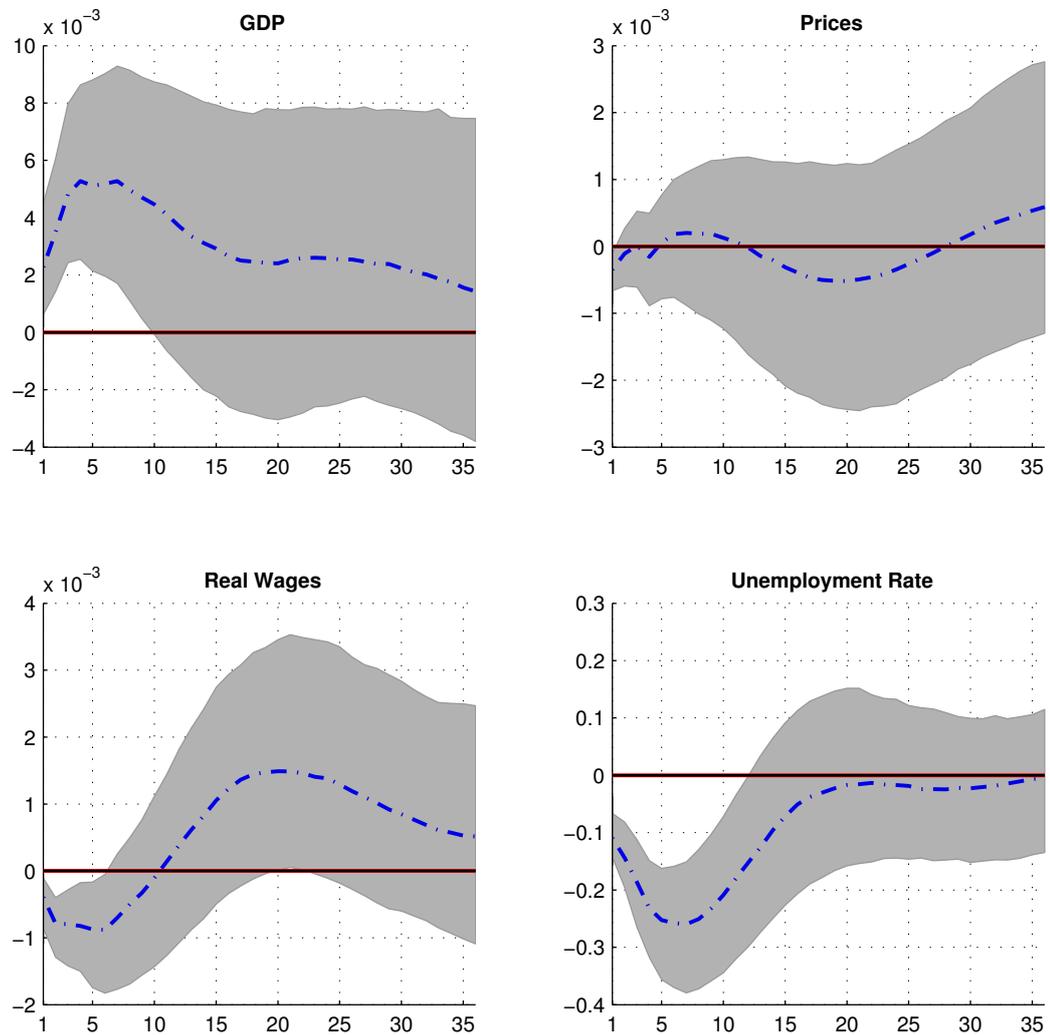


Figure 1.9.7 : Impulse responses to a wage bargaining shock in the baseline VAR model. The dashed-dotted line represents the posterior median at each horizon and the shaded area indicates the 16th and 84th percentiles of the impulse responses.

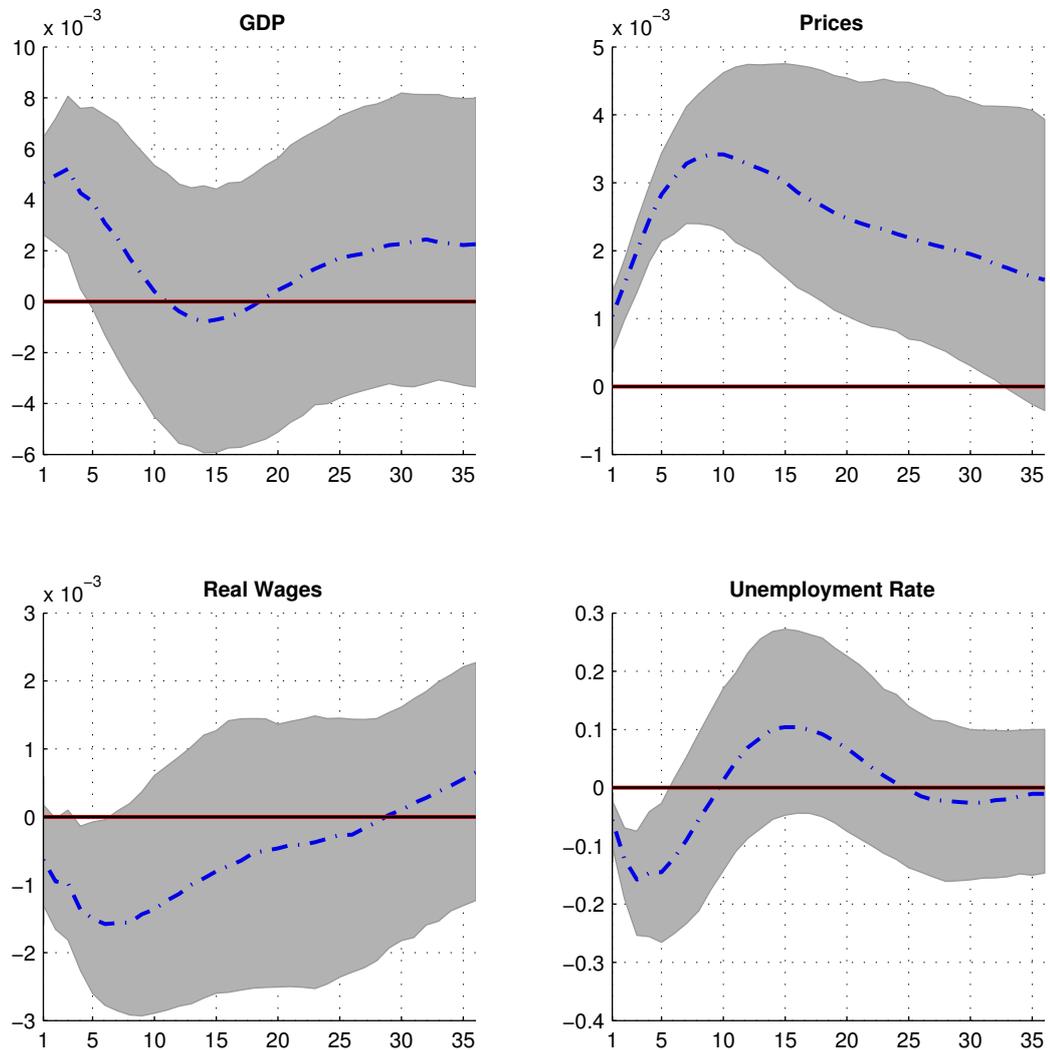


Figure 1.9.8 : Impulse responses to a demand shock in the baseline VAR model. The dashed-dotted line represents the posterior median at each horizon and the shaded area indicates the 16th and 84th percentiles of the impulse responses.

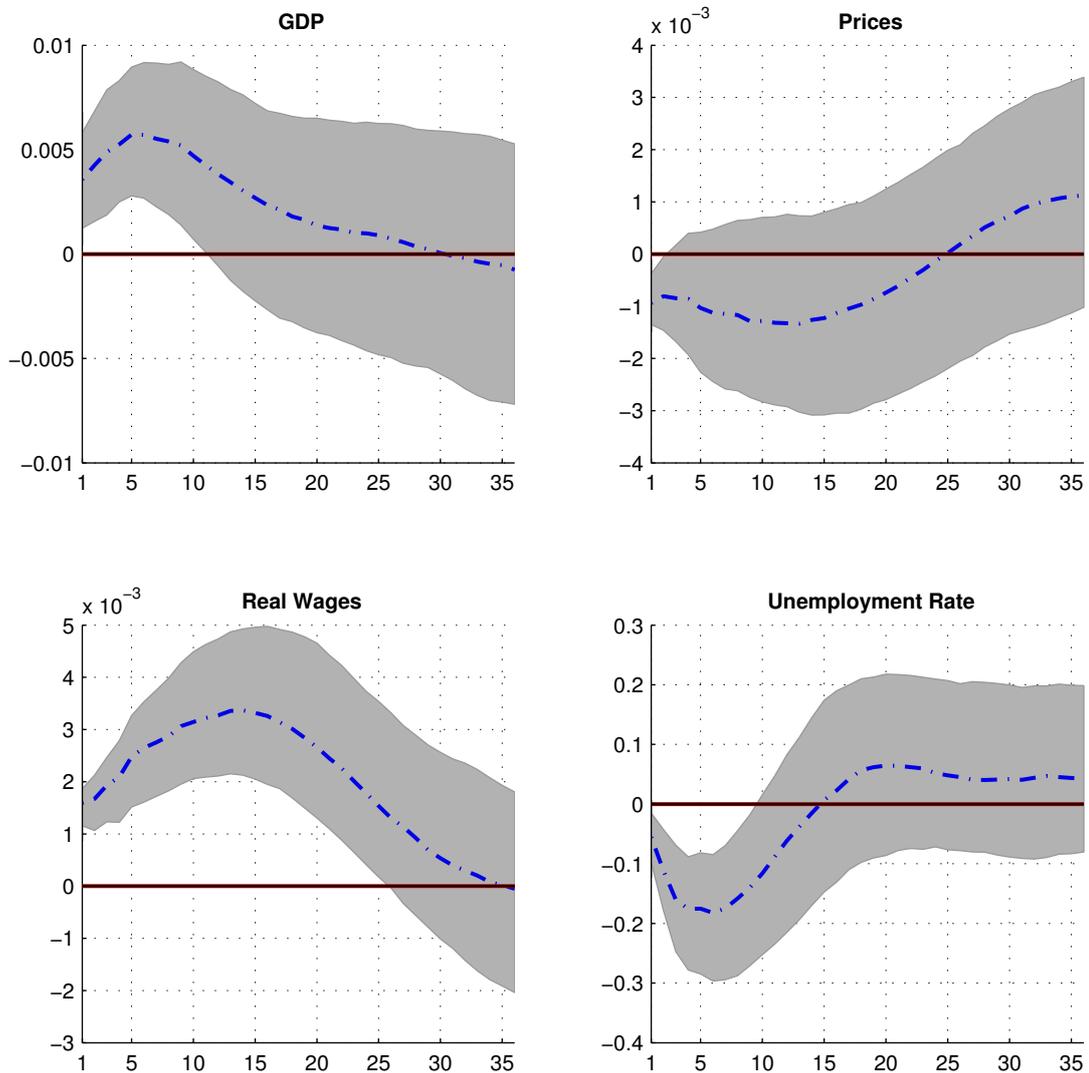


Figure 1.9.9 : Impulse responses to a technology shock in the baseline VAR model. The dashed-dotted line represents the posterior median at each horizon and the shaded area indicates the 16th and 84th percentiles of the impulse responses.

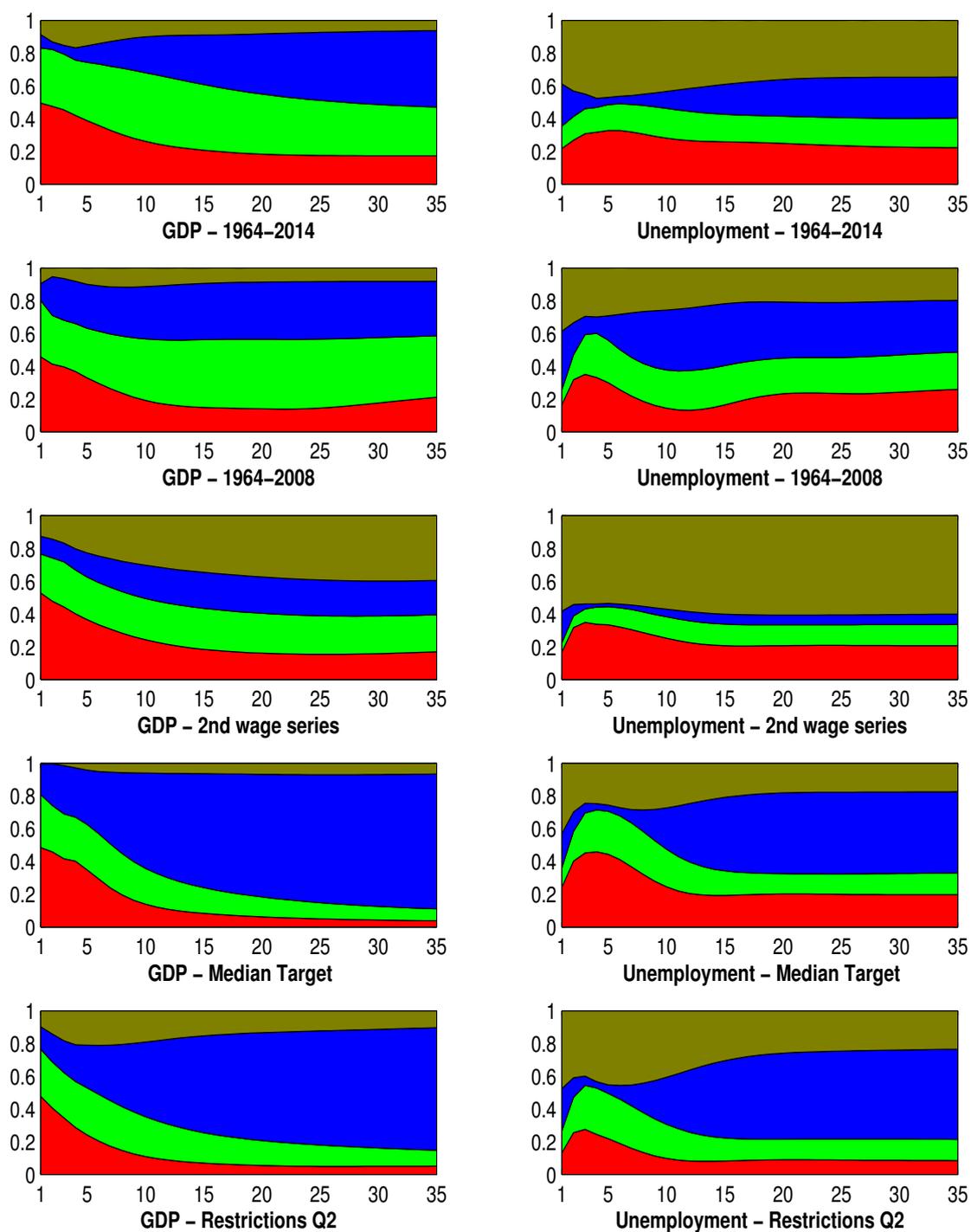


Figure 1.9.10 : Sensitivity analysis for the baseline VAR model.

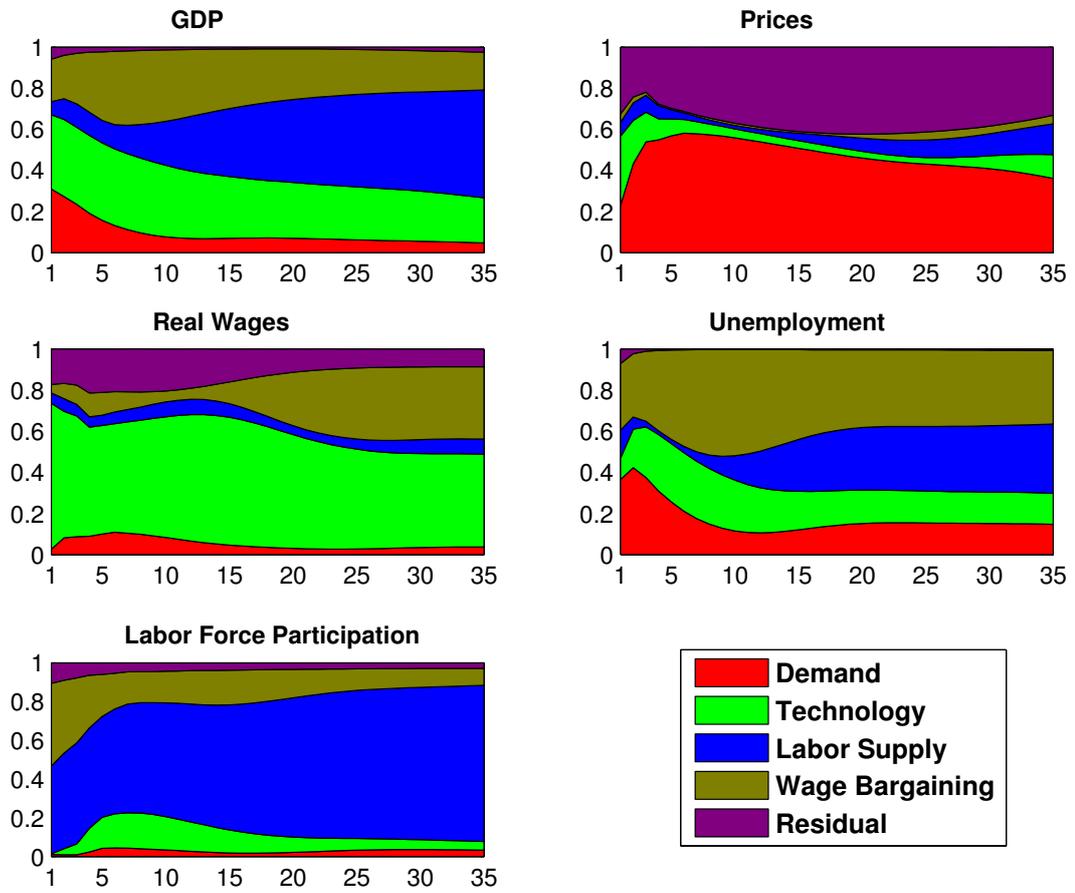


Figure 1.9.11 : Variance decomposition for the extended VAR model with data on labor force participation

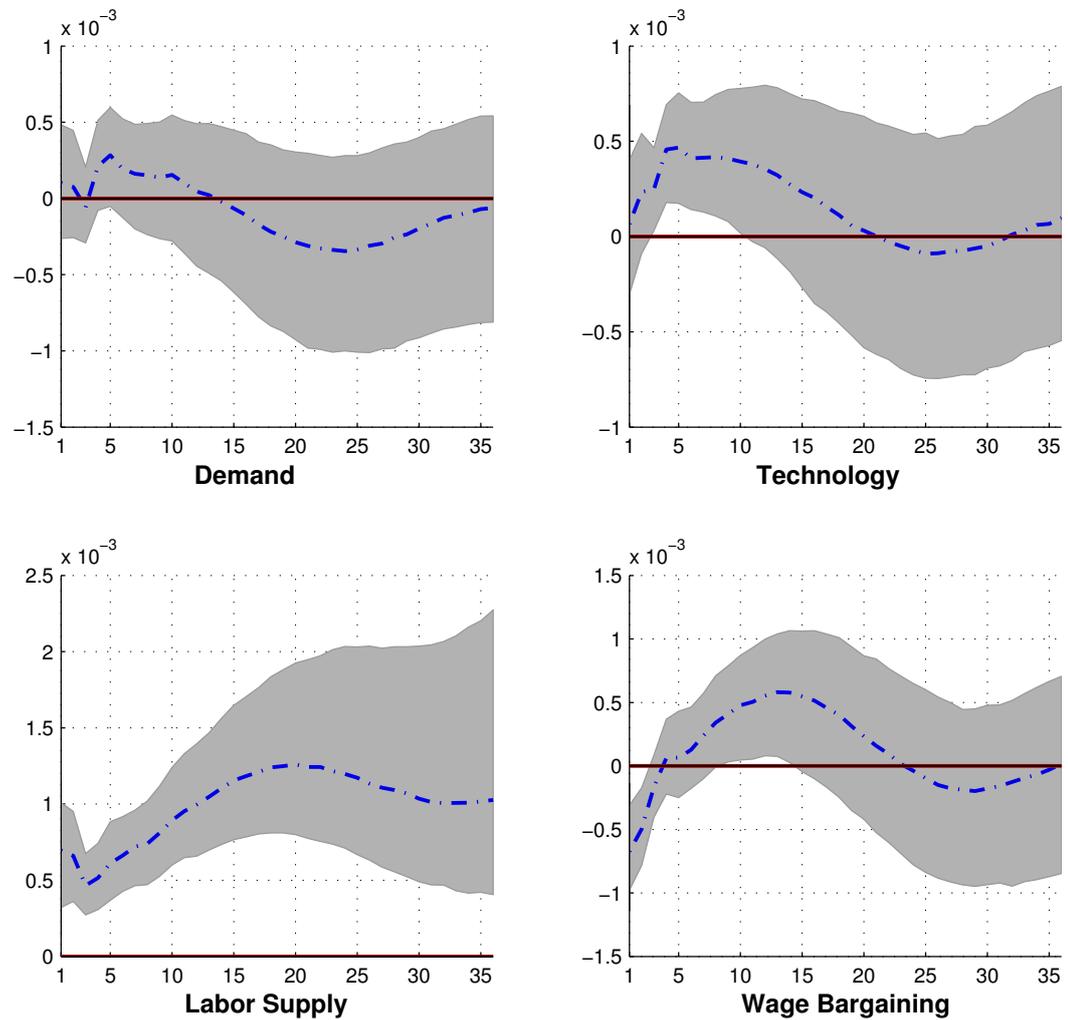


Figure 1.9.12 : Impulse responses of the participation rate to the four identified shocks. The dashed-dotted line represents the posterior median at each horizon and the shaded area indicates the 16th and 84th percentiles of the impulse responses.

