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Redistributive effects and labour market dynamics

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Redistributive Effects and Labour Market Dynamics*

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Abstract

We propose and estimate, using Bayesian techniques, a Dynamic Stochastic General Equilibrium model featuring search and matching frictions with redistributive productivity shocks – which account for fluctuations in the distribution of income across factors of production. We first find supporting evidence that the model is able to replicate cyclical properties of labour market variables. We then disentangle two endogenous sources of labour market amplification: (i) deep habits and (ii) the replacement ratio. The latter appears to be a powerful endogenous amplification mechanism given the shock structure of the model. As far as the exogenous amplification is concerned, labour market variability can be largely explained by redistributive innovations. Finally, contrary to Total Factor Productivity shocks, redistributive shocks increase total hours.

Keywords: redistributive shocks, search and matching frictions, Bayesian estimation

JEL codes: E24, E25, E32, J64

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1 Introduction

Empirical evidence shows that labour market variables, such as vacancies and unemployment, display high volatility over the business cycle. In a seminal study, Shimer (2005) shows that the standard search and matching model driven purely by Total Factor Productivity (TFP) innovations cannot match the volatility of labour market variables as observed in the US data. This lack of amplification is known in the literature as the *unemployment volatility puzzle*. A large number of endogenous mechanisms, together with an alternative set of innovations, have been proposed in order to improve the performance of the standard search and matching model. This study is an attempt to further understand the dynamic properties of the labour market.

To this end, we develop and estimate, using Bayesian techniques, a Dynamic Stochastic General Equilibrium (DSGE) model featuring diminishing returns to the factors of production, search and matching frictions, efficient Nash bargaining and nominal price rigidities. Two main modelling devices are new to our model. First, the DSGE model features a redistributive innovation following Ríos-Rull and Santaella-Llopis (2010). This shock represents a way to allow time variations in the distribution of income across factors of production, in line with empirical evidence. Second, our search and matching model introduces two endogenous sources of amplification: *deep habits* in private consumption and *high total replacement ratios*. We focus on these sources of amplification because they are relatively analytically tractable into a general equilibrium setting.

Our paper addresses the following research questions: *What is the most important exogenous shock for explaining the volatility of labour market variables? And is there evidence for endogenous amplification mechanisms working alongside structural shocks?*

The purpose of our study is not only to empirically validate, through the lenses of the model, the role of endogenous amplification mechanisms but primarily to quantify the extent to which exogenous shocks matter for amplification. To the best of our knowledge, this study is the first to estimate, in the context of a DSGE model featuring search and matching frictions, the role of redistributive innovations. We argue that TFP innovations explain only a small part of the conditional variance of labour market variables over shorter horizons even after accounting for a set of real frictions that have the potential to improve the performance of the standard model. Redistributive shocks, instead, explain large part of the volatility of labour market variables at both short and long horizons.

By focusing purely on standard TFP shocks, a large number of studies has attempted to provide a solution to the *unemployment volatility puzzle*. None of the proposed solutions on their own has been fully satisfactory and subject to scrutiny. The most intuitive solution has been to introduce wage rigidities for newly hired workers in order to generate amplification in labour quantities. Microeconomic evidence by Pissarides (2009) and Haefke et al. (2013) suggests however that wages for newly hired workers are more cyclical than average wages. Based on this evidence, we assume that wages for newly hired workers can be negotiated period by period at no cost.¹ Another approach to solve the anomaly of the standard model is taken by Hagedorn and Manovskii (2008), where a simple calibration exercise is conducted in an otherwise standard search and matching model. Their calibration consists of setting the value of non-market activity close to the value of search to the worker. However, Costain and Reiter (2008) point out that this calibration implies an implausibly large elasticity of unemployment to unemployment benefits. An alternative approach has been proposed by Di Pace and Faccini

¹See Hall (2005a) and Shimer (2005) for a discussion on real wage rigidities. Gertler et al. (2008), Gertler and Trigari (2009) and Blanchard and Gali (2010) introduce this idea into general equilibrium models to show that the model can match the second moments of the data. Christoffel and Kuester (2008) show that, although nominal wage rigidities play an important role for restoring the wage channel in models featuring right-to-manage bargaining, it is the size of profits that lies at the source of amplification and not the assumption of nominal wage rigidities *per se*. The list of solutions to the unemployment volatility puzzle is not exhaustive and includes studies such as Reiter (2007), Guerrieri (2008), Quadrini and Trigari (2008), Gomes (2011), Menzio and Shi (2011), Robin (2011), Alves (2012), Petrosky-Nadeau (2013), amongst others.

(2012), where it is argued that, so long as final good prices are flexible, the standard search and matching model augmented with deep habits in consumption can solve the puzzle through endogenous fluctuations in mark-ups. Their study generates highly cyclical mark-ups and wages and their solution is only applicable to highly habitual economies.

The limited role of TFP innovations calls for a re-assessment of the role of frictions in models with a wider set of productivity innovations. A large number of studies has attempted to improve the performance of the standard search and matching model by simply introducing other sources of exogenous fluctuations into the standard model. Rotemberg (2008) shows that price-elasticity innovations, which can be understood as redistributive innovations between firm's profits and factor payments, have the ability to match the volatility of labour market variables when introduced into a search and matching featuring imperfect competition in the goods market. However, these innovations have the following drawbacks: i) price-elasticity innovations are highly controversial because they entail large shifts in the economy's competitive structure over shorter horizons (see Chari et al., 2007) and ii) the size of the innovations needed to match relative volatilities, as observed by Rotemberg (2008), which can be interpreted as a very large shift in the competitive structure in the goods market. A later study by Krause et al. (2008) quantitatively validates Rotemberg's claim but shows that matching efficiency shocks are important sources of variation in labour market variables.² Building on the work by Gertler et al. (2008), Furlanetto and Goshenny (2013) show that matching efficiency innovations play a minor role in explaining unemployment fluctuations in "normal times", while demand shocks – such as investment-specific and risk premium shocks – as well as bargaining and mark-up shocks are important sources of unemployment fluctuations. A study by Monacelli et al. (2011) highlights the importance of credit shocks in accounting for the observed swings in unemployment during the current crisis. A recent analysis by Zanetti (2013) uncovers that innovations to the separation rate are nearly the most important sources of exogenous variation but finds little role for credit market innovations.

Ríos-Rull and Santaaulàlia-Llopis (2010) introduce another type of productivity shock, which differs from the standard TFP innovation, that play a key role for matching the counter-cyclical fluctuations in the labour share that are present in the data.³ Due to a change in their relative efficiency of factors, redistributive productivity innovations give rise to a re-allocation of resources between factors of production. Their modelling strategy adopts a standard Cobb-Douglas technology that exhibits constant returns to scale at the goods level but exhibits diminishing returns to both labour and capital.⁴ Productivity innovations are decomposed into standard TFP innovations and redistributive innovations in order to analyse the amplification properties of total hours. Innovations that change relative efficiency of the factors of production have the potential, by changing the scale of production of the labour input, to shift the labour demand schedule and to explain a great deal of the variation in total hours. This approach has not yet been quan-

²However, their study is somewhat silent about the standard deviation of mark-up shocks needed to match the volatility of labour market variables.

³A few explanations have been sought to explain this counter-cyclical pattern in the labour share. One explanation is that firms insure workers against income fluctuations (Boldrin and Horvath, 1995; Gomme and Greenwood, 1995). In bad times workers receive an insurance payout, while in good times they pay into the insurance. Fluctuations in the labor share are the result of a risk-sharing arrangement between firms and workers. This state-contingent arrangement can be private but can also take place through public transfers of resources between workers and firms. Another explanation given by Choi and Ríos-Rull (2009) and Cantore et al. (2013) is to introduce of a more general production process, i.e. a *normalised* factor-augmenting CES technology. Shao and Silos (2008) and Colciago and Rossi (2013) show that endogenous firm entry in a model with search and matching frictions can generate, through fluctuations in mark-ups, a fall in the labour share that overshoots in line with the data. This mechanism works only when mark-ups are largely volatile.

⁴The idea of introducing decreasing returns in labour is not new to settings with labour market frictions. Krause et al. (2008) develop and estimate a New Keynesian model featuring a production function with decreasing returns to scale. Building on this work, Di Pace and Faccini (2012) show that decreasing returns coupled with deep habits in consumption à la Ravn et al. (2006), have the potential to change the incentives for vacancy posting after a TFP innovation. Michaillat (2012) also assumes decreasing returns technology and wage rigidities.

titatively assessed in models featuring search and matching frictions. We believe that doing an exercise of the sort is key because search and matching models display an endogenous and time-varying labour share even when redistributive shocks are absent. Our study is therefore an attempt to bridge this gap so as to measure the extent to which redistributive shocks can help match the volatilities of unemployment and vacancies with the data.

The model we present in this study differs from Ríos-Rull and Santaaulàlia-Llopis (2010) in that we not only include both a larger set of frictions and shocks but also estimate the main structural parameters of our model using Bayesian techniques. A redistributive innovation in our model can be interpreted a transfer of resources between factors of production due to shifts in their relative efficiency. Shocks to the relative productivity of factors have the potential to explain the amplification of labour market variables through shifts in the labour demand schedule because they change firm's incentive to hire at the margin by increasing the marginal revenue product of labour directly. Firms are therefore able to employ more workers and to pay higher hourly wages by re-allocating resources towards workers to compensate them because of their higher relative efficiency. This type of exogenous innovations can generate output fluctuations through changes to the labour demand schedule at shorter horizons because - due to our timing assumption - while labour can adjust immediately, capital can only adjust with a lag. A positive redistributive innovation, as introduced in our model, has therefore a large *re-scaling* effect in labour but a substantially smaller *de-scaling* effect on capital.

The study of the fluctuations in the labour share has been linked to the behaviour of inflation. Galí et al. (2001) have argued for a casual relationship between the behaviour of the labour share and inflation in the Euro area. Their study claims that the fall in inflation coincided with that of the labor share over the period of the Great Moderation. The standard New Keynesian model proposes a relationship between inflation and marginal costs but the absence of data on real marginal costs has motivated the use of the labor share of income as a proxy in a number of empirical applications. There is however no unified measure of the labour share that can be used in economic application and the different measures are subject to considerable measurement errors. Moreover, as shown by Krause et al. (2008), in the presence of search and matching frictions, the real marginal cost of production depends on a frictional component as well as the labour share. For this reason, we argue that unemployment, vacancies and inflation can be somewhat informative of the labour share. According to Pissarides (2009) and Sontag and van Rens (2013), wages for newly hired workers are more cyclical relative to average wages. The resulting labour share is equal to the ratio between wage income to newly hired workers and output in model featuring labour market frictions as opposed to the ratio between average wage income and output in model featuring Walrasian labour markets.

Our main findings are as follows. First, the model is able to generate volatilities in unemployment and vacancies so as to match the empirical moments in the US data. As far as the exogenous amplification is concerned, we find that the labour market variability can be mainly explained by redistributive innovations, while TFP innovations play a larger role at explaining the volatility of unemployment and vacancies only on impact. The estimated dispersion of redistributive shocks is relatively low, which provides an improvement over models where labour market fluctuations are driven by price-elasticity shocks. As far as the endogenous amplification mechanisms are concerned, high mean estimates of the replacement ratio provide strong support in favour of the well known Hagedorn and Manovskii (2008) calibration under our proposed shock structure. The estimates of deep habits in consumption are statistically significant but not sufficiently high to generate amplification in labour market variables. The deep habit mechanism adds however endogenous persistence and helps generate hump-shaped responses in output, consumption and inflation. In addition, our model generates the prediction that, due to the assumptions of nominal price stickiness, TFP innovations reduce employment (on impact) as well as total hours, while redistributive shocks increase employment and total hours. Finally, due to the assumptions of nominal price stickiness, deep habits and search frictions, our model

is able to match the sign of the responses of the labour share to a TFP innovation but it is unable to replicate labour share overshooting.

The paper is organised as follows. Section 2 presents the model. Section 3 discusses the endogenous amplification mechanisms at work in the model as well as the shock structure of the model. Section 4 illustrates the estimation strategy, evaluates the quantitative performance of the model and presents some robustness exercises. The final section concludes. An appendix complements the paper by providing: a detailed explanation of the dataset; the full set of the DSGE model equilibrium conditions, linearised equations as well as the derivation of the deterministic steady state; and an analysis aiming at disentangling the effects of non-standard modeling features.

2 The Model

The model features labour market frictions, deep habits in consumption, nominal rigidities and a technology that exhibits constant return to scale technology in both labour and capital. This type of technology exhibits diminishing marginal returns to each individual factor of production. The monetary authority follows a Taylor rule that targets the deviations of inflation from its steady state value and output growth but it is operationally implemented with some degree of inertia. The dynamics of the model is driven by seven exogenous AR(1) processes: two productivity shocks - a TFP shock and a redistributive shock -, a preference shock, an investment-specific technology shock, a government expenditure shock, a monetary shock and a matching efficiency shock.

2.1 The Labour Market

The labour market is frictional in that firms fill jobs by posting vacancies at a unit cost. The technology that matches jobs with workers is given by

$$m_t = \bar{m}_t v_t^\gamma \tilde{u}_t^{1-\gamma}, \quad (1)$$

where m_t denotes the aggregate flow of hires at time t , \tilde{u}_t denotes job searchers and v_t aggregate vacancies. The matching efficiency innovation, \bar{m}_t , follows an AR(1) process of the form

$$\ln \left(\frac{\bar{m}_t}{\bar{m}} \right) = \varrho_m \ln \left(\frac{\bar{m}_{t-1}}{\bar{m}} \right) + \varepsilon_{mt} \quad \text{with} \quad \varepsilon_{mt} \sim N(0, \varsigma_m), \quad (2)$$

where ϱ_m is the persistence of the shock and ς_m the standard deviation of the innovation ε_{mt} . The parameter $\gamma \in (0, 1)$ is the elasticity of the matching function with respect to aggregate vacancies. At time t , vacancies are filled with probability $q(\theta_t) \equiv m_t/v_t = \bar{m}_t \theta_t^{\gamma-1}$, where $\theta_t = v_t/\tilde{u}_t$ denotes a measure labour market tightness. The assumption of constant returns to scale in the matching function implies that workers find jobs with probability $m_t/\tilde{u}_t = \theta_t q(\theta_t)$.

Following Ravenna and Walsh (2008) and Blanchard and Gali (2010), we assume that workers matched with firms at the beginning of time t become immediately productive. The law of motion for aggregate employment, denoted by n_t , can be written as

$$n_t = m_t + (1 - \rho) n_{t-1}, \quad (3)$$

where ρ is the exogenous separation rate. The number of searchers are given by

$$\tilde{u}_t = 1 - (1 - \rho) n_{t-1}. \quad (4)$$

This condition states that the stock of workers searching for a job at time t is given by the measure of workers who did not have a job at $t - 1$, $1 - n_{t-1}$, plus the measure of workers who lost their job at the end of $t - 1$, ρn_{t-1} . The unemployment rate is defined as

$$u_t = 1 - n_t. \quad (5)$$

2.2 The Household's Problem

The economy is populated by a unit measure of identical households, indexed by $j \in [0, 1]$. Workers within each households can either be employed or unemployed. While the employed members of the household at firm i earn a nominal hourly wage rate W_{it}^j and suffer disutility while working h_{it}^j amount of hours, the unemployed members receive unemployment benefits for the amount \bar{b} . We assume that the workers can perfectly insure against idiosyncratic shocks within the household. Households have preferences over different consumption varieties, indexed by $i \in [0, 1]$. Following Ravn et al. (2006), we assume that household preferences exhibit external habit formation in consumption at the good-specific level rather than at the aggregate level. This consumption externality has been coined as external deep habits or, alternatively, as *catching-up with the Joneses good by good*.

Household j solves an intra-temporal and an inter-temporal problem. The former is to minimise total consumption expenditure, $\int_0^1 P_{it} c_{it}^j di$, subject to the following consumption object

$$x_{ct}^j = \left[\int_0^1 \left(c_{it}^j - \zeta_c s_{it-1}^c \right)^{1-1/\epsilon} di \right]^{1/(1-1/\epsilon)}, \quad (6)$$

where s_{it}^c denotes the stock of external habit in the consumption of good i at time t , $\zeta_c \in [0, 1]$ the degree of external habit formation of each variety and ϵ the intra-temporal elasticity of substitution of habit adjusted consumption across varieties. The stock of habits for each variety i evolves over time according to the following law of motion

$$s_{it}^c = \vartheta_c s_{it-1}^c + (1 - \vartheta_c) c_{it}, \quad (7)$$

where the parameter $\vartheta_c \in (0, 1)$ measures the speed of adjustment of the habit stock to changes in the average level of consumption of variety i . A value of ϑ_c equal to 0 implies that the habit stock exhibits no persistence. By minimising expenditure with respect to c_{it}^j , we can derive the individual consumption demands of variety i by household j

$$c_{it}^j = \left(\frac{P_{it}}{P_t} \right)^{-\epsilon} x_{ct}^j + \zeta_c s_{it-1}^c, \quad (8)$$

where $P_t \equiv \left[\int_0^1 P_{it}^{1-\epsilon} di \right]^{\frac{1}{1-\epsilon}}$ is the nominal price index and P_{it} is the price of good i . The consumption demand for each variety i is decreasing in the relative price of good i , P_{it}/P_t , and increasing in both the level of habit adjusted consumption, x_{ct}^j , and, for positive values of ζ_c , in the external level of consumption habits, s_{it-1}^c . Nominal expenditure in habit adjusted consumption can be also expressed as $P_t x_{ct}^j = \int_0^1 P_{it} \left(c_{it}^j - \zeta_c s_{it-1}^c \right) di$.

