A Fiscal Stimulus and Jobless Recovery*

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Abstract

We analyse the effects of a government spending expansion in a dynamic stochastic general equilibrium (DSGE) model with Mortensen-Pissarides labour market frictions, deep habits and a constant-elasticity-of-substitution (CES) production function. The combination of deep habits and CES technology is crucial. If the elasticity of substitution between capital and labour approaches one, i.e. the production function approximates a Cobb-Douglas, the presence of deep habits enables the model to deliver output and unemployment multipliers in the high range of recent empirical estimates. But as the elasticity of substitution is allowed to drop to values in the range of available estimates, while the output multiplier falls only marginally, the unemployment multiplier experiences a sizeable contraction. Thus CES technology with an empirically supported elasticity of substitution is able to produce a scenario compatible with the observed jobless recovery. An accommodative monetary policy with respect to the output gap alongside sticky prices also plays an important role for the stabilization properties of the fiscal stimulus.

Keywords: Fiscal policy; deep habits; labour market search-match frictions; unemployment; CES production function.

JEL Codes: E24; E62.

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1 Introduction

In the recent financial crisis an important dimension along which many governments have taken action has been fiscal policy. The economic profession and much of the academic discussion placed emphasis on the issue of whether and to what extent fiscal stimulus delivers the dual outcome of (i) moderating the output collapse and (ii) boosting job creation. In other words, there has been a considerable interest on the multiplier effects of government spending on output and unemployment. This assumes great importance also in the light of the *jobless recovery* that the US are experiencing in the aftermath of the *great recession*. As shown in Figure 1, the cyclical component of hours worked per employee closely comoves with the cyclical fluctuations of real output, and the cyclical component of unemployment is negatively correlated with that of output as reported in Table 1. However, while hours worked per employee and output have been on a recovery path from 2009 Q2 (the trough of the great recession), the unemployment rate has persistently remained well above average. In the recovery period, while the correlation between output and hours worked per employee is 0.99, the correlation between the unemployment rate and output is -0.18. Figure 1 also shows the well known fact in the business cycle literature that the unemployment rate is around ten times more volatile than output. Hours worked per employee are less volatile than output, but the volatility has the same order of magnitude.

The analysis of quantitative implications of fiscal policy was a contentious matter well before the financial crisis. Although we do not aim at reconciling the literature on fiscal stimulus, in this paper we provide a new perspective on a fiscal expansion with low job creation. In particular we analyse the effects of a government spending expansion in a dynamic stochastic general equilibrium (DSGE) model with Mortensen-Pissarides labour market frictions, deep habits in private and public consumption and a constant-elasticity-of-substitution (CES) production function. The main results are that: (i) we obtain output and unemployment multipliers inside the range of empirical estimates without the need to introduce nominal rigidities and the imposition of the zero lower bound (ZLB) on the nominal interest rate; (ii) we can reproduce a fiscal expansion with low job creation; and (iii) we can simulate a fiscal stimulus

	Correlation coefficients	
	Hours/employee - Output	Unemployment rate - Output
1995 Q1 - 2011 Q1	0.92	-0.63
2009 Q2 - 2011 Q1	0.99	-0.18

Table 1: Correlation coefficients between (i) hours worked per employee and real output; and (ii) the unemployment rate and real output. (Cyclical components: Percentage deviations from HP-trend for GDP and hours per employee, percentage deviations from the sample mean for the unemployment rate. Source: ALFRED, Federal Reserve Bank of St. Louis and authors' computations).

that mitigates the output collapse in a recession but contains the rise in unemployment only marginally. This scenario is in line with what we observe in the data in the aftermath of the *great recession*.