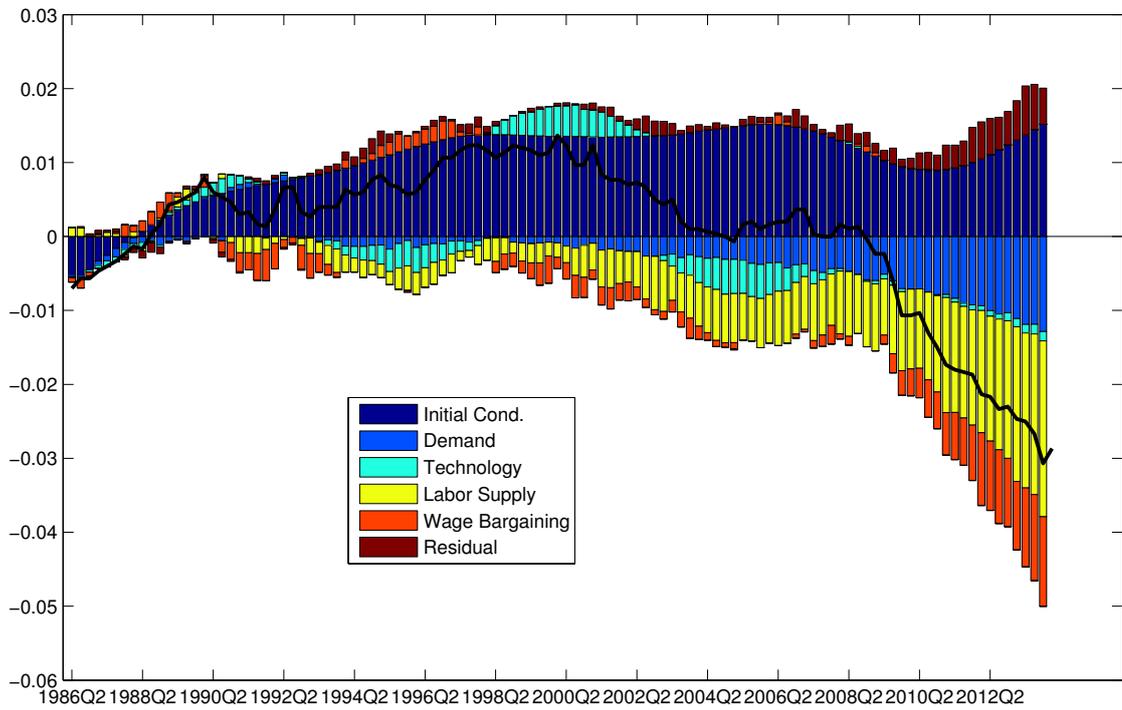


Figure 1.9.13 : Historical decomposition for the labor force participation rate in deviation from its mean (solid line)

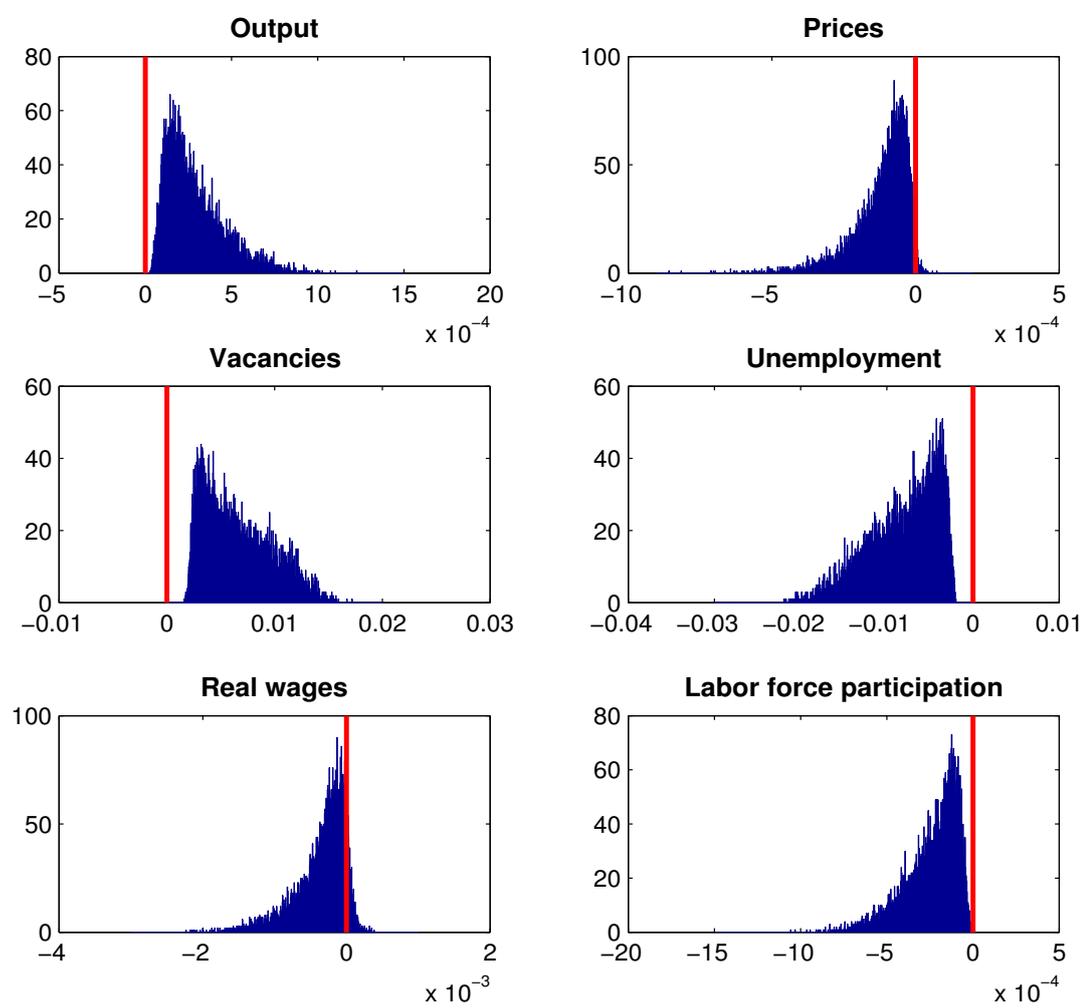


Figure 1.9.14 : Distribution of impact responses to a 1% unemployment benefits shock.

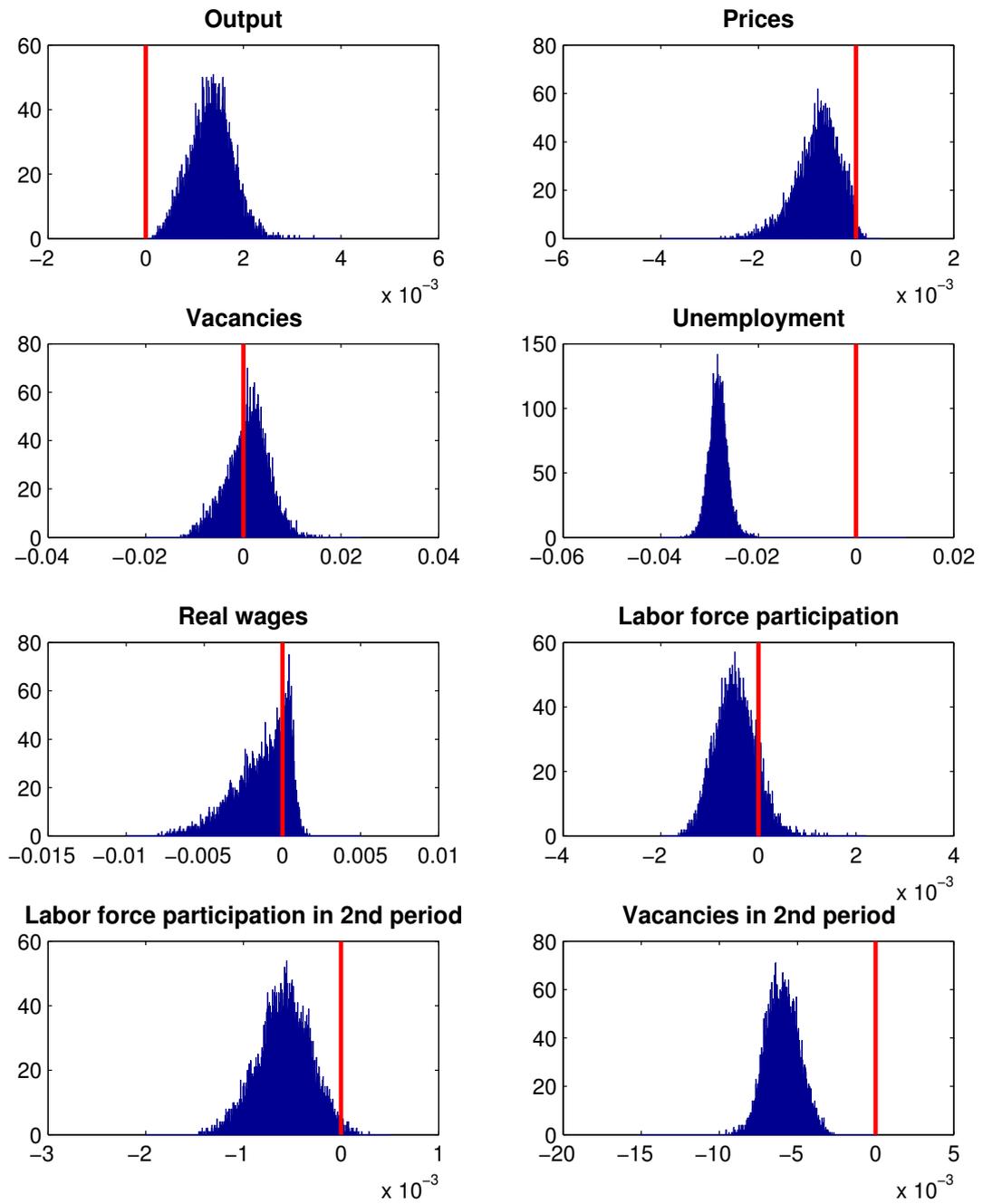


Figure 1.9.15 : Distribution of impact responses to a 1% matching efficiency shock.

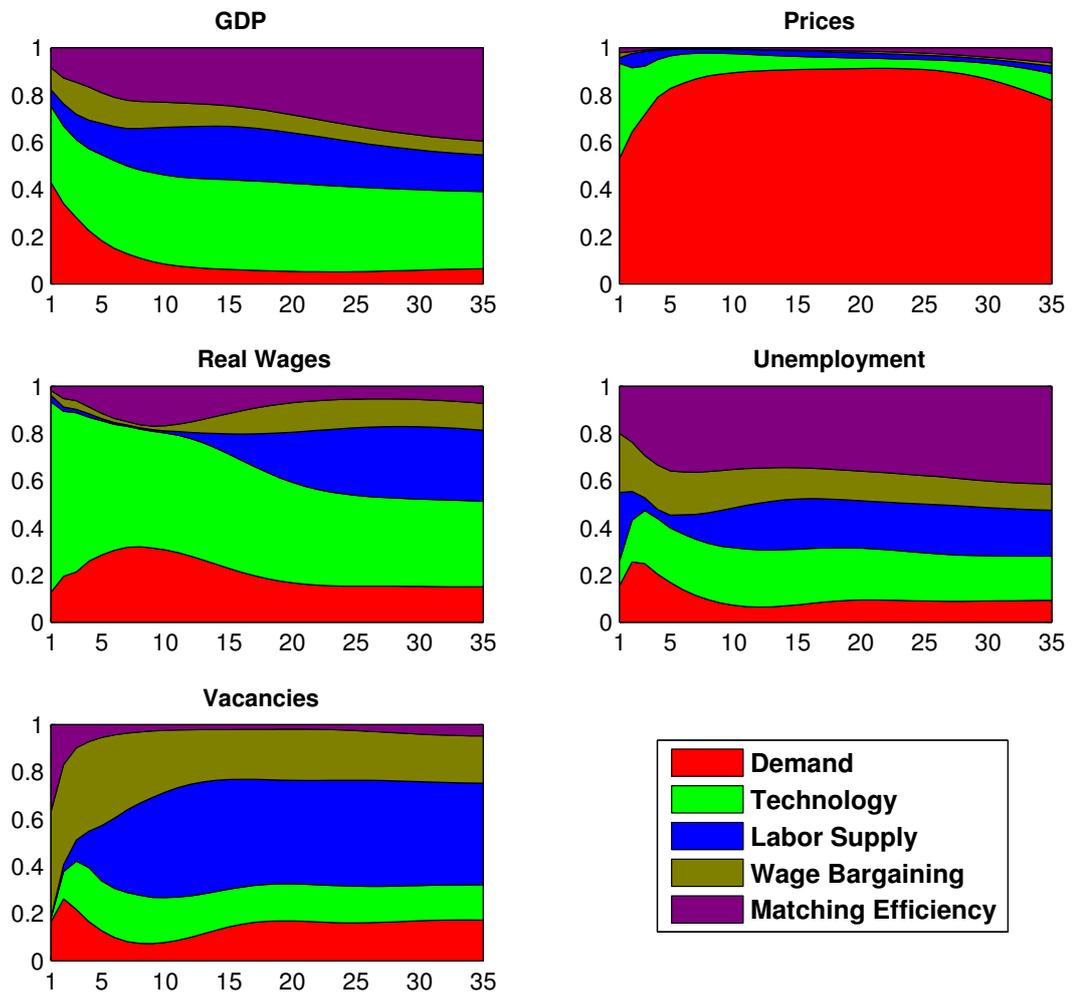


Figure 1.9.16 : Variance decomposition in the VAR model extended with data on vacancies.

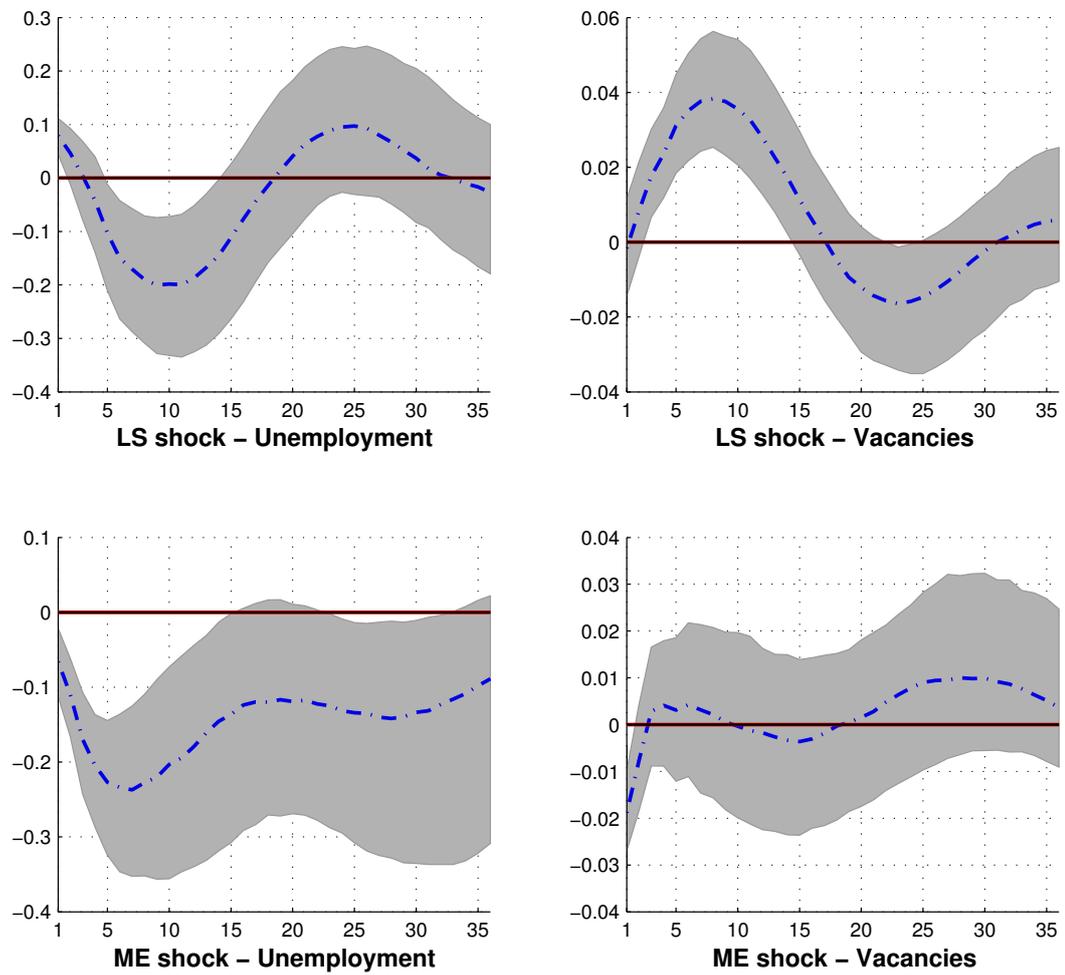


Figure 1.9.17 : Impulse responses of unemployment and vacancies to labor supply and matching efficiency shocks. The dashed-dotted line represents the posterior median at each horizon and the shaded area indicates the 16th and 84th percentiles of the impulse responses.

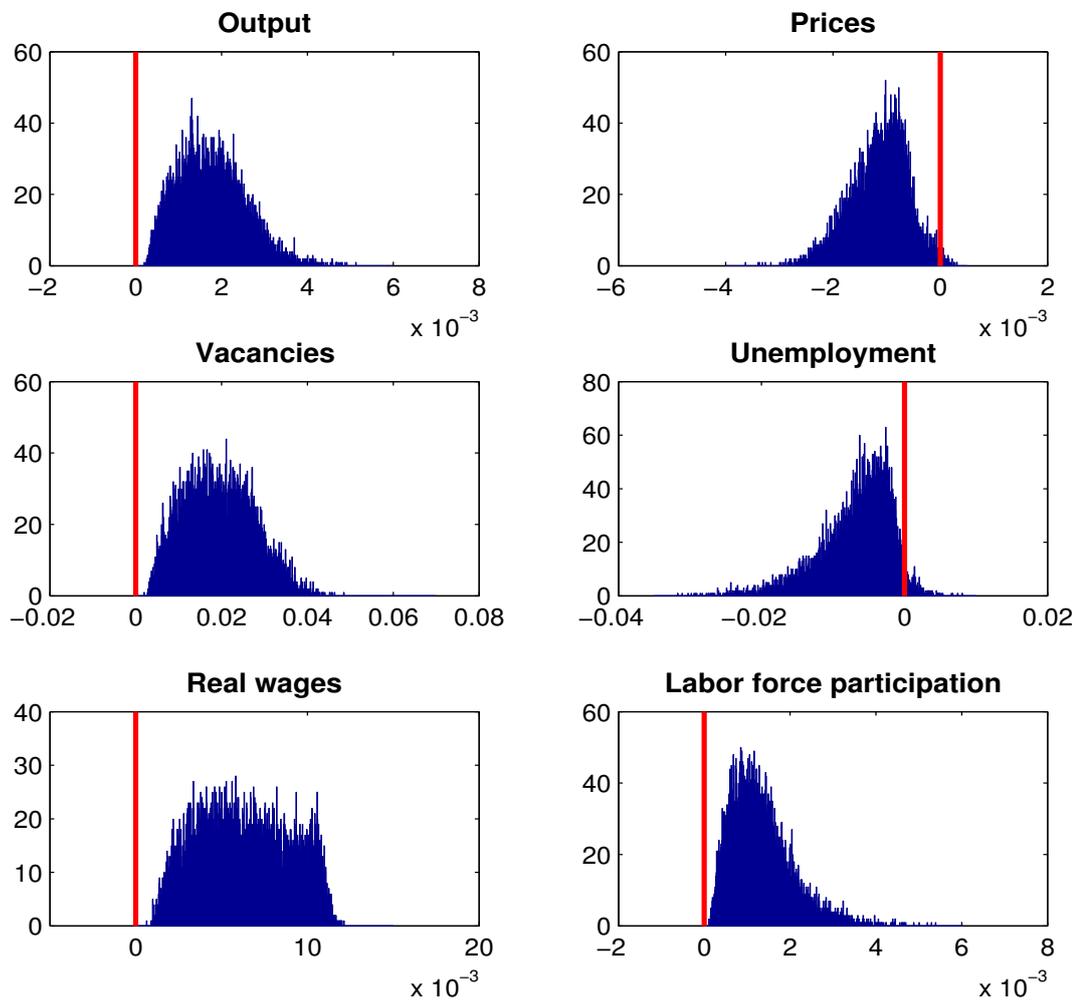


Figure 1.9.18 : Distribution of impact responses to a 1% price-markup shock

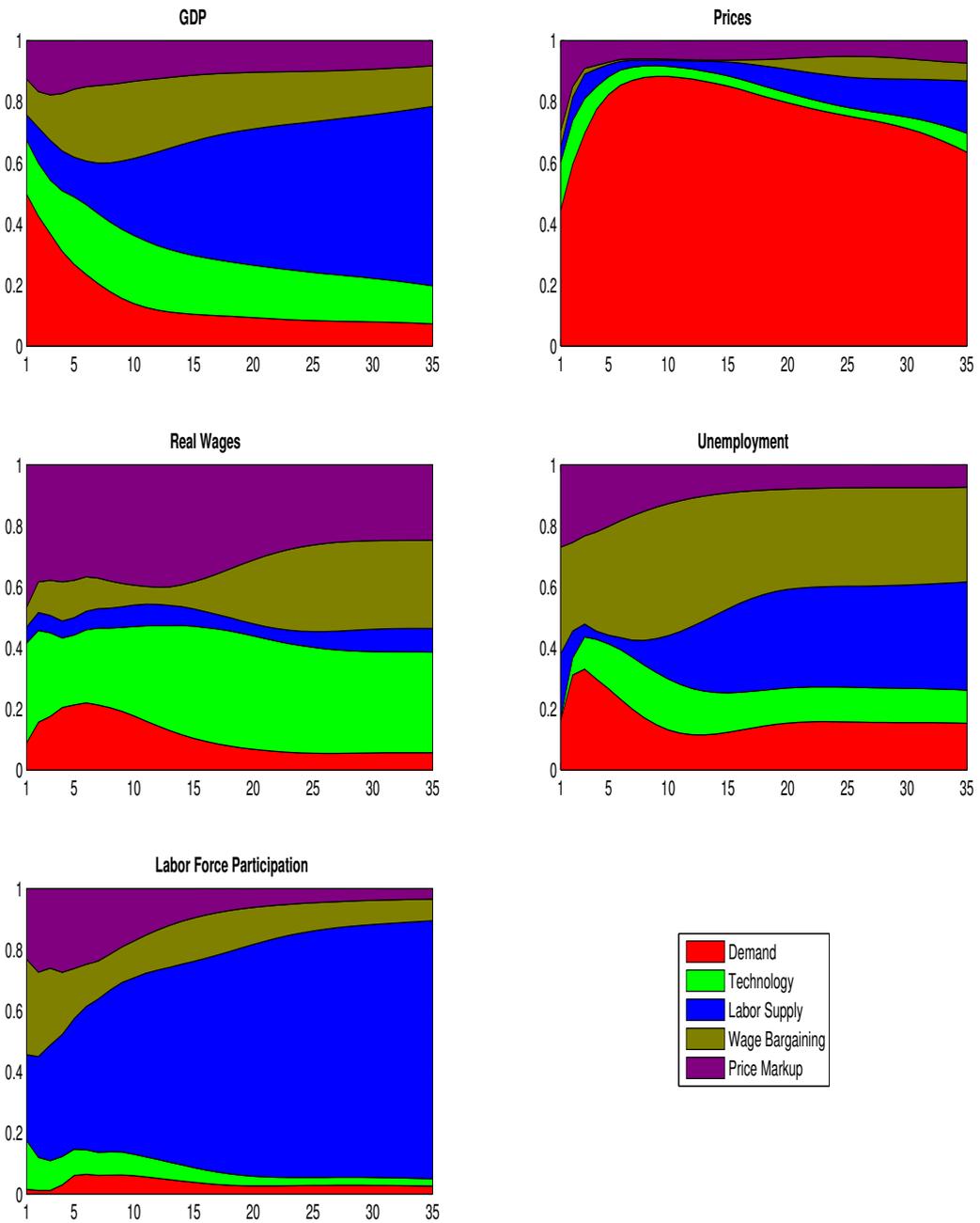


Figure 1.9.19 : Variance decomposition in the VAR model extended with price-markup shocks.



## Chapter 2

# Reduced form wage equations in the credible bargaining model

This paper is co-authored with Vincent Boitier from Université Paris I Panthéon-Sorbonne.

### 2.1 Introduction

The search and matching framework has become an essential tool for the analysis of unemployment and the labor market. Because search frictions give rise to a surplus that has to be shared between firms and workers, the private efficiency of employment relationships is consistent with a broad range of wage setting mechanisms. Hall and Milgrom (2008) have proposed an increasingly popular alternative to the standard Nash model of wage determination. It offers the advantage of addressing the so-called “Shimer puzzle”, namely the inability of the canonical search and matching model to replicate the volatility of labor market variables observed

in the data. It does so by providing a micro-foundation for wage rigidity. These authors argue that the threat points of both employers and job seekers are to delay bargaining rather than terminate it. This tends to insulate wages from outside conditions in the labor market and make them endogenously «rigid».

In the baseline version of this model, an analytical expression for real wages cannot be derived. As a consequence, introducing it in an otherwise standard search and matching frictions framework can substantially complexify the analysis. We show that it is possible to circumvent this problem and derive a reduced form wage equation from an alternating-offer wage bargaining game à la Hall and Milgrom (2008) by imposing a plausible parameter restriction. More precisely, we impose that the probability of breakdown in bargaining is equal to the separation rate. This restriction is supported by empirical evidence presented in Christiano et al. (2015). In our specification, wages are partially connected to outside labor market conditions through the difference between the current and the expected values of unemployment. We provide a detailed account of how our simple wage equation could be used in a wide range of models incorporating the search and matching theory of unemployment to simplify the analysis.

The note is structured as follows. Section 2 develops a standard search and matching model of the labor market. Section 3 presents the alternating-offer bargaining game and derives the analytical solution for the wage. Section 4 analyzes the driving forces of wages and discusses how our simple expression could be used in the literature. Section 5 concludes.