The second problem of household j is to maximise his or her lifetime utility by choosing the consumption object, x_{ct}^j , and a set of state contingent bonds, D_t^j . The period utility depends positively on habit-adjusted consumption and negatively on labour supply and it is defined as

$$\mathcal{U} \left(x_{ct}^j, h_{it}^j, n_{it}^j \right) = \frac{\left[x_{ct}^j - \ln(z_t) \right]^{1-\sigma} - 1}{1-\sigma} - \chi \int_0^1 n_{it}^j \frac{\left(h_{it}^j \right)^{1+\varphi}}{1+\varphi} di, \quad (9)$$

where χ is a constant. The term n_{it}^j denotes the employment rate by household j . Here, σ denotes the inverse of the inter-temporal elasticity of substitution between the consumption object at time t and $t+1$ and parameter φ the inverse of the Frisch elasticity of labour supply. The variable z_t is a preference shock that evolves according to the following law of motion

$$\ln z_t = \varrho_z \ln z_{t-1} + \varepsilon_{zt} \quad \text{with} \quad \varepsilon_{zt} \sim N(0, \varsigma_z), \quad (10)$$

where ϱ_z is the persistence of the preference shock and ς_z is the standard deviation of the innovation ε_{zt} . As the preference shock enters additively in the utility function, a positive

preference shock will lead to higher levels of habit adjusted consumption in order to maintain the same level of utility as in Ravn et al. (2006). The life-time utility of household j is given by

$$\mathcal{V}_t = E_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} \mathcal{U} \left(x_{c\tau}^j, n_{i\tau}^j, h_{i\tau}^j \right), \quad (11)$$

where E_t is the mathematical expectation operator conditional on the information available at time t and $\beta \in (0, 1)$ is the subjective discount factor. The nominal budget constraint of household j is given by

$$P_t x_{ct}^j + P_t \tilde{x}_t + P_t i_t^j + Q_t D_t^j = D_{t-1}^j + \int_0^1 W_{it}^j n_{it}^j h_{it}^j di + (1 - n_t^j) P_t \bar{b} + P_t r_{kt} k_{t-1}^j + \Phi_t^j + P_t \bar{\tau}_t^j, \quad (12)$$

where \tilde{x}_{ct} is equal to $\zeta_c \int_0^1 \frac{P_{it}}{P_t} s_{it-1}^c di$, i_t^j investment in physical capital by the household, the term $(1 - n_t^j) P_t \bar{b}$ are the benefits received by the unemployed members of household j , k_{t-1}^j the amount of physical capital, r_{kt} the real rental rate of capital, Φ_t^j are the aggregate nominal profits distributed to each household j at time t and $\bar{\tau}_t^j$ the lump-sum taxes paid by the household to the government at time t . We denote by Q_t the price of the nominal bond, D_t , that pays one unit of money at maturity. We assume that households face an additional constraint that prevents them from engaging in Ponzi games. For each household j , the law of motion of employment evolves according to

$$n_t^j = (1 - \rho) n_{t-1}^j + \theta_t q (\theta_t) u_t^j. \quad (13)$$

And the law of motion of physical capital is

$$\left[1 - \frac{\kappa_i}{2} \left(\frac{i_t^j}{i_{t-1}^j} - 1 \right)^2 \right] z_{it} i_t^j = k_t^j - (1 - \Gamma) k_{t-1}^j, \quad (14)$$

where κ_i is an adjustment cost associated with changes in investment and z_{it} is an investment-specific shock that obeys the following exogenous process

$$\ln(z_{it}) = \varrho_i \ln(z_{it-1}) + \varepsilon_{it} \quad \text{with} \quad \varepsilon_{it} \sim N(0, \varsigma_i). \quad (15)$$

Household j maximises (11) by choosing the processes x_{ct}^j and D_t^j subject to condition (12) and (14). The household takes Φ_t^j , \tilde{x}_t^c , P_t , D_{t-1}^j , k_{t-1}^j and $\bar{\tau}_t^j$ as given. The first order conditions of this problem are

$$\lambda_t^j = \left[x_{ct}^j - \ln(z_t) \right]^{-\sigma}, \quad (16)$$

and

$$Q_t = \frac{1}{R_t} = \beta E_t \frac{\lambda_{t+1}^j}{\lambda_t^j \pi_{t+1}}, \quad (17)$$

$$\lambda_t^j q_{kt} = \lambda_{t+1}^j \beta E_t \left[r_{kt+1} + \lambda_{t+1}^j \beta (1 - \Gamma) q_{kt+1} \right], \quad (18)$$

$$\begin{aligned} \lambda_t^j &= q_{kt} \lambda_t^j z_{it} \left\{ \left[1 - \frac{\kappa_i}{2} \left(\frac{i_t^j}{i_{t-1}^j} - 1 \right)^2 \right] - \kappa_i \frac{i_t^j}{i_{t-1}^j} \left(\frac{i_t^j}{i_{t-1}^j} - 1 \right) \right\} + \\ &+ \beta \kappa_i E_t q_{kt+1} \lambda_{t+1}^j z_{it+1} \left(\frac{i_{t+1}^j}{i_t^j} \right)^2 \left(\frac{i_{t+1}^j}{i_t^j} - 1 \right), \end{aligned} \quad (19)$$

where π_t denotes the gross inflation rate at time t , R_t the policy rate set by the central bank, λ_t^j and $\lambda_t^j q_{kt}$ is the Lagrange multiplier associated with constraint (12) and (14). The first of these equations represents the marginal utility of habit adjusted consumption, the second equation

the standard Euler condition that sets the marginal cost of habit adjusted consumption at time t equal to the marginal benefit at time $t + 1$, equation (18) is the Euler equation with respect to capital and, finally, equation (19) describe the relationship between investment dynamics and the relative price of capital, also known as Tobin's q .

In addition, the non-arbitrage condition with respect to employment is given by

$$\mathcal{W}_{it}^j = \frac{W_{it}^j}{P_t} h_{it}^j - \left[\bar{b} + \frac{\chi (h_{it}^j)^{1+\varphi}}{(1+\varphi) \lambda_t^i} \right] + E_t \beta \frac{\lambda_{t+1}^j}{\lambda_t^j} (1-\rho) \mathcal{W}_{it+1}^j [1 - \theta_{t+1} q(\theta_{t+1})], \quad (20)$$

where \mathcal{W}_{it}^j denotes the net value to the household of having an additional worker employed at firm i . The net value of employment to household j is equal to the flow value of employment, wage income minus the opportunity cost of being employed at firm i , plus the net continuation value of employment at the firm minus the net value of finding an equivalent job elsewhere whilst searching for a job at time t . It is worth noting that the aggregate labour market conditions influence employment at the household level through the job finding rate, $\theta_t q(\theta_t)$.

2.3 The Firm's Problem

There is a unit mass of monopolistically competitively large firms, each of which produces a particular variety of the final good i . Each variety i is produced using labour, $n_{it} h_{it}$, and capital k_{it-1} . The labour input can vary both along the intensive margin, h_{it} , and the extensive margin, n_{it} , but physical capital can only vary along the extensive margin. We assume that, while firms can hire workers immediately, firms can only adjust capital at time $t + 1$. However, due to the calibration of the Frisch elasticity of labour supply, output adjusts more along the labour extensive margin. In addition to the TFP innovations we introduce a redistributive shock that changes the relative factor payments. The production process is given by the following function

$$y_{it} = c_{it} + g_{it} + i_{it} = a_t (\Gamma h_{it} n_{it})^{\alpha_t} k_{it-1}^{1-\alpha_t}, \quad (21)$$

where variable y_{it} denotes the output of firm i , g_{it} public consumption and α_t denotes the elasticity of total output with respect to the labour input. The value of TFP in steady state, a , is used as a scale factor that normalises output to 1 and the constant Γ controls the extent to which re-distributional effects affect output directly or indirectly. We will explain extensively in Subsection 3.1 that these scale factors are of highly important for our analysis. As in Krause et al. (2008), Di Pace and Faccini (2012) and Michaillat (2012), the production function exhibits decreasing returns to scale in labour input. While these papers assume that employment is the only input of production, we introduce both physical capital and hours in addition to employment. The variable α_t is the redistributive shock that evolves according to

$$\ln(\alpha_t/\alpha) = \varrho_\alpha \ln(\alpha_{t-1}/\alpha) + \varepsilon_{\alpha t} \quad \text{with} \quad \varepsilon_{\alpha t} \sim N(0, \varsigma_\alpha), \quad (22)$$

where α is the steady state elasticity of output with respect to labour, ϱ_α the persistence of the shock and ς_α the standard deviation of the innovation $\varepsilon_{\alpha t}$. The TFP shock follows a stochastic process of the form

$$\ln(a_t/a) = \varrho_a \ln(a_{t-1}/a) + \varepsilon_{at} \quad \text{with} \quad \varepsilon_{at} \sim N(0, \varsigma_a), \quad (23)$$

where ϱ_a is the persistence of the technology shock and ς_a is the standard deviation of the innovation ε_{at} .

Each firm i faces a consumption demand schedule that can be retrieved from the inter-temporal maximisation problem of the households. By adding up the cross-sectional individual

consumption demands, we can recover the demand for good i . Analytically, we simply integrate expression (8) over j to obtain

$$c_{it} = \left(\frac{P_{it}}{P_t} \right)^{-\epsilon} x_{ct} + \zeta_c s_{it-1}^c, \quad (24)$$

where $x_{ct} = \int_0^1 x_{ct}^i di$ is a habit adjusted measure of aggregate consumption across households. The individual demand of good i depends on the sum of a price elastic term, $(P_{it}/P_t)^{-\epsilon} x_{ct}$, and a price inelastic term $\zeta_c s_{it-1}^c$. An expansion in aggregate demand increases the weight of the price elastic term in the demand function, which implies that the price elasticity of demand for good i is positively related to aggregate demand. Since mark-ups are inversely related to the price elasticity of demand, the deep habits mechanism predicts that demand/supply shocks generate counter-cyclical/pro-cyclical movements in mark-ups. The assumption of monopolistic competition entails that each firm sets their price by taking the prices of all other firms as given.

Unlike the individual demands for private consumption, the demands of public consumption and investment for each variety are not subject to deep habits and are given by, respectively,

$$g_{it} = \left(\frac{P_{it}}{P_t} \right)^{-\epsilon} g_t, \quad (25)$$

$$i_{it} = \left(\frac{P_{it}}{P_t} \right)^{-\epsilon} i_t. \quad (26)$$

Real profits of firm i at time t can be written

$$\phi_{it} = \frac{P_{it}}{P_t} (c_{it} + g_{it} + i_{it}) - w_{it} n_{it} h_{it} - r_{kt} k_{t-1} - \kappa_v v_{it} - \mathcal{A}_{it},$$

where w_{it} denotes real hourly wages for newly hired workers, \mathcal{A}_{it} is defined as a quadratic adjustment costs in output terms associated to price adjustments, $\frac{\kappa_p}{2} \left(\frac{P_{it}}{P_{it-1} \tilde{\pi}_t} - 1 \right)^2 y_t$, $\tilde{\pi}_t = \pi_{t-1}^{\omega_p} \pi^{1-\omega_p}$ and ω_p is the degree of price indexation to past inflation. The problem of firm i is to choose the processes c_{it} , s_{it}^c , P_{it} and v_{it} so as to maximise the present discounted value of expected profits,

$$E_t \sum_{\tau=t}^{\infty} Q_{t,\tau} P_{\tau} \phi_{i\tau},$$

subject to the technological constraint, equation (21), the law of motion of employment,

$$n_{it} = (1 - \rho) n_{it-1} + v_{it} q(\theta_t) \quad (27)$$

private aggregate demand for good i , equation (24) and the law of motion of the stock of habit, equation (7). As is standard in the search and matching literature, opening vacancies is costly in that the resources that could be otherwise devoted to producing the consumption good are diverted to hiring. The unit costs of vacancy posting are given by κ_v . Firms open vacancies at the beginning of each period to potentially match these to job seekers. When posting vacancies, firm i takes the job filling probability as given by the measure of labour market tightness.

The first order conditions with respect to private consumption, the habit stock, prices, vacancies and physical capital are respectively:

$$\frac{1}{\mu_{it}} = \frac{P_{it}}{P_t} - \nu_{it}^c + (1 - \vartheta_c) \psi_{it}^c, \quad (28)$$

$$\psi_{it}^c = \beta \vartheta_c E_t \frac{\lambda_{t+1}}{\lambda_t} \psi_{it+1} + \beta \zeta_c E_t \frac{\lambda_{t+1}}{\lambda_t} \nu_{t+1}^c, \quad (29)$$

$$\begin{aligned}
c_{it} + g_{it}(1 - \epsilon) + g_{it} \frac{\epsilon}{\mu_{it}} + i_{it}(1 - \epsilon) + i_{it} \frac{\epsilon}{\mu_{it}} + \beta \kappa_p E_t \frac{\lambda_{t+1}}{\lambda_t} \frac{P_{it+1}}{P_{it} \tilde{\pi}_{t+1}} \left(\frac{P_{it+1}}{P_{it} \tilde{\pi}_{t+1}} - 1 \right) y_{t+1} = \nu_{it}^c x_{ct} \epsilon + \\
+ \frac{P_{it}}{P_{it-1} \tilde{\pi}_t} \left(\frac{P_{it}}{P_{it-1} \tilde{\pi}_t^p} - 1 \right) y_t,
\end{aligned} \tag{30}$$

$$\mathcal{J}_{it} = \frac{\kappa_v}{q(\theta_t)}, \tag{31}$$

and

$$r_{kt} = (1 - \alpha_t) \frac{y_{it}}{\mu_{it} k_{it-1}}, \tag{32}$$

where $1/\mu_{it}$, ν_{it}^c , ψ_{it}^c and \mathcal{J}_{it} are the Lagrange multipliers associated with constraints (21), (24), (7) and (27) respectively. The shadow value of output, denoted by $1/\mu_{it}$, is the contribution of an additional unit of output to the profits of the firm. Alternatively, we can interpret μ_{it} as a measure of mark-ups, defined as the price of good i over its marginal cost of production. The first order condition with respect to private consumption, equation (28), sets the inverse of the mark-up equal to the sum of three components. The first two terms in these two equations represent the current period revenues associated with a marginal increase in sales. This is equal to the revenue P_{it}/P_t , obtained on the marginal sale net of the forgone revenue on inframarginal quantities, ν_{it} . The third component denotes the shadow value of future consumption. Absent nominal price rigidities, the awareness of high future profits, coupled with the notion that consumers form habit at the individual level, induces firms to give up current profits in order to lock-in new consumers into customer/firm relationships. Therefore, firms face an inter-temporal trade-off between current and future profits (see also Melina and Villa, 2013). Adding nominal price rigidities changes the pricing incentive of firms and, as it turns out with most models featuring nominal rigidities, the impact on mark-ups becomes conditional upon the source of the shock, whether it is a supply-side or a demand-side shock. By adding price rigidities, we can formulate equation (30) to describe the dynamics of prices under deep habits in an analogous fashion as the standard New Keynesian Phillips curve.⁵

In addition, the non-arbitrage condition with respect to employment is

$$\mathcal{J}_{it} = \alpha_t \frac{y_{it}}{\mu_{it} n_{it}} - w_{it} h_{it} + \beta (1 - \rho) \frac{\lambda_{t+1}}{\lambda_t} \mathcal{J}_{it+1}, \tag{33}$$

where \mathcal{J}_{it} is the marginal value of employment at the firm. This value is equal to the current flow value of employment, which in turn is equal to the marginal revenue product of employment minus wage costs, plus the continuation value of employment at the firm. By combining (31) with (33), we can find an expression for the job creation condition

$$\frac{\kappa_v}{q(\theta_t)} = \alpha_t \frac{y_{it}}{\mu_{it} n_{it}} - w_{it} h_{it} + \beta (1 - \rho) E_t \frac{\lambda_{t+1}}{\lambda_t} \frac{\kappa_v}{q(\theta_{t+1})}. \tag{34}$$

This condition states that firms will expand employment up to the point where the marginal cost equals the marginal benefit of employing an additional worker. The LHS of equation (34) measures the expected cost of increasing employment at the margin. Since the adjustment costs in our set-up are interpreted as forgone output, the expected cost of employment must be equal to the additional cost of posting a vacancy, denoted by κ_v , times the average duration of a vacancy, $1/q(\theta_t)$. Fluctuations in mark-ups due to deep habits and nominal price rigidities alter the job creation condition directly.