On the size of fiscal multipliers the literature has provided a variety of results. Auerbach et al. (2010) describe the range of mainstream estimate for multiplier effects as "almost embarassingly large". Recent VAR estimates of the output multiplier are generally greater than those predicted by DSGE models with no zero-lower-bound constraints. More pessimistic estimates of the output multiplier are around 0.7 (Barro and Redlick, 2011; Ramey, 2009); some contributions find values around one (see Hall, 2009, among others); while in other contributions these are greater than one (see Blanchard and Perotti, 2002; Monacelli et al., 2010; Blinder and Zandi, 2010; Fragetta and Melina, 2011, among others). Auerbach and Gorodnichenko (2011) study asymmetries in the propagation of fiscal shocks in booms and downturns and report output multiplier of up to 2.5 during recessions.

Cogan et al. (2010) have shown that standard "new Keynesian" (NK) models, embedding agents' rational expectations and various forms of frictions, deliver much smaller government spending multipliers than "old Keynesian" models of the kind used, for instance, by Bernstein and Romer (2009) to assess the effectiveness of the *American Recovery and Reinvestment Act* (ARRA) of 2009 and, in general, of the empirical literature.

The main reason why government spending multipliers are small in models with rational expectation is to be found in the negative wealth effect triggered by the increase in government purchases. This, in fact, crowds out private consumption and investment and makes output respond in a less than proportional way. Woodford (2011), through rather simple algebraic manipulations, shows that the government spending multiplier is (i) necessarily below one in a neoclassical Real Business Cycle (RBC) model and exactly the same both in an RBC with monopolistic competition and in a sticky-price NK model with strict inflation targeting; (ii) exactly one in an NK model with fixed real interest rate; (iii) somewhere between the two values in a model featuring a Taylor rule. In general, the more accommodative the monetary policy, the higher the fiscal multiplier. On the last point Canova and Pappa (2011) also provide empirical support using VARs. Moreover, substantially larger-than-one multipliers can be obtained in standard NK models if the ZLB binds. Christiano et al. (2009) find that the spending multiplier may also reach 10 at the ZLB if the fiscal stimulus lasts for exactly the quarters when the ZLB is binding.

The standard NK models Cogan et al. (2010) and Woodford (2011) refer to are models where only changes in the intensive margin of employment are taken into account as, by construction, they always feature a full-employment equilibrium. In such models, the impact of fiscal policy on job creation can only be "guessed" via a rule of thumb according to which a certain percentage point increase in output corresponds to the creation of a given number of jobs. To examine the issue of unemployment, the modern macroeconomic literature has made significant progress in embedding Mortensen-Pissarides search-matching (MPMF) frictions into otherwise standard NK models. Examples include Campolmi et al. (2010), Faia et al. (2010) and Monacelli et al. (2010). These models allow one to obtain unemployment equilibria, investigate the traditional unemployment-inflation trade-off, and evaluate the policy effects on the extensive margin of employment. Many models featuring MPMF frictions focus only on the extensive margin, but there also are examples of models (Thomas, 2008; Krause et al., 2008) that embed also the intensive margin (in terms of hours worked) in addition to the (un)employment rate.

A typical problem that arises in RBC and NK models featuring MPMF frictions is their difficulty in matching the unemployment volatility observed in the data (the so-called "unemployment volatility puzzle"). In the literature, this has mainly been addressed via the introduction of staggered nominal wages (Gertler and Trigari, 2006; Sala et al., 2008). Staggered nominal wages are a useful tool to improve the performances of estimated models such as Smets and Wouters (2007). However, Pissarides (2009) criticizes their introduction as a device to solve the unemployment volatility puzzle on the grounds that while time-series estimates provide evidence for (average) sticky wages, panel-data estimates support the claim that wages in the new matches are pro-cyclical. In the literature there has been a great effort to improve the ability of the standard search and matching model to generate cyclical fluctuations of unemployment and vacancies in response to productivity shocks. Di Pace and Faccini (2011) tackle the unemployment volatility puzzle via the introduction of "deep habits" in consumption as in Ravn et al. (2006). This implies that households form habits on the consumption of varieties as opposed to overall consumption, which leads to counter-cyclical mark-ups also in a model with flexible prices. Under deep habits monopolistically-competitive firms become more competitive because the elasticity of demand becomes procyclical. In addition, expected higher future profits, in a model with deep habits, induce firms, *ceteris paribus*, to post more vacancies and this leads to a greater amplification for the labour market tightness and, hence, equilibrium employment.