## 2.2 Model

Consider a discrete time version of the search and matching model of Pissarides (2000). Firms and workers must match in the labor market in order to become productive. Matches are formed according to a constant returns to scale production function  $m_t = \mu u_t^\alpha v_t^{1-\alpha}$  where  $u$  is the number of job seekers,  $v$  the number of open vacancies and  $0 < \alpha < 1$ . Unemployed workers find a job with probability  $f(\theta) = \frac{m_t}{u_t}$  and vacancies are filled at a rate  $q(\theta) = \frac{m_t}{v_t}$  where  $\theta = \frac{v}{u}$  is a measure of labor market tightness. At the beginning of each period, a fraction  $s$  of existing employment relationships is exogenously destroyed. Matches formed in one period become operational in the next period. The law of motion of employment  $n_t$  is accordingly given by:

$$n_t = (1 - s)n_{t-1} + m_{t-1} \quad (2.2.1)$$

Workers are risk neutral and do not have access to financial markets. They can be either employed or unemployed. The values  $W_t$  and  $U_t$  associated with those two states are given by:

$$W_t = w_t + e^{-r} [(1 - s)E_t W_{t+1} + sE_t U_{t+1}] \quad (2.2.2)$$

$$U_t = b + e^{-r} [f(\theta_t)E_t W_{t+1} + (1 - f(\theta_t))E_t U_{t+1}] \quad (2.2.3)$$

where  $r$  is the discount rate and  $\beta = \frac{1}{1+r} \approx e^{-r}$  is the discount factor. When employed, workers receive a wage  $w_t$  and can expect to remain employed with probability  $1 - s$ . When unemployed, workers receive the flow value of unemploy-

ment  $b$  and can expect to find a job with probability  $f(\theta_t)$ . Firms operate with a constant returns to scale production function  $y_t = z_t n_t$  where  $z_t$ , the state of technology, evolves according to an AR(1) process. They must pay a cost  $c$  to post a vacancy. The firm's values of a filled and an unfilled vacancy  $J_t$  and  $V_t$  are thus given by:

$$J_t = z_t - w_t + e^{-r} [(1 - s)E_t J_{t+1} + sE_t V_{t+1}] \quad (2.2.4)$$

$$V_t = -c + e^{-r} [q(\theta_t)E_t J_{t+1} + (1 - q(\theta_t))E_t V_{t+1}] \quad (2.2.5)$$

Free entry in the posting of vacancies implies  $V_t = 0$ . Therefore the job creation equation is:

$$\frac{c}{q(\theta_t)} = e^{-r} E_t J_{t+1} \quad (2.2.6)$$

## 2.3 The alternating-offer wage bargain

Wages are determined according to a sequential bargaining game à la Binmore et al. (1986). Hall and Milgrom (2005) note that “many rounds of bargaining can occur within each period of search and employment”. In line with this intuition, we assume that each period is divided into sub-periods during which bargaining takes place. The time interval separating one sub-period from another is  $\tau$ . Firms begin the game by making an offer  $w$  to the worker. If the offer is accepted, the game ends. If the offer is rejected, the game goes on to the next sub-period when the worker makes a counter-offer  $w'$  to the firm. During this time interval, the firm incurs a flow cost  $\gamma\tau$  while the worker receives flow benefits  $b\tau$ . Moreover, before the worker makes his counter-offer, negotiations can breakdown with hazard  $\delta$ . In

### 2.3 The alternating-offer wage bargain

this case, the worker gets  $U$  whereas the firm gets nothing. Otherwise, the game continues to the next sub-period. In this setting, it is optimal for each party to always make a just acceptable offer to the other side. Thus, the following equations govern the game:<sup>1</sup>

$$W_t^w = b\tau + e^{-r\tau} \left[ (1 - e^{-\delta\tau})U_t + e^{-\delta\tau}W_t^{w'} \right] \quad (2.3.1)$$

$$J_t^{w'} = -\gamma\tau + e^{-(r+\delta)\tau} J_t^w \quad (2.3.2)$$

Solving equations (7) and (8) for  $w$  (or equivalently for  $w'$ ) and letting  $\tau \rightarrow 0$ , we obtain the following sharing rule:<sup>2</sup>

$$W_t - \frac{b}{r + \delta} - \frac{\delta U_t}{r + \delta} = J_t + \frac{\gamma}{r + \delta} \quad (2.3.3)$$

This equation is similar to equation (17) in Hall and Milgrom (2005). Under the assumption that the probability of breakdown during bargaining  $\delta$  is equal to the separation rate  $s$ , and after using this sharing rule along with equations (2.2.2) and (2.2.4), we obtain:

$$w_t = \frac{1}{2} \left[ z_t + \beta(b + \gamma) + \frac{\delta}{r + \delta} (U_t - E_t U_{t+1}) \right] \quad (2.3.4)$$

This simple wage equation is our main result. Hall and Milgrom (2008) set  $\delta$  in order to match the volatility of the unemployment rate. The employer's cost of delay,  $\gamma$ , plays a similar role than  $\delta$  in that it influences directly the volatility of

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<sup>1</sup>We follow strictly Hall and Milgrom (2005) when defining the equations governing the game.

<sup>2</sup>See Appendix 2.6.1.

unemployment. When  $\gamma$  is high, firms' surplus is small and changes significantly in percentage terms in response to shocks. As a result, stochastic variations in technology lead to important movements in job creation and unemployment. The converse reasoning holds when  $\gamma$  is low. Since knowledge about both the values of  $\gamma$  and  $\delta$  is limited, we believe it is equivalent to fix one to a particular value and let the other adjust to match the volatility of the unemployment rate. Unlike Hall and Milgrom (2008), we choose  $\delta = s$  and propose to fix  $\gamma$  to match the volatility of the unemployment rate. This calibration strategy has the advantage of enabling us to derive a simple analytical expression for the wage. It is also consistent with results presented in Christiano et al. (2015). These authors estimate a medium-scale dynamic stochastic general equilibrium model encompassing an alternating-offer model of wage-setting on U.S. data and find a value of the probability of breakdown that is very close to the value of the separation rate.<sup>3</sup>

## 2.4 The wage equation: potential use

### 2.4.1 The steady-state equation

In steady-state, equation (2.3.4) collapses to

$$w = \frac{1}{2} [z + \beta(b + \gamma)] \quad (2.4.1)$$

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<sup>3</sup>Christiano et al. (2015) set the quarterly separation rate to 0.1. They also consider that each period is divided into sub-periods during which bargaining takes place. They set this number of sub-periods within a quarter to 60 (the average number of business days in a quarter). They find a daily probability of breakdown  $\delta_d$  of 0.0019. We compute the equivalent quarterly rate as  $\delta_q = \delta_d + (1 - \delta_d)\delta_d + \dots + (1 - \delta_d)^{59}\delta_d = 0.1078$ .

## 2.4 The wage equation: potential use

The complete isolation of the wage from labor market conditions in that case has a simple intuitive explanation. On one hand, an increase in the value of unemployment  $U$  leads to an increase in the threat point of workers in bargaining and puts an upward pressure on wages. On the other hand, an increase in  $U$  leads to an increase in the value of employment  $W$  for the worker. As workers value more employment, they accept lower wages. When  $\delta = s$ , those two effects cancel out. Mortensen and Nágypál (2007) obtain a similar expression within the context of an alternating-offer game with no probability of breakdown during bargaining by imposing that the separation rate  $s$  is equal to zero. We show that it is possible to find a simple analytical solution for the wage in a more realistic setup. We allow for a positive probability of breakdown during bargaining and do not impose that the separation rate is equal to zero. A similar result was also uncovered by Ljungqvist and Sargent (2014) in recent and independent work.

We believe equation (2.4.1) could be of great use in articles incorporating a steady-state labor market frictions model. In that type of framework, when wages are determined according to a generalized Nash bargaining game, the job creation equation becomes non-linear in labor market tightness. One needs to solve for it numerically and this rules out the possibility of obtaining analytical results. This problem does not arise when using our simple wage solution. Because wages do not depend on labor market tightness in equation (2.4.1), analytical expressions for all variables in the model can readily be obtained.

## 2.4.2 The dynamic case

In the more general dynamic case, the wage is not completely isolated from labor market conditions as  $U_t$  and  $E_t U_{t+1}$  may differ (see equation (2.3.4)). Consider that the value of unemployment increases both today and in the future in response to a positive technology shock. In the event that  $U_t - E_t U_{t+1} > 0$ , the improvement in labor market conditions puts upward pressure on wages. When  $U_t - E_t U_{t+1} < 0$ , the improvement in labor market conditions depresses wages.

In recent years, a large literature has incorporated the search and matching theory of unemployment in dynamic stochastic general equilibrium models (DSGE) to study, among others things, the impact of fiscal and monetary policies on the labor market and the joint dynamics of inflation and unemployment. As pointed out in the introduction, when wages are Nash-bargained, these models embedding a search structure are unable to account for the volatility of labor market variables observed in U.S. data. Several fixes, including wage rigidity, have been proposed to solve this problem. Because of its micro-founded nature and its ability to generate wage rigidity endogenously, the credible bargaining model of wage-setting is becoming increasingly popular in the literature. However, in the setup proposed by Hall and Milgrom (2008), an analytical expression for wages cannot be derived. This has an undesirable consequence; when this model of wage-setting is used, it is generally impossible to find analytical and easily interpretable results. Some authors have circumvented this problem by using simple ad-hoc wage equations which preserve the main feature of the setup, that is, the partial isolation of wages from labor market conditions. In Jung and Kuester (2011), wages are a weighted

## 2.4 The wage equation: potential use

average of the technological level and the fixed outside option of workers during bargaining and are fully insulated from labor market conditions. We nest their specification when  $\delta = s = 0$  and  $\beta = 1$ . Hall (2014) justifies the introduction of a parameter that controls the role of labor market tightness in the Nash-bargained wage equation by invoking the logic of the alternating-offer bargaining game. Although his equation cannot be formally derived from a bargaining game, a low value for this parameter corresponds to a low value for the probability of breakdown in the credible bargaining model.

We believe our wage solution could permit a wider use of the credible bargaining framework in these dynamic models. In equation (2.3.4), the expression is both micro-founded and simple to use, and the driving forces of wages are transparent. Moreover, in the appendix, we show that when calibrating the model to standard values and matching the standard deviation of the component of unemployment driven by productivity as in Hall and Milgrom (2008), we obtain a short-run elasticity of wages with respect to labor productivity of about 0.8, in line with empirical estimates reported in Haefke et al. (2013).<sup>4</sup> This is because the  $U_t - E_t U_{t+1}$  term reacts in a pro-cyclical way to technology shocks. Thus, on top of its simplicity, our wage equation is consistent with important labor market facts.

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<sup>4</sup>See Appendix 2.6.2.

## **2.5 Conclusion**

We derive a reduced form wage equation from an alternating-offer wage bargaining game à la Hall and Milgrom (2008) under a plausible parameter restriction. Our simple equation connects wages to outside labor market conditions through the difference between the current and the future values of unemployment. It can easily be used in studies wishing to obtain analytical results, permits a transparent analysis of the driving forces of wages, and is consistent with key labor market facts

## 2.6 Appendix

### 2.6.1 Derivations

The subgame perfect equilibrium of the sequential game satisfies:

$$W_t^w = b\tau + e^{-r\tau} \left[ (1 - e^{-\delta\tau}) U_t + e^{-\delta\tau} W_t^{w'} \right] \quad (2.6.1)$$

and

$$J_t^{w'} = -\gamma\tau + e^{-(r+\delta)\tau} J_t^w \quad (2.6.2)$$

with

$$W_t^w = w_t + e^{-r} [(1 - s)E_t W_{t+1} + sE_t U_{t+1}] \quad (2.6.3)$$

$$W_t^{w'} = w'_t + e^{-r} [(1 - s)E_t W_{t+1} + sE_t U_{t+1}] \quad (2.6.4)$$

$$J_t^{w'} = z_t - w'_t + e^{-r}(1 - s)E_t J_{t+1} \quad (2.6.5)$$

$$J_t^w = z_t - w_t + e^{-r}(1 - s)E_t J_{t+1} \quad (2.6.6)$$

because  $V_t = V_{t+1} = 0$ . Plugging (2.6.3) and (2.6.4) in (2.6.1) leads to:

$$w_t + [1 - e^{-(r+\delta)\tau}] e^{-r} [(1 - s)E_t W_{t+1} + sE_t U_{t+1}] = b\tau + e^{-r\tau} (1 - e^{-\delta\tau}) U_t + e^{-(r+\delta)\tau} w'_t$$

Likewise, integrating equations (2.6.5) and (2.6.6) in equation (2.6.2) gives:

$$w'_t = \gamma\tau + [1 - e^{-(r+\delta)\tau}] z_t + [1 - e^{-(r+\delta)\tau}] e^{-r}(1 - s)E_t J_{t+1} + e^{-(r+\delta)\tau} w_t$$

Chapter 2 Reduced form wage equations in the credible bargaining model

Combining the two equations above and letting  $\tau \rightarrow 0$ , we find:

$$2w_t + e^{-r} [(1-s)E_t W_{t+1} + sE_t U_{t+1}] = \frac{b+\gamma}{r+\delta} + \frac{\delta U_t}{r+\delta} + z_t + e^{-r}(1-s)E_t J_{t+1}$$

because, when  $\tau \rightarrow 0$ ,  $e^{-a\tau} = 1 - a\tau$  with  $a$  a constant. Noting that  $W_t^w = W_t$  and  $J_t^w = J_t$ , we get:

$$W_t - \frac{b}{r+\delta} - \frac{\delta U_t}{r+\delta} = J_t + \frac{\gamma}{r+\delta} \quad (2.6.7)$$

Introducing the expressions of  $W_t$  and  $J_t$  in (2.6.7) leads to:

$$2w_t + \beta(1-s)[E_t W_{t+1} - E_t J_{t+1}] = z_t + \frac{b+\gamma}{r+\delta} + \frac{\delta U_t}{r+\delta} - \beta s E_t U_{t+1}$$

since  $e^{-r} \approx \beta = \frac{1}{1+r}$  Using the sharing rule, we obtain:

$$E_t W_{t+1} - E_t J_{t+1} = \frac{\delta E_t U_{t+1}}{r+\delta} + \frac{b+\gamma}{r+\delta}$$

Using the above equation and (2.6.7), we have:

$$2w_t = z_t + \frac{[1 - \beta(1-s)](b+\gamma)}{(r+\delta)} + \frac{\delta U_t}{r+\delta} - \left[ \beta s + \frac{\beta(1-s)\delta}{r+\delta} \right] E_t U_{t+1}$$

that is:

$$w_t = \frac{z_t}{2} + \frac{(r+s)(b+\gamma)}{2(r+\delta)(1+r)} + \frac{\delta U_t}{2(r+\delta)} - \frac{(sr+\delta)E_t U_{t+1}}{2(r+\delta)(1+r)}$$

If  $\delta = s$  then:

$$w_t = \frac{1}{2} \left[ z + \beta(b+\gamma) + \frac{\delta(U_t - E_t U_{t+1})}{r+\delta} \right]$$

Last, at steady state,  $E_t U_{t+1} = U_t = U$  implying that:

$$w = \frac{1}{2} [z + \beta(b + \gamma)]$$

## 2.6.2 Calibration exercise

We calibrate the model in a conventional manner. We take one period to be a month. The discount factor is set to  $\beta = 0.99$ , which yields an interest rate of 4% annually. The elasticity of matches with respect to unemployment is assumed to be  $\alpha = 0.5$ , in line with estimates in Petrongolo and Pissarides (2000). Following Shimer (2005), the separation rate is set to 0.034 and the steady-state job finding rate to 0.45. Given a steady-state labor market tightness of 0.7, matching efficiency  $\mu$  is then determined through steady-state relationships. We set the flow value of unemployment to 0.71 and choose the employer's cost of delay  $\gamma$  to match a standard deviation of the component of unemployment driven by productivity of 0.68 percentage points, following Hall and Milgrom (2008). Vacancy posting costs  $c$  are then determined through steady-state relationships. Finally, we use standard values for the autoregressive parameter and the standard deviation of the technology shock,  $\rho = 0.95^{1/3}$  and  $\sigma_z = 0.0075$ . Figure 2.6.1 presents the impulse response functions of selected variables to a positive technology shock. The short-run elasticity of wages with respect to labor productivity is computed in each period by using the following formula  $\varepsilon_t^{w,z} = \frac{\frac{w_t - w}{w}}{\frac{z_t - z}{z}}$  with  $w$  and  $z$  being the steady-state values of wages and technology. It is approximately equal to 0.84 from period 1 to period 30.

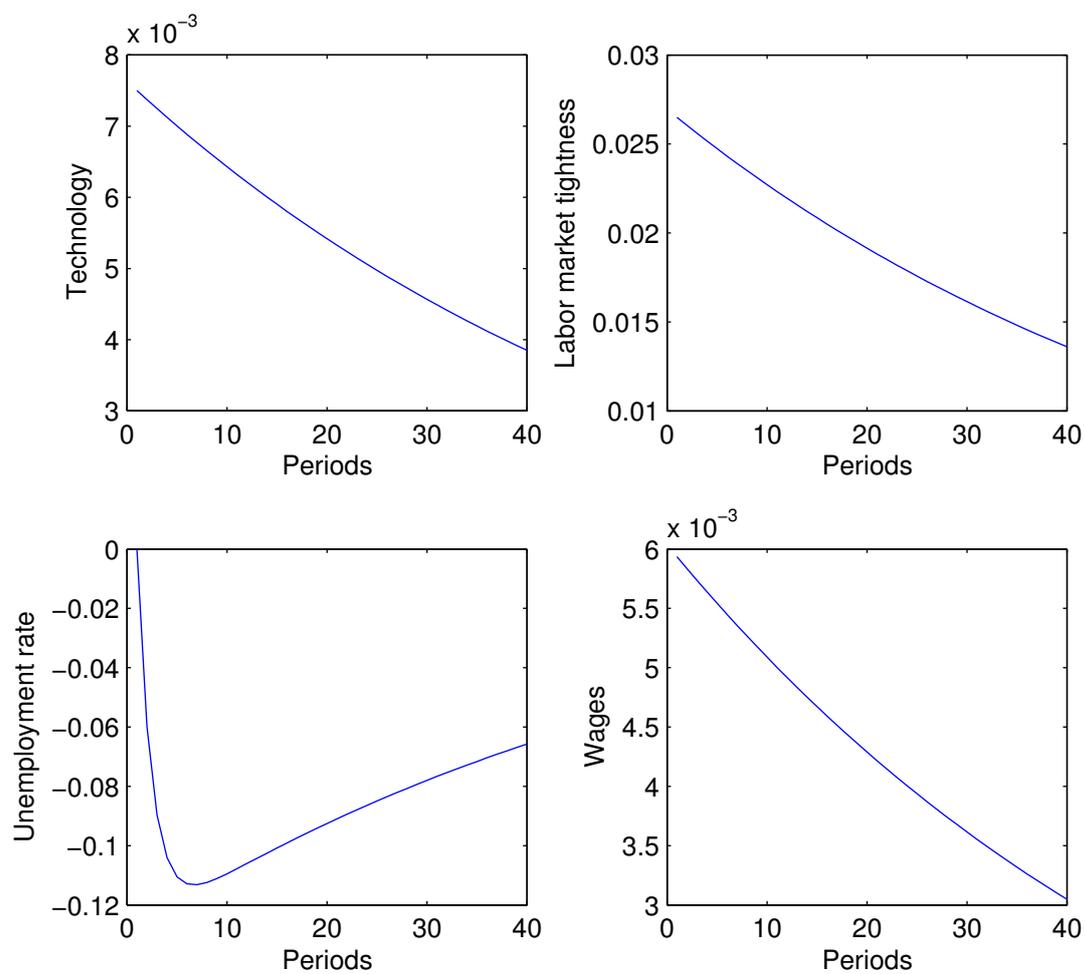


Figure 2.6.1 : Impulse response functions of selected variables to a one standard deviation positive technology shock.

## Chapter 3

# Asymmetric unemployment fluctuations and monetary policy trade-offs

### 3.1 Introduction

How much weight should policymakers place on inflation, and how much on employment? In practice most central banks seem to assign a non-negligible role to the stabilization of real activity. Most notably, in the United States, the Federal Reserve pursues the dual objective of promoting price stability and maximum sustainable employment. This behavior of central banks is at odds with the recommendations that have emerged from a literature that seeks to describe optimal monetary policy in dynamic stochastic general equilibrium models featuring nominal and real rigidities. These studies generally find that an exclusive focus on

inflation stabilization is close to optimal (Walsh 2014). This paper employs a similar framework, a New Keynesian model with search and matching frictions in the labor market, and comes up with a different conclusion, namely that a dual mandate such as the one of the Federal Reserve is desirable in economies which experience sizeable asymmetric unemployment fluctuations. In such an environment, the standard macroeconomic trade-off between inflation and unemployment volatility described in Taylor (1994) becomes a trade-off between inflation volatility and *average unemployment*. By responding strongly to employment alongside inflation, the monetary authority can reduce unemployment volatility as well as average unemployment. This reduction in unemployment brings about potentially large welfare gains.

I use a standard model with two essential features. First, inflation volatility is costly as producers must face quadratic price adjustment costs. This gives rise to a Phillips Curve that relates firms' markups to inflation and gives monetary policy some leverage over job creation. Second, unemployment, which results from the presence of search and matching frictions in the labor market, rises more in a recession than it decreases in an expansion. In the model, fluctuations in technology lead to shifts in firms' real revenues and about symmetric shifts in the job-finding rate. However, because of the negative covariance between the job-finding rate and the unemployment rate, a notable feature of U.S. data, these fluctuations in the job-finding rate have an asymmetric effect on employment. In an expansion, the positive impact on employment of an increase in the job-finding rate is *dampened* by the decrease in the size of the pool of job seekers. In a recession, the negative impact on employment of the decrease in the job-finding rate is *amplified*

by the increase in the size of the pool of job seekers. This asymmetric nature of unemployment fluctuations implies that aggregate fluctuations lead to a potentially costly increase in average unemployment. In this setting, the central bank may try to use inflation over the business cycle to influence markups, with the goal of affecting job creation and unemployment volatility. The objective of this paper is to study how this costly asymmetry in unemployment fluctuations shapes the trade-offs faced by the central bank and the optimal conduct of monetary policy.

Results are as follows. I find that the adoption of different monetary policy rules leads to different outcomes in terms of average unemployment. In the baseline calibrated version of the model, average unemployment is higher than steady-state unemployment by 0.2 percentage points when the monetary authority responds to both inflation and output. However, under a policy of price stability, this gap doubles to 0.44 percentage points. More generally, holding the response to output constant, average unemployment is increasing in the central bank's response to inflation. The intuition for this result is as follows. When responding mildly to inflation and/or strongly to output, the monetary authority engineers procyclical markups in response to technology shocks. This behavior of markups limits the procyclicality of firms' real revenues and the volatility of job creation. Under a policy of price stability, markups are constant over the business cycle and real revenues and job creation are accordingly more volatile. This larger volatility of job creation under price stability translates in larger unemployment fluctuations, and because the latter are asymmetric, in higher average unemployment. Thus, the standard macroeconomic trade-off between inflation and unemployment volatility described in Taylor (1994) and analyzed in a similar estimated model by Sala et al.

(2008) becomes a trade-off between inflation volatility and average unemployment when unemployment fluctuations are asymmetric.

The presence of this trade-off has some implications for the optimal conduct of monetary policy. The design of optimal monetary policy in this paper follows the Ramsey approach, which has been applied in a wide range of New-Keynesian models (for example King and Wolman 1999, Khan et al. 2003, Schmitt-Grohe and Uribe 2006, Bilbiie et al. 2014). I find that the central bank should optimally adopt a dual mandate, that is a policy that features a strong response to employment alongside inflation. By tolerating some inflation volatility along the cycle, the Ramsey planner is able to reduce both labor market volatility and average unemployment. The welfare gains of adopting this policy rather than a policy of price stability are substantial. The bulk of these gains comes from an increase in mean consumption, which is itself due to the increase in average employment achieved by the Ramsey policymaker. Thus, these results point to the crucial role played by the asymmetric nature of unemployment fluctuations in shaping the optimal conduct of monetary policy. In the absence of such asymmetry, the monetary authority would be unable to influence average unemployment and average consumption and would accordingly have less incentives to deviate from price stability to stabilize unemployment fluctuations. This importance of the asymmetry in unemployment fluctuations can be magnified, or reduced, depending on the value of a parameter, the value of home production for unemployed workers. This parameter has no influence on the cyclical properties of the model. However, it does determine how an increase in mean unemployment translates in a decrease in mean consumption. When it is high, an increase in average unemployment has a

very limited impact on average consumption and a policy of price stability remains nearly optimal. However, when it is low, a similar increase in average unemployment leads to a much larger decline in average consumption and it becomes more beneficial to stabilize employment.

Several papers have showed that the asymmetric unemployment dynamics generated by a simple search and matching model of the labor market can lead to substantial business cycle costs (Hairault et al. (2010), Jung and Kuester (2011) and Petrosky-Nadeau and Zhang (2014)). Ferraro (2014) also documents that the employment rate fluctuates asymmetrically over the business cycle in the U.S. and proposes an alternative explanation, based on endogenous job destruction and worker heterogeneity in skills. I build on these studies and draw the monetary policy implications of the presence of this costly asymmetry in unemployment fluctuations. My results also contribute to a large literature on the optimal design of monetary policy. The conclusion that monetary policy should focus exclusively on stabilizing inflation is robust in the models generally used for monetary policy analysis, regardless of the different frictions that are included (Walsh 2014). A large literature has focused on the specific case of labor market frictions. Faia (2008, 2009) shows that a trade-off between inflation and unemployment stabilization arises in the presence of search and matching frictions as a central bank can use inflation to correct for an inefficient level of labor market activity. However, she finds that the gains of adopting this policy rather than a policy of price stability are very small. Ravenna and Walsh (2012) confirm these results by showing that inefficiencies due to matching frictions can be large but that the incentive to deviate from price stability is nonetheless small. Thomas (2008) and Blanchard and

Galí (2010) challenge this conclusion and show that an exclusive focus on inflation can lead to large welfare losses when nominal wages are staggered or when there is a direct utility cost of employment fluctuations. The fact that unemployment fluctuations are asymmetric in the presence of search and matching frictions had gone unnoticed in this literature<sup>1</sup>. This paper shows that this feature is critical in shaping monetary policy trade-offs and in determining the welfare consequences of alternative policies.