⁵See Appendix C for a derivation.

2.4 Wage and Hours Bargaining

Wages and hours per worker are determined by maximising the joint surplus of a match following a Nash bargaining protocol. Formally, hours and wages are negotiated according to the following bargaining game

$$\max_{W_{it}, h_{it}} \mathcal{W}_{it}^\xi \mathcal{J}_{it}^{1-\xi},$$

where ξ is the nominal bargaining power of the worker. In the process of wage negotiation, a firm-worker pair takes the price level P_t as given so bargaining over the nominal wage makes no difference relative to wage negotiation over the real wage. In other words, choosing the nominal wage rate pins down the real wage and *viceversa*. Without impediments to wage adjustments, the desired split of the surplus is achieved and this split turns out independent of the unit of account. The solution to Nash bargaining problem is given by

$$\xi \mathcal{J}_{it} = (1 - \xi) \mathcal{W}_{it}. \quad (35)$$

The real wage paid to newly hired workers is

$$w_{it} h_{it} = \xi \left[\alpha_t \frac{y_{it}}{\mu_{it} n_{it}} + \kappa \beta (1 - \rho) E_t \frac{\lambda_{t+1}}{\lambda_t} \theta_{t+1} \right] + (1 - \xi) \left[\bar{b} + \chi \frac{h_{it}^{1+\varphi}}{\lambda_t (1 + \varphi)} \right]. \quad (36)$$

Unlike in the Walrasian labour market setting, the real wage is a function of the marginal revenue product of employment, the opportunity cost of replacing the worker and the opportunity cost of being employed at firm i . The higher the bargaining power of firms, $(1 - \xi)$, the higher the weight on the outside option of the worker, the higher the wages and the lower profits. Hours per workers are chosen optimally such that the marginal revenue product of labour equals the marginal rate of substitution

$$\alpha_t^2 \frac{y_{it}}{\mu_{it} n_{it} h_{it}} = \frac{\chi h_{it}^\varphi}{\lambda_t}. \quad (37)$$

This result implies that hours worked are independent of the hourly wage under Nash bargaining.

2.5 Closing the model

We assume symmetry across firms and households, which entails identical choices for all variables, and we define aggregate variables as averages. Therefore, we have that $n_{it} = n_{it}^j = n_t$, $h_{it} = h_{it}^j = h_t$, $v_{it} = v_t$, $c_{it}^j = c_{it} = c_t$, $g_{it} = g_t$, $i_{it} = i_t^j = i_t$, $k_{it} = k_t^j = k_t$, $s_{it}^c = s_t^c$, $\mu_{it} = \mu_t$, $\psi_{it}^c = \psi_t^c$, $\nu_{it}^c = \nu_t^c$, $P_{it} = P_t$, $W_{it}^j = W_{it} = W_t$ for all t . All households pay the same taxes, $\bar{\tau}_t = \bar{\tau}_t^j$.

The model is closed by specifying a monetary rule. The monetary authority is assumed to set the nominal interest rate R_t following a Taylor interest rate rule of the form:

$$\frac{R_t}{R} = \left(\frac{R_t}{R} \right)^{r_r} \left[\left(\frac{\pi_t}{\pi} \right)^{r_\pi} \left(\frac{y_t}{y_{t-1}} \right)^{r_y} \right]^{1-r_r} \exp(\varepsilon_{rt}), \quad \text{with } \varepsilon_{rt} \sim N(0, \varsigma_r), \quad (38)$$

where $r_r \in (0, 1)$ captures the degree of inertia in monetary policy with r_π and r_y being positive real numbers. In addition, the government budget constraint is given by

$$g_t + \frac{R_{t-1}}{\pi_t} b_{t-1} = b_t + \bar{\tau}_t, \quad (39)$$

where b_t are the real risk-free bonds issued by the fiscal authority to finance current government expenditure. Finally, by adding together the household budget constraints to firms profits, we derive the following identity

$$y_t = c_t + g_t + i_t + \kappa_v v_t + \mathcal{A}_t. \quad (40)$$

This market clearing condition simply says that aggregate output is consumed, invested and also used to pay for both vacancy costs, $\kappa_v v_t$, and price adjustment costs, \mathcal{A}_t .

3 Transmission mechanism

This section disentangles the exogenous and endogenous sources of amplification by studying the main features of our model. We start our section by examining the role of productivity shocks as potential exogenous sources. We show that TFP innovations affect output both directly and indirectly through changes in marginal product of labour, while redistributive innovations affect output only through changes in the labour demand schedule. Redistributive shocks also have first order effects on the marginal revenue product of labour via shifts in the labour intensity. We argue that, as in the standard NK model, the qualitative response of total hours to a TFP innovation is conditional upon nominal price rigidities but that redistributive shocks always have a positive impact on employment and hours. We then focus the analysis on the study of the two main endogenous sources of amplification: deep habits and high income replacement ratios. Frictions such as deep habits, nominal price rigidities and search and matching break the direct correspondence between the parameters governing the scale of production and the labour share. We also show that the labour share depends on a frictional component originating from search and matching, a measure of mark-ups and on the redistributive innovations.

3.1 The role of productivity shocks

This subsection argues that, while TFP shocks affect production both directly and indirectly, redistributive shocks have only an indirect effect through changes in total hours. We use the procedure adopted by Ríos-Rull and Santaaulàlia-Llopis (2010) to identify productivity shocks at the good's level in a model with labour frictions. The assumption in their study that TFP shocks and redistributive shocks are negatively correlated generates a counter-cyclical labour share and low volatility in total hours. We assume however that TFP and redistributive shocks are uncorrelated given that a) our model displays richer dynamics as it includes a more comprehensive set of frictions and b) a larger set of shocks is considered.

We first take the production function, equation (21), and apply the natural logarithm to uncover the effect of the two productivity shocks on output

$$\ln y_t = \ln a_t + \alpha_t \ln(\Gamma n_t h_t) + (1 - \alpha_t) \ln k_{t-1}. \quad (41)$$

We then add and subtract the logarithm of the value of steady state value of y from both sides of equation (41)

$$\ln y_t - \ln y = \ln a_t - \ln a + \alpha_t \ln(\Gamma n_t h_t) - \alpha \ln(\Gamma n h) + (1 - \alpha_t) \ln k_{t-1} - (1 - \alpha) \ln k, \quad (42)$$

where the variables without the time subscripts correspond to the steady state values. We then add and subtract $\alpha_t \ln(\Gamma n h)$ and $(1 - \alpha_t) \ln(k)$ to the RHS of the above expression and rearrange to get

$$\hat{a}_t = \underbrace{\hat{y}_t - \alpha (\hat{n}_t + \hat{h}_t)}_{\text{Solow Residual}} - (1 - \alpha) \hat{k}_{t-1} - \underbrace{\hat{\alpha}_t (\hat{n}_t + \hat{h}_t - \hat{k}_{t-1})}_{\text{Re-distributional effect}} - \hat{\alpha}_t \ln \left(\frac{\Gamma n h}{k} \right). \quad (43)$$

The normalisation point, the chosen value of Γ , in this model turns out to be particularly important in that we want to isolate the direct impact of redistributive shocks on output and focus on the indirect impact via changes in the labour input. Thus, we set $\Gamma = k/(nh)$ such that any direct effect of redistributive innovations do not enter the log-linearised equation for output. Equation (43) can be written as

$$\underbrace{\hat{a}_t}_{\text{TFP Shock}} + \underbrace{\hat{\alpha}_t (\hat{n}_t + \hat{h}_t - \hat{k}_{t-1})}_{\text{Redistributive effect}} = \underbrace{\hat{y}_t - \alpha (\hat{n}_t + \hat{h}_t) - (1 - \alpha) \hat{k}_{t-1}}_{\text{Solow Residual}}. \quad (44)$$

Up to first order, the product $\hat{\alpha}_t (\hat{n}_t + \hat{h}_t - \hat{k}_{t-1})$ is indeed very small and has a negligible direct impact on output, so the above expression simplifies to

$$\hat{y}_t \approx \hat{a}_t + \alpha (\hat{n}_t + \hat{h}_t) + (1 - \alpha) \hat{k}_{t-1}. \quad (45)$$

It follows from this expression that TFP shocks have both a direct and an indirect effect on output due to changes in employment and hours. Absent frictions, Figure 1 shows the direct impact of a TFP innovation on output – a change in a – but it also shows that a redistributive shock – a change in α – has a negligible effect on output around the chosen normalisation point. Unlike the TFP innovation, the redistributive shock affects the curvature of the production function for a given level of physical capital.

An alternative way to understand the role of productivity shocks in our model is to simply write the production function in its intensive form as in Solow (1956). Here we divide aggregate production by physical capital instead. Output per unit of capital can thus be expressed as:

$$\mathcal{Y}_t = \frac{y_t}{k_{t-1}} = a_t \left(\frac{\Gamma h_t n_t}{k_{t-1}} \right)^{\alpha_t} = a_t \ell_t^{\alpha_t}, \quad (46)$$

where ℓ_t denotes labour per unit of capital and \mathcal{Y}_t output per unit of capital. Our definition of ℓ_t is simply the inverse of the one adopted in Solow's seminal work. There are three important points to notice here. First, the standard TFP shock is a shock to the level of production and does not affect the curvature of the production function. Second, due to normalisation, the value of ℓ_t in the steady state is equal to 1, which means that redistributive shocks do not have any direct impact on output. Third, since the variable ℓ_t is the ratio between the factors of production, a shock that is redistributive implies a change in the relative efficiency of factors. A higher α induces firms to hire more workers because they are relatively more productive and physical capital cannot be accumulated on impact.

In order to assess the impact of both productivity shocks on labour demand, let us for now assume away search and matching frictions and imperfect competition. In such simple setting, the marginal product of labour is given by $\alpha_t y_t / (n_t h_t) = w_t$, where w_t is the wage rate. The labour demand schedule is downward sloping as in models featuring decreasing returns to labour. The curvature of the labour demand schedule depends on the elasticity of output with respect to the labour input (α), which in this case it coincides with the labour share. Figure 2 shows that the impact on the marginal product of labour to a *ceteris paribus* increase in the relative labour efficiency – α changing from a value of 0.67 to value of 0.8 – but also shows the impact on labour demand to a positive TFP innovation – a changing from a value of 1 to a value of 1.1. The demand curve becomes flatter after a redistributive innovation but maintains its curvature after a TFP innovation around the normalisation point. The impact on the marginal product appears to be higher as α increases. Redistributive shocks change the composition to factor payments, made out of labour and capital income, while standard TFP innovations generate an increase in both factor payments. An increase in the relative efficiency of labour reduces the rental rate of capital and the capital share, but increases the wage rate and the labour share.

Both TFP and redistributive shocks affect the marginal revenue product of labour and labour demand directly. In order to show the impact of both productivity shocks on employment, we log-linearise the job creation condition and use the optimality conditions to eliminate wage and hours worked to get

$$\begin{aligned} -\hat{q}_t = & \varpi_1 \left[\hat{a}_t - \hat{\mu}_t + (\alpha - 1) (\hat{n}_t - \hat{k}_{t-1}) + \hat{\alpha}_t \right] + \left(\varpi_1 \frac{\alpha}{1 + \varphi} - \varpi_3 (1 - q\xi) \right) \hat{\lambda}_t + \\ & + E_t \left\{ \varpi_3 (1 - q\xi) \hat{\lambda}_{t+1} - \varpi_3 \hat{m}_{t+1} + \varpi_3 \left[(1 - \gamma - q\xi) \hat{\theta}_{t+1} \right] \right\}, \end{aligned} \quad (47)$$

where $\varpi_1 = \frac{(1-\xi)q}{\kappa_v} \alpha \frac{y}{n\mu}$, $\varpi_2 = \frac{(1-\xi)q}{(1+\varphi)\kappa_v} \alpha^2 \frac{y}{n\mu}$ and $\varpi_3 = \beta(1 - \rho)$. This expression shows that positive productivity innovations shift the marginal revenue product of employment and, therefore, labour demand.

The incentive to employ workers for production purposes depends largely on the price setting assumption - i.e. on the behaviour of mark-ups. When prices are flexible, a positive TFP innovation increases total hours and wages as in the standard RBC model. Adding nominal price rigidities leads however to a fall in total hours worked because prices can no longer adjust downwards to increase aggregate demand. To meet this relative lower level of aggregate demand, more output can be produced using less labour due to the fact that productivity is higher. This means that total hours must fall after a TFP innovation (see also Subsection 4.3). After a redistributive innovation, workers are relatively more efficient at producing output, and therefore firms have an incentive to employ more workers in equilibrium. In addition, workers are paid higher wages because their higher relative efficiency increases the marginal product of labour. Profits per additional hire tend to fall on impact after a TFP productivity shocks but to increase after a redistributive innovation. This means that while the TFP shock has both a direct and indirect effects on output, the redistributive shock has only an indirect effect through changes in labour demand. It is precisely for this reason that, present nominal price rigidities, employment is likely to expand after a redistributive shock but to contract after a positive TFP innovation.

3.2 Frictions and Endogenous Amplification Mechanisms

We start by examining the determinants of the labour share in the standard New Keynesian model featuring decreasing returns to labour and redistributive shocks. We then introduce search and matching frictions to show that the labour share is also a function of a *frictional component*. By examining the job creation condition, we study the potential role of deep habits and the so called Hagedorn and Manovskii (2008) (HM) calibration as potential sources of amplification in the model with frictions.

In the standard New Keynesian model there is a direct link between mark-ups, the wage rate and TFP innovations. This direct relationship breaks as we relax the assumption of constant returns in labour. Under the assumption of decreasing returns to labour, the dynamics of mark-ups depends both on a measure of the labour share and on redistributive innovations

$$\underbrace{\frac{1}{\mu_t} = \frac{w_t}{a_t}}_{\text{constant returns to labour}} \quad \text{and} \quad \underbrace{\frac{1}{\mu_t} = \frac{w_t \mathcal{H}_t}{\alpha_t y_t}}_{\text{diminishing returns to labour}}, \quad (48)$$

where $\mathcal{H}_t = n_t h_t$ denotes total hours and where μ_t is a measure of the mark-ups. Moreover, the labour share is a positive function of the redistributive innovations and a negative function of mark-ups.

In model featuring search and matching frictions, it is simple to show that, by re-arranging equation (34), the measure of mark-ups is given by

$$\frac{1}{\mu_t} = \frac{w_t n_t h_t}{\alpha_t y_t} \left\{ 1 + \underbrace{\frac{1}{w_t h_t} \left[\frac{\kappa_v}{q(\theta_t)} - \beta (1 - \rho) E_t \frac{\lambda_{t+1}}{\lambda_t} \frac{\kappa_v}{q(\theta_{t+1})} \right]}_{f_t: \text{frictional component}} \right\}. \quad (49)$$

According to this equation, the measure of mark-ups also depends on a frictional component. This component is a function of the inverse of income per worker and the net savings of employing an additional worker. For a value of κ_v equal to zero, the model collapses to a model with Walrasian labour markets and mark-ups are determined as in equation (48). Re-writing (49), we get

$$\frac{1}{\mu_t} = \frac{l_{s_t}}{\alpha_t} (1 + f_t), \quad (50)$$

where l_{s_t} denotes the labour share. Using the above equation, we can show that the labour share depends positively on redistributive shocks and negatively both on mark-ups and the

frictional component f_t

$$ls_t = \frac{\alpha_t}{\mu_t (1 + f_t)}. \quad (51)$$

Note that in models featuring Walrasian labour markets and perfect competition ($\mu = 1$ and $f_t = 0$), α_t and the labour share coincide. This is the approach taken by Ríos-Rull and Santaaulávia-Llopis (2010). It follows from (51) that a redistributive shock has a direct impact on the labour share but also an indirect effect through changes in mark-ups and the frictional component.