The introduction of deep habits in a DSGE model, as shown by Ravn et al. (2006), imply also that a government spending expansion, even in the presence of flexible prices, reduces the mark-up, fosters the real wage, and crowds in private consumption. In fact, the reduction in the mark-up determines a strong shift in labour demand which prevails on the shift in supply (determined by the negative wealth effect) and wages rise. Consumption rises because the negative wealth effect is offset by a strong substitution effect away from leisure and into consumption induced by the increase in wages.

These are desirable effects, as there is empirical evidence that (i) private consumption is typically crowded in by a government spending expansion as opposed to being crowded out as a canonical DSGE model predicts (Blanchard and Perotti, 2002; Gali et al., 2007; Pappa, 2009; Monacelli et al., 2010; Fragetta and Melina, 2011); (ii) the real wage increases after a government spending expansion (Pappa, 2005; Gali et al., 2007; Caldara and Kamps, 2008; Pappa, 2009; Fragetta and Melina, 2011) as opposed to falling as in the canonical model; (iii) the mark-up is typically countercyclical and, more specifically, Monacelli and Perotti (2008) and Canova and Pappa (2011) show that a government spending expansion is accompanied by a fall in the mark-up in the data.

In the empirical literature there is also evidence that the elasticity of substitution between capital and labour is not one (Klump et al., 2007; Chirinko, 2008; Cantore et al., 2010a, 2011; León-Ledesma et al., 2010). In addition there is also evidence that factor shares are time-varying (Blanchard, 1997; Jones, 2003, 2005; McAdam and Willman, 2008; Ríos-Rull and Santaeulália-Llopis, 2010). However, the standard use of Cobb-Douglas production functions prevents any model from replicating this regularity as the Cobb-Douglas implies constant factor shares.[1]

In this paper we build a model that is able to match these *empirical regularities* by merging a standard RBC model with Mortensen-Pissarides labour market frictions, deep habits in private and public consumption and a constant-elasticity-of-substitution (CES) production function. The combination of deep habits and CES technology is crucial. If the elasticity of substitution between capital and labour approaches one, i.e. the production function approximates a Cobb-Douglas, the presence of deep habits in consumption enables the model to deliver output and unemployment multipliers in the range of recent empirical estimates. As the elasticity of substitution is allowed to drop to values in the range of available estimates – i.e. the degree of complementarity between capital and labour increases – while the output multiplier falls only marginally, the unemployment multiplier experiences a sizeable contraction. In fact, in response to a fiscal stimulus and for a given level of capital, the smaller the elasticity of substitution, the smaller the number of vacancies posted. In such a case, the expansion in output is driven relatively more by an increase in the hours of work rather than new job creation. Thus, the CES technology with an empirically supported elasticity of substitution proves to be a useful tool to produce a scenario in line with the observed jobless recovery.

Finally, adding sticky prices into the DSGE model augmented with deep habits in general enhances the effects of a government spending expansion, similarly to what happens in more standard models. However, if the degree of deep habit formation is sufficiently high the reverse may also be true (Jacob, 2010). In this respect, an accommodative monetary policy with respect to the output gap alongside sticky prices plays an important role for the size of fiscal multipliers and, more generally, the expansionary properties of the fiscal stimulus. Optimal fiscal and monetary policy implications of the addition of deep habits in a NK model are studied by (Leith et al., 2009).

The remainder of the paper is structured as follows. Section 2 develops a flexible-price

[1] See (Cantore et al., 2010b) for more details.

model with deep habits in consumption and labour market frictions. Section 3 illustrates functional forms and the calibration. Section 4 presents the results in the flexible-price model and isolates the effects of several features of the model on the size of the output and unemployment multipliers. Section 5 shows how the model can be extended to include sticky prices and monetary policy. Finally, Section 6 concludes and sets the agenda for future research.