The paper is organized as follows. Section 2 develops the model. Section 3 undertakes a comparative statics exercise to understand the origin of the asymmetry in unemployment fluctuations. Section 4 calibrates the model and shows that the monetary authority faces a trade-off between inflation volatility and average unemployment. Section 5 derives the Ramsey optimal monetary policy, provides a welfare ranking of alternative policies and compares the results of the paper with those of the existing literature. Section 6 concludes.

## **3.2 A New Keynesian model with search and matching frictions**

This section develops a model with sticky prices in which monetary policy has a meaningful role to play. It departs from the standard New Keynesian model in several ways. The labor market is not perfectly competitive but is characterized

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<sup>1</sup>This may be due to the fact that it is necessary to use both non-linear solution methods and a model with a strong internal propagation mechanism in order to capture the large costs arising from the asymmetry in unemployment fluctuations. An extensive review of the literature in section 5 provides further explanation.

### 3.2 A New Keynesian model with search and matching frictions

by search and matching frictions. The surplus of a match is divided between the worker and the firm according to an exogenous rule that determines the real wage. The economy consists of two sectors of production. Wholesale firms operate in perfectly competitive markets. They use labor as the sole input in the production process and have to post vacancies in order to match with workers. Their output is sold to monopolistically competitive retail firms which transform the homogeneous goods one for one into differentiated goods and must pay a quadratic adjustment cost to change their prices.

#### 3.2.1 Model

##### 3.2.1.1 Labor market

The size of the labor force is normalized to unity. Workers and firms need to match in order to become productive. The number of matches in period  $t$  is given by a Cobb-Douglas matching function  $m_t = \chi s_t^\alpha v_t^{1-\alpha}$ ,  $s_t$  being the number of job-seekers and  $v_t$  the number of vacancies posted by firms. The parameter  $\chi$  reflects the efficiency of the matching process and  $\alpha \in (0, 1)$  is the elasticity of the matching function with respect to unemployment. Define  $\theta_t = \frac{v_t}{s_t}$  as labor market tightness. The probability  $q_t$  for a firm to fill a vacancy and the probability  $p_t$  for a worker to find a job are, respectively,  $q_t = \frac{m_t}{v_t} = \chi \theta_t^{-\alpha}$  and  $p_t = \frac{m_t}{s_t} = \chi \theta_t^{1-\alpha}$ . At the beginning of each period  $t$ , a fraction  $\rho$  of existing employment relationships  $N_{t-1}$  is exogenously destroyed. Those  $\rho N_{t-1}$  newly separated workers and the  $1 - N_{t-1}$  workers unemployed in the previous period form the pool of job seekers  $s_t = 1 - (1 - \rho)N_{t-1}$ . Job seekers have a probability  $p_t$  of finding a job within the

period. The law of motion of employment  $N_t$  is accordingly given by

$$N_t = (1 - \rho)N_{t-1} + p_t(1 - (1 - \rho)N_{t-1}) \quad (3.2.1)$$

The number of unemployed workers in period  $t$  is  $u_t = 1 - N_t$ .

### 3.2.1.2 Households

Household members either receive a real wage  $w_t$  when employed or the value of home production  $b$  when unemployed. I assume that consumption risks are fully pooled within the household. Household members have expected intertemporal utility

$$E_0 \sum_{t=0}^{\infty} \beta^t \frac{C_t^{1-\sigma}}{1-\sigma} \quad (3.2.2)$$

where  $\beta$  is the household's subjective discount factor,  $\sigma$  the coefficient of relative risk aversion and  $C_t$  the consumption level of each household member. Households receive profits  $\Pi_t^r$  from retail firms and invest in risk-free bonds  $B_t$  that promise a unit of currency tomorrow and cost  $(1 + I_t)^{-1}$  today. They face the following per period budget constraint

$$P_t C_t + (1 + I_t)^{-1} B_{t+1} = P_t [w_t N_t + b(1 - N_t)] + B_t + P_t \Pi_t^r \quad (3.2.3)$$

Consumption of market goods is given by  $C_t^m = C_t - b(1 - N_t)$ .  $C_t^m \equiv \int_0^1 [C_t^m(j)]^{\frac{\varepsilon-1}{\varepsilon}} dj]^{\frac{\varepsilon}{\varepsilon-1}}$

is a Dixit-Stiglitz aggregator of the different varieties of goods produced by the retail sector and  $\varepsilon$  is the elasticity of substitution between the different varieties.

The optimal allocation of income on each variety is given by  $C_t^m(j) = \left[ \frac{P_t(j)}{P_t} \right]^{-\varepsilon} C_t^m$ ,

### 3.2 A New Keynesian model with search and matching frictions

where  $P_t = \left[ \int_0^1 P_t(j)^{\frac{\varepsilon-1}{\varepsilon}} dj \right]^{\varepsilon/(1-\varepsilon)}$  is the price index and  $P_t(j)$  is the price of a good of variety  $j$ . Households choose consumption and bonds holding so as to maximize (3.2.2) subject to (3.2.3). The household's optimal consumption path is governed by a standard Euler equation

$$\beta E_t \frac{1 + I_t}{\Pi_{t+1}} \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} = 1 \quad (3.2.4)$$

where  $\Pi_{t+1} = \frac{P_{t+1}}{P_t}$  is the gross inflation rate between periods  $t$  and  $t + 1$ .

#### 3.2.1.3 Wholesale firms

A measure one of wholesale firms, indexed by  $i$ , produces according to the following technology

$$Y_{it}^w = Z_t N_{it} \quad (3.2.5)$$

where  $Z_t$  is a common, aggregate productivity disturbance. Wholesale firms sell their output in a competitive market at a price  $P_t^w$ . Posting a vacancy comes at a cost  $\kappa$ . Firm  $i$  chooses its level of employment  $N_{it}$  and the number of vacancies  $v_{it}$  in order to maximize the expected sum of its discounted profits

$$E_0 \sum_{t=0}^{\infty} \beta^t \frac{C_t^{-\sigma}}{C_0^{-\sigma}} \left[ \frac{P_t^w}{P_t} Y_{it}^w - \kappa v_{it} - w_t N_{it} \right] \quad (3.2.6)$$

subject to its perceived law of evolution of employment  $N_{it} = (1 - \rho)N_{it-1} + v_{it}q(\theta_t)$  and taking the wage schedule as given. Profits are equal to real revenues minus vacancy posting costs and wage payments. They are discounted using the household's discount factor  $\beta^t \frac{C_t^{-\sigma}}{C_0^{-\sigma}}$  since households ultimately own firms. In equilibrium

all firms will post the same number of vacancies and employ the same number of workers. I therefore drop individual firm subscripts  $i$ . After rearranging the first-order conditions, the following job creation equation obtains

$$\frac{\kappa}{q(\theta_t)} = \frac{Z_t}{\mu_t} - w_t + E_t \beta_{t+1} (1 - \rho) \frac{\kappa}{q(\theta_{t+1})} \quad (3.2.7)$$

where  $\beta_{t+1} = \beta \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma}$  is the stochastic discount factor of households between periods  $t$  and  $t + 1$  and  $\mu_t = \frac{P_t}{P_t^w}$  is the markup of retail over wholesale prices. This equation is an arbitrage condition for the posting of vacancies. It states that the cost of posting a vacancy, the deadweight cost  $\kappa$  divided by the time it takes to fill the vacancy, must be equal to the expected discounted benefit of a filled vacancy. These benefits consist of the revenues from output net of wages and the future savings on vacancy posting costs.

### 3.2.1.4 Retail firms

There is a large number of retailers, indexed by  $j$ , which buy the goods produced by wholesale firms at a price  $P_t^w$  and transform them one for one into differentiated goods.  $P_t^w$  represents the nominal marginal cost of production for retailers. They face quadratic costs of adjusting prices  $\Theta_t(j) = \frac{\phi^p}{2} \left( \frac{P_t(j)}{P_{t-1}(j)} - 1 \right)^2 Y_t$  which are measured in terms of aggregate output  $Y_t$ . Retail firms choose  $P_t(j)$  in order to maximize

$$E_0 \sum_{t=0}^{\infty} \beta^t \frac{C_t^{-\sigma}}{C_0^{-\sigma}} \left[ \frac{P_t(j) - P_t^w}{P_t} Y_t(j) - \Theta_t(j) \right]$$

subject to the demand for each variety  $Y_t(j) = (P_t(j)/P_t)^{-\epsilon} Y_t^d$  where  $Y_t^d$  is aggre-

### 3.2 A New Keynesian model with search and matching frictions

gate demand for final goods. Noting that in the symmetric equilibrium  $P_t(j) = P_t$ , we obtain

$$1 - \epsilon + \frac{\epsilon}{\mu_t} - \phi^p \Pi_t (\Pi_t - 1) + E_t \beta_{t+1} \phi^p \Pi_{t+1} (\Pi_{t+1} - 1) \frac{Z_{t+1} N_{t+1}}{Z_t N_t} = 0 \quad (3.2.8)$$

This equation is a non-linear expectational Phillips Curve linking marginal cost and inflation. Because of the presence of sticky prices, inflation has an influence on markups. The higher the difference between today's and tomorrow's inflation, the lower is the inefficiency arising from monopolistic competition. Importantly, lower markups (and higher marginal costs) for retail firms imply higher relative prices for wholesale firms and greater benefits from a filled vacancy. Thus by engineering an increasing path for inflation, monetary policy can encourage firms to hire more workers and thereby reduce unemployment. It should also be noted that the stochastic discount factor, which is used by firms to discount the future benefits of a posted vacancy, is the inverse of the real interest rate. Thus, monetary policy can also influence labor market activity through this channel.

#### 3.2.1.5 Wage setting

In order for the costs arising from the asymmetry in unemployment fluctuations to be significant, one needs a model which generates sizeable fluctuations in labor market activity. As first emphasized by Shimer (2005), the Mortensen-Pissarides model is unable to account for the volatility of labor market variables observed in U.S. data. In the case of Nash-bargained flexible wages, the wage is too sensitive

to aggregate conditions and “eats” all the incentives of firms to adjust through the employment margin. Several authors have shown that the introduction of real wage rigidity helps mitigate this problem. Thus, I choose to introduce real wage rigidity<sup>2</sup> in my framework in the form of the simple wage schedule proposed by Blanchard and Galí (2010)

$$w_t = \omega Z_t^\gamma \tag{3.2.9}$$

where  $\gamma \in [0, 1]$  is the elasticity of wages with respect to technology. When  $\gamma < 1$ , the wage adjusts only partially to technology shocks. As emphasized by Hall (2005), search frictions create a bargaining set between employer and employee. Thus, any (sticky) wage that remains between the worker’s and the employer’s reservation wages is consistent with the private efficiency of employment relationships. I check in the different simulations conducted in sections 4 and 5 that wages always lie in the bargaining set.

### 3.2.1.6 Monetary policy and equilibrium

It is assumed that monetary policy adjusts interest rates in response to movements in inflation and output growth according to the following rule

$$\log\left(\frac{1 + I_t}{1 + I}\right) = \phi_r \log\left(\frac{1 + I_{t-1}}{1 + I}\right) + (1 - \phi_r) (\phi_\pi \log(\Pi_t) + \phi_{\Delta y} \log(Y_t/Y_{t-1})) \tag{3.2.10}$$

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<sup>2</sup>It should be noted that the results do not depend on the existence of real wage rigidities per se but rather on the presence of an amplification mechanism in response to shocks. Introducing real wage rigidities is only one of the many possible ways of solving the “Shimer puzzle”.

### 3.3 Steady-state analysis: uncovering the asymmetry in unemployment fluctuations

The economy-wide resource constraint is obtained by aggregating the budget constraints of households. Final output and home production can be used for consumption or to cover the deadweight costs of changing prices and posting vacancies

$$C_t = Z_t N_t \left( 1 - \frac{\phi^p}{2} (\Pi_t - 1)^2 \right) + b(1 - N_t) - \kappa v_t \quad (3.2.11)$$

We can now define an equilibrium.

DEFINITION: A competitive equilibrium is a set of plans  $\{C_t, I_t, N_t, \mu_t, \theta_t, \pi_t, w_t\}$  satisfying equations (3.2.1), (3.2.4), (3.2.7), (3.2.8), (3.2.9), (3.2.10), (3.2.11), and (11) given a specification for the exogenous process  $\{Z_t\}$  and initial conditions  $N_{-1}$  and  $I_{-1}$ .

Technology will be modeled as a first-order autoregressive process

$$Z_t - \bar{Z} = \delta_Z (Z_{t-1} - \bar{Z}) + \varepsilon_t^Z$$

where  $0 < \delta_Z < 1$  and  $\varepsilon_t^Z \sim (0, \sigma_{\varepsilon^Z}^2)$  is a white noise innovation.

## 3.3 Steady-state analysis: uncovering the asymmetry in unemployment fluctuations

This section undertakes a comparative statics exercise in order to understand the origin of the asymmetry in unemployment fluctuations. I solve for the zero-inflation steady state equilibrium of the model. In that case, markups are constant and the equilibrium consists of three endogenous variables: labor market tightness, unem-

ployment and consumption. In the following equations, steady-state variables are indicated by the absence of a time subscript. Equilibrium labor market tightness is given by the job creation equation

$$\frac{\kappa}{q(\theta)} = \frac{1}{1 - (1 - \rho)\beta} \left( \frac{Z}{\mu} - \omega Z^\gamma \right)$$

When  $\alpha = 0.5$ , we have that  $p(\theta) = \frac{\chi^2}{q(\theta)}$ , hence the previous equation can be rewritten in the following way

$$p = \frac{\chi^2}{\kappa (1 - (1 - \rho)\beta)} \left( \frac{Z}{\mu} - \omega Z^\gamma \right)$$

Thus, the job finding rate  $p$  is entirely determined by the level of productivity  $Z$ . In the  $(u, p)$  plane of Figure 3.8.1, the job creation curve is a horizontal line. Now that we have obtained the job-finding rate, we can deduce the unemployment rate from the steady-state version of equation (1),  $p = \frac{\rho(1-u)}{1-(1-\rho)(1-u)}$ . This employment flow curve is decreasing and convex in the  $(u, p)$  plane of Figure 3.8.1.

This figure shows that shifts in productivity lead to almost symmetric shifts in the job finding rate, but asymmetric shifts in unemployment. When  $Z = 1$ , steady-state unemployment is equal to 6%. When productivity increases by 2.5%, steady-state unemployment decreases by 4%. However, when productivity decreases by 2.5%, steady-state unemployment increases dramatically and reaches 14.5%. The intuition behind this result is simple. In an expansion, the impact on unemployment of an increase in the job-finding rate is *dampened* by the fact that the pool of job seekers is shrinking. In a recession, the impact on unemployment of a decrease in the job-finding rate is *amplified* by the fact that the pool of job seekers

### 3.3 Steady-state analysis: uncovering the asymmetry in unemployment fluctuations

is expanding. In other words, in a search and matching model of the labor market, unemployment losses in recessions tend to be greater than unemployment gains in expansions. Unemployment fluctuations are asymmetric, and mean unemployment is higher in an economy with business cycles than in steady-state. Following Jung and Kuester (2011), we can obtain an analytical expression for  $E(u_t) - u$ , the extra unemployment brought about by business cycles. Assuming that all variables in the employment-flow equation (3.2.1) are covariance stationary,  $E(u_t) - u$  is given by

$$E(u_t) - u = -\frac{1 - \rho}{\rho + (1 - \rho)p} \left[ \text{cov}(p_t, u_{t-1}) + \left( \frac{\rho}{1 - \rho} + E(u_t) \right) (E(p_t) - p) \right] \quad (3.3.1)$$

The proof of this result is presented in the appendix. The covariance between the job-finding rate and the unemployment rate captures the asymmetry in unemployment fluctuations brought about by symmetric shifts in the job-finding rate. The second term  $E(p_t) - p$  captures the extent to which fluctuations in the job-finding rate are asymmetric. In this comparative steady-states example, fluctuations in the job-finding rate are symmetric only if  $\gamma = 0$ . Out of steady-state, fluctuations in the stochastic discount factor and markups will also drive a wedge between  $E(p_t)$  and  $p$ . However, the following sections show that the bulk of the unemployment losses due to business cycles is accounted for by the negative covariance between the job-finding rate and the unemployment rate.

The analysis carried out so far suggests that an increase in the volatility of the job-finding rate leads to higher average unemployment. Through its influence

on firms' markups, monetary policy has the ability to influence job creation and labor market volatility. The next section explores in a quantitative manner how different monetary policy rules can lead to different outcomes in terms of mean unemployment.

## **3.4 Monetary policy, labor market volatility and mean unemployment**

### **3.4.1 Calibration and solution method**

I calibrate the model to U.S. data. I take one period to be a quarter. Table 3.1 gives a summary of the values of the parameters.

A few parameters are calibrated using conventional values. The discount factor is set to  $\beta = 0.99$ , which yields an annual interest rate of 4%. The elasticity of substitution between goods is  $\varepsilon = 6$ , which corresponds to a steady-state markup of 20%. I choose a coefficient of relative risk aversion  $\sigma = 1.5$ . The price adjustment cost parameter  $\phi^p$  is chosen according to the following logic. The linearized Phillips Curve of the model is observationally equivalent to the one derived under Calvo pricing, and structural estimates of New Keynesian models find an elasticity of inflation with respect to marginal cost  $\omega$  of 0.5 (Lubik and Schorfheide 2004). In my model  $\omega = \frac{\varepsilon-1}{\phi^p}$ , which implies that  $\phi^p = 10$ . Alternatively, assuming an average contract duration of 4 quarters, the coefficient  $\omega$  under Calvo pricing would be equal to 0.0858. This implies  $\phi^p = 60$ . I choose an intermediate value  $\phi^p = 40$ . This is also the value chosen by Krause and Lubik (2007).

### 3.4 Monetary policy, labor market volatility and mean unemployment

Next, I calibrate labor market parameters. I set the elasticity of matches with respect to unemployment at  $\alpha = 0.5$ , within the range of plausible values proposed by Petrongolo and Pissarides (2001). I set the steady-state values of unemployment and labor market tightness to their empirical counterparts. I use the seasonally-adjusted monthly unemployment rate constructed by the Bureau of Labor Statistics (BLS) from the Current Population Survey (CPS). Labor market tightness is computed as the ratio of a measure of the vacancy level to this measure of unemployment. The measure of the vacancy level is obtained by merging the vacancy data of the Conference Board help-wanted advertisement index for 1951-2001 and the seasonally-adjusted monthly vacancy level constructed by the BLS from JOLTS for 2001-2012. Over the period 1951-2012, the mean of the unemployment rate is 5.8% and the mean of labor market tightness is 0.61. For practical purposes, my targets will be 6% and 0.6 respectively. The separation rate is set to 0.08. These targets imply through the steady-state employment flow equation a quarterly job-finding probability of 0.56, and through the definition of the job-finding probability, a matching efficiency of 0.7181. Silva and Toledo (2009) report that hiring costs amount to about 14% of quarterly employee compensation when expenses such as advertisement costs, agency fees or travel costs for applicants are accounted for on top of the number of hours spent by company employees on recruiting. Thus, the vacancy posting cost is assumed to be equal to  $\kappa = 0.14qw$ . I can then back out the steady-state value of the real wage from the job creation equation. I obtain  $\omega = \frac{\frac{1}{\mu}}{1+0.14(1-\beta(1-\rho))} = 0.8231$  and  $\kappa = 0.1068$ . Pissarides (2009) and Haefke et al. (2013) emphasize that job creation depends on the expected net present value of wages over the entire duration of the newly created jobs. Since

wages in existing matches are known to be unresponsive to changes in aggregate conditions, it is the elasticity of the wages of new hires with respect to technology that matters for job creation. Following estimates in Haefke et al. (2013), I set this elasticity  $\gamma$  to 0.8. Finally, I choose a value of home production  $b$  equal to 0.4 in the baseline calibration. However, given the uncertainty surrounding the precise value of this parameter, I also report results for alternative values in section 5.

The parameters of the technological process,  $\delta_Z$  and  $\sigma_{\varepsilon Z}$ , are chosen in order to match U.S. labor productivity standard deviation and persistence. Finally estimates from Galí and Rabanal (2004) are used to fix the parameters of the monetary policy rule,  $\phi_r = 0.69$ ,  $\phi_\pi = 1.35$  and  $\phi_{\Delta y} = 0.26$ .

	Parameter/SS value	Justification
$\beta$	0.99	Corresponds to an interest rate of 4% annually
$\phi^p$	40	Intermediate value
$\sigma$	1.5	Conventional value
$\varepsilon$	6	Steady state markup of 20%
$\alpha$	0.5	Petrongolo and Pissarides (2001)
$\rho$	0.08	Conventional value
$u$	6%	Mean over the period 1951-2012
$\theta$	0.6	Mean over the period 1951-2012
$\kappa$	0.1068	Hiring costs = 14% of quarterly compensation
$b$	0.4	Conventional value
$\gamma$	0.8	Haefke et al. (2013)
$\zeta$	0.9	Matches U.S. standard deviation and persistence
$\sigma_{\varepsilon Z}$	0.009	of labor productivity
$\phi_r$	0.69	Galí and Rabanal (2005)
$\phi_\pi$	1.35	Galí and Rabanal (2005)
$\phi_{\Delta y}$	0.26	Galí and Rabanal (2005)

Table 3.1 : Calibrated parameters

The model is solved by taking a second-order approximation to the equilibrium conditions around the deterministic steady state. The solution method is explained

### *3.4 Monetary policy, labor market volatility and mean unemployment*

in Schmitt-Grohé and Uribe (2004). Using a second-order approximation to the equilibrium conditions rather than a first-order approximation has several advantages. As the main purpose of this paper is to study the implications for monetary policy of non-linearities induced by matching frictions, it is crucial to be able to capture these non-linearities. First-order approximations cannot by construction account for non-linearities. Moreover, the use of first-order approximations to the equilibrium conditions may lead to incorrect welfare rankings. In an economy with a distorted steady-state (as is the case here), when welfare is evaluated using a first-order approximation to the equilibrium law of motion of endogenous variables, some second-order terms of the welfare function are omitted while others are included. The resulting welfare criterion will be inaccurate to order two or higher.

However, perturbation methods may not be appropriate if the lower-order derivatives evaluated at the deterministic steady-state do not accurately capture the global behavior of the policy functions that are solved for. For this reason, I also solved the model with projection methods (the algorithm that is used is presented in the appendix). I find that the results obtained with this method are qualitatively and quantitatively similar to the ones obtained with the second-order perturbation method.

#### **3.4.2 Labor market volatility and unemployment losses in the baseline economy**

The model was calibrated so as to ensure its consistency with salient micro and macro features of the U.S. economy. I now check that the model does a good job at

capturing the behavior of the U.S. economy over the business cycle by comparing the simulated moments of some key variables to their empirical counterparts in U.S. data over the period 1951q1 to 2012q4. In order to compute those empirical moments, I use the data for unemployment and vacancies described previously as well as series for output and labor productivity taken from the Bureau of Labor Statistics MSPC program <sup>3</sup>. I take quarterly averages of monthly series. Fluctuations at business cycle frequencies are isolated by taking the difference between the log of the variables and a Hodrick-Prescott filter with smoothing parameter  $10^5$ , as is common practice in the literature. Table 3.2 presents these empirical moments.