Deep habits affects the supply side of the model, the pricing decision of firms and the behaviour of mark-ups. If fluctuations in the mark-up, μ_t , induced by the deep habit mechanism, were relatively large over the cycle, then profits per hire will exhibit a great deal of variation, which will then generate amplification in labour market variables. The optimal behaviour of mark-ups under deep habits is given by

$$\frac{1}{\mu_t} = 1 - \nu_t + (1 - \vartheta) \psi_t.$$

The behaviour of mark-ups depends on two effects: a price elasticity effect and an inter-temporal effect. After a positive productivity shock, mark-ups exhibit a counter-cyclical behaviour because the price elasticity increases through a fall in ν_t and the value of future customer relationships rises through a higher shadow value of the stock of habits, ψ_t . The intuition is simply that after a productivity innovation firms have an incentive to lower prices and to hire more worker to meet a higher demand for goods. As shown by Di Pace and Faccini (2012), the higher the pricing effect on demand - the higher ζ and ϑ -, the higher the incentive for firms to hire new workers. This pricing behaviour is however constrained by the inability of firms to adjust prices optimally. Persistence in the aggregate price level implies less impact on aggregate demand, production and labour demand. Thus, the model featuring nominal rigidities and deep habits is less likely to generate amplification in labour market variables. Moreover, nominal price rigidities alter the cyclicity of mark-ups according to the nature of shocks: supply/demand shocks tend to generate pro/counter-cyclical mark-ups.

The second endogenous mechanism that we analyse in this paper is the HM calibration strategy, which consists of setting value of non-employment utility close to market productivity as well as very low values to the bargaining power of workers. i.e., a low γ and high total replacement ratio, defined as $\bar{b}/wh + \chi h^{(1+\varphi)}/[\lambda(1+\varphi)]/wh$ in the steady state. The higher the bargaining power of firms, $(1 - \xi)$, the higher the weight on the outside option of the worker, the higher wages and the lower profits. The total replacement ratio can increase because i) unemployment benefits (\bar{b}) are high, and ii) the degree of habit formation in consumption (ζ_c) is low. A rise in \bar{b} increases the outside option of employment to the worker, making steady state wages higher and marginal profits per hire lower. A less habitual level of consumption will increase the disutility of work and the outside option to the worker. Profits per additional hire tend to be more responsive to TFP innovations when their size is small, leading labour market variables to exhibit higher variation over the cycle. The deep habit mechanism and the HM calibration thus appear to be competing forces.⁶

⁶An additional source of endogenous source of amplification such as nominal wages rigidities could be easily added to our framework. In an earlier version of our paper, we introduced nominal wage rigidities but we decided to exclude it from the final version because, given the shock structure and observables in our model, the wage adjustment cost parameter was not well identified. The economic intuition as to why amplification can be generated in the standard model, as pointed out by Shimer (2005) and Hall (2005b), is rather simple. If the standard model is unable to generate amplification in quantities, then fixing wages will increase the volatility of vacancies and unemployment by generating larger fluctuations in the flow value of employment at the margin. The marginal profits per hire will respond more to TFP innovations and firms have a further incentive to post vacancies when wages are rigid. This simple solution has been criticised on the grounds that the empirical evidence shows that wages for newly hired worker are highly cyclical. Krause and Lubik (2007) show that introducing real wage rigidities in the standard search and matching model does not affect the marginal cost of production in models featuring nominal price rigidities and Nash bargaining. The model with search and matching frictions

4 Model estimation - Results

This section presents the results of our estimation using Bayesian techniques. Subsection 4.1 discusses the calibration and subsequent estimation of the structural parameters of our model. Subsection 4.2 investigates the role of the structural shocks at driving the fluctuations of labour market variables, it compares the model implied volatilities with those in the data and it presents a counterfactual exercises in which we analyse the role of both endogenous and exogenous sources of amplification. Subsection 4.3 presents impulse responses to the two productivity shocks and to the matching efficiency shock. The appendix investigates the role of an exogenous source of amplification alternative to redistributive shocks.

4.1 Estimation strategy

We estimate the model using Bayesian methods following An and Schorfheide (2007). To solve the model, we take a first-order (log) approximation of the system of equations around a deterministic steady state.⁷ We use standard methods to solve linear rational expectation models and then we apply the Kalman filter to evaluate the likelihood function of the observable variables. The likelihood function and the prior distribution of the parameters are combined to calculate the posterior distributions. The posterior Kernel is then simulated numerically using the Metropolis-Hasting algorithm. The posterior distribution of all estimated parameters is obtained in two steps. First, we use the *csmmwel* algorithm by Christopher Sims to explore the posterior mode and to approximate the variance-covariance matrix, based on the inverse Hessian matrix evaluated at the mode, by numerical optimisation on the log posterior density. Second, the posterior is explored using the random walk Metropolis Hastings algorithm with two chains of 250,000 draws each. This Markov Chain Monte Carlo method generates draws from the posterior density and updates the candidate parameter after each draw.⁸ The model is estimated for the US over the Great Moderation period, 1984Q1–2007Q4, using the following observable variables: GDP, investment, consumption, federal funds rate, GDP deflator inflation, unemployment and vacancies.⁹ Although observations on all variables are available at least from 1955 onward, we concentrate on this period because it is characterised by a single and unified monetary policy regime. The number of variables in the data coincides with the number of shocks in the model.

Our general estimation and calibration strategy follows the standard procedure proposed by Smets and Wouters (2007) but it is extended to a model with search and matching frictions. In particular, we calibrate the parameters i) using *a priori* source of information and ii) to match some stylised facts over the period of consideration. The time period in the model corresponds to one quarter in the data. As shown in Table 1, the discount factor, β , is set equal to 0.99, implying a quarterly steady state real interest rate of 1%. The depreciation rate of physical capital, δ , is set equal to 0.025. Following the literature, we set the elasticity of substitution of habit adjusted consumption to 11. The value of elasticity of inter-temporal substitution in the supply of hours, $1/\varphi$, has been a source of controversy in the literature. Although the business cycle literature tends to work with elasticities that are higher than microeconomic estimates, a value greater than 1, most microeconomic studies estimate much smaller elasticities ranging from 0 to 0.5.¹⁰ We set the value of φ to be equal to 5, which corresponds to an Frisch elasticity

displays mark-up dynamics that are disassociated from the behaviour of the real wage for newly hired workers. This finding is in stark contract with models featuring Walrasian labour markets, where wage rigidities directly influence the behaviour of mark-ups. Hence, altering the wage dynamics does not affect mark-ups directly due to the fact that the frictional component offsets any changes to the labour share.

⁷A log-linearised version of the model can be found in the Appendix.

⁸See An and Schorfheide (2007) and Fernández-Villaverde (2010) for details.

⁹See the Appendix for a detailed discussion of data sources, definitions and transformations.

¹⁰For a survey of the literature, see Card (1991).

of labour supply of 0.2. The value of φ is chosen so that output adjusts relatively more over the extensive labour margin as suggested by the empirical evidence.

We set the unemployment rate equal to 10% and the job filling rate to its long-run targets in an approach similar to the one taken by Furlanetto and Groshenny (2013). This measure of unemployment, which is somewhat higher than the data, can be justified by interpreting workers who are unmatched in the model as being both actively and passively searching for a job. Passive job seekers, also known as workers marginally attached to the labour force, are those workers that would be willing to work if they received a job offer. By introducing the alternative measure of unemployment as proposed by Hall (2005b), we make the assumption that the dynamics properties of the measure of unemployment as calculated using the standard ILO approach with this measure coincide. The parameter ξ is chosen to pin down the unemployment rate target. We set the steady state hours of work at 0.33. In line with Cooley and Quadrini (1999) and den Haan et al. (2000), we normalise the vacancy-filling rate to 0.70 and find the matching efficiency parameter, \bar{m} , that attains this target. And, finally, the job separation rate, ρ , is set to 0.1 in line with den Haan et al. (2000) and Shimer (2005). The choice of this parameter is also based on the observation that around 8 or 10 percent of workers separate from their employer each quarter (Hall, 1995, p. 235) and the finding by Davis et al. (1996) that this probability is around 11 percent. The choice of this separation rate implies that jobs last for around 2 and half years. We set the ratio of vacancies to GDP to be 1% of GDP, a value that is consistent with Andolfatto (1996), Gertler and Trigari (2009) and Blanchard and Gali (2010). Finally, as it is standard in the literature, we set the labour share to 0.67. Thus, great ratios are calibrated in line with the data.

The remaining 28 parameters governing the dynamics of the model are estimated using Bayesian techniques. The data employed is chosen to add informational content for the estimation of the posterior of the different parameters of interest.¹¹ The locations of the prior mean correspond to a large extent to those in previous studies on the US economy, e.g. Smets and Wouters (2007). We use the Inverse Gamma (IG) distribution for the standard deviation of the shocks, setting a loose prior with 2 degrees of freedom, and the Beta distribution for all parameters bounded between 0 and 1. For parameters measuring elasticities we choose the Gamma distribution, and for the unbounded parameters the Normal distribution. The priors chosen are indeed very loose so as to allow the data provide relevant information for estimating the main parameters of interest. Table 2 shows the prior distributions chosen to estimate the deep structural parameters.

We find that the estimates of the deep habits and the replacement ratio parameters to be significantly different from zero. This means that the model favours the presence of the frictions as possible sources of endogenous amplification. The deep habit parameters are lower compared to the estimates found by Ravn et al. (2006) and Zubairy (2013), which means that the HM effect appears to be *a priori* the main endogenous driver of labour market amplification. In addition, models whose deep habit parameters are high suffer from determinacy problems. In particular, the degree of deep habits in private consumption is 0.60 and the habit persistence is equal to 0.56. As discussed earlier, nominal price rigidities somehow restrict the extent to which deep habits can generate amplification in labour market variables. The posterior mean of the price adjustment cost turns out to be equal to 85.4. There is some evidence of price indexation similar to Smets and Wouters (2007). The estimate of the posterior mean of the investment adjustment cost parameter is equal to 3.59.

The estimate of the posterior mean of γ , a value equal to 0.42, is lower than the estimates used in the literature but closer to the values suggested by Shimer (2005). Since the resulting value of the ξ is around 0.48. The estimated posterior mean value of the income replacement ratio, $\tilde{b} = \bar{b}/wh$, is 0.79. This value corresponds approximately to the upper bound suggested by Mortensen and Nagypal (2007). The total replacement ratio however is equal to 0.92, which

¹¹Version 4.3.1 of the Dynare toolbox for Matlab is used for the computations.

is closer to the value set by Hagedorn and Manovskii (2008). These estimates are suggestive that a large part of the endogenous amplification in labour market outcomes is driven by the HM effect. Moreover, the implied value of κ is 0.08.

We find that, during the period of the Great Moderation, the monetary authority was highly aggressive on inflation and output growth, with posterior mean estimates of around 3.78 and 0.66 respectively. A standard result in models featuring habit formation is a highly inertial interest rate rule. Our estimations suggests that persistence parameter of the Taylor rule in the order of 0.87. In the process of estimation, we encounter serious determinacy problems while adopting reaction functions that targeted deviations of output from its long-run equilibrium. We attribute this finding to the fact that New Keynesian Phillips curve changes significantly with the assumption of deep habits because the Phillips curve depends on current and past values of consumption as shown in equation (52) in the Appendix. A Taylor rule that targets output growth is more consistent with the model specification under deep habits and, at the same time, it helps circumvent some of the determinacy problems that are characteristic of sticky price models featuring search and matching frictions and deep habits.¹² Our findings are also line with with recent studies on the role of fiscal policy under optimal monetary policy.¹³

The government spending shock and, to a minor extent, the two productivity shocks are indeed persistent. The standard deviation of the monetary policy shocks is relatively low compared to all other shocks, with the investment-specific shock being the most volatile. The other two shocks that display high volatilities are the matching efficiency and the government spending shocks. The estimates of the standard deviations of the remaining parameters are however maintained within reasonable boundaries. We found that the volatility of the preference shock is positively related to the parameter measuring the degree of habits. i.e., the higher the degree of habit formation, the higher the dispersion needed to match the consumption data. However, the size of this shock is small because the degree of habit formation is relatively lower than the literature suggests. An advantage of our approach is that the size of the dispersion of the relevant shocks needed to explain fluctuations in labour market variables is lower than the estimates found in studies featuring other sources of exogenous fluctuations such as price-elasticity shocks. Figures 3 and 4 show the priors and posteriors of the estimated parameters and the overall convergence of the estimated model.

4.2 Sources of Amplification

We compute the volatilities of the relevant labour market variables relative to the aggregate measure of output. Table 3 compares the results generated by the model with moments in the data over the period of Great Moderation in the US economy. Since the variables in the model are measured as percentage deviations from the steady state, we detrend both the macroeconomic aggregates and the labour market variables using a common linear trend given that our method of estimation assumes a linear trend in the data. A stylised fact in the labour market literature is the large volatility of unemployment and vacancies, which according to our calculations is about more than 7 times and 8 times, respectively, more volatile than output in the data. Table 3 reveals that our model can replicate the data reasonably well along this dimension. We attribute this finding to the fact that not only there is evidence of endogenous sources of amplification but also that productivity shocks play a key role at matching the second moments of the labour market data.

We now turn to the analysis of the variance decomposition to assess the importance of exogenous sources of amplification. The estimation of our model shows considerable heterogeneity in the analysis of the conditional variance decomposition across the variables of interest over different horizons. We focus the analysis on a set of labour market variables such as wage, unemployment, vacancies and hours. As shown in Table 4, TFP shocks explain only part of the

¹²See Kurozumi and Van Zandweghe (2010).

¹³Cantore et al. (2012b) and Jacob (2010).

variance of labour market variables over a relative short horizon. Redistributive shocks play a key role for explaining the dynamics of unemployment, vacancies and wages. It is somewhat surprising that these shocks appear to be the single most important exogenous source of variation for explaining wages for newly hired workers, whilst other shocks have a negligible effect both at short and long horizons. The conditional variance of unemployment over shorter horizons can be explained by a combination of shocks with the TFP being the most important exogenous source of variation after one period. The explanatory power of TFP shocks decays after four quarters and from then on redistributive shocks turn out the single most important source of variation. This means that TFP shocks are important for explaining short-run unemployment but redistributive shocks more important at explaining the variation of long-run unemployment. We also show in Table 4 the variance decomposition of output and mark-ups. Demand shocks appear to be an important component of the variation in output over the very short-run but supply-side shocks can explain the variance of output over time. TFP innovations help explain about 40% of the variance of output in the longer horizon and well over 50% of the variance of mark-ups and inflation.

The analysis of the conditional variance decomposition is very similar to the conditional variance decomposition of unemployment. The unconditional variance decomposition shown in Table 5 indeed corroborates the importance of redistributive innovations. In particular, redistributive shocks play an important role at explaining the variance of labour market variables whilst TFP shocks appear to be important at explaining the variance of mark-ups and output. The analysis of the unconditional variance decomposition shows that investment-specific shocks play a non-negligible role, explaining under 10% of the variance of labour market variables and over than 10% of the variance of consumption, output and hours. The monetary shock however appears to have a negligible effect on the variables here chosen but it is likely to be a good predictor of the interest rate and inflation.

Figures 8, 9 and 10 show the historical decomposition of GDP, unemployment and vacancies respectively during the Great Moderation. These charts confirm previous findings on unemployment and vacancies: they can mainly be explained by productivity shocks, with redistributive shocks playing a larger role over the sample period in particular for unemployment. As far as GDP is concerned, the most important demand shock is the investment-specific shock. The main drivers of output fluctuations turn out to be the two productivity shocks, with TFP shocks being relatively more important only at the end of the sample period. It is also evident that the two productivity shocks affecting the goods market have opposing effect over output, unemployment and vacancies. Productivity shocks capture different exogenous sources of variations over these three variables.

After studying the exogenous sources of amplification, we perform a counterfactual exercise in order to disentangle to which extent the different endogenous sources of amplification can help explain the relative volatilities of labour market variables. Table 3 shows that, keeping the long-run targets for unemployment rate and the job filling constant together with the estimated parameters, the preferred endogenous source of amplification is due to HM. This finding is in line with Gertler et al. (2008), who find that the HM calibration is important for explaining labour market dynamics. By shutting down deep habits (DH) and keeping the income replacement ratio, \bar{b} , equal to its posterior estimate, the model is able to explain nearly all the volatility in the data. This means that this particular shock structure favours a high replacement ratio alongside a relative low bargaining power for workers in line with Shimer (2005). Decreasing the income replacement ratio to 0.45 and setting the DH parameters to zero reduces the relative volatilities of vacancies by more than half and the relative volatility of unemployment by more than 1/3. Therefore, the endogenous mechanisms of amplification account for a large part of the variation in vacancies, while the exogenous sources of amplification help explain a larger part of the amplification in unemployment. The deep habits mechanisms seem to play a minor role in terms of labour market amplification. There are two reasons why deep habits are less

effective at generating amplification: i) the standard TFP innovations play less of a role given the shock structure of the model; and ii) while the habits parameter are low, the estimates of the price adjustment costs are reasonably high. However, the mean estimates of the deep habits in private consumption are statistically different from zero, which means that the deep habits mechanism is able to capture other properties in the data such as the hump-shaped responses in output, aggregate consumption, unemployment and to some extent vacancies.¹⁴

We run an additional exercise to investigate the role of elasticity of substitution across varieties. We find that labour market amplification is smaller when the elasticity of substitution between consumption varieties is smaller because of the behaviour in mark-ups. When we set a lower ϵ – equal to 5.3 as in Ravn et al. (2006) – the estimated posterior mean of κ_p also tends to be lower. On the one hand, this result arises because, when the market power of firms is higher, firms are likely to have less incentive to adjust their prices and hence their mark-ups optimally. This corresponds to a suboptimal source of mark-up variation that arises from a lower cost of nominal price adjustment. On the other hand, when the degree of substitution across varieties is high, firms would like to adjust their mark-ups more. To match this optimal source of mark-up fluctuations the estimate of κ_p has to increase.

4.3 Impulse responses

This section describes the responses of labour market variables following a TFP shock, a redistributive shock and a matching efficiency shock. The rationale behind this choice is that these are all productivity-type innovations and, thus, have the potential to affect the incentive for vacancy posting. Moreover, the first two shocks turn out to be the most important drivers of the labour market variables, as shown by the analysis of the forecast error variance decomposition at different horizons. One key difference between these shocks is that, while the matching efficiency shock and the technology shocks can be understood as level shocks, the redistributive shock is precisely re-distributional in nature. This means that the impact of this shock tends to shift income between the factors of production whilst it generates limited additional resources.

By dissecting the standard productivity shock into a TFP shock and redistributive shock, we find that total hours respond differently to the two technological innovations hitting the goods market. Our findings are consistent with Ríos-Rull and Santaaulàlia-Llopis (2010) in that TFP and redistributive shocks have different implications for hours and employment. This result provides an alternative view to the debate initiated by Galí (1999) on the response of total hours to technology shocks. He shows using a structural VAR approach that standard TFP innovations lead to a fall in total hours. This evidence is consistent with the prediction of the New Keynesian (NK) model but in stark contrast with the conventional real business cycle model.¹⁵ We normalise the shocks to 1 standard deviation in order to assess the order of magnitude of such shocks on the dynamics of employment, vacancies and other labour market outcomes.

A positive TFP innovation leads to an increase in output as shown by Figure 5. The TFP shock reduces inflation and increases mark-ups. The fall in inflation induces the monetary policy to respond by lowering nominal interest rates, which reduces the real interest rate and increases aggregate demand and output. Due to the assumption of nominal price rigidities, aggregate demand is not as responsive to the TFP innovation. Since labour becomes more productive, aggregate demand can be met by employing less workers and reducing the number of hours

¹⁴The Appendix presents the results of the model featuring superficial habits.

¹⁵A later study by Christiano et al. (2004) provides empirical support against Galí's hypothesis that TFP shocks reduce total hours. A series of later studies by Uhlig (2004), Pesavento and Rossi (2005), Dedola and Neri (2007), Fernald (2007) and Cantore et al. (2013) propose alternative ways to identify the technological innovation. In line with the work by Galí (1999) recent studies by Balleer (2012) and Canova et al. (2013) show that employment falls after a positive TFP shock, while Cantore et al. (2012a) find that the response of hours crucially depends on the magnitude of the elasticity of capital-labour substitution.

worked similar to Galí (1999), Pesavento and Rossi (2005) and Fernald (2007). Wages for the newly hired workers tend to fall on impact but tend to overshoot after the first quarter. The larger reduction in hours tends to reduce the profits per additional hire further, which reduces the incentive for vacancy creation at the firm level. Aggregate profits tend to rise due to the increase in current sales. In line with previous empirical evidence, we find that, although the labour share falls after a TFP innovation, we observe negligible overshooting of the labour share.¹⁶ We find however that the assumption of nominal price rigidities is able to generate a counter-cyclical response in the labour share in the presence of search and matching frictions.

Figure 6 illustrates the impact of a redistributive innovation on the variables of interest. While the responses of most variables are similar to those of the TFP innovation, the effects of the redistributive shock on labour market variables are substantially different. From the log-linearised job creation condition, equation (47), it follows that a positive redistributive shock has a direct effect on the marginal revenue product of employment. The redistributive innovation therefore reduces the job filling rate and increases both the marginal costs and benefits of employing workers on the margin. The response on hours depends on the fact that α enters quadratically into the optimality condition for hours, equation (37). The effect of the redistributive shock is larger along the extensive margin relative to the intensive margin. More re-distribution towards labour shifts the labour demand curve and increases the incentive for vacancy posting. Our model is able to reconcile the argument that productivity shocks increase labour demand. Due to the fact that output increases by less than the amount of re-distribution that takes place between firms and workers, the labour share tends to display a positive and persistent response. From a quantitative viewpoint, the redistributive shock exerts a lower impact on inflation compared to TFP shock because less output is produced in equilibrium. One key feature of the redistributive shock is that it has a *re-scaling* effect on labour but a *de-scaling* effect on capital. This means that the production process becomes more labour-intensive but less capital-intensive. Although on average capital appears to increase, the 95% confident bands of investment are significantly wider, and the lower band displays a clear negative response. The reason why on average capital tends to increase is related to the fact that capital adjustment are costly and take long to adjust. Therefore, we state that the capital has reasonably low *de-scaling* effect.

A positive matching efficiency shock increases the productivity of the match between vacancies and workers. As depicted in Figure 7, this innovation increases both the job finding rate and the job filling rate. An increase in the job filling rate leads to fall in the marginal cost of hiring, which increases the incentives for job creation. As a result, employment increases and inflation falls. As it is standard in most models featuring nominal price rigidities, mark-ups and inflation respond in opposite directions. The increase in employment is however partially offset by the fall in hours because the marginal rate of substitution falls. This technological shock reduces the aggregate surplus of the match because both job finding and filling rate increase. As a result, both marginal profits per additional worker and the wage per worker fall.

5 Conclusions

We assess the role of both exogenous and endogenous sources of amplification for explaining the volatility of the labour market variables. Our DSGE model featuring labour market frictions, efficient Nash bargaining, deep habits and nominal price rigidities, is able to replicate the volatilities of unemployment and vacancies as observed in US data. As far as the exogenous sources of amplification are concerned, we first show that TFP shocks play a role at explaining fluctuations in labour market variables only on impact. Second, redistributive shocks – which account for fluctuations in the labour share – are the single most important exogenous source of variation for generating amplification in unemployment and vacancies over longer horizons.

¹⁶See Ríos-Rull and Santaaulàlia-Llopis (2010).

Third, due to a lesser role of TFP innovations and to the presence of nominal price rigidities, the amplification mechanism that involves large mark-up fluctuations indeed plays a minor role for generating endogenous amplification over the period of the Great Moderation. Given the shock structure of the model, the estimated degree of deep habit formation is relatively lower compared to the literature, while the estimates of the replacement ratio give support to Hagedorn and Manovskii (2008) type calibration. In addition, the impulse response analysis shows that, while TFP innovations lead to a contraction in employment and hours, redistributive shocks lead to an expansion in employment and hours worked. In line with previous evidence, our model also displays a negative response of the labour share to a TFP innovation.

Our paper sought to shed some light about the role of redistributive shocks on the amplification of labour market variables. A sensible extension of our study would be to endogenise the exogenous sources of variation. Our findings pose a challenge to the use of conventional production technologies, such as the Cobb-Douglas production, in conjunction with TFP innovations as the sole productivity innovation affecting the goods market for explaining fluctuations in the labour market variables. Since redistributive shocks appear to be key innovations, our results are suggestive that the introduction of more general production technologies, such as the Constant Elasticity of Substitution production function as in, for example, Cantore et al. (2012a), coupled with both labour and capital augmenting shocks have the potential to match cyclical properties of labour market variables.

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Appendix

A Data transformation

Data on real personal consumption expenditure (PCE), investment, GDP and the implicit price deflator of GDP are taken from the Bureau of Economic Analysis. Data on civilian noninstitutional labour force (LNS11000000Q) and the unemployment rate (LNS14000000Q) are taken from the Bureau of Labor Statistics. The fed funds rate is downloaded from the FRED(c) database of the Federal Reserve Bank of St. Louis. We build a composite measure of the Help-Wanted Index (HWI) following Barnichon (2010).

Data are transformed following Smets and Wouters (2007) with some minor adjustments. Consumption is expressed in per worker terms rather than in per capita terms and then logged. Nominal variables are deflated using the implicit price deflator of GDP. The inflation rate is computed as a quarter on quarter difference of the log of the implicit GDP deflator. The federal funds rate is expressed in quarterly terms. We take the log of the unemployment rate and the log of vacancies. The series on vacancies is computed as a vacancy rate, denoted as the ratio between total vacancies and the civilian labor force (LNS11000000Q). The vacancy rate is computed as the product of the composite HWI index and the number of unemployed workers (LNS13000000Q) in 1987, which is the base year of the HWI.

We add the following measurement equations to establish a link between the observable variables with the corresponding endogenous variables in our model

$$\begin{bmatrix} dc_t \\ di_t \\ dy_t \\ infl_t \\ ffr_t \\ du_t \\ dv_t \end{bmatrix} = \begin{bmatrix} \bar{g}_r \\ \bar{g}_r \\ \bar{g}_r \\ \bar{\pi} \\ \bar{r} \\ \bar{u}_n \\ \bar{u}_n \end{bmatrix} + \begin{bmatrix} c_t - c_{t-1} \\ i_t - i_{t-1} \\ y_t - y_{t-1} \\ \pi_t \\ r_t \\ \hat{u}_t - \hat{u}_{t-1} \\ \hat{v}_t - \hat{v}_{t-1} \end{bmatrix},$$

where \bar{g}_r represents the trend growth rate of consumption, investment and output; $\bar{\pi}$ is the net steady state inflation rate, which is not equal to π , the gross inflation rate; and the bar over the variables, \bar{r} and \bar{u}_n indicate the sample mean.

B Tables and graphs

Parameter	Description	Value
β	Discount factor	0.99
c	Consumption to GDP ratio	0.67
g	Government Expenditure to GDP ratio	0.19
δ	Depreciation rate	0.025
α	Elasticity of output with respect to labour	0.67
ϵ	Elasticity of substitution	11
φ	Inv. Frisch elasticity	5
Target	Description	Value
u	Unemployment rate	0.1
$q(\theta)$	Job filling rate	0.7
ρ	Separation Rate	0.1

Table 1: Calibrated parameters/Targets

Parameters	Description	Distribution	Prior		Posterior	
			Mean	Std/df	Mean	
<i>Structural</i>						
ζ_c	Degree of habits	Beta	0.5	0.15	0.60	[0.42:0.79]
ϑ_c	Habit persistence	Beta	0.5	0.15	0.56	[0.35:0.76]
σ	Risk aversion coefficient	Normal	2	0.2	2.13	[1.82:2.44]
κ_p	Price stickiness	Gamma	60.0	20.0	85.44	[61.39:108.02]
ω_p	Price indexation	Beta	0.5	0.15	0.17	[0.05:0.27]
κ_i	Investment adj. costs	Gamma	2	0.5	3.59	[2.58:4.58]
r_π	Taylor rule	Normal	2.5	0.75	3.78	[3.12:4.46]
r_r	Interest rate smoothing	Beta	0.5	0.15	0.87	[0.85:0.90]
r_y	Taylor rule	Normal	0.5	0.15	0.66	[0.44:0.85]
$\tilde{b} = \bar{b}/wh$	Income Replacement Ratio	Beta	0.4	0.15	0.79	[0.75:0.82]
γ	Elasticity of matching w.r.t v	Beta	0.5	0.15	0.42	[0.36:0.48]
<i>Shocks</i>						
ϱ_a	Technology shock	Beta	0.5	0.15	0.87	[0.82:0.92]
s_a		IG	0.1	2	0.63	[0.55:0.72]
ϱ_α	Redistributive shock	Beta	0.5	0.15	0.90	[0.87:0.93]
s_α		IG	0.1	2	1.33	[1.00:1.68]
ϱ_m	Matching efficiency	Beta	0.5	0.15	0.63	[0.49:0.78]
s_m		IG	0.1	2	2.70	[2.34:3.05]
ϱ_z	Preference shock	Beta	0.5	0.15	0.72	[0.56:0.88]
s_z		IG	0.1	2	0.32	[0.26:0.37]
ϱ_{zi}	Investment specific shock	Beta	0.5	0.15	0.75	[0.68:0.83]
s_{zi}		IG	0.1	2	3.29	[2.48:4.10]
ϱ_g	Government Spending shock	Beta	0.5	0.15	0.97	[0.96:0.99]
s_g		IG	0.1	2	2.21	[1.94:2.46]
s_r	Monetary policy shock	IG	0.1	2	0.14	[0.12:0.16]
<i>Rates</i>						
$\bar{\pi}$	Inflation rate	Gamma	0.625	0.10	0.74	[0.67:0.80]
\bar{v}_n	Unemployment and vacancies	Normal	0.0	0.3	-0.38	[-0.43:-0.32]
g_r	Trend	Normal	0.4	0.1	0.45	[0.43:0.47]
Log-marginal likelihood	-911.57					

Table 2: Prior and posterior distributions

	\hat{y}_t	\hat{i}_t	\hat{n}_t	\hat{u}_t	\hat{v}_t
<i>Relative standard deviations</i>					
US data: 1984-2007	1	3.58	0.53	6.76	8.08
Model (HM + DH)	1	3.85	0.75	6.79	7.56
Model with HM only	1	3.57	0.76	6.80	7.39
Model without endogenous ampl.	1	4.70	0.45	4.00	3.17

Table 3: Relative standard deviations in the data *versus* the models. DH stands for deep habits, while HM stands for Hagedorn and Manovskii

Horizon		Structural shocks					
		TFP, \hat{a}_t	Redistrib., $\hat{\alpha}_t$	Preference, \hat{z}_t	Mon. & fiscal policy, ϵ_{rt}, \hat{g}_t	Invest. spec., \hat{z}_{it}	Matching effic., \hat{m}_t
Output, \hat{y}_t	1	9.35	19.95	22.77	39.58	8.04	0.31
	4	33.17	28.31	8.16	16.37	13.02	0.97
	8	40.27	32.91	4.00	9.84	12.01	0.97
	20	42.82	34.38	2.56	7.55	11.98	0.71
	40	42.92	33.16	2.45	7.43	13.38	0.66
Mark up, $\hat{\mu}_t$	1	62.43	12.90	6.76	11.13	0.64	6.13
	4	55.77	18.62	5.85	9.88	2.14	7.75
	8	55.29	18.79	5.80	9.92	2.50	7.70
	20	55.28	18.78	5.81	9.92	2.50	7.71
	40	55.28	18.78	5.81	9.92	2.50	7.71
Wage, \hat{w}_t	1	9.84	50.74	8.17	17.82	1.94	11.49
	4	15.46	68.02	2.44	7.01	2.27	4.80
	8	19.48	69.43	1.49	4.51	2.35	2.75
	20	22.08	65.62	1.26	4.01	5.11	1.93
	40	23.19	61.42	1.28	4.78	7.57	1.77
Unempl., \hat{u}_t	1	23.49	22.68	12.71	21.71	5.24	14.17
	4	7.84	54.24	6.11	11.65	9.50	10.66
	8	12.30	64.19	2.97	6.49	7.65	6.40
	20	16.06	66.27	1.98	4.72	6.74	4.23
	40	16.88	65.07	1.92	4.68	7.44	4.00
Vacancies, \hat{v}_t	1	26.29	25.37	14.22	24.29	5.87	3.97
	4	21.40	44.14	7.79	13.73	7.59	5.35
	8	21.93	51.66	5.71	10.22	6.56	3.93
	20	22.31	54.46	4.79	8.77	6.42	3.25
	40	22.61	54.02	4.68	8.64	6.90	3.16
Hours, \hat{h}_t	1	50.35	2.99	11.11	24.02	3.28	8.24
	4	42.74	2.82	10.18	27.48	7.50	9.28
	8	39.19	3.62	9.52	32.68	7.21	7.79
	20	33.03	3.78	7.57	39.98	9.79	5.86
	40	29.93	3.09	6.24	43.46	12.60	4.69

Table 4: Conditional variance decomposition at different horizons

	\hat{y}_t	\hat{c}_t	\hat{n}_t	\hat{h}_t	$\hat{\mu}_t$	\hat{u}_t	\hat{v}_t	\hat{w}_t	\hat{l}_{s_t}
\hat{a}_t	42.94	21.62	17.07	28.03	55.28	17.07	22.70	23.30	20.91
$\hat{\alpha}_t$	32.76	29.63	64.68	2.88	18.78	64.68	53.83	59.73	72.00
e_{rt}	0.58	0.25	1.49	0.05	5.13	1.49	2.96	1.87	2.15
\hat{z}_t	2.45	6.59	1.92	5.65	5.81	1.92	4.67	1.28	1.44
\hat{g}_t	6.80	30.97	3.18	46.65	4.79	3.18	5.66	3.97	0.98
\hat{z}_{it}	13.81	10.56	7.68	12.53	2.50	7.68	7.04	8.13	1.09
\hat{m}_t	0.65	0.37	3.97	4.21	7.71	3.97	3.15	1.72	1.42

Table 5: Unconditional variance decomposition (in percent)

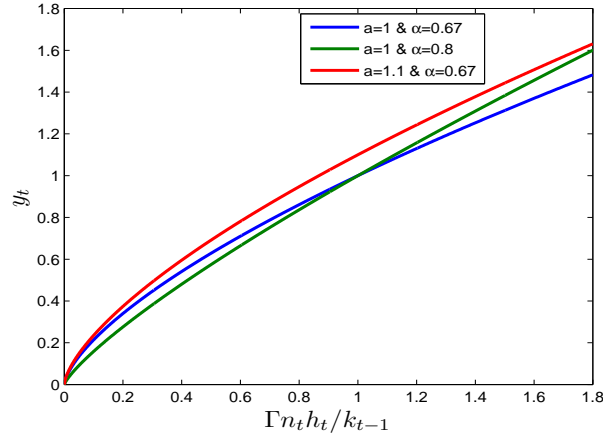


Figure 1: Production function. The blue line shows the baseline production function. The green line shows how redistributive shocks affect the curvature of the production function and the red shows changes in the shape of the production function as the level of technology increases.