	$u$	$v$	$\theta$	$y$	$z$
Standard deviation	0.192	0.188	0.37	0.033	0.02
Autocorrelation	0.946	0.947	0.952	0.934	0.899
Correlation	1	-0.86	-0.96	-0.858	-0.412
	/	1	0.962	0.818	0.439
	/	/	1	0.871	0.458
	/	/	/	1	0.711
	/	/	/		1

Table 3.2 : Summary Statistics, Quarterly U.S. data, 1951q1 to 2012q4

In order to compute simulated moments from the model, I generate quarterly series for all variables by perturbing the model with i.i.d technology shocks  $\varepsilon_t^Z \sim (0, \sigma_{\varepsilon^Z}^2)$ . I discard the first 100 quarters of simulation and obtain 248 quarters of simulated data corresponding to data from 1951q1 to 2012q4 and detrend it with a HP filter of smoothing parameter  $10^5$ . I repeat this exercise a hundred

<sup>3</sup>Output is quarterly real output in the non farm business sector (series ID PRS85006043) and labor productivity is quarterly real output per job in the non farm business sector (series ID PRS85006163)

### 3.4 Monetary policy, labor market volatility and mean unemployment

times and compute the standard deviations and autocorrelations of variables and correlations between variables in each corresponding sample. Table 3.3 presents the mean standard deviations, autocorrelations and correlations across samples and the means of the variables generated by the model. The model does a fairly good job at amplifying technology shocks and generating a significant amount of labor market volatility. It also reproduces the strong negative correlation between unemployment and vacancies – the Beveridge Curve. However, it does not perform well along an important dimension; the autocorrelations of labor market variables are substantially lower than in the data. Moreover the correlations of vacancies and labor market tightness with labor productivity are not significantly different from zero and unemployment and labor productivity are positively correlated. Although these correlations are at odds with those presented in Table 3.2, they are consistent with what we observe in the data over the post-1985 period (Barnichon 2007 and table 4 in Pizzo 2014).

	$u$	$v$	$\theta$	$y$	$z$
Standard deviation	0.135	0.156	0.202	0.016	0.016
Autocorrelation	0.414	-0.19	-0.055	0.932	0.82
Correlation	1	-0.808	-0.89	-0.296	0.254
	/	1	0.988	0.364	-0.08
	/	/	1	0.362	-0.13
	/	/	/	1	0.845
	/	/	/		1
Simulated means	0.0622	0.0795	0.586	0.9375	1

Table 3.3 : Model - Simulated moments in the baseline economy

The last line in Table 3.3 presents the simulated means of the variables in the model. Unemployment losses due to business cycles are modest in the baseline

economy – average unemployment is only 0.22 percentage points higher than steady-state unemployment. As expected from the analysis carried out in section 3, this is due to two factors. First, the model generates a negative covariance between the unemployment rate and the job finding rate equal to -4.4, measuring both rates in percentage points. Second, the mean job-finding rate in the fluctuating economy  $E(p_t) = 0.5468$  is lower than the steady-state job-finding rate  $p = 0.5562$ . The latter result can be understood by deriving an analytical expression for the job-finding rate. Define  $x_t = \frac{Z_t}{\mu_t}$  as real revenues and assume all variables in the job creation equation (3.2.7) are covariance stationary. Under the maintained assumption that  $\alpha = 0.5$ , we can write

$$E(p_t) = \frac{\chi^2}{\kappa(1 - (1 - \rho)E(\beta_t))} \left[ E(x_t) - E(w_t) + (1 - \rho) \frac{\kappa}{\chi^2} \text{cov}(\beta_t, p_t) \right] \quad (3.4.1)$$

A positive technology shock results in a fall in marginal cost. This negative comovement between labor productivity and marginal cost tends to reduce average real revenues ( $E(x_t) < x$ ). This effect has a negative impact on job creation. However, two other effects tend to favor job creation. First, since wages are a concave function of technology, we have that  $E(w_t) < w$ . Second, the stochastic discount factor, which is inversely related to consumption growth, co-moves with the job finding rate. That is, firms put a larger weight on the future in expansions when the future gains of creating a vacancy today are high than they do in recessions, when those gains are low. Quantitatively, the negative impact of lower average real revenues on job creation dominates and we have that  $E(p_t) < p$ . The job-finding

### 3.4 Monetary policy, labor market volatility and mean unemployment

rate is lower in an economy with business cycles than in steady-state.

Through their influence on markups, alternative monetary policies will lead to different outcomes in terms of labor market volatility and average unemployment. I now examine the behavior of the economy under price stability. I focus on this specific policy as it has been shown to be the optimal policy in a wide range of studies (Walsh 2014), including some using a framework similar to the one presented in this paper (Faia 2009, Ravenna and Walsh 2012).

#### 3.4.3 A trade-off between inflation volatility and average unemployment

	$u$	$v$	$\theta$	$y$	$z$
Standard deviation	0.283	0.201	0.308	0.034	0.016
Autocorrelation	0.91	0.761	0.832	0.883	0.82
Correlation	1	-0.897	-0.948	-0.974	-0.958
	/	1	0.989	0.961	0.983
	/	/	1	0.991	0.993
	/	/	/	1	0.983
	/	/	/		1
Simulated means	0.0644	0.0806	0.6127	0.9357	1

Table 3.4 : Model - Simulated moments with technology shocks and a strong response to inflation

Table 3.4 presents some simulated moments of the model under a policy of price stability (that is,  $\phi_r = \phi_{\Delta y} = 0$  and an arbitrarily large weight is put on inflation). The labor market becomes more volatile under this policy as the standard deviation of unemployment more than doubles. Mean unemployment is higher by about 0.44 percentage points than in steady-state. This increase in unemployment

is not due to a greater asymmetry in job-finding rate fluctuations since the mean job-finding rate  $E(p_t) = 0.5519$  is higher under price stability than in the baseline economy. Because markups are constant under price stability, average real revenues are not affected by business cycles. This explains the slight difference in the average job-finding rate between the two regimes. Rather, the unemployment losses are due to the spectacular increase in the absolute value of the covariance between the job-finding rate and the unemployment rate at  $-22.5$ . That is, it is the increase in the volatility of the job-finding rate that accounts for the rise in average unemployment. This result can be understood by solving forward the job creation equation.

$$\frac{\kappa}{q(\theta_t)} = \sum_{j=0}^{\infty} E_t \beta^j \left( \frac{C_{t+j}}{C_t} \right)^{-\sigma} (1 - \rho)^j \left( \frac{Z_{t+j}}{\mu_{t+j}} - \omega Z_{t+j}^\gamma \right)$$

This equation states that vacancy posting today is driven by the sum of future expected discounted real revenues minus wage payments. Since the paths of labor productivity and real wages are identical under the policies considered, the differences in vacancy posting activity must come from differences in the path of markups. Markups are influenced by monetary policy as they depend on current inflation and future expected inflation through equation (3.2.8). Thus, through its impact on markups, monetary policy has an influence on the reaction of labor market activity to technology shocks. A positive technology shock leads to a decrease in marginal cost. Under price stability, the monetary authority reacts aggressively by cutting interest rates. This leads to an expansion in aggregate demand and forces firms to hire more workers in order to meet demand. This increase in hiring activities raises marginal cost back to its previous level. Firms

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do not have to adjust prices and markups remain constant. Under the Taylor rule considered in the baseline economy, the monetary authority does not cut interest rates as aggressively as under price stability. As a result, the expansion in aggregate demand is limited. Since firms can now produce the same level of output with less workers, they actually cut employment on impact. Markups go upwards at the time of the shock because marginal cost decreases and firms are unable to decrease prices as much as they would like to. In the periods following the shock, firms start adjusting prices and employment increases, but much less than under price stability. Figure 3.8.2 illustrates this graphically by plotting the response of markups, inflation, labor market tightness and employment both under price stability and under the baseline Taylor rule following a positive productivity shock of one standard deviation.

Thus, by engineering procyclical markups, the monetary authority can limit the impact of technology shocks on hiring. This will tend to reduce the magnitude of fluctuations in the job-finding rate and the unemployment rate, and because unemployment fluctuations are asymmetric, lead to lower average unemployment. However, in order to generate procyclical markups, the central bank must tolerate deviations from price stability. Therefore, this analysis suggests that the monetary authority faces a trade-off between inflation volatility and average unemployment. This intuition can be confirmed with a simple exercise. I assume that the monetary authority responds only to inflation and compute  $E(u_t) - u$  for different values of  $\phi_\pi$  ranging from 1.5 to 10. Figure 3.8.3 plots the standard deviation of inflation and the unemployment losses under those different monetary rules. It shows that there is a clear relationship between inflation volatility and average

unemployment. A higher standard deviation of inflation is associated with a lower level of unemployment.

Thus, the first main contribution of this paper is to show that a long-run trade-off between inflation volatility and average unemployment arises when unemployment fluctuations are asymmetric. The next section undertakes a more normative analysis. It studies the characteristics of the optimal policy and provides a welfare ranking of alternative policies. Notably, it tries to answer the following question: is a policy of price stability still nearly optimal in this framework, despite its costs in terms of higher average unemployment?

### **3.5 Optimal policy and welfare analysis**

In a standard New-Keynesian model, the monetary authority does not face a trade-off between stabilizing inflation and real activity. Stabilizing inflation also implies stabilizing the welfare-relevant output-gap, a result referred to as the “divine coincidence” (Blanchard and Galí 2007) in the literature. This conclusion is no longer valid in the presence of search and matching frictions in the labor market. Whenever job creation is inefficient, the monetary authority has an incentive to deviate from price stability to stabilize labor market activity (Faia 2009). However, quantitatively, the level of welfare attained by a policy of price stability is very close to the one obtained under the optimal policy. This point is forcefully emphasized in Ravenna and Walsh (2012). This section examines whether this conclusion is still valid within the framework presented in this paper.

### 3.5.1 Ramsey-optimal monetary policy

The optimal policy is the process  $\{I_t\}$  associated with the competitive equilibrium that yields the highest level of welfare. The monetary authority chooses the optimal paths of  $\{C_t, I_t, N_t, \mu_t, \theta_t, \pi_t, v_t\}$  that maximize the present discounted value of household utility, taking as constraints equations (3.2.1), (3.2.4), (3.2.7), (3.2.8), (3.2.11) and the definition of labor market tightness. This problem can be simplified in several ways. First, note that once the paths of consumption and inflation are known, the path of the interest rate can be backed out from the Euler equation. Similarly, once the paths of labor market tightness and employment are known, the path of vacancies can be obtained. Thus, the problem can be transformed in one in which the Ramsey planner chooses  $\{C_t, N_t, \mu_t, \theta_t, \pi_t\}$  subject to the law of motion of employment (3.2.1), the job creation equation (3.2.7), the non-linear Phillips curve (3.2.8), and the resource constraint (3.2.11).

$$\begin{aligned}
 Max_{C_t, N_t, \mu_t, \theta_t, \pi_t} L &= E_0 \sum_{t=0}^{\infty} \beta^t \left( \frac{C_t^{1-\sigma}}{1-\sigma} \right. \\
 &+ \lambda_{1t} \left[ Z_t N_t \left( 1 - \frac{\phi^p}{2} (\Pi_t - 1)^2 \right) - \kappa \theta_t (1 - (1 - \rho) N_{t-1}) + b(1 - N_t) - C_t \right] \\
 &+ \lambda_{2t} \left[ (1 - \rho) N_{t-1} + \chi (1 - (1 - \rho) N_{t-1}) \theta_t^{1-\alpha} - N_t \right] \\
 &+ \lambda_{3t} \left[ C_t^{-\sigma} \left[ Z_t m c_t - \omega Z_t^\gamma - \frac{\kappa}{\chi} \theta_t^\alpha \right] + E_t \beta C_{t+1}^{-\sigma} (1 - \rho) \frac{\kappa}{\chi} \theta_{t+1}^\alpha \right]
 \end{aligned}$$

$$+\lambda_{4t} \left[ C_t^{-\sigma} (1 - \epsilon + \epsilon m c_t - \phi^p \Pi_t (\Pi_t - 1)) + E_t \beta C_{t+1}^{-\sigma} \phi^p \Pi_{t+1} (\Pi_{t+1} - 1) \frac{Z_{t+1} N_{t+1}}{Z_t N_t} = 0 \right]$$

where  $\{\lambda_{1t}, \lambda_{2t}, \lambda_{3t}, \lambda_{4t}\}$  represent sequences of Lagrange multipliers associated with the four constraints. Due to the forward-looking nature of the last two constraints, this problem is non-stationary. This issue can be addressed by introducing lagged multipliers  $\lambda_{3,-1}, \lambda_{4,-1}$  corresponding to the forward-looking constraints in the initial period. Their value is set equal to their solution in steady-state. Thus, I study the behavior of the economy after the effects of an initial start-up period have worn away, that is I assume that the central bank has long been following the optimal policy (King and Wolman 1999). A system of nine equations (the four equations just mentioned and five first-order conditions) and nine unknowns (the five endogenous variables and the four Lagrange multipliers) is obtained. It is solved numerically with second-order perturbation methods. The optimal long-run inflation rate in this economy is equal to zero (see the appendix). In what follows, I study the behavior of the economy under the optimal policy in response to technology shocks. I compare the outcomes in terms of labor market volatility and average unemployment to those that are obtained in the baseline economy and under a policy of price stability. Table 3.5 reports the simulated moments of selected variables of the model under the optimal policy.

Labor market volatility is much lower than under the previous policies. This lower volatility is reflected in the value of the covariance between the unemployment rate and the job finding rate which stands at  $-1.4$ . Because the average job-finding rate  $E(p_t) = 0.5517$  is sensibly equal to its value under price stability,

### 3.5 Optimal policy and welfare analysis

the unemployment losses due to business cycles are much lower – average unemployment is equal to 6.13%. Figure 3.8.4 compares the reaction of markups, inflation, labor market tightness and employment to a positive productivity shock under three different monetary policies - the baseline Taylor rule, the optimal policy and the policy of price stability. The behavior of markups is smoother under the optimal policy than under a Taylor rule and this enables the Ramsey planner to avoid the large drops in labor market tightness and employment in the first period after the shock. However, the procyclicality of markups still helps cushion the effects of the shock on hiring. As a result, the reactions of labor market tightness and employment are lower than under price stability. This smooth, yet procyclical, behavior of markups helps explain why labor market volatility is much lower than under the two policies considered in section 4.

	$u$	$v$	$\theta$	$y$	$z$
Standard deviation	0.062	0.041	0.065	0.019	0.016
Autocorrelation	0.922	0.753	0.832	0.844	0.82
Correlation	1	-0.912	-0.968	-0.955	-0.931
	/	1	0.988	0.983	0.985
	/	/	1	0.992	0.986
	/	/	/	1	0.997
	/	/	/		1
Simulated means	0.0613	0.0804	0.592	0.9384	1

Table 3.5 : Model - Simulated moments with technology shocks under the optimal monetary policy

#### 3.5.2 Welfare analysis

The preceding analysis shows that the qualitative behavior of the economy is markedly different under the optimal policy than under price stability. However,

as emphasized in the introduction, previous studies have found that adopting the optimal policy rather than a policy of price stability brings only modest welfare gains. In this section, I evaluate whether this conclusion is still valid within the framework presented in this paper. In order to do so, I compare the levels of lifetime utility associated with the two policies. Welfare will be characterized conditional upon the initial steady-state being the deterministic steady-state. Since the deterministic steady-state is the same in the two regimes, this ensures that the economy begins from the same initial point under both policies and that the welfare measure takes into account the transition path to the stochastic steady-state associated with each policy. Following the method and notations used in Schmitt-Grohe and Uribe (2005), the equilibrium process for consumption associated with a particular policy regime will be denoted by  $\{c_t\}$ . Welfare,  $V_0$ , is measured as the conditional expectation of lifetime utility as of time 0 evaluated at  $\{c_t\}$ . Formally

$$V_0 = E_0 \sum_{t=0}^{\infty} \beta^t U(c_t)$$

The levels of welfare associated with the Ramsey regime  $V_0^r$  and the regime of price stability  $V_0^{PS}$  are

$$V_0^r = E_0 \sum_{t=0}^{\infty} \beta^t U(c_t^r)$$

$$V_0^{PS} = E_0 \sum_{t=0}^{\infty} \beta^t U(c_t^{PS})$$

where  $\{c_t^r\}$  and  $\{c_t^{PS}\}$  are the consumption processes under the Ramsey regime and the regime of price stability, respectively. The welfare cost of adopting a regime

### 3.5 Optimal policy and welfare analysis

of price stability instead of the Ramsey regime,  $\lambda$ , is measured as the fraction of the Ramsey consumption process that a household would be willing to give up to be as well-off under the price stability regime as under the Ramsey regime.  $\lambda$  is implicitly defined as

$$V_0^{PS} = E_0 \sum_{t=0}^{\infty} \beta^t U(c_t^r(1 - \lambda))$$

Given the form of the utility function  $U(c) = \frac{c^{1-\sigma}}{1-\sigma}$ , this yields

$$\lambda = 1 - \left( \frac{V_0^{PS}}{V_0^r} \right)^{\frac{1}{1-\sigma}}$$

	$\bar{C}^{PS}$	$\sigma(C^{PS})$	$\bar{C}^R$	$\sigma(C^R)$	$\lambda$	% of gain due to increase in $\bar{C}$
$b = 0$	0.9266	0.033	0.9295	0.017	0.43%	72.1%
$b = 0.4$	0.9529	0.024	0.9542	0.017	0.18%	77.8%
$b = 0.6$	0.9659	0.020	0.9665	0.017	0.09%	69%
$b = 0.7$	0.9723	0.018	0.9727	0.016	0.05%	82.3%

Table 3.6 : Welfare analysis - Optimal policy versus Price stability

The welfare gain is computed for different values of  $b$ , the value of home production. Table 3.6 reports this welfare measure along with the mean and standard deviation of consumption under each policy. The gain in aggregate welfare is 0.18% in the baseline calibration. This gain is an order of magnitude higher than what has been found in other studies using a similar framework (Thomas 2008, Faia 2009). Section 5.3 provides an explanation for this discrepancy in the findings. Adopting the Ramsey policy yields a modest decline in consumption volatility and a 0.14% increase in average consumption. The final column gives an estimate of the welfare gain that is due to the increase in average consumption. Note that households

would be willing to pay exactly 0.14%  $((0.9542 - 0.9529)/0.9542)$  of the Ramsey consumption process for mean consumption to attain its level under the optimal policy. Thus we can deduce that approximately 77.8%  $(0.14/0.18 \times 100)$  of the total gain in welfare is due to the increase in average consumption. It is possible to understand where this increase comes from by considering equation (3.2.11), the resource constraint of the economy. This equation shows that consumption depends positively on employment and negatively on the number of vacancies and on deviations of inflation from its steady-state value. Since the mean level of vacancies is sensibly the same under the two policies, it follows that the Ramsey planner attains a higher level of consumption by exploiting the long-run trade-off between inflation volatility and average unemployment. By allowing for deviations from price stability ( $\Pi = 1$ ), the optimal policy incurs some losses that are more than compensated for by the increase in employment that it is able to achieve.

Table 3.6 also shows that the welfare cost of price stability is a decreasing function of the value of home production. For  $b = 0$ , the welfare gain attains 0.43% of the Ramsey consumption process. For  $b = 0.7$ , the welfare gain is only equal to 0.05% of the Ramsey consumption process. Since the wage process is exogenous, a change in the value of home production barely affects the cyclical properties of the model under price stability. Average unemployment is about the same for values of  $b$  ranging from 0 to 0.7. However, this parameter is critical for welfare as it determines how given unemployment losses translate in consumption losses. When  $b$  is high, unemployment losses are not very costly from the point of view of the household since unemployed household members generate about as much revenues as if they were employed. For  $b = 0.7$ , a 0.25 percentage points differ-

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ence in average unemployment between the Ramsey policy and the policy of price stability results in a mere 0.04 difference in average consumption. However for  $b = 0$ , the 0.37 percentage points difference in average unemployment between the two policies leads to a more sizeable 0.31 difference in average consumption. It follows that the value of  $b$  is key in shaping monetary policy trade-offs. The Ramsey planner has much more incentive to use costly inflation volatility in order to stabilize unemployment fluctuations when the flow value of unemployment is low. Indeed, the standard deviation of inflation under the Ramsey regime nearly doubles when  $b$  goes from 0.7 to 0.

Thus, the main result that emerges from this analysis is twofold: (1) The welfare costs of adopting a policy of price stability rather than the optimal policy can be large; (2) Those costs are accounted for by the difference in the levels of employment under the two policies. This shows that the asymmetry in unemployment fluctuations is critical in shaping welfare outcomes. In the absence of such asymmetry, the central bank's actions would be largely ineffective at influencing average employment and average consumption and the welfare ranking of alternative policies would be modified.

#### 3.5.3 The performance of simple rules

This section complements the preceding analysis by evaluating the performance of alternative simple and implementable rules. The implementability condition requires the rules to deliver uniqueness of the rational expectations equilibrium. Simplicity implies that only rules for which the interest rate is set as a function of easily observable macroeconomic indicators are considered. Specifically, I consider

rules that respond to the output gap, the employment gap or output growth alongside inflation. I search the grid of parameters  $\{\phi_\pi, \phi_y, \phi_N, \phi_{\Delta y}\}$  over the intervals  $[1.5, 5]$  for  $\phi_\pi$  and  $[0, 0.5]$  for  $\phi_N, \phi_y, \phi_{\Delta y}$  for the parameter combination that yields the highest level of welfare.

Several results emerge. First, in the baseline calibration, the rule that performs best features a vigorous response to both inflation and the employment gap,  $\phi_\pi = 2.5$  and  $\phi_N = 0.5$ , and yields a level of welfare close to the one attained under the optimal policy (the welfare cost of adopting this policy rather than the Ramsey policy is equal to  $\lambda = 0.0087$ ). Second, responding solely and strongly to inflation is always welfare detrimental. This can be seen in figures 3.8.5, 3.8.6 and 3.8.7 in the appendix which plot the level of conditional welfare according to the response to inflation and the employment gap for different values of  $b$ . Finally, the relative weight that a policymaker should place on inflation is an increasing function of the value of home production. When  $b = 0$ , a mild respond to inflation alongside a strong response to employment is warranted. However, when  $b = 0.7$ , this policy does not perform as well. In that case, the monetary policymaker should stabilize inflation more vigorously.

### **3.5.4 Relation to the literature**

This paper builds on a very rich literature that has endeavoured to introduce the modern theory of unemployment in dynamic stochastic general equilibrium models and study how monetary policy should trade-off between inflation and unemployment stabilization. A robust result of this literature is that even when job creation is inefficient, the monetary authority should focus almost exclusively

### *3.5 Optimal policy and welfare analysis*

on stabilizing prices. This paper comes up with a different conclusion, namely that the asymmetric nature of unemployment fluctuations tends to generate important business cycle costs and a meaningful tradeoff between inflation and unemployment stabilization for the monetary policymaker. The aim of this section is to explain the discrepancy between these findings.

First, an important number of papers rely on first-order approximations to the equilibrium conditions when solving the model. This is the case of papers by Thomas (2008) and Ravenna and Walsh (2011) who follow the linear quadratic approach to studying optimal monetary policy. As emphasized in section 4.1, by using first-order approximations, one suppresses by construction any non-linearity from the analysis. In that case, the unconditional mean of a variable in the stochastic steady-state is not different from its deterministic steady-state value, and the way monetary policy is conducted has no influence on mean unemployment. I have argued in the previous section that most of the welfare costs of a policy of price stability are due to mean effects. Thus it is not surprising that those papers find very small costs of price stability when real wages are rigid. However, Thomas (2008) and Blanchard and Galí (2010) do find significant costs of price stability when nominal wages are staggered or when there is a direct utility cost of employment fluctuations. This suggests that adding those ingredients in the analysis could potentially strengthen the case for stabilizing employment.

Other papers such as Faia (2008, 2009) and Ravenna & Walsh (2012) have relied on second-order approximations to the equilibrium conditions. As emphasized in section 3, the size of the employment losses due to business cycles depends on the volatility of the job-finding rate. Therefore, the model must generate enough

amplification in response to technology shocks for the cost of unemployment fluctuations to be substantial. It has been well known since at least Shimer (2005) that models with search and matching frictions and flexible wages generate very little volatility in labor market variables. Following a shock, the immediate adjustment of the wage does not leave any incentive for firms to adjust through the employment margin. Thus, in the flexible wage model of Faia (2009), mean unemployment must be very close to its steady-state value. Not surprisingly, in her baseline calibration, the optimal deviations from price stability are negligible. However, it is worth noting that only a small degree of wage rigidity is necessary for the model to amplify shocks and for average unemployment to differ significantly from its steady-state value. Indeed, in my analysis, the elasticity of wages with respect to technology is set to 0.8, in line with empirical estimates in Haefke et al. (2013). Finally, the results presented here are consistent with some of the findings in Ravenna and Walsh (2012). These authors use a similar framework with wage rigidity and find that the gains from deviating from price stability are larger in economies with more volatile labor flows. My findings can provide an explanation for this observation. Given the asymmetric nature of unemployment fluctuations in the presence of search and matching frictions, the more volatile is unemployment, the larger is average unemployment and the greater are the mean consumption gains that a central bank can achieve by deviating from price stability.

## 3.6 Conclusion

An important literature seeks to describe optimal monetary policy in dynamic economies featuring nominal and real rigidities. These studies generally find that an exclusive focus on stabilizing inflation over the business cycle is close to optimal when technology is the only source of uncertainty. This paper shows that this conclusion is no longer valid when unemployment fluctuations are asymmetric. In such an environment, the monetary authority faces a long-run tradeoff between inflation volatility and average unemployment. Policies of price stability exacerbate unemployment volatility in response to shocks, and because unemployment fluctuations are asymmetric, lead to higher average unemployment. This increase in average unemployment brings about potentially large welfare losses. The size of these losses depends on the value of home production for unemployed workers. When it is high, a given increase in average unemployment results in a modest decrease in average consumption and price stability is nearly optimal. However, when it is low, the same increase in average unemployment brings about a much larger decrease in average consumption and it becomes preferable for the monetary policymaker to deviate significantly from price stability to stabilize unemployment fluctuations.

In order to focus on the effects of the asymmetry in unemployment fluctuations on the design of optimal monetary policy, I have assumed that households are able to insure their members against consumption risks associated with unemployment. Several authors (Faia 2008, Walsh 2014 among others) have speculated that limited risk sharing within the household should increase the cost of unemployment

fluctuations and reinforce policymaker's incentives to stabilize labor market variables. In the appendix, I check that my results are robust to the inclusion of this feature. Interestingly, I also find that the welfare costs of price stability increase as the ratio of the consumption level of unemployed workers to the consumption level of employed workers decreases. This suggests that there might be strong complementarities between labor market policies aiming at bringing income support for unemployed workers and the conduct of monetary policy. I leave such an analysis for future research.

## 3.7 Appendix

### 3.7.1 The model in details

#### 3.7.1.1 Labor market

The size of the labor force is normalized to unity. Workers and firms need to match in order to become productive. The number of matches in period  $t$  is given by a Cobb-Douglas matching function  $m_t = \chi s_t^\alpha v_t^{1-\alpha}$ ,  $s_t$  being the number of job-seekers and  $v_t$  the number of vacancies posted by firms. The parameter  $\chi$  reflects the efficiency of the matching process and  $\alpha \in (0, 1)$  is the elasticity of the matching function with respect to unemployment. Define  $\theta_t = \frac{v_t}{s_t}$  as labor market tightness. The probability  $q_t$  for a firm to fill a vacancy and the probability  $p_t$  for a worker to find a job are, respectively,  $q_t = \frac{m_t}{v_t} = \chi \theta_t^{-\alpha}$  and  $p_t = \frac{m_t}{s_t} = \chi \theta_t^{1-\alpha}$ . At the beginning of each period  $t$ , a fraction  $\rho$  of existing employment relationships  $N_{t-1}$  is exogenously destroyed. Those  $\rho N_{t-1}$  newly separated workers and the  $1 - N_{t-1}$  workers unemployed in the previous period form the pool of job seekers  $s_t = 1 - (1 - \rho)N_{t-1}$ . Job seekers have a probability  $p_t$  of finding a job within the period. The law of motion of employment  $N_t$  is accordingly given by

$$N_t = (1 - \rho)N_{t-1} + p_t(1 - (1 - \rho)N_{t-1}) \quad (3.7.1)$$

The number of unemployed workers in period  $t$  is  $u_t = 1 - N_t$ .

### 3.7.1.2 Households

The household chooses consumption  $C_t$  and next period bond holdings  $B_{t+1}$  in order to maximize intertemporal utility

$$E_0 \sum_{t=0}^{\infty} \beta^t \frac{C_t^{1-\sigma}}{1-\sigma} \quad (3.7.2)$$

subject to its budget constraint

$$P_t C_t + (1 + I_t)^{-1} B_{t+1} = P_t [w_t N_t + b(1 - N_t)] + B_t + P_t \Pi_t^r \quad (3.7.3)$$

where  $\beta$  is the household's subjective discount factor and  $\sigma$  the coefficient of relative risk aversion. Total labour income is given by  $w_t N_t$  and  $b$  is the value of home production of unemployed household members. Households receive profits  $\Pi_t^r$  from retail firms and invest in risk-free bonds that promise a unit of currency tomorrow and cost  $(1 + I_t)^{-1}$  today. Consumption of market goods is given by  $C_t^m = C_t - b(1 - N_t)$ .  $C_t^m \equiv \int_0^1 [C_t^m(j)^{\frac{\varepsilon-1}{\varepsilon}} dj]^{\frac{\varepsilon}{\varepsilon-1}}$  is a Dixit-Stiglitz aggregator of the different varieties of goods produced by the retail sector and  $\varepsilon$  is the elasticity of substitution between the different varieties. The optimal allocation of income on each variety is given by  $C_t^m(j) = \left[ \frac{P_t(j)}{P_t} \right]^{-\varepsilon} C_t^m$ , where  $P_t = \left[ \int_0^1 P_t(j)^{\frac{\varepsilon-1}{\varepsilon}} dj \right]^{\varepsilon/(1-\varepsilon)}$  is the price index and  $P_t(j)$  is the price of a good of variety  $j$ . Define  $\lambda_t$  as the multiplier associated with the budget constraint. First-order conditions are as follows

- $C_t^{-\sigma} = \lambda_t P_t$
- $-\lambda_t (1 + I_t)^{-1} + \beta E_t \lambda_{t+1} = 0$

Combining these two equations yields the Euler Equation

$$\beta E_t \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} \frac{1 + I_t}{\Pi_{t+1}} = 1 \quad (3.7.4)$$

where  $\Pi_{t+1} = \frac{P_{t+1}}{P_t}$  is the gross inflation rate. The household's intertemporal utility can be rewritten in recursive form

$$H_t = \frac{C_t^{1-\sigma}}{1-\sigma} + \beta E_t H_{t+1}$$

Differentiating this expression with respect to  $N_t$  yields

$$\frac{\partial H_t}{\partial N_t} = C_t^{-\sigma} \frac{\partial C_t}{\partial N_t} + \beta E_t \frac{\partial H_{t+1}}{\partial N_{t+1}} \frac{\partial N_{t+1}}{\partial N_t}$$

We know that  $\frac{\partial C_t}{\partial N_t} = w_t - b$  from the budget constraint (3.7.3) and  $\frac{\partial N_{t+1}}{\partial N_t} = (1 - \rho)(1 - p_{t+1})$  from the law of evolution of employment (3.7.1) since households takes  $p_{t+1}$  as given.  $W_t = \frac{\partial H_t}{\partial N_t}$  with  $U_{c,t} = C_t^{-\sigma}$  is the marginal value of an additional employed worker for the household, expressed in consumption units.  $W_t$  is equal to

$$W_t = w_t - b + E_t \beta_{t+1} (1 - \rho)(1 - p_{t+1}) W_{t+1} \quad (3.7.5)$$

where  $\beta_{t+1} = \beta \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma}$  is the stochastic discount factor of households.

### 3.7.1.3 Firms

#### Wholesale firms

A measure one of wholesale firms, indexed by  $i$ , produces according to the following technology

$$Y_{it}^w = Z_t N_{it} \quad (3.7.6)$$

where  $Z_t$  is a common, aggregate productivity disturbance. Wholesale firms sell their output in a competitive market at a price  $P_t^w$ . Posting a vacancy comes at a cost  $\kappa$ . Firm  $i$  chooses its level of employment  $N_{it}$  and the number of vacancies  $v_{it}$  in order to maximize the expected sum of its discounted profits.

$$E_0 \sum_{t=0}^{\infty} \beta^t \frac{C_t^{-\sigma}}{C_0^{-\sigma}} \left[ \frac{P_t^w}{P_t} Z_t N_{it} - \kappa v_{it} - w_t N_{it} \right] \quad (3.7.7)$$

subject to

$$N_{it} = (1 - \rho) N_{it-1} + v_{it} q(\theta_t) \quad (3.7.8)$$

Profits are discounted using the household's discount factor since households ultimately own firms. Let  $\chi_{it}$  be the multiplier associated with the constraint. First-order conditions are as follows

- $\frac{P_t^w}{P_t} Z_t - w_t - \chi_{it} + \beta E_t \frac{C_{t+1}^{-\sigma}}{C_t^{-\sigma}} (1 - \rho) \chi_{it+1} = 0$
- $-\kappa + \chi_{it} q(\theta_t) = 0$

The second equation implies that  $\chi_{it} = \chi_t \forall i$ . Combining the two equations, we obtain

$$\frac{\kappa}{q(\theta_t)} = \frac{P_t^w}{P_t} Z_t - w_t + E_t \beta_{t+1} (1 - \rho) \frac{\kappa}{q(\theta_{t+1})} \quad (3.7.9)$$

The expected discounted sum of firms' profits can be rewritten in recursive form

$$V_t = \frac{P_t^w}{P_t} Z_t N_t - \kappa v_t - w_t N_t + E_t \beta_{t+1} V_{t+1}$$

Differentiating this expression with respect to  $N_t$  and using constraint (3.7.8) yields

$$J_t = \frac{\partial V_t}{\partial N_t} = \frac{P_t^w}{P_t} Z_t - w_t + E_t \beta_{t+1} (1 - \rho) J_{t+1} \quad (3.7.10)$$

where  $J$  is the value of an additional worker for the firm. Free entry in vacancy posting implies that the cost of filling a vacancy is equalized with the expected benefit of a filled job. We have  $J_t = \frac{\kappa}{q(\theta_t)}$ .

### Retail firms

There is a large number of retailers, indexed by  $j$ , which buy the goods produced by wholesale firms at a price  $P_t^w$  and transform them one for one into differentiated goods.  $P_t^w$  represents the nominal marginal cost of production for retailers. They face quadratic costs of adjusting prices  $\Theta_t(j) = \frac{\phi^p}{2} \left( \frac{P_t(j)}{P_{t-1}(j)} - 1 \right)^2 Y_t$  which are measured in terms of aggregate output  $Y_t$ . Retail firms choose  $P_t(j)$  in order to maximize

$$E_0 \sum_{t=0}^{\infty} \beta^t \frac{C_t^{-\sigma}}{C_0^{-\sigma}} \left[ \frac{P_t(j) - P_t^w}{P_t} (P_t(j)/P_t)^{-\epsilon} Y_t^d - \frac{\phi^p}{2} \left( \frac{P_t(j)}{P_{t-1}(j)} - 1 \right)^2 Y_t \right] \quad (3.7.11)$$

where  $Y_t^d$  is aggregate demand for final goods. The first-order condition is

$$\begin{aligned} & \bullet \beta^t \frac{C_t^{-\sigma}}{C_0^{-\sigma}} \left[ (1 - \varepsilon) \frac{P_t(j)^{-\varepsilon}}{P_t^{1-\varepsilon}} Y_t^d + \varepsilon P_t^w \frac{P_t(j)^{-\varepsilon-1}}{P_t^{1-\varepsilon}} Y_t^d - \frac{\phi^p}{P_{t-1}(j)} \left( \frac{P_t(j)}{P_{t-1}(j)} - 1 \right) Y_t \right] \\ & \bullet + E_t \beta^{t+1} \frac{C_{t+1}^{-\sigma}}{C_0^{-\sigma}} \phi^p \frac{P_{t+1}(j)}{P_t(j)^2} \left( \frac{P_{t+1}(j)}{P_t(j)} - 1 \right) Y_{t+1} = 0 \end{aligned}$$

Imposing symmetry  $P_t(j) = P_t$  and dividing by  $\frac{Y_t}{P_t}$  (market clearing implies  $Y_t^d = Y_t = Y_t^w$ ), we obtain

$$1 - \varepsilon + \frac{\varepsilon}{\mu_t} - \phi^p \Pi_t (\Pi_t - 1) + \beta E_t \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} \phi^p \Pi_{t+1} (\Pi_{t+1} - 1) \frac{Y_{t+1}}{Y_t} = 0 \quad (3.7.12)$$

where  $\mu_t = \frac{P_t}{P_t^w}$  is the markup of retail over wholesale prices.

### Wage setting

Wage rigidity is introduced in the form of the Blanchard and Galí (2010) wage schedule

$$w_t = \omega Z_t^\gamma \quad (3.7.13)$$

where  $\gamma \in [0, 1]$  is the elasticity of wages with respect to technology.

#### 3.7.1.4 Monetary policy and stochastic process for technology

The monetary authority sets interest rates  $I_t$  according to the following feedback rule

$$\log\left(\frac{1 + I_t}{1 + I}\right) = \phi_r \log\left(\frac{1 + I_{t-1}}{1 + I}\right) + (1 - \phi_r) (\phi_\pi \log(\Pi_t) + \phi_{\Delta y} \log(Y_t/Y_{t-1})) \quad (3.7.14)$$

Technology is modeled as a first-order autoregressive process  $Z_t - \bar{Z} = \delta_Z(Z_{t-1} - \bar{Z}) + \varepsilon_t^Z$  where  $0 < \delta_Z < 1$  and  $\varepsilon_t^Z \sim (0, \sigma_{\varepsilon^Z}^2)$  is a white noise innovation.

### 3.7.1.5 Aggregation

In equilibrium, there is zero net supply of bonds. The household's budget constraint becomes

$$C_t = w_t N_t + b(1 - N_t) + \Pi_t^r$$

Let  $\Pi_t^w$  and  $\Pi_t^r$  be the profits of wholesale and retail firms. Since the wholesale sector is in perfect competition, profits  $\Pi_t^w$  are equal to zero and

$$\frac{P_t^w}{P_t} Y_t = \kappa v_t + w_t N_t$$

Profits in the retail sector are equal to

$$\Pi_t^r = \frac{P_t - P_t^w}{P_t} Y_t^d - \Theta_t$$

Market clearing implies  $Y_t^d = Y_t = Y_t^w$ . Thus

$$\Pi_t^r = Y_t - \frac{P_t^w}{P_t} Y_t^w - \Theta_t$$

$$Y_t = C_t + b(1 - N_t) + \kappa v_t - \Theta_t$$

$$C_t = \left(1 - \frac{\phi^p}{2} (\Pi_t - 1)^2\right) Y_t + b(1 - N_t) - \kappa v_t \quad (3.7.15)$$

### 3.7.1.6 Decentralized equilibrium

A competitive equilibrium is a set of plans  $\{C_t, I_t, N_t, \mu_t, \theta_t, \pi_t, w_t\}$  satisfying the following equations given initial conditions  $N_{-1}$  and  $I_{-1}$  and a specification for the exogenous process  $\{Z_t\}$ .

- $\beta E_t \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} \frac{1+I_t}{\Pi_{t+1}} = 1$
- $N_t = (1 - \rho)N_{t-1} + \chi \theta_t^{1-\alpha} (1 - (1 - \rho)N_{t-1})$
- $\frac{\kappa}{q(\theta_t)} = \frac{Z_t}{\mu_t} - \omega Z_t^\gamma + E_t \beta_{t+1} (1 - \rho) \frac{\kappa}{q(\theta_{t+1})}$
- $1 - \varepsilon + \frac{\varepsilon}{\mu_t} - \phi^p \Pi_t (\Pi_t - 1) + \beta E_t \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} \phi^p \Pi_{t+1} (\Pi_{t+1} - 1) \frac{Z_{t+1} N_{t+1}}{Z_t N_t} = 0$
- $C_t = \left( 1 - \frac{\phi^p}{2} (\Pi_t - 1)^2 \right) Z_t N_t + b(1 - N_t) - \kappa v_t$
- $\log\left(\frac{1+I_t}{1+I}\right) = \phi_r \log\left(\frac{1+I_{t-1}}{1+I}\right) + (1 - \phi_r) \left( \phi_\pi \log(\Pi_t) + \phi_y \log\left(\frac{Z_t N_t}{Z_{t-1} N_{t-1}}\right) \right)$

Technology will be modeled as a first-order autoregressive process  $Z_t - \bar{Z} = \delta_Z (Z_{t-1} - \bar{Z}) + \varepsilon_t^Z$  where  $0 < \delta_Z < 1$  and  $\varepsilon_t^Z \sim (0, \sigma_{\varepsilon^Z}^2)$  is a white noise innovation.

### 3.7.2 Unemployment gap

Consider the employment flow equation

$$N_t = (1 - \rho)N_{t-1} + p_t [1 - (1 - \rho)N_{t-1}]$$

and unemployment is  $u_t = 1 - N_t$ . The terms in brackets can be rewritten  $\rho + (1 - \rho)u_{t-1}$ . Assuming all variables are covariance-stationary, we have that

$$\rho E(N_t) = \rho E(p_t) + (1 - \rho) [\text{cov}(p_t, u_{t-1}) + E(u_t)E(p_t)]$$

In steady state  $\rho N = \rho p + (1 - \rho)up$ . We can rewrite

$$\rho [E(N_t) - N] = \rho [E(p_t) - p] + (1 - \rho) \text{cov}(p_t, u_{t-1}) + (1 - \rho) [E(p_t) - p] E(u_t) + (1 - \rho) [E(u_t) - u] p$$

We have that  $E(N_t) - N = -(E(u_t) - u)$ . Thus

$$E(u_t) - u = -\frac{1 - \rho}{\rho + (1 - \rho)p} \left[ \text{cov}(p_t, u_{t-1}) + \left( \frac{\rho}{1 - \rho} + E(u_t) \right) (E(p_t) - p) \right] \quad (3.7.16)$$

### 3.7.3 Bargaining set

The marginal value of an additional employed worker for the household and the marginal value of an additional employed worker for the firm are

$$W_t = w_t - b + E_t \beta \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} (1 - \rho)(1 - p_{t+1})W_{t+1}$$

$$J_t = \frac{P_t^w}{P_t} Z_t - w_t + E_t \beta_{t+1} (1 - \rho) J_{t+1}$$

Every employer and employee must always enjoy a non-negative surplus, that is  $W_t$  and  $J_t$  must always be positive. Define  $r_t^w$  and  $r_t^f$  as the reservations wages of workers and firms. They verify the following equations

$$r_t^w = b - E_t \beta \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} (1 - \rho)(1 - p_{t+1})W_{t+1}$$

$$r_t^f = \frac{\kappa}{q(\theta_t)} - \frac{P_t^w}{P_t} Z_t - E_t \beta_{t+1} (1 - \rho) \frac{\kappa}{q(\theta_{t+1})}$$

since  $J_t = \frac{\kappa}{q(\theta_t)}$ . As long as  $w_t \in [r_t^w, r_t^f]$ , wages are in the bargaining set.

### 3.7.4 Ramsey problem

In this section  $\mu_t$  is substituted by  $\frac{1}{mc_t}$ . The Ramsey planner seeks to solve the following maximization problem

$$\begin{aligned} Max_{C_t, N_t, mc_t, \theta_t, \pi_t} L = & E_0 \sum_{t=0}^{\infty} \beta^t \left( \frac{C_t^{1-\sigma}}{1-\sigma} \right. \\ & + \lambda_{1t} \left[ Z_t N_t \left( 1 - \frac{\phi^p}{2} (\Pi_t - 1)^2 \right) - \kappa \theta_t (1 - (1 - \rho) N_{t-1}) + b(1 - N_t) - C_t \right] \\ & + \lambda_{2t} \left[ (1 - \rho) N_{t-1} + \chi (1 - (1 - \rho) N_{t-1}) \theta_t^{1-\alpha} - N_t \right] \\ & + \lambda_{3t} \left[ C_t^{-\sigma} \left( Z_t mc_t - \omega Z_t^\gamma - \frac{\kappa}{\chi} \theta_t^\alpha \right) + E_t \beta C_{t+1}^{-\sigma} (1 - \rho) \frac{\kappa}{\chi} \theta_{t+1}^\alpha \right] \\ & \left. + \lambda_{4t} \left[ C_t^{-\sigma} (1 - \epsilon + \epsilon mc_t - \phi^p \Pi_t (\Pi_t - 1)) + E_t \beta C_{t+1}^{-\sigma} \phi^p \Pi_{t+1} (\Pi_{t+1} - 1) \frac{Z_{t+1} N_{t+1}}{Z_t N_t} \right] \right) \end{aligned}$$

The first-order conditions are:

- $mc_t : \lambda_{3t}Z_t + \lambda_{4t}\varepsilon = 0$
- $\Pi_t : -\lambda_{1t}\phi^p(\Pi_t - 1)Z_tN_t + \phi^p(2\Pi_t - 1)C_t^{-\sigma} \left( \lambda_{4t-1}\frac{Z_tN_t}{Z_{t-1}N_{t-1}} - \lambda_{4t} \right) = 0$
- $\theta_t : -\lambda_{1t}\kappa(1-(1-\rho)N_{t-1}) + \lambda_{2t}\chi(1-\alpha)(1-(1-\rho)N_{t-1})\theta_t^{-\alpha} + \frac{\kappa}{\chi}\alpha\theta_t^{\alpha-1}C_t^{-\sigma}((1-\rho)\lambda_{3t-1} - \lambda_{3t}) = 0$
- $N_t : \lambda_{1t} \left[ Z_t \left( 1 - \frac{\phi^p}{2}(\Pi_t - 1)^2 \right) - b \right] - \lambda_{2t} + \beta E_t \lambda_{2t+1}(1-\rho)(1 - \chi\theta_{t+1}^{1-\alpha}) + \beta E_t \lambda_{1t+1}(1-\rho)\kappa\theta_{t+1}$
- $-\lambda_{4t}\beta E_t C_{t+1}^{-\sigma} \phi^p \Pi_{t+1}(\Pi_{t+1} - 1) \frac{Z_{t+1}N_{t+1}}{Z_t N_t^2} + \lambda_{4t-1} C_t^{-\sigma} \phi^p \Pi_t(\Pi_t - 1) \frac{Z_t}{Z_{t-1}N_{t-1}} = 0$
- $C_t : C_t^{-\sigma} - \lambda_{1t} - \lambda_{3t}\sigma C_t^{-\sigma-1} \left( Z_t mc_t - \omega Z_t^\gamma - \frac{\kappa}{\chi}\theta_t^\alpha \right) - \lambda_{4t}\sigma C_t^{-\sigma-1} [1 - \varepsilon + \varepsilon mc_t - \phi^p \Pi_t(\Pi_t - 1)] - \lambda_{3t-1}\sigma C_t^{-\sigma-1}(1-\rho)\frac{\kappa}{\chi}\theta_t^\alpha - \lambda_{4t-1}\sigma C_t^{-\sigma-1} \phi^p \Pi_t(\Pi_t - 1) \frac{Z_t N_t}{Z_{t-1}N_{t-1}} = 0$

In steady-state, the first-order condition with respect to  $\Pi_t$  collapses to  $\lambda_1 \phi^p (\Pi - 1) ZN = 0$ . Since the aggregate budget constraint is binding in equilibrium, we have that  $\lambda_1 \neq 0$ . This implies that  $\Pi = 1$ . We obtain the follow system of four equations and four unknowns,  $\lambda_1, \lambda_2, \lambda_3, \lambda_4$ :

- $\lambda_3 Z + \lambda_4 \varepsilon = 0$
- $[1 - (1 - \rho)N] (\lambda_2(1 - \alpha)\chi\theta^{-\alpha} - \lambda_1\kappa) - \frac{\kappa}{\chi}\rho\alpha\theta^{\alpha-1}C^{-\sigma}\lambda_3 = 0$
- $\lambda_1 [Z - b + \beta(1 - \rho)\kappa\theta] + \lambda_2 [\beta(1 - \rho)(1 - \chi\theta^{1-\alpha}) - 1] = 0$
- $C^{-\sigma} - \lambda_1 + \lambda_3\sigma C^{-\sigma-1} [\omega Z^\gamma - Zmc + \rho\frac{\kappa}{\chi}\theta^\alpha] = 0$

It is then possible to solve analytically for the steady-state values of  $\lambda_1, \lambda_2, \lambda_3$  and  $\lambda_4$ .

### 3.7.5 Solution algorithm

The model is solved in two different ways: by using second-order perturbation methods in Dynare and by using projection methods. This section describes this second solution algorithm. The model can be summarized by the following set of equations<sup>4</sup>

- $\beta C_t^\sigma (1 + I_t) = \Xi_t^1$
- $N_t = (1 - \rho)N_{t-1} + \chi\theta_t^{1-\alpha}(1 - (1 - \rho)N_{t-1})$
- $\frac{\kappa}{\chi}\theta_t^\alpha = \frac{Z_t}{\mu_t} - \omega Z_t^\gamma + \beta\frac{\kappa}{\chi}(1 - \rho)C_t^\sigma \Xi_t^2$
- $1 - \varepsilon + \frac{\varepsilon}{\mu_t} - \phi^p \Pi_t (\Pi_t - 1) + \beta\phi^p \frac{C_t^\sigma}{Z_t N_t} \Xi_t^3 = 0$
- $C_t = \left(1 - \frac{\phi^p}{2} (\Pi_t - 1)^2\right) Z_t N_t + b(1 - N_t) - \kappa\theta_t(1 - (1 - \rho)N_{t-1})$
- $\log\left(\frac{1+I_t}{1+I}\right) = \phi_\pi \log(\Pi_t) + \phi_y \log\left(\frac{Z_t N_t}{ZN}\right)$
- $Z_t - Z = \delta_Z(Z_{t-1} - Z) + \varepsilon_t^Z$  with  $\varepsilon_t^Z \sim (0, \sigma_{\varepsilon^Z}^2)$

with the expectations given by

- $\Xi_t^1 = E_t C_{t+1}^\sigma \Pi_{t+1}$
- $\Xi_t^2 = E_t C_{t+1}^{-\sigma} \theta_{t+1}^\alpha$
- $\Xi_t^3 = E_t C_{t+1}^{-\sigma} \Pi_{t+1} (\Pi_{t+1} - 1) Z_{t+1} N_{t+1}$

There are two state variables,  $N_{t-1}$  and  $Z_t$ .