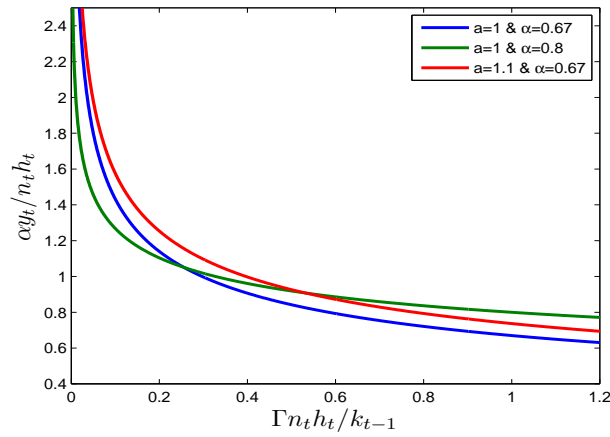


Figure 2: Marginal product of labour in a model with Walrasian labour markets. The blue line denotes the demand function in the baseline case. The green line shows how labour demand changes after a redistributive shock.

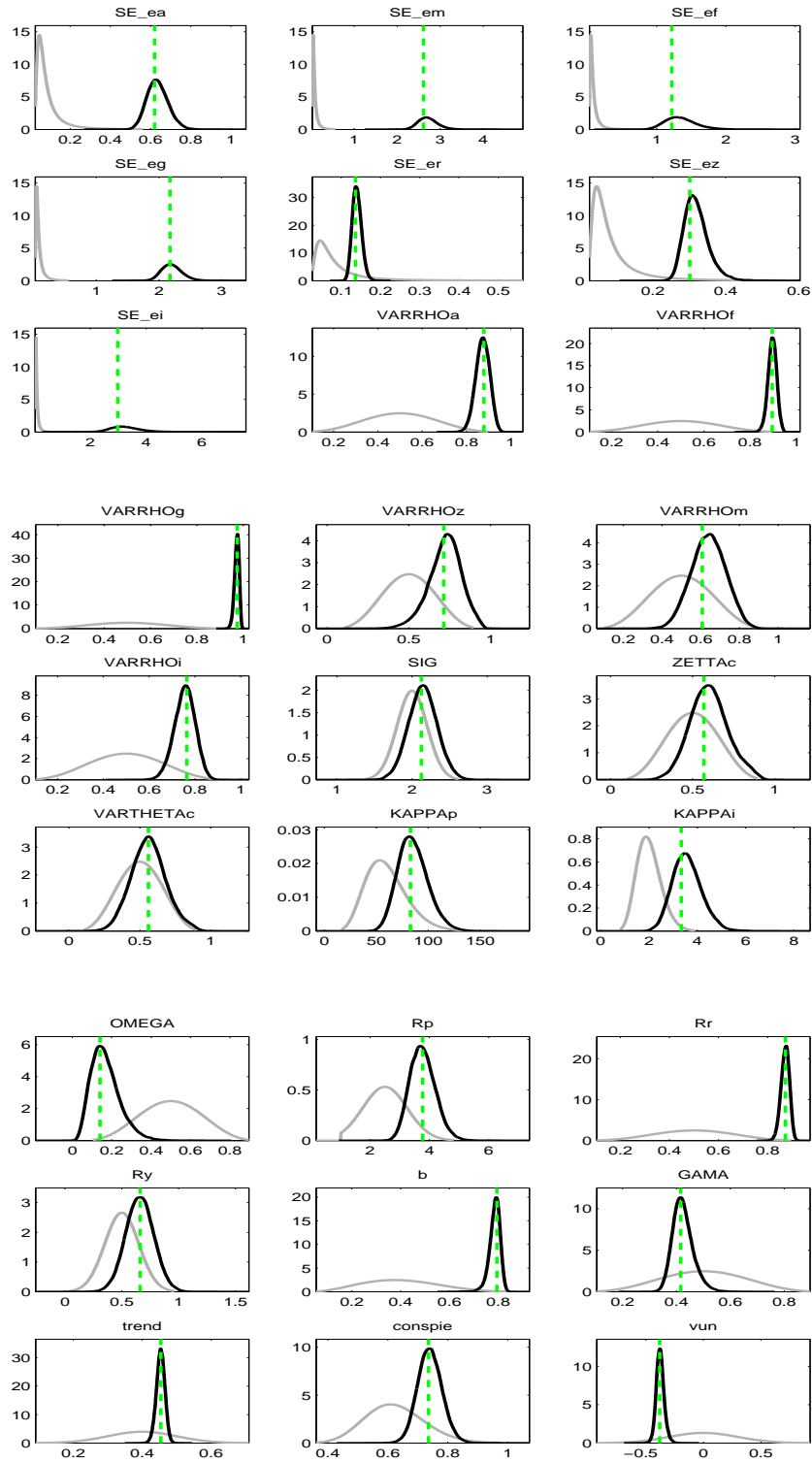


Figure 3: Priors and posteriors of estimated parameters

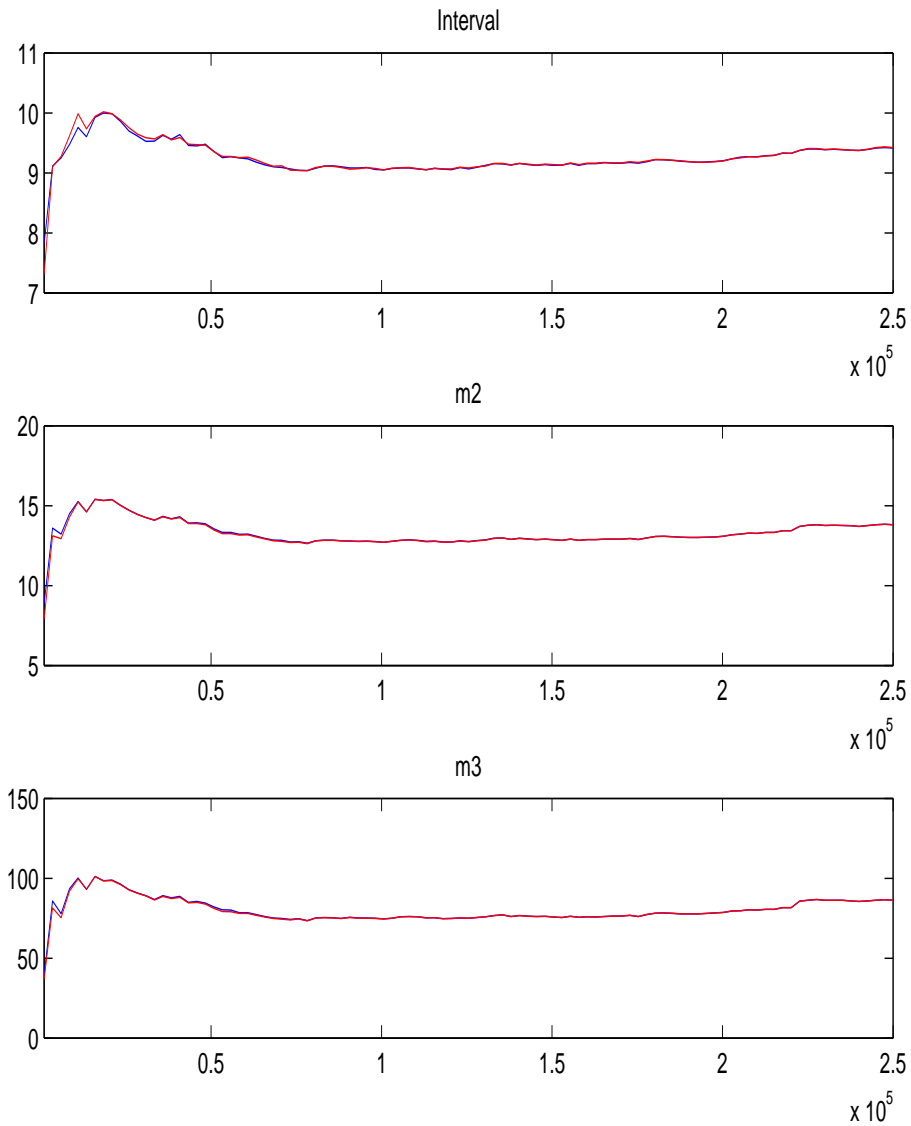


Figure 4: Overall convergence of the model. “Interval” is constructed from an 80% confidence interval around the parameter mean, “m2” is a measure of the variance and “m3” is based on third moments. The horizontal axis represents the number of Metropolis-Hastings iterations undertaken, and the vertical axis the measure of the parameter moments, with the first, corresponding to the measure at the initial value of the Metropolis-Hastings iterations.

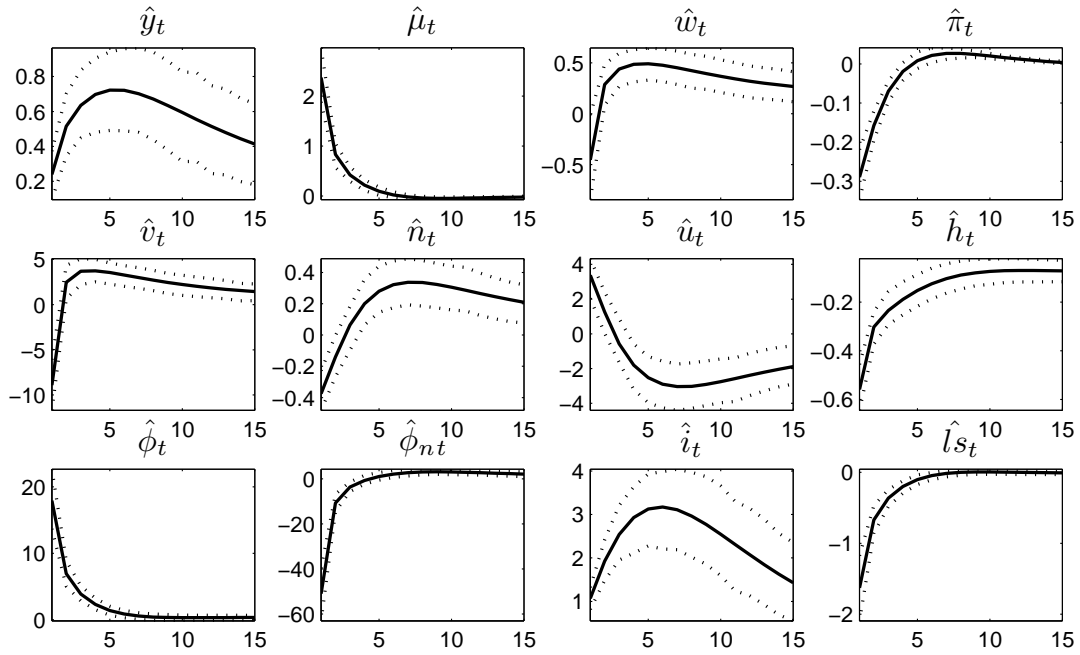


Figure 5: Technology shock. Solid lines represent mean IRF and dashed lines represent the 95% confidence intervals. The size of the shock is normalized to one standard deviation.

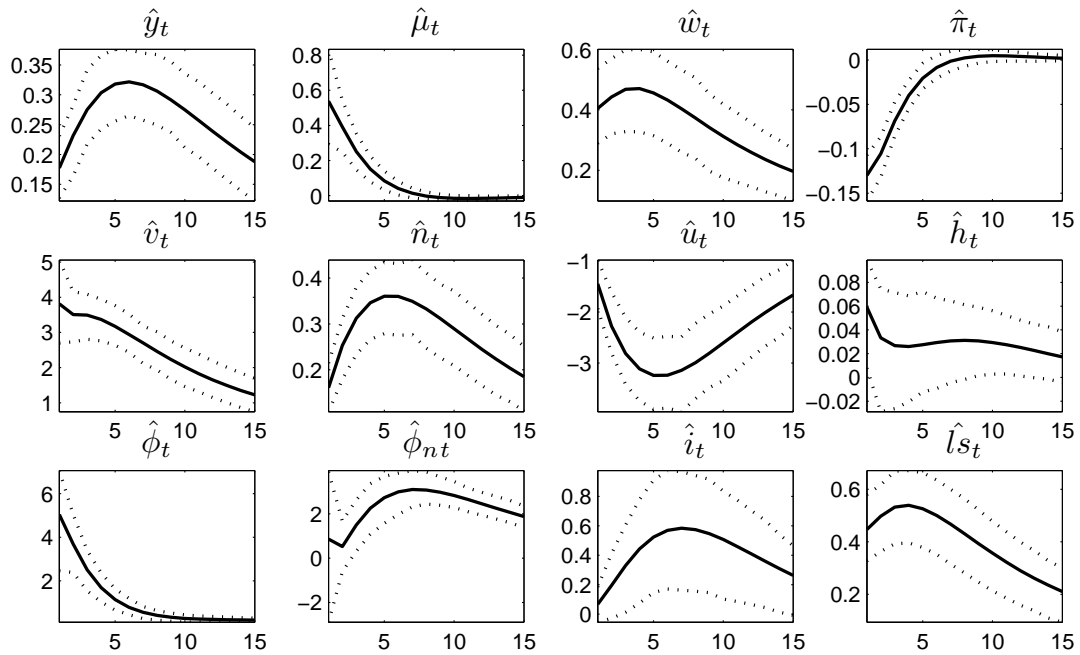


Figure 6: Redistributive shock. Solid lines represent mean IRF and dashed lines represent the 95% confidence intervals. The size of the shock is normalized to one standard deviation.

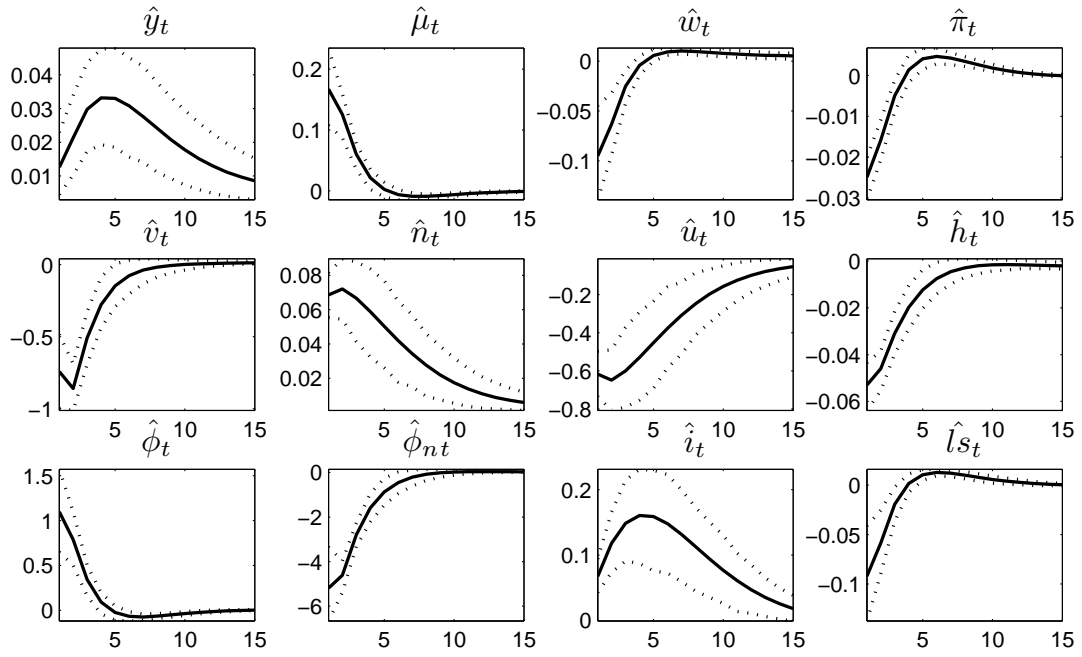


Figure 7: Matching efficiency shock. Solid lines represent mean IRF and dashed lines represent the 95% confidence intervals. The size of the shock is normalized to one standard deviation.