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<sup>4</sup>I use here a standard Taylor Rule but the model can also be solved with other monetary policy rules including interest rate smoothing and a systematic response of monetary policy to other variables than the output gap

### 3.7.5.1 Principle

The description of the projection method used in this paper, a minimum weighted residual method, draws heavily from lectures notes by Fabrice Collard. The model admits the following representation

$$E_t F(y_{t+1}, x_{t+1}, y_t, x_t, \varepsilon_{t+1}) = 0$$

where  $y$  are control variables,  $x$  are state variables and  $\varepsilon$  is the set of innovations that hit the economy. Once a decision rule for control variables of the form  $y_t = g(x_t, \tau)$  is obtained, it is possible to express next period state variables as  $x_{t+1} = h(y_t, x_t, \varepsilon_{t+1}) = h(g(x_t, \tau), x_t, \varepsilon_{t+1})$ . The model can then be rewritten

$$E_t R(x_t, \varepsilon_{t+1}; g, \tau) = 0$$

The idea of the minimum weighted residual method is to approximate the decision rule by a simple polynomial function of the state variables  $x_t$  and find a vector of parameters  $\tau$  so that the residuals  $E_t R(x_t, \varepsilon_{t+1}; g, \tau)$  can be made as small as possible. The notion of “small” is operationalized by imposing that the residuals are orthogonal with respect to the basis functions we are using to approximate the decisions rules (Galerkin method).

### 3.7.5.2 Technical preliminaries

The decision rules are approximated with the following third-order complete polynomial

$$\Phi(x_1, x_2, \tau) = \sum_{i=0}^3 \sum_{j=0}^3 \mathbb{N}_{\tau_{i,j}} T_i(\varphi_1(x_1)) T_j(\varphi_2(x_2))$$

where  $T_i$  is a Chebyshev polynomial of order  $i$  and  $x_1$  and  $x_2$  are the values taken by the first and the second state variables.  $\mathbb{N}$  is an indicative variable taking the value of 1 if  $i + j \leq 3$  and 0 otherwise. Chebyshev polynomials are defined on the interval  $[-1, 1]$ . Thus the functions  $\varphi_1$  and  $\varphi_2$  map  $[a_1, b_1]$  and  $[a_2, b_2]$ , the intervals on which the two state variables are defined, in  $[-1, 1]$ .

The grid is constructed as follows. I compute the  $n = 4$  roots of the Chebyshev polynomial of order  $n$  as  $x_i^C = \cos(\frac{(2i-1)\pi}{2n})$  for  $i = 1, \dots, n$ . The possible values taken by the two state variables are then defined as

$$x_{i1}^{val} = \frac{a_1 + b_1}{2} + \frac{b_1 - a_1}{2} x_i^C$$

$$x_{i2}^{val} = \frac{a_2 + b_2}{2} + \frac{b_2 - a_2}{2} x_i^C$$

to map  $[-1, 1]$  in  $[a_1, b_1]$  and  $[a_2, b_2]$ . We have  $x_1 = x_1^{val} \otimes I_4$  and  $x_2 = I_4 \otimes x_2^{val}$  where  $I_4$  is a  $4 * 1$  matrix of ones. Thus the grid  $X = [x_1, x_2]$  is constructed so that all the  $m = 16$  combinations of the values of the two state variables are tried. Notation: The function  $\Phi$  is made of ten elements (which are products of the basis Chebyshev polynomials)  $A_p[\varphi(x)]$  for  $p = 0, \dots, 9$ .

### 3.7.5.3 Procedure

I approximate the decision rules for two variables, labor market tightness  $\theta_t$  and inflation  $\Pi_t$ . Once the values of these variables are known, the values of the other variables and of the expectations can readily be computed. The procedure goes as follows:

1. Choose a value for the learning parameter  $\zeta$ .
2. Start with an initial guess for the parameters associated with the decisions rules for  $\theta_t$  and  $\Pi_t$ . This initial guess is obtained by solving the model with a first-order approximation to the equilibrium conditions in Dynare.
3. Given these decisions rules, compute the other variables of the model and the expectations  $\Xi_t^1, \Xi_t^2, \Xi_t^3$  using Gaussian-Hermite quadrature techniques.
4. Compute the residuals  $E_t R(x_t, \varepsilon_{t+1}; \Phi, \tau)$  in each equation and evaluate  $\Lambda[\varphi(x)] R(x_t, \varepsilon_{t+1}; \Phi, \tau) = 0$  where  $\Lambda[\varphi(x)] = \begin{Bmatrix} \Lambda_0[\varphi(x_1)] & \dots & \Lambda_0[\varphi(x_m)] \\ \dots & \dots & \dots \\ \Lambda_p[\varphi(x_1)] & \dots & \Lambda_p[\varphi(x_m)] \end{Bmatrix}$ .
5. If it is close enough to zero, then stop. Otherwise update the parameters of the decisions rules using a Newton algorithm. You obtain a new set of parameters  $\tau_n$ . Form  $\tau_i = \zeta\tau_n + (1 - \zeta)\tau_{i-1}$  ( $i$  referring to the  $i$ th iteration) and go back to step 3.

A similar procedure is used to solve the Ramsey problem of the model.

### 3.7.6 An extension with imperfect unemployment insurance

Several authors (Faia 2008, Walsh 2014) have argued that the presence of imperfect unemployment insurance should make unemployment fluctuations more costly and reinforce policymaker's incentives to stabilize labor market variables. I examine this possibility by introducing imperfect unemployment insurance in the model of section 2. Following the efficiency wages literature (Alexopoulos 2004, Nakajima 2010), I assume that individual household members are not allowed to participate

in asset markets; it is the household itself that is in charge of savings decisions. This assumption has the advantage of limiting the amount of heterogeneity between individuals and helps keep the model tractable.

### 3.7.6.1 Modifications to the existing model

The household has expected utility

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[ N_t \frac{C_{e,t}^{1-\sigma}}{1-\sigma} + (1 - N_t) \frac{C_{u,t}^{1-\sigma}}{1-\sigma} \right] \quad (3.7.17)$$

where  $C_{e,t}$  and  $C_{u,t}$  are the date  $t$  consumption levels of employed and unemployed individuals, respectively. The household receives profits from firms  $\Pi_t^r$ , can acquire risk-free bonds that promise a unit of currency tomorrow and cost  $(1 + I_t)^{-1}$  today, and redistributes an amount  $\Omega_t$  equally among household members. Its flow budget constraint is given by

$$P_t \Omega_t + (1 + I_t)^{-1} B_{t+1} = B_t + P_t \Pi_t^r \quad (3.7.18)$$

Employed individuals are paid a wage  $w_t$  by firms, receive the amount  $\Omega_t$  and have to pay a fee  $f_t$  to fund the unemployment insurance system. Unemployed individuals receive  $\Omega_t$ , the value of home production  $b$  and unemployment benefits  $w_t^u$ . The budget constraints of employed and unemployed individuals are accordingly given by

$$C_{e,t} = w_t + \Omega_t + f_t \quad (3.7.19)$$

$$C_{u,t} = b + \Omega_t + w_t^u \quad (3.7.20)$$

The unemployment insurance system runs a balanced budget

$$N_t f_t = (1 - N_t) w_t^u \quad (3.7.21)$$

Households choose  $\Omega_t$  and  $B_{t+1}$  to maximize the average utility of its members, equation (3.7.17), subject to the three budget constraints (3.7.19), (3.7.20), (3.7.21). The Euler equation describing the household's optimal consumption path now involves the average marginal utilities at date  $t$  and  $t + 1$

$$\beta E_t \frac{1 + I_t}{\Pi_{t+1}} \left( \frac{N_{t+1} C_{e,t+1}^{-\sigma} + (1 - N_{t+1}) C_{u,t+1}^{-\sigma}}{N_t C_{e,t}^{-\sigma} + (1 - N_t) C_{u,t}^{-\sigma}} \right) = 1 \quad (3.7.22)$$

On the firm side, job creation and pricing decisions are affected by the introduction of imperfect unemployment insurance only to the extent that the household's stochastic discount factor is modified. Moreover, it can be verified that aggregate consumption  $C_t = N_t C_{e,t} + (1 - N_t) C_{u,t}$  is still given by equation (3.7.15). We can now define an equilibrium.

DEFINITION: A competitive equilibrium is a set of plans  $\{C_{e,t}, C_{u,t}, I_t, N_t, \mu_t, \theta_t, \pi_t, w_t, f_t\}$  satisfying equations (3.7.1), (3.7.9), (3.7.12), (3.7.14), (3.7.15), (3.7.19), (3.7.20), (3.7.21) and (3.7.22) given a specification for the exogenous process  $\{Z_t\}$  and initial conditions  $N_{-1}$  and  $I_{-1}$ .

### 3.7.6.2 Qualitative analysis

In order to build intuition for the results that will be obtained in the quantitative analysis, I first seek to obtain analytical results. Let  $R_t = \frac{C_{u,t}}{C_{e,t}}$  denote the ratio of the level of consumption of the unemployed to that of the employed. Given that  $C_t = N_t C_{e,t} + (1 - N_t) C_{u,t}$ , it follows that

$$C_{e,t} = \frac{1}{N_t + (1 - N_t)R_t} C_t$$

$$C_{u,t} = \frac{R_t}{N_t + (1 - N_t)R_t} C_t$$

A couple of simplifying assumptions will make the analysis easier.

ASSUMPTION 1:  $R_t = R \forall t$ .

ASSUMPTION 2: Utility is given by the log of consumption,  $U(C_t) = \ln(C_t)$ .

Period utility  $U_t$  can now be written

$$U_t = \ln(C_t) + (1 - N_t) \ln(R) - \ln[N_t + (1 - N_t)R] \quad (3.7.23)$$

Under perfect insurance, when  $R = 1$ , period utility collapses to  $U_t = \ln(C_t)$ . For reasonable values of  $N$  and  $R$ , the extra term due to the presence of imperfect insurance is negative. Because the utility function is concave, the unequal allocation of a given level of aggregate consumption  $C_t$  between employed and unemployed individuals lowers the level of utility. I now use equation (3.7.20) to derive an expression for the welfare cost of business-cycle fluctuations under imperfect insurance. A second-order approximation of  $U_t$  around its steady-state value gives

$$E(U_t) - U = \frac{E(C_t) - C}{C} - \frac{1}{2} \frac{Var(C_t)}{C^2} - \tau_1 [E(N_t) - N] + \frac{1}{2} \tau_2 Var(N_t) \quad (3.7.24)$$

where  $\tau_1 = \ln(R) + \frac{1-R}{N+(1-N)R}$  and  $\tau_2 = \left( \frac{1-R}{N+(1-N)R} \right)^2$ .  $\tau_2$  is unambiguously positive and  $\tau_1$  is negative for  $N > g(R) = \frac{1-R+R \ln(R)}{\ln(R)(R-1)}$ . This condition is always verified for  $N > 0.5$ .

Thus, under imperfect insurance, fluctuations in employment have an indirect

impact on utility through their influence on consumption but also a direct one as is apparent from the presence of the last two terms. The indirect effect is also at work under perfect insurance but not the direct one ( $\tau_1$  and  $\tau_2$  are equal to zero when  $R = 1$ ). Since  $\tau_1 < 0$  and  $\tau_2 > 0$ , both the average level and the volatility of employment have a positive impact on average utility. The intuition for this result is as follows. The utility of the household is a weighted average of the individual utilities of employed and unemployed workers, with the weights given by the employment level. Since  $U(C_{u,t}) < U(C_{e,t})$ , a lower average employment level decreases mechanically the average utility of the household. Moreover,  $C_{e,t}$  and  $C_{u,t}$  are both convex functions of  $N_t$ . Thus for a given  $C_t$ , fluctuations in employment tend to increase the average levels of consumption of employed and unemployed workers. In the main analysis, I found that average employment is lower than steady-state employment and that the variability of employment is positive under all the policies considered. Therefore, a priori, the impact of the introduction of imperfect insurance on the welfare cost of business cycle fluctuations<sup>5</sup> is ambiguous.

### 3.7.6.3 Quantitative analysis

I now turn to a more quantitative analysis. The calibration of the model is the same as in section 3. There are two new parameters that need to be calibrated,  $R$  and  $w^u$ . Karabarounis and Chodorow-Reis (2014) find a 21% decline in expenditure on nondurable goods and services during unemployment and show that the size of

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<sup>5</sup>It is important to keep in mind that the welfare measure given by equation (24) cannot be used to accurately rank alternative policies. It gives the stochastic steady-state level of welfare that is attained by each policy but does not take into account the transition path from the deterministic steady-state to the stochastic steady-state associated with each policy. The aim of this exercise is merely to build some intuition about how the introduction of imperfect insurance may affect welfare.

this decline is acyclical. In line with those results, unemployment benefits  $w_t^u$  are assumed to evolve so as to target a constant value of  $R$  of 0.8. The two models with perfect and imperfect unemployment insurance share the same steady-state and exhibit almost exactly the same cyclical properties. Thus, the expected utility gap that follows from the introduction of imperfect insurance is approximately equal to

$$E(U_t^{PI}) - E(U_t^{IP}) \approx \tau_1 [E(N_t) - N] - \frac{1}{2}\tau_2 \text{Var}(N_t)$$

where *PI* stands for perfect insurance and *IP* for imperfect insurance. In the baseline calibration,  $\tau_1 = -0.0207$  and  $\tau_2 = 0.0410$ . However because the variance of  $N_t$  is small relative to the employment gap  $E(N_t) - N$ , the effect arising from the lower average level of employment dominates and expected utility is lower under imperfect insurance. Thus the introduction of imperfect insurance makes the asymmetry in unemployment fluctuations more costly. Here, the decrease in average employment arising from this asymmetry is not only costly because of its impact on average consumption but also because unemployed workers have a lower level of utility than employed workers. This should give the central bank additional incentives to stabilize employment. I verify whether this conjecture is true by conducting a welfare analysis. Welfare,  $V_0$ , is measured as the conditional expectation of lifetime utility as of time 0 evaluated at  $\{C_{et}, C_{ut}, N_t\}$

$$V_0 = E_0 \sum_{t=0}^{\infty} \beta^t \left[ N_t \frac{C_{e,t}^{1-\sigma}}{1-\sigma} + (1 - N_t) \frac{C_{u,t}^{1-\sigma}}{1-\sigma} \right]$$

The welfare cost of adopting a regime of price stability instead of the Ramsey

regime,  $\lambda$ , is defined as the fraction of the Ramsey consumption processes of employed and unemployed individuals that a household would be willing to give up to be as well off under the Ramsey policy as under a policy of price stability. It is equal to

$$\lambda = 1 - \left( \frac{V_0^{PS}}{V_0^r} \right)^{\frac{1}{1-\sigma}}$$

Since  $\tau_1$  is an increasing function of  $R$ , a lower average level of employment is more costly for lower values of the consumption ratio. Thus the welfare gain of adopting the optimal policy rather than a policy of price stability should be a decreasing function of  $R$ . This intuition is confirmed in figure 3.8.8, which plots  $\lambda$  and  $R$  jointly for values of the consumption ratio ranging from 0.6 to 1. The additional welfare costs of adopting a policy of price stability brought about by the introduction of imperfect insurance are relatively modest. In the baseline calibration, the welfare costs are only 0.014 percentage points higher than under perfect insurance. This result can be understood by considering equation (3.7.24). In the baseline calibration, the coefficient in front of the consumption gap is much larger than that in front of the employment gap. Even when  $R = 0.6$ ,  $-\tau_1 = 0.1$  is much smaller than  $1/\bar{C} > 1$ . Thus a decrease in average employment mainly affects welfare through its impact on average consumption. Nakajima (2010) studies the design of optimal monetary policy in a framework with efficiency wages and imperfect unemployment insurance, and finds that the welfare costs of price stability are negligible when the idiosyncratic earning loss due to unemployment is acyclical. This section carries out the same type of exercise in a different model with search and matching frictions in the labor market. In this framework, the existence of a consumption gap between employed and unemployed workers makes

the asymmetry in unemployment fluctuations more costly. However, this effect does not seem to be quantitatively important. The introduction of imperfect unemployment insurance does not itself call for much larger deviations from price stability.

## 3.8 Figures

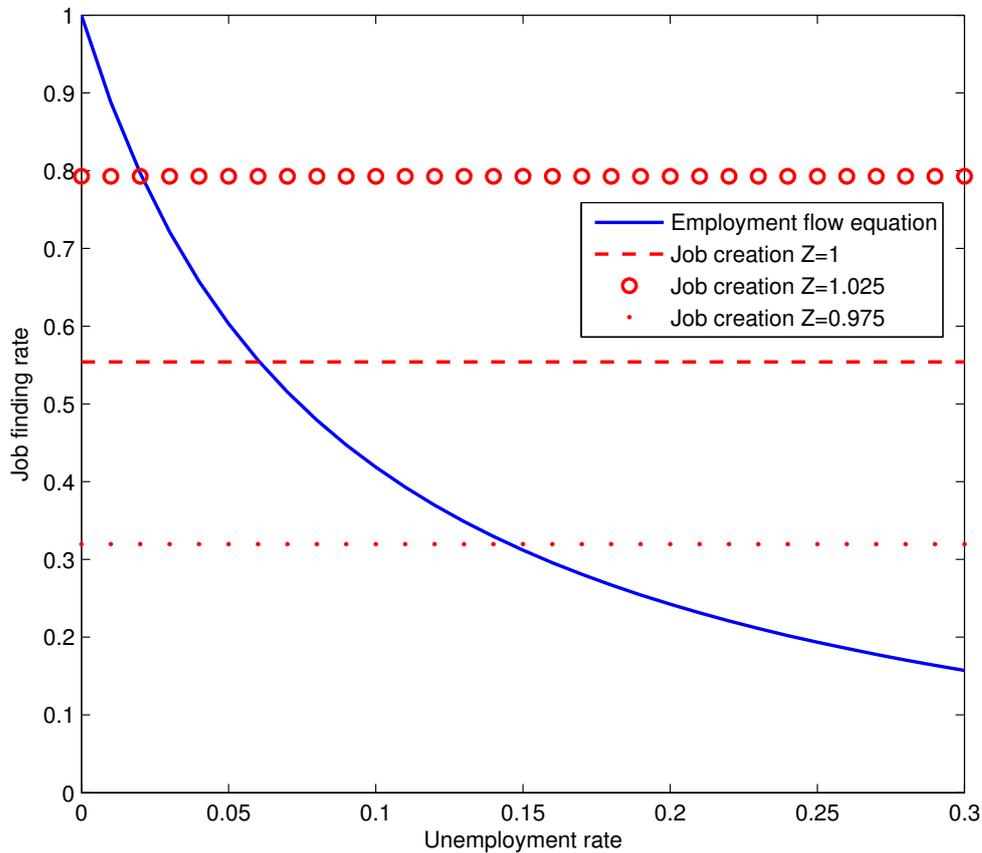


Figure 3.8.1 : Steady-state equilibrium of the model. The solid blue line represents the steady-state version of the employment flow equation. The red, dashed line represents the steady-state version of the job creation equation for  $Z = 1$ . The red, circled line represents the steady-state version of the job creation equation for  $Z = 1.025$ . The red, pointed line represents the steady-state version of the job creation equation for  $Z = 0.975$ . The calibration required to obtain the figure is detailed in section 4.1.

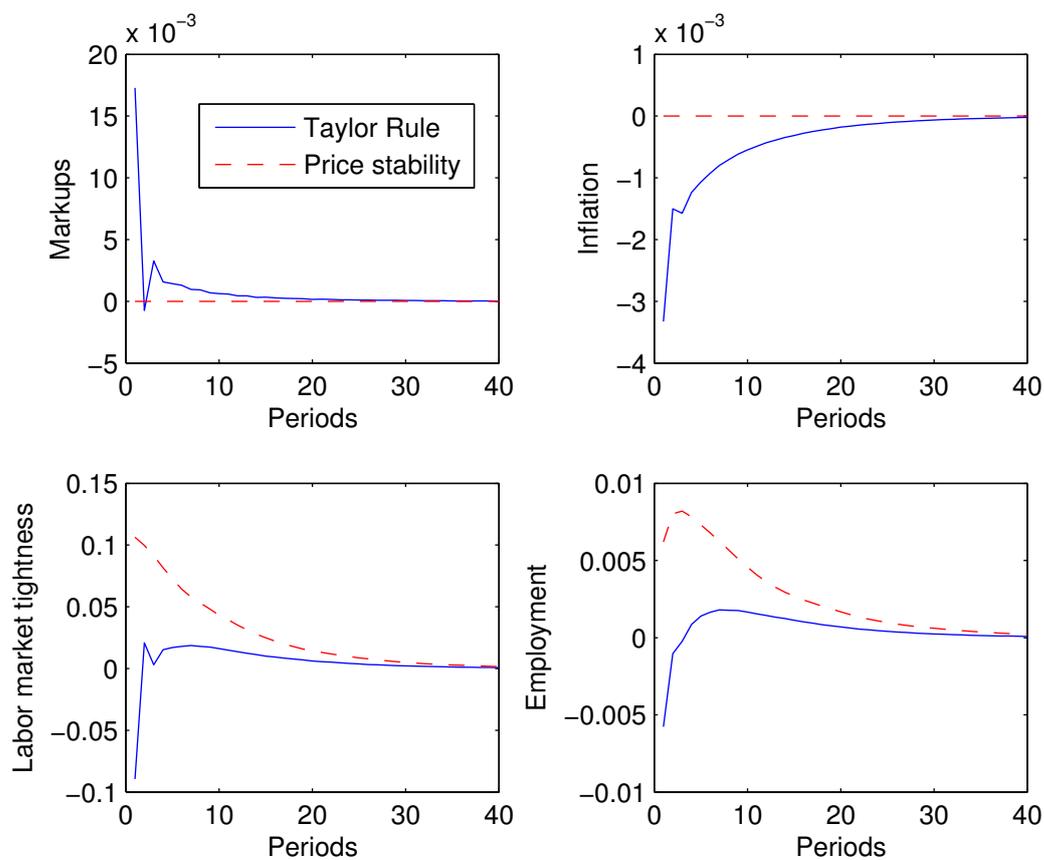


Figure 3.8.2 : Impulse responses of selected variables following a positive productivity shock of one standard deviation under different rules: (1) Taylor rule, (2) Price Stability. The IRFs that are reported are average IRFs. I compute different IRFs for different initial conditions and different sequences of future shocks and average them.