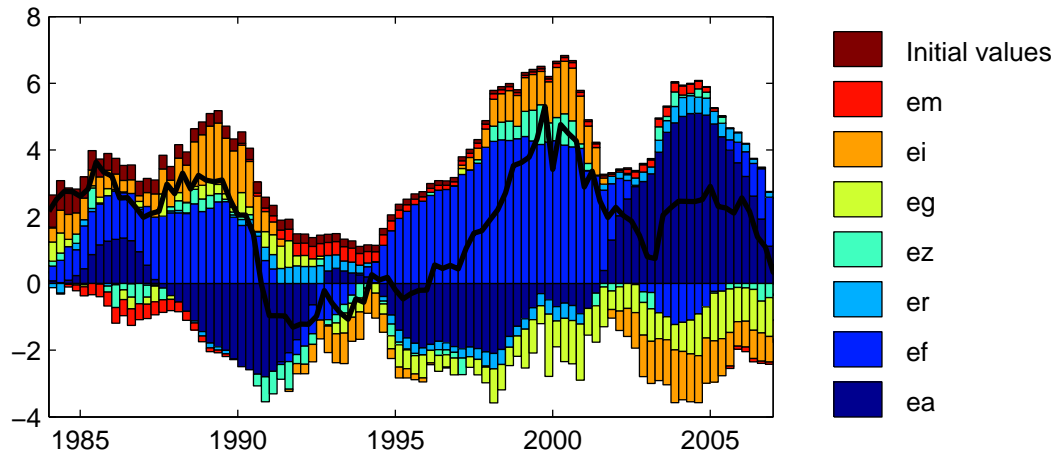


Figure 8: Historical decomposition of GDP.

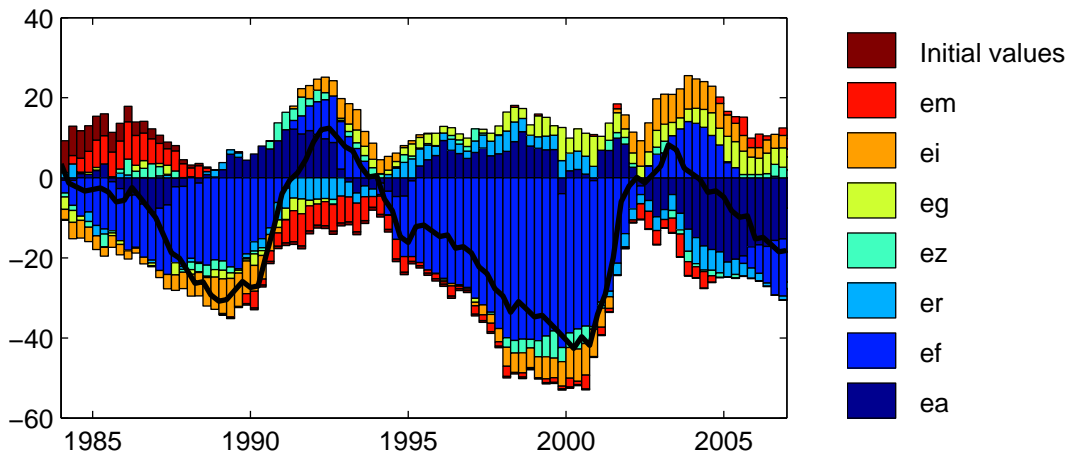


Figure 9: Historical decomposition of unemployment

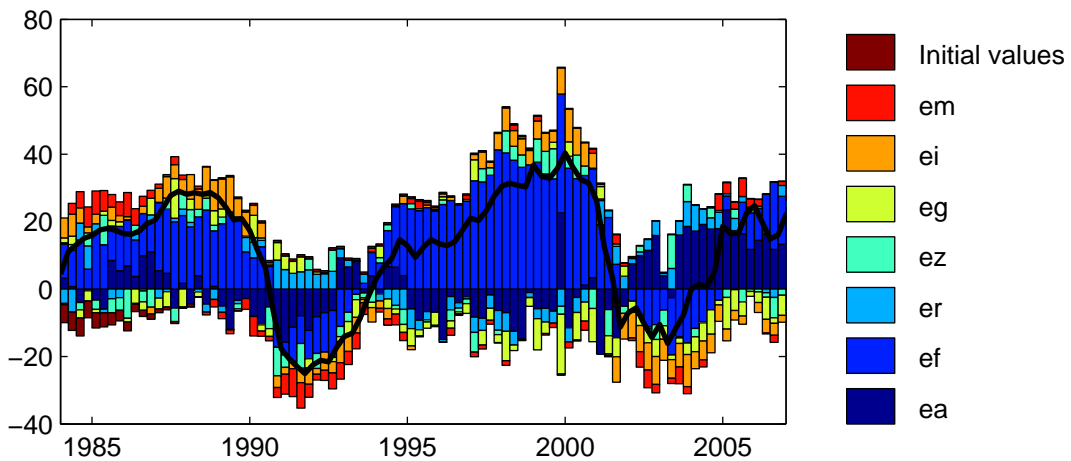


Figure 10: Historical decomposition of vacancies

C Model, Log-linearised Equations and Steady State

C.1 Baseline Model

$$\begin{aligned}
m_t &= \bar{m}_t v_t^\gamma \tilde{u}_t^{1-\gamma}, \\
\ln\left(\frac{\bar{m}_t}{\bar{m}}\right) &= \varrho_m \ln\left(\frac{\bar{m}_{t-1}}{\bar{m}}\right) + \varepsilon_{mt}, \\
q(\theta_t) &= m_t/v_t, \\
n_t &= m_t + (1-\rho)n_{t-1}, \\
\tilde{u}_t &= 1 - (1-\rho)n_{t-1}, \\
u_t &= 1 - n_t, \\
\lambda_t &= [x_{ct} - \ln(z_t)]^{-\sigma}, \\
x_{ct} &= c_t - \zeta_c s_{ct-1}, \\
\ln(z_t) &= \varrho_z \ln(z_{t-1}) + \varepsilon_{zt}, \\
1 &= \beta R_t E_t \beta_{t,t+1} / \pi_{t+1}, \\
\lambda_t q_{kt} &= \beta E_t \lambda_{t+1} [r_{kt+1} + (1-\delta)q_{kt+1}], \\
\lambda_t &= q_{kt} \lambda_t z_{it} \left\{ \left[1 - \frac{\kappa_i}{2} \left(\frac{i_t}{i_{t-1}} - 1 \right)^2 \right] - \kappa_i \frac{i_t}{i_{t-1}} \left(\frac{i_t}{i_{t-1}} - 1 \right) \right\} + \\
&\quad + \beta \kappa_i E_t q_{kt+1} \lambda_{t+1} z_{it+1} \left(\frac{i_{t+1}}{i_t} \right)^2 \left(\frac{i_{t+1}}{i_t} - 1 \right), \\
\ln(z_{it}) &= \varrho_i \ln(z_{it-1}) + \varepsilon_{it}, \\
\mathcal{W}_t &= w_t h_t - \left[\bar{b} + \chi (h_t)^{1+\varphi} / [(1+\varphi)\lambda_t] \right] + (1-\rho) E_t \beta_{t,t+1} \mathcal{W}_{t+1} [1 - \theta_{t+1} q(\theta_{t+1})], \\
y_t &= a_t (\Delta h_t n_t)^{\alpha_t} k_{t-1}^{1-\alpha_t}, \\
\ln(a_t/a) &= \varrho_a \ln(a_{t-1}/a) + \varepsilon_{at}, \\
\ln(\alpha_t/\alpha) &= \varrho_\alpha \ln(\alpha_{t-1}/\alpha) + \varepsilon_{\alpha t}, \\
y_t &= c_t + g_t + i_t + \kappa_v v_t + \frac{\kappa_p}{2} (\pi_t / \tilde{\pi}_t^p - 1)^2 y_t \\
k_t &= z_{it} i_t \left[1 - \frac{\kappa_i}{2} \left(\frac{i_t}{i_{t-1}} - 1 \right)^2 \right] + (1-\delta)k_{t-1}, \\
s_{ct} &= \vartheta s_{ct-1} + (1-\vartheta_c) c_t, \\
\ln(g_t/g) &= \varrho_g \ln(g_{t-1}/g) + \varepsilon_{gt}, \\
1/\mu_t &= 1 - \nu_{ct} + (1-\vartheta_c) \psi_{ct}, \\
\psi_{ct} &= \vartheta_c E_t \beta_{t,t+1} \psi_{ct+1} + \zeta_c E_t \beta_{t,t+1} \nu_{ct+1}, \\
c_t + g_t (1-\epsilon) + g_t \frac{\epsilon}{\mu_t} &= \nu_{ct} x_{ct} \epsilon + \pi_t / \tilde{\pi}_t^p (\pi_t / \tilde{\pi}_t^p - 1) y_t - \kappa_p E_t \beta_{t,t+1} \pi_{t+1} / \tilde{\pi}_{t+1}^p (\pi_{t+1} / \tilde{\pi}_{t+1}^p - 1) y_{t+1} - \\
&\quad (1-\epsilon) i_t - \epsilon \frac{i_t}{\mu_t}, \\
r_{kt} &= (1-\alpha_t) \frac{y_t}{\mu_t k_{t-1}}, \\
\mathcal{J}_t &= \alpha_t y_t / (\mu_t n_t) - w_t h_t + (1-\rho) E_t \beta_{t,t+1} \mathcal{J}_{t+1}, \\
\mathcal{J}_t &= \kappa / q(\theta_t), \\
w_t h_t &= \xi [\alpha_t y_t / (\mu_t n_t) + \kappa_v (1-\rho) E_t \beta_{t,t+1} \theta_{t+1}] + (1-\xi) \left\{ \bar{b} + \chi (h_t)^{1+\varphi} / [(1+\varphi)\lambda_t] \right\}, \\
\chi h_t^\varphi / \lambda_t &= \alpha_t^2 y_t / (\mu_t n_t h_t), \\
\frac{R_t}{R^*} &= \left(\frac{R_t}{R^*} \right)^{r_r} \left[\left(\frac{\pi_t}{\pi^*} \right)^{r_\pi} \left(\frac{y_t}{y_{t-1}} \right)^{r_y} \right]^{1-r_r} z_{rt}, \\
\ln(z_{rt}) &= \varrho_r \ln(z_{rt-1}) + \varepsilon_{rt}.
\end{aligned}$$

C.2 Log-linearised equations

$$\begin{aligned}
\widehat{m}_t &= \widehat{m}_t + \gamma \widehat{v}_t + (1 - \gamma) \widehat{u}_t, \\
\widehat{m}_t &= \varrho_m \widehat{m}_{t-1} + \varepsilon_{mt}, \\
\widehat{q}_t &= \widehat{m}_t + (\gamma - 1) \widehat{\theta}_t, \\
\widehat{\theta}_t &= \widehat{v}_t - \widehat{u}_t, \\
\widehat{m}_t &= \frac{1}{\rho} [\widehat{n}_t - (1 - \rho) \widehat{n}_{t-1}], \\
\widehat{u}_t &= -\frac{(1-\rho)n}{u} \widehat{n}_{t-1}, \\
\widehat{u}_t &= -\frac{n}{u} \widehat{n}_t, \\
\widehat{\lambda}_t &= -\sigma (\widehat{x}_{ct} - \widehat{z}_t), \\
(1 - \zeta_c) \widehat{x}_{ct} &= \widehat{c}_t - \zeta_c \widehat{s}_{ct-1}, \\
\widehat{z}_t &= \varrho_z \widehat{z}_{t-1} + \varepsilon_{zt}, \\
\widehat{\lambda}_t &= \widehat{R}_t + E_t [\widehat{\lambda}_{t+1} - \widehat{\pi}_{t+1}], \\
\widehat{q}_{kt} &= E_t [\widehat{\lambda}_{t+1} - \widehat{\lambda}_t + \widehat{r}_{kt+1}] + \beta (1 - \delta) E_t [\widehat{q}_{kt+1} - \widehat{r}_{kt+1}], \\
\widehat{i}_t &= \widehat{i}_{t-1} + \frac{1}{\kappa_i(1+\beta)} (\widehat{q}_{kt} + \widehat{z}_{it}) + \frac{\beta}{1+\beta} E_t \widehat{i}_{t+1}, \\
\widehat{z}_{it} &= \varrho_i \widehat{z}_{it-1} + \varepsilon_{it}, \\
\widehat{y}_t &= \widehat{a}_t + \alpha (\widehat{n}_t + \widehat{h}_t + \widehat{\alpha}_t) + (1 - \alpha) \widehat{k}_{t-1}, \\
\widehat{a}_t &= \varrho_a \widehat{a}_{t-1} + \varepsilon_{at}, \\
\widehat{\alpha}_t &= \varrho_\alpha \widehat{\alpha}_{t-1} + \varepsilon_{\alpha t}, \\
\widehat{y}_t &= \frac{c}{y} \widehat{c}_t + \frac{g}{y} \widehat{g}_t + \frac{i}{y} \widehat{i}_t + \frac{\kappa_v}{y} \widehat{v}_t, \\
\widehat{k}_t &= \delta (\widehat{z}_{it} + \widehat{i}_t) + (1 - \delta) \widehat{k}_{t-1}, \\
\widehat{s}_{ct} &= (1 - \vartheta_c) \widehat{c}_t + \vartheta_c \widehat{s}_{ct-1}, \\
\widehat{g}_t &= \varrho_g \widehat{g}_{t-1} + \varepsilon_{gt}, \\
-\frac{1}{\mu} \widehat{\mu}_t &= -\nu_c \widehat{v}_{ct} + (1 - \vartheta_c) \psi_c \widehat{\psi}_{ct}, \\
\widehat{\psi}_{ct} &= E_t \widehat{\lambda}_{t+1} - \widehat{\lambda}_t + \beta \vartheta_c E_t \widehat{\psi}_{ct+1} + \frac{\beta \zeta_c \nu_c}{\psi_c} E_t \widehat{v}_{ct+1}, \\
\frac{c}{y} \widehat{c}_t + (1 - \epsilon) \frac{i}{y} \widehat{i}_t + \epsilon \frac{i}{y} \frac{1}{\mu} (\widehat{i}_t - \widehat{\mu}_t) &+ (1 - \epsilon) \frac{g}{y} \widehat{g}_t + \epsilon \frac{g}{y} \frac{1}{\mu} (\widehat{g}_t - \widehat{\mu}_t) + \beta \kappa_p E_t [\widehat{\pi}_{t+1} - \omega \widehat{\pi}_t] = \\
\frac{\nu_c \alpha c \epsilon}{y} (\widehat{v}_{ct} + \widehat{x}_{ct}) + \kappa_p (\widehat{\pi}_t - \omega \widehat{\pi}_{t-1}), & \\
\widehat{r}_{kt} &= (1 - \alpha) (\widehat{y}_t - \widehat{k}_{t-1} - \frac{\alpha}{1-\alpha} \widehat{\alpha}_t), \\
-\mathcal{J} \widehat{q}_t &= \alpha \frac{\alpha}{\mu} \Delta h^\alpha [\widehat{a}_t - \widehat{\mu}_t + \widehat{\alpha}_t + (\alpha - 1) \widehat{n}_t + \alpha \widehat{h}_t + (1 - \alpha) \widehat{k}_{t-1}] - \\
-wh (\widehat{w}_t + \widehat{h}_t) &+ \beta (1 - \rho) \mathcal{J} E_t [\widehat{\lambda}_{t+1} - \widehat{\lambda}_t - \widehat{q}_{t+1}], \\
wh (\widehat{w}_t + \widehat{h}_t) &= \xi \left\{ \alpha y / (\mu n) [\widehat{\alpha}_t + \widehat{y}_t - (\widehat{\mu}_t + \widehat{n}_t)] + \kappa_v (1 - \rho) \theta E_t (\widehat{\lambda}_{t+1} - \widehat{\lambda}_t - \widehat{\theta}_{t+1}) \right\} + \\
+(1 - \xi) \chi (h)^{1+\varphi} / [(1 + \varphi) \lambda] &[(1 + \varphi) \widehat{h}_t - \widehat{\lambda}_t], \\
\varphi \widehat{h}_t - \widehat{\lambda}_t &= 2 \widehat{\alpha}_t + \widehat{y}_t - (\widehat{\mu}_t + \widehat{n}_t + \widehat{h}_t), \\
\widehat{R}_t &= r_r \widehat{R}_{t-1} + (1 - r_r) [r_p \widehat{\pi}_t + r_y (\widehat{y}_t - \widehat{y}_{t-1})] + z_{rt}, \\
\widehat{z}_{rt} &= \varrho_r \widehat{z}_{rt-1} + \varepsilon_{rt}^r.
\end{aligned}$$