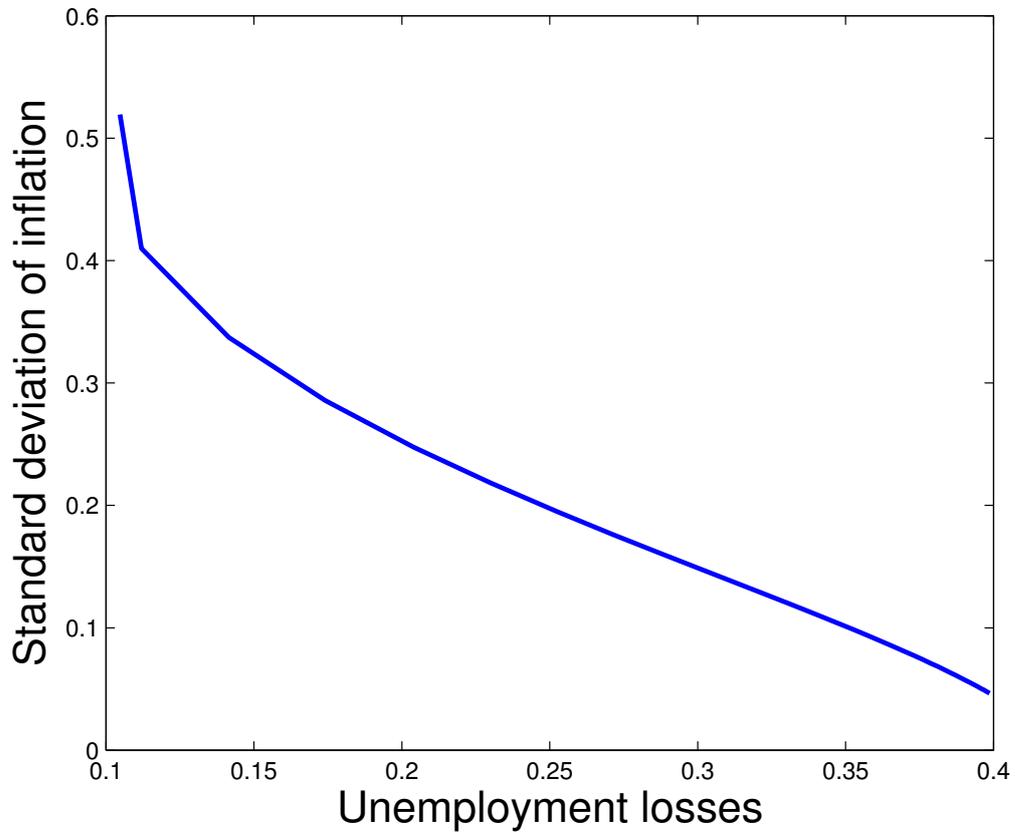


Figure 3.8.3 : Standard deviation of inflation and unemployment losses (difference between average unemployment and steady-state unemployment) in percentage points under alternative monetary regimes

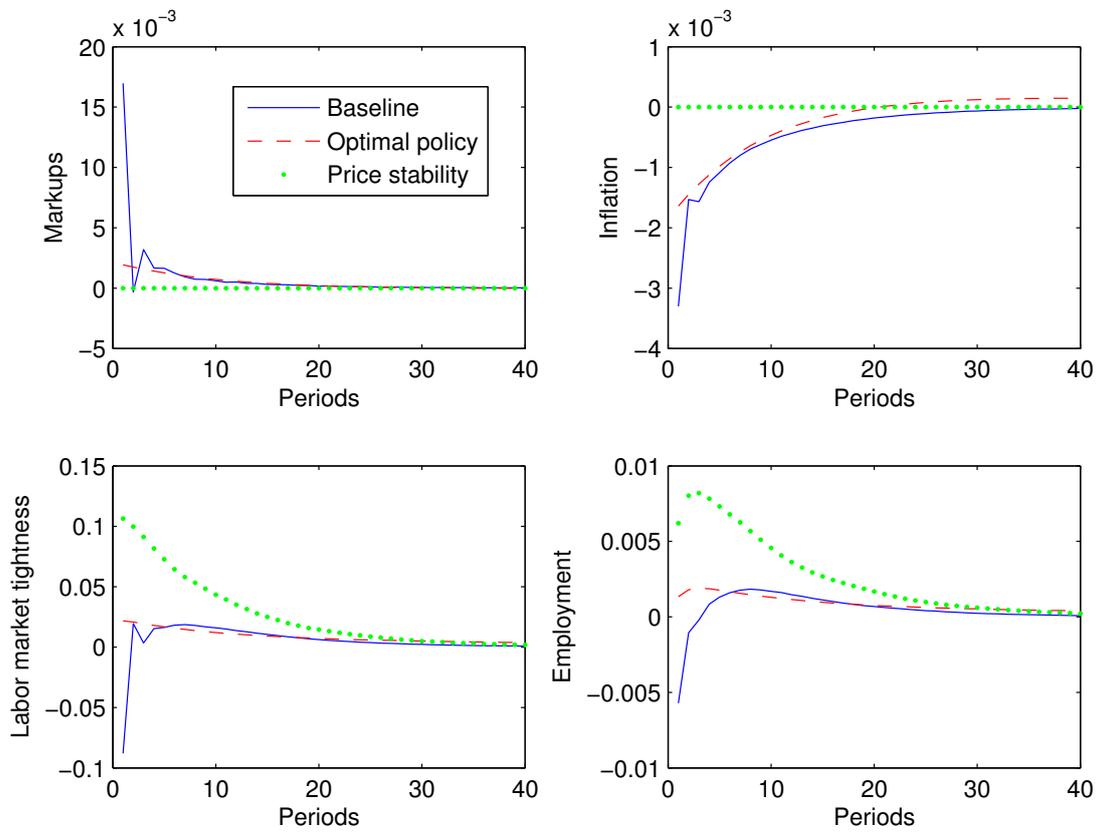


Figure 3.8.4 : Impulse responses of selected variables to a positive productivity shock of one standard deviation under different rules: (1) Baseline, (2) Ramsey policy, (3) Price Stability. The IRFs that are reported are average IRFs. I compute different IRFs for different initial conditions and different sequences of future shocks and average them.

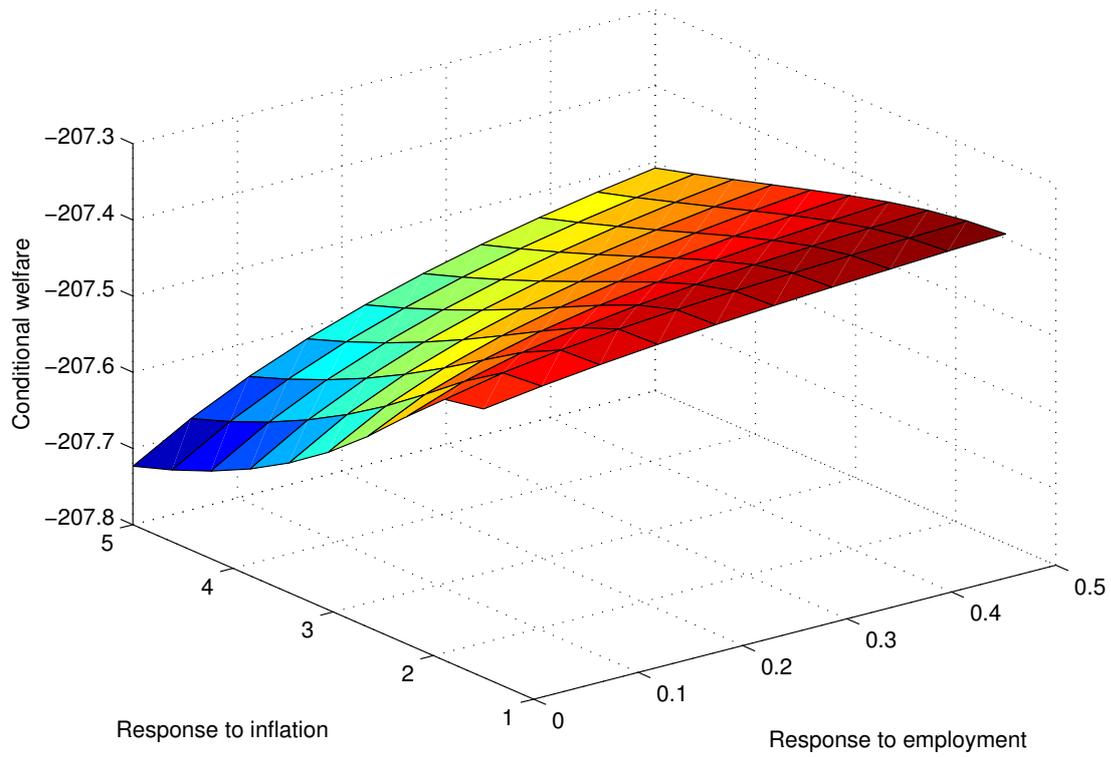


Figure 3.8.5 : Conditional welfare according to the response to inflation and employment when  $b = 0$

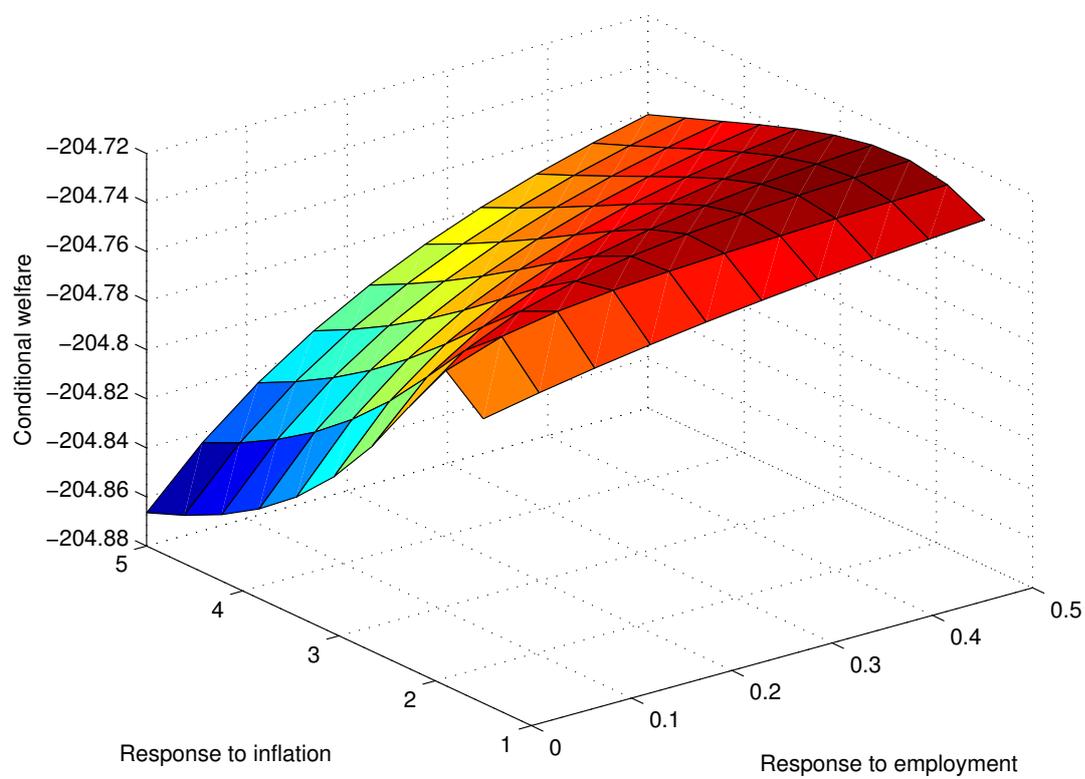


Figure 3.8.6 : Conditional welfare according to the response to inflation and employment when  $b = 0.4$

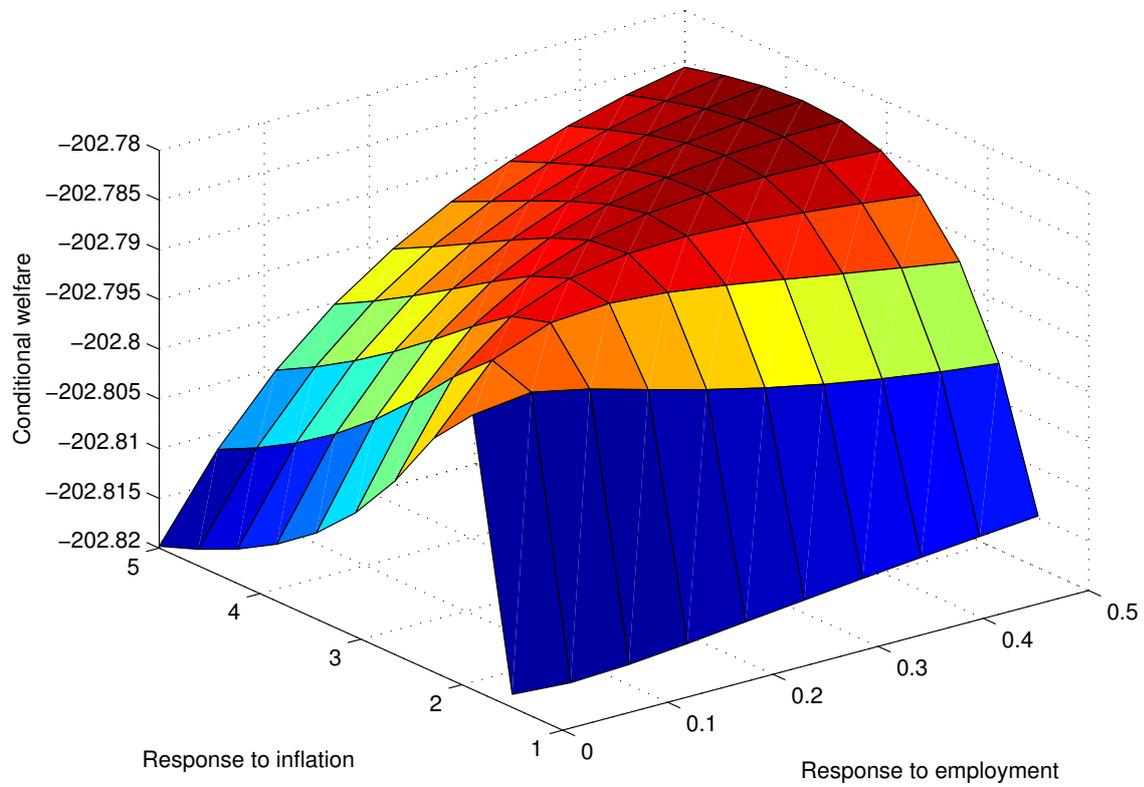


Figure 3.8.7 : Conditional welfare according to the response to inflation and employment when  $b = 0.7$

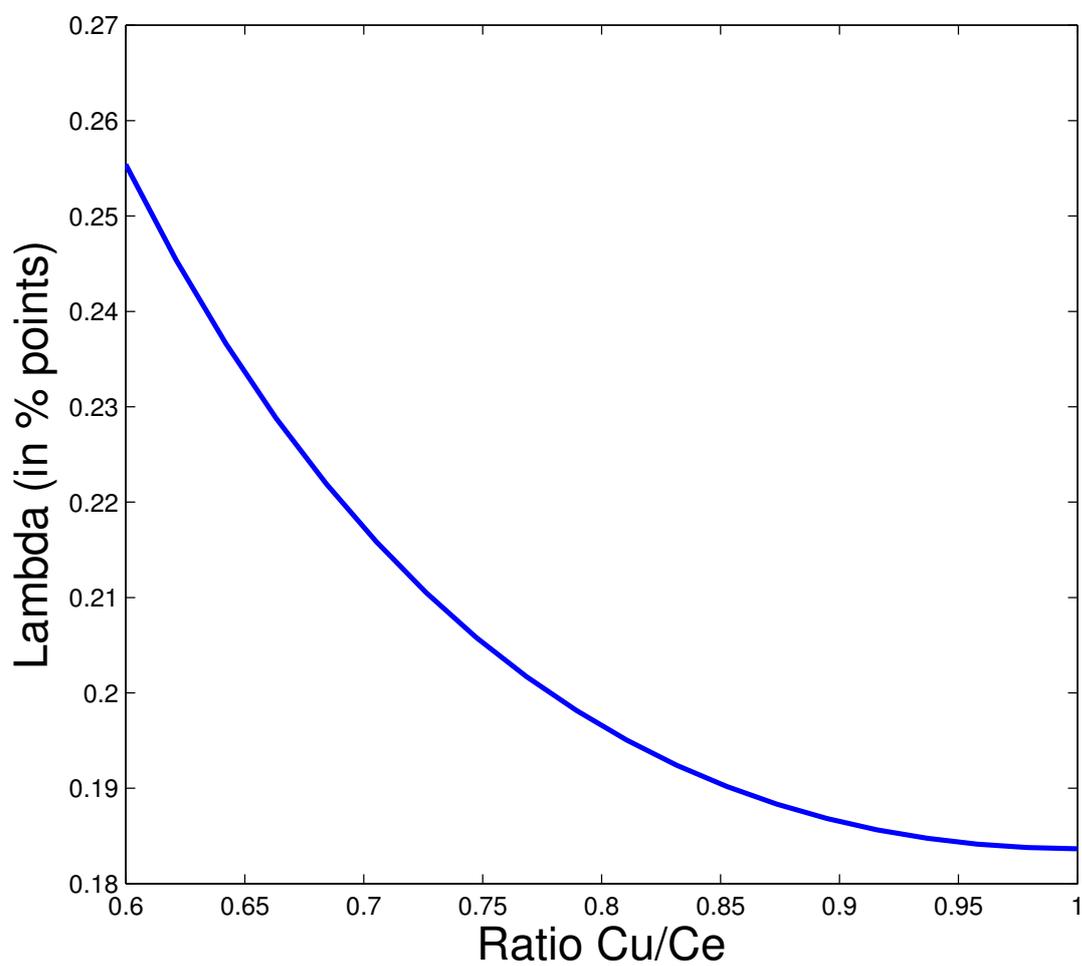


Figure 3.8.8 : Welfare costs of adopting a policy of price stability according to the ratio of the level of consumption of the unemployed to that of the employed

# Conclusion

The goal of this thesis was to contribute to the study of labor market fluctuations. Notably, it broadly tried to address the following set of questions. First, which disturbances underlie labor market fluctuations? Do they find their origin within or outside the labor market? Second, are there key characteristics of the labor market that tend to amplify or dampen the effects of these shocks on economic activity? Third, how costly are these fluctuations and what does this imply for stabilization policies, especially monetary policy?

The first chapter, co-authored with Claudia Foroni and Francesco Furlanetto from Norges Bank, addresses the first question. Its objective is to separately identify two labor market shocks, a labor supply shock and a wage bargaining shock, in the context of a Vector Auto Regressive (VAR) model and quantify their importance for economic fluctuations. In order to do so, we propose a new identification scheme based on sign-restrictions. We show that in different theoretical models and under a wide range of parameter combinations, labor supply shocks generate pro-cyclical fluctuations in unemployment and labor-force participation whereas wage-bargaining shocks lead to counter-cyclical fluctuations in these two variables. This asymmetric behavior of unemployment and participation in response to the

## *Conclusion*

two shocks is used for identification purposes in the VAR. Our main result is that both shocks originating in the labor market are important drivers of output and unemployment fluctuations. Labor supply shocks are particularly relevant to capture macroeconomic dynamics in the long run whereas wage bargaining shocks are more important at short horizons but also play a non-negligible role in the long run, especially for unemployment. While these results provide a tentative answer to the first question, they may also contribute to our understanding of the third. In the dynamic stochastic general equilibrium (DSGE) literature, wage-markup shocks have been assumed to be unimportant at low frequencies (Justiniano et al. 2013) or the only drivers of unemployment in the long-run (Galí et al. 2011). We do not find support for either of these assumptions. This has potentially important consequences for the policy recommendations that are drawn from these models. Indeed wage-markup shocks are a major determinant of the nature of the trade-off between inflation and output stabilization faced by central banks.

The second chapter, co-authored with Vincent Boitier of Paris I Panthéon-Sorbonne University, is related to the second question. A large body of literature has advocated that real wage rigidity is key to explaining the size of labor market fluctuations. While most studies rely on the idea that wage rigidities arise from norms or social consensus (Hall 2005 or Blanchard and Galí 2010), Hall and Milgrom (2008) have instead shown that these rigidities can arise from a bargaining process between employers and job seekers. These authors argued that, during bargaining, the threats points of both employers and job seekers are to delay bargaining than to terminate it. This tends to insulate wages from outside conditions in the labor market and make them endogenously rigid. While this model is getting

increasingly popular in the literature, its complexity has limited its use. Indeed, in its baseline version, an analytical expression for wages cannot be derived. In this chapter, we show that this problem can be circumvented and that a reduced-form wage equation can be derived from an alternating-offer bargaining game when a plausible parameter restriction is imposed. This restriction is supported by empirical evidence presented in Christiano et al. (2015). This simple micro-founded wage equation can readily be used in studies that rely on wage rigidities to generate sizeable labor market fluctuations and that seek to obtain analytical results. When used in a steady-state search and matching model, the value of all the endogenous variables can be expressed as a function of the parameters of the model and of the laws of motion of exogenous variables. In its dynamic version, it also presents the distinct advantage of being consistent with estimates of the short-run elasticity of wages to labor productivity presented in Haefke et al. (2013).

The third chapter addresses the third question. It focuses on the design of optimal monetary policy in the presence of asymmetric unemployment fluctuations. Unemployment tends to increase more in recessions than it decreases in expansions in the United States. According to several authors, this feature may lead to sizeable business-cycle costs (Hairault et al. (2010) and Jung and Kuester (2011)). This paper draws the monetary policy implications of the presence of this costly asymmetry in unemployment fluctuations. I find that, in such an environment, the standard macroeconomic trade-off between inflation volatility and unemployment volatility described in Taylor (1994) becomes a trade-off between inflation volatility and average unemployment. By responding strongly to employment alongside inflation, the monetary authority can reduce unemployment volatility as well as

## *Conclusion*

average unemployment. This reduction in unemployment brings about potentially large welfare gains. Thus, the novelty of this paper is to show that the costs arising from asymmetric unemployment fluctuations provide a rationale for tolerating some inflation volatility in order to stabilize labor market activity. Unlike in most studies that deal with the optimal design of monetary policy, the welfare gains of adopting a policy that reduces macroeconomic volatility rather than a policy of price stability are found to be positive and quite large.

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## Summary

The goal of this thesis is twofold: (1) uncover the sources of labor market fluctuations and evaluate their costs, (2) understand whether monetary policy should be concerned with stabilizing these fluctuations. More precisely, it addresses a certain number of intertwined questions. First, which disturbances underlie labor market fluctuations? Do they find their origin within or outside the labor market? Second, are there key characteristics of the labor market that tend to amplify or dampen the effects of these shocks on economic activity? Third, how costly are these fluctuations, and what does this imply for stabilization policies, especially monetary policy? The first chapter addresses the first question. It identifies and quantifies the importance for economic fluctuations of two labor market shocks, a labor supply shock and a wage bargaining shock, within a Vector Auto Regressive (VAR) model. The shocks are identified with sign restrictions. The main result that emerges from this analysis is that both shocks are important for output and unemployment fluctuations in the short run and in the long run. The second chapter is related to the literature that argues that wage rigidity is key to explaining the size of labor market fluctuations. It derives an analytical solution for the wage from an alternating-offer wage bargaining game à la Hall and Milgrom (2008) under a plausible parameter restriction. The third chapter addresses the third question. It tries to understand how the nature of unemployment fluctuations shapes the optimal design of monetary policy. It shows that, when unemployment fluctuations are asymmetric, the standard macroeconomic trade-off between inflation and unemployment stabilization becomes a trade-off between inflation stabilization and average unemployment. In this environment, it is optimal for the central bank to adopt a dual mandate, that is, a policy that features a strong response to employment alongside inflation. The welfare gains of adopting this policy rather than a policy of price stability are found to be substantial.

## Keywords

Search and matching frictions, labor market shocks, wage rigidity, asymmetric unemployment fluctuations, optimal monetary policy

## Résumé

Cette thèse cherche à expliquer les origines des fluctuations sur le marché du travail, à évaluer le coût de ses fluctuations et à comprendre si la politique monétaire doit chercher à les stabiliser. Notamment elle aborde plusieurs questions. Premièrement, quelles forces sous-tendent les fluctuations du marché du travail ? Ces forces trouvent-elles leur origine sur le marché du travail ? Deuxièmement, le marché du travail a-t-il tendance à amplifier ou atténuer l'effet de ces « chocs » sur l'activité économique ? Finalement, quel est le coût de ces fluctuations et quel rôle doivent jouer les politiques de stabilisation économique, notamment la politique monétaire ? Le premier chapitre cherche à répondre à la première question. Il identifie séparément deux chocs trouvant leur origine sur le marché du travail, un choc d'offre de travail et un choc sur le pouvoir de négociation des salariés, et quantifie leurs contributions respectives aux fluctuations d'un certain nombre de variables macroéconomiques au sein d'un modèle Vector Auto Regressive (VAR). Les deux chocs sont identifiés à l'aide de restrictions de signe. Le résultat principal de cette analyse est que les deux chocs expliquent une part importante des fluctuations de la production et du chômage à court terme comme à long terme. Le deuxième chapitre s'intéresse à la littérature sur les rigidités de salaire. Il montre qu'une forme analytique simple pour le salaire réel peut être obtenue à partir d'un modèle de négociations salariales à offres alternées à la Hall et Milgrom (2008) lorsqu'une restriction paramétrique plausible est imposée. Le troisième chapitre cherche à comprendre comment la nature des fluctuations du chômage affecte la conduite optimale de la politique monétaire. Il montre qu'en présence de fluctuations du chômage asymétriques, l'arbitrage de politique monétaire entre la stabilisation de l'inflation et la stabilisation du chômage décrit par Taylor (1994) devient un arbitrage entre la stabilisation de l'inflation et le chômage moyen. Dans ce cadre, il est préférable pour une banque centrale de mettre un poids important sur la stabilisation de l'activité réelle. En adoptant cette politique plutôt qu'une politique de stabilité des prix, l'autorité monétaire peut générer des gains de bien-être conséquents.

## Mots clés

Frictions d'appariement, chocs sur le marché du travail, rigidité des salaires, fluctuations du chômage asymétriques, politique monétaire optimale