D Phillips Curve

The Phillips curve under deep habits can be written as

$$\begin{aligned}
\widehat{\pi}_t &= \frac{\beta}{1 + \beta \omega} E_t \widehat{\pi}_{t+1} + \frac{\omega}{1 + \beta \omega} \widehat{\pi}_{t-1} + \frac{\nu (1 - \zeta) c \epsilon}{(1 + \beta \omega) \kappa_p y} (\widehat{x}_t + \widehat{v}_t) - \\
&\quad - \frac{1}{(1 + \beta \omega) \kappa_p} \left[\frac{c}{y} \widehat{c}_t + (1 - \epsilon) \frac{i}{y} \widehat{i}_t + \epsilon \frac{i}{y} \frac{1}{\mu} (\widehat{i}_t - \widehat{\mu}_t) \right]. \tag{52}
\end{aligned}$$

E Steady State

$$\begin{aligned}
u &= 0.1, \\
q &= 0.7, \\
n &= 1 - u, \\
\tilde{u} &= 1 - (1 - \rho)n, \\
h &= 1, \\
y &= 1, \\
v &= \frac{\rho n}{q}, \\
\bar{m} &= q \left(\frac{v}{\tilde{u}}\right)^{1-\gamma}, \\
m &= \rho n, \\
R &= \frac{\pi}{\beta}, \\
r_k &= \pi/\beta - (1 - \delta), \\
q_k &= 1, \\
\Gamma_c &= (1 - \vartheta_c \beta) / [(1 - \vartheta_c \beta) - (1 - \vartheta_c) \zeta_c \beta], \\
k &= (1 - c - g - \mathcal{C}) / \delta, \\
a &= 1/k, \\
\mu &= [\epsilon \delta k + \epsilon (1 - \zeta_c) c \Gamma_c + \epsilon g] / [\epsilon (1 - \zeta_c) c \Gamma_c c - (1 - \epsilon) g - (1 - \epsilon) k \delta], \\
\nu_c &= (1 - 1/\mu) \Gamma_c, \\
\psi_c &= \frac{\zeta_c \beta}{(1 - \vartheta_c \beta)(1 - \zeta_c) \nu_c}, \\
\alpha &= 1 - r_k \mu k, \\
\Delta &= k / (nh), \\
i &= \delta k, \\
\frac{whn}{y} &= \frac{1}{\mu} \alpha - \frac{\mathcal{C}}{\rho} [1 - \beta (1 - \rho)], \\
\kappa &= \frac{\mathcal{C} y}{v}, \\
w &= \frac{wnhy}{yhn}, \\
\bar{b} &= \frac{(1 - \bar{b}) \frac{wnh}{y} - \frac{\alpha^2}{\mu(1+\varphi)}}{\frac{1}{\mu} \alpha - \frac{\alpha^2}{\mu(1+\varphi)} - \bar{b} \frac{wnh}{y} + \beta(1-\rho) \mathcal{C} \frac{n}{\tilde{u}}}, \\
\chi &= \alpha^2 y [c(1 - \zeta)]^{-\sigma} / [\mu nh (h^\varphi)], \\
\chi &= \frac{\alpha^2 (nh)^{\alpha-1} [c(1-\zeta)]^{-\sigma}}{\mu h^\varphi}, \\
\bar{b} &= \bar{b} wh, \\
s_c &= c, \\
x_c &= (1 - \zeta_c) c, \\
\lambda &= x_c^{-\sigma}, \\
\theta &= \frac{v}{\tilde{u}}.
\end{aligned}$$

F Superficial habits in private consumption

This section analyses the effects of superficial habits in private consumption instead of the deep habits setting presented in the paper in order to: (i) investigate the role of a different type of habit formation; and (ii) analyze the robustness of the main results.

In the DSGE model the presence of superficial external habits in consumption simplifies the optimization problem of households. They solve only the standard problem of maximise utility, and the consumption object, x_{ct}^j , is simply equal to:

$$x_{ct}^j = c_t^j - \zeta_{sc}c_{t-1} \quad (53)$$

where ζ_{sc} denotes the external habit parameter and c_{t-1} aggregate consumption. The problem of firm i becomes standard as it chooses prices, vacancies and physical capital to maximise the present discounted value of expected profits subject to the production function and the law of motion of employment. In the presence of superficial habits, the price elasticity of demand is constantly equal to the intratemporal elasticity of substitution. Hence, firms no longer face the inter-temporal trade-off between current and future profits.

We estimate the model featuring superficial instead of deep habits using Bayesian techniques. Calibrated parameters are the same as in Table 1, while Table 6 shows the mean estimates of the remaining parameters. Overall parameters are remarkably similar across the two models since in all cases the median estimate of a parameter in the model with deep habits falls in the estimated confidence band for the same parameter of the model with superficial habits. The mean value of price stickiness is somewhat higher in the latter model and the high estimate of the income replacement ratio is confirmed. A log-likelihood comparison reveals that there is strong evidence in favour of the model featuring deep habits (see Kass and Raftery, 1995, for details). It should be noted that superficial habits do not display an exogenous persistent component. A proper Bayesian comparison with the model featuring deep habits could include this component.

The better fit of the deep habits model is evident from the analysis of the simulated moments. Table 7 shows that the model with superficial habits is still able to generate high volatilities of unemployment and vacancies, equal to 6.31 and 7.04 respectively. But the comparison between Table 7 and Table 3 reveals that the model featuring deep habits gets closer to the data, although the difference between the two models is not striking. In addition, Table 7 confirms the dominant role of the Hagedorn and Manovskii effect as the most important endogenous mechanism accounting for labour market amplification.

As far as the exogenous sources of labour market amplifications are concerned, Tables 8 and 9 confirm the results of the model featuring deep habits: redistributive shocks play a major role in explaining the variability of unemployment and vacancies at both short and long horizons. This exercise has shown that the two following results of the model are robust to the mechanism of habit formation: (i) the HM effect is a powerful source of endogenous amplification of labour market variables; and (ii) redistributive shocks largely explain the variability of these variables.

Parameters	Description	Distribution	Prior		Posterior
			Mean	Std/df	Mean
<i>Structural</i>					
ζ_{sc}	Habit parameter	Beta	0.5	0.15	0.39 [0.23:0.55]
σ	Risk aversion coefficient	Normal	2	0.2	2.16 [1.88:2.47]
κ_p	Price stickiness	Gamma	60.0	20.0	92.65 [67.06:118.04]
ω_p	Price indexation	Beta	0.5	0.15	0.22 [0.08:0.36]
κ_i	Investment adj. costs	Gamma	2	0.5	3.60 [2.64:4.57]
r_π	Taylor rule	Normal	2.5	0.75	3.72 [3.05:4.38]
r_r	Interest rate smoothing	Beta	0.5	0.15	0.86 [0.83:0.89]
r_y	Taylor rule	Normal	0.5	0.15	0.66 [0.46:0.86]
$\tilde{b} = \tilde{b}/wh$	Income Replacement Ratio	Beta	0.4	0.15	0.79 [0.76:0.82]
γ	Elasticity of matching w.r.t v	Beta	0.5	0.15	0.42 [0.35:0.48]
<i>Shocks</i>					
ϱ_a	Technology shock	Beta	0.5	0.15	0.88 [0.84:0.93]
ς_a		IG	0.1	2	0.67 [0.58:0.75]
ϱ_α	Redistributive shock	Beta	0.5	0.15	0.88 [0.86:0.91]
ς_α		IG	0.1	2	1.28 [0.97:1.58]
ϱ_m	Matching efficiency	Beta	0.5	0.15	0.67 [0.54:0.82]
ς_m		IG	0.1	2	2.70 [2.34:3.05]
ϱ_z	Preference shock	Beta	0.5	0.15	0.70 [0.54:0.86]
ς_z		IG	0.1	2	0.32 [0.27:0.37]
ϱ_{zi}	Investment specific shock	Beta	0.5	0.15	0.77 [0.70:0.84]
ς_{zi}		IG	0.1	2	3.24 [2.46:3.99]
ϱ_g	Government Spending shock	Beta	0.5	0.15	0.97 [0.95:0.99]
ς_g		IG	0.1	2	2.21 [1.95:2.47]
ς_r	Monetary policy shock	IG	0.1	2	0.14 [0.12:0.16]
<i>Rates</i>					
$\bar{\pi}$	Inflation rate	Gamma	0.625	0.10	0.74 [0.67:0.80]
\bar{v}_n	Unemployment and vacancies	Normal	0.0	0.3	-0.38 [-0.44:-0.31]
g_r	Trend	Normal	0.4	0.1	0.46 [0.44:0.47]
Log-marginal likelihood	-916.48				

Table 6: Prior and posterior distributions in the model with superficial habits

	\hat{y}_t	\hat{i}_t	\hat{n}_t	\hat{u}_t	\hat{v}_t
<i>Relative standard deviations</i>					
US data: 1984-2007	1	3.58	0.53	6.76	8.08
Model (HM + SH)	1	3.75	0.70	6.31	7.04
Model with HM only	1	3.71	0.70	6.30	6.96
Model without HM and SH	1	4.65	0.42	3.74	2.88

Table 7: Relative standard deviations in the data *versus* the models. SH stands for superficial habits, while HM stands for Hagedorn and Manovskii

	\hat{y}_t	\hat{c}_t	\hat{n}_t	\hat{h}_t	$\hat{\mu}_t$	\hat{u}_t	\hat{v}_t	\hat{w}_t	\hat{l}_{s_t}
\hat{a}_t	53.19	30.73	22.62	31.83	57.38	22.62	25.15	32.46	17.87
$\hat{\alpha}_t$	26.60	26.05	59.09	5.07	16.17	59.09	54.96	52.92	76.16
e_{rt}	0.43	0.26	1.20	0.04	6.61	1.20	2.93	1.59	2.19
\hat{z}_t	1.84	4.73	1.72	4.52	7.12	1.72	4.56	0.98	1.60
\hat{g}_t	5.06	26.70	2.46	42.00	4.92	2.46	4.26	3.48	0.75
\hat{z}_{it}	11.88	10.84	6.77	12.59	1.54	6.77	6.03	7.56	0.59
\hat{m}_t	1.01	0.69	6.14	3.95	6.27	6.14	2.10	1.00	0.84

Table 8: Unconditional variance decomposition (in percent)

Horizon		Structural shocks					
		TFP, \hat{a}_t	Redistrib., $\hat{\alpha}_t$	Preference, \hat{z}_t	Mon. & fiscal policy, ϵ_{rt}, \hat{g}_t	Invest. spec., \hat{z}_{it}	Matching effic., \hat{m}_t
Output, \hat{y}_t	1	21.53	26.73	17.70	28.14	4.83	1.09
	4	44.65	30.76	5.86	9.15	7.82	1.77
	8	49.56	30.61	3.00	6.26	9.08	1.50
	20	52.59	28.28	1.99	5.50	10.55	1.09
	40	53.12	26.92	1.86	5.52	11.56	1.02
Mark up, $\hat{\mu}_t$	1	63.36	12.99	6.55	12.12	0.28	4.71
	4	57.72	16.09	7.15	11.55	1.22	6.26
	8	57.40	16.18	7.12	11.53	1.52	6.26
	20	57.39	16.17	7.12	11.53	1.53	6.27
	40	57.38	16.17	7.12	11.53	1.54	6.27
Wage, \hat{w}_t	1	2.19	63.77	8.19	17.61	0.75	7.48
	4	21.47	67.27	2.16	5.66	1.00	2.43
	8	26.38	65.49	1.38	3.73	1.52	1.50
	20	30.58	59.30	1.06	3.39	4.56	1.11
	40	32.27	54.63	1.00	4.08	6.99	1.03
Unempl., \hat{u}_t	1	10.92	33.99	12.51	18.69	3.25	20.64
	4	57.72	16.09	7.15	11.55	1.22	6.26
	8	15.51	62.85	2.58	4.31	5.55	9.21
	20	20.94	61.16	1.81	3.63	5.94	6.51
	40	22.35	59.50	1.73	3.67	6.56	6.19
Vacancies, \hat{v}_t	1	13.45	41.85	15.40	23.02	4.01	2.27
	4	19.59	54.41	7.27	10.44	5.01	3.28
	8	22.01	56.66	5.55	8.17	5.05	2.56
	20	24.24	56.12	4.71	7.30	5.46	2.16
	40	24.99	55.20	4.58	7.22	5.90	2.11
Hours, \hat{h}_t	1	51.20	6.29	10.28	21.76	2.95	7.52
	4	42.02	8.29	10.07	23.41	7.17	9.03
	8	39.48	8.50	8.55	28.64	7.23	7.60
	20	35.43	6.79	6.41	36.48	9.24	5.64
	40	33.30	5.48	5.04	39.26	12.50	4.42

Table 9: Conditional variance decomposition at different horizons in the model featuring superficial habits

G The role of an alternative exogenous innovation

In this section we analyse the role of price mark-up shocks in a model where redistributive shocks are absent.

The reason why mark-up shocks are introduced is that with diminishing returns to labour, these shocks turn out to be also redistributive between factors of production and firm's aggregate profits. Rotemberg (2008) argues that amplification in labour market frictions can be generated through mark-up shocks:

While variations in market power emerge as an attractive source of aggregate fluctuations in employment, the particular source of these variations considered here does not. In particular, the variations in the elasticity of demand that are needed to explain employment fluctuations are too large.¹⁷

In order to verify Rotemberg's claim, we substitute redistributive shocks with mark-up shocks in an otherwise identical model and find that the posterior mean estimates of the dispersion of the mark-up shocks necessary to generate amplification as in the US data is indeed very large. Krause et al. (2008) estimate a NK model using Bayesian techniques but they are silent about the size of the price-elasticity shocks needed to match the volatility in the data. We find that with a calibration of $\epsilon = 11$, a dispersion of 19 (19%) is needed to generate these results – and the posterior mean of the estimated standard deviation coincides with the x-axis. The size of the standard deviation of the price-elasticity shock is unrealistically too large. To gain intuition as to why price-elasticity shocks are indeed too volatile, we strip out the model from nominal rigidities and deep habits but maintain the assumption of search and matching frictions. As pointed out in Section 3, the labour share can be expressed as a function of mark-ups as well as a frictional component. In a model featuring monopolistic competition, the mark-up measure is given by $\epsilon_t / (\epsilon_t - 1)$, where ϵ_t is the time-varying price-elasticity of demand that follows an AR(1) process. This means that a simple log-linearisation of the measure of mark-ups in a model driven by price-elasticity shocks implies that

$$\hat{\mu}_t = \frac{-\hat{\epsilon}_t}{\epsilon - 1}. \quad (54)$$

In Section 3, we found an inverse relationship between mark-ups, the labour share and labour market amplification given by the frictional component. For values of ϵ equal to 11, then $\epsilon - 1$ term is equal to 10. This means that the standard deviation of the price-elasticity needed to generate sufficient amplification must be more than 10 times as volatile as the baseline model featuring redistributive shocks. The lower the value of ϵ , the lower the dispersion needed to match the amplification in labour market variables.

Although price-elasticity and redistributive shocks enter in the job creation condition in a similar way, there are at least three important differences between these two model specifications. The first point of difference is conceptual: while mark-up shocks affect the market power of firms operating in a given economy, leaving unaffected the shares between labour income and capital income, redistributive shocks change directly the shares between labour income and capital income – leaving the degree of market power unchanged. The deep habit model gives rise to an endogenous source of variation in the market power variation due to the fact that firms have the incentive to price goods in order to build up their customer base. A second point of difference is that a redistributive shock affects the rate of return of capital and capital accumulation. A third point of divergence is the effect of mark-up shocks on inflation. While price-elasticity shocks affect directly the inflation rate via the Phillips curve, redistributive shocks however affect inflation only indirectly through changes in production.

¹⁷See Rotemberg (2008), page 33.