2 A flexible-price model

The model structure is represented in Figure 2. Households have a fraction of their members employed and a fraction unemployed. They offer labour services and capital to firms, who hire members of the households via vacancy posting and operate in an impefectly competitive market. Households and firms bargain over a wage. Households and the goverment exhibit deep habit formation in the consumption of differentiated goods produced by firms. The goverment buys a fraction of those goods, pays unemployment benefits to the unemployed members of the households and finances its expenditures by taxing households (and issuing government bonds in a version of the model). In the NK extension of the model we add price stickiness and a central bank who takes the interest rate decision.

2.1 Search-match technology

The labour market is characterized by standard Mortensen-Pissarides search-match frictions in that firms fill jobs by posting vacancies. Let n_t be the number of employed workers and total population be normalized to one. Conventionally, we assume that the number of new hires or "matches", M_t, is a Cobb-Douglas function of unemployed workers, $u_t \equiv 1 - n_t$, and vacancies, v_t, $M_t = \kappa u_t^{\omega} v_t^{1-\omega}$, where κ represents the efficiency of the matching process and $\omega \in (0, 1)$ is the elasticity of the number of matches to unemployment. Thus, the current probability that a worker finds a match is $p_t = \frac{M_t}{u_t} = k \left(\frac{u_t}{v_t}\right)^{\omega-1} = k\theta_t^{1-\omega}$, where $\theta_t \equiv \frac{v_t}{u_t}$ is commonly labelled as the labour market "tightness". The more vacancies are posted, given a certain level of unemployment, the tighter the labour market is said to be. Analogously, the current probability that a firm fills a vacancy is given by $q_t = \frac{M_t}{v_t} = k\theta_t^{-\omega}$. Both firms and workers take p_t and q_t as given. The two probabilities are linked by $p(\theta_t) = \theta_t q(\theta_t)$ and $q'(\theta_t) < 0$, $p'(\theta_t) > 0$. The law of motion of aggregate employment can be written as:

$$n_{t+1} = M_t + (1 - \lambda)n_t, \tag{1}$$

where λ is an exogenous job destruction rate.

2.2 Households

The economy is populated by a continuum of identical households indexed by $j \in [0,1]$ who have preferences over a continuum of differentiated consumption varieties indexed by $i \in [0,1]$. Household members can be either employed or unemployed. The employed at firm $i \in [0,1]$ earn a real wage w_{it} and suffer disutility from working, while the unemployed receive an unemployment benefit w_u. Following Ravn et al. (2006), we assume that households exhibit external deep habit formation in consumption, i.e. habits are formed on the average consumption level of each variety of good. This consumption externality is also known as "catching up with the Joneses good by good". Let n_t^j be the number of employed household members, and h_t^j be the hours that each employed individual devotes to work activities. Then, the total hours of labour supplied by household j is $N_t^j \equiv n_t^j h_t^j$. Let the total number of household members be normalized to one, so that n_t^j can be interpreted as an employment rate. Let also the total time available to individuals be normalized to one. Then, the leisure time for the employed members of household j is $l_t^j \equiv 1 - h_t^j$, while the unemployed "enjoy" leisure $l_t^j = 1$. Let us also assume that workers can perfectly insure themselves against idiosyncratic shocks, i.e. that income is pooled between the employed and the unemployed. Then, the representative household's instantaneous utility function is given by:

$$U((X_t^c)^j, n_t^j, 1 - h_t^j) = n_t^j U((X_t^c)^j, 1 - h_t^j) + (1 - n_t^j) U((X_t^c)^j, 1), \tag{2}$$

where $(X_t^c)^j$ is a habit-adjusted composite of differentiated consumption goods:

$$(X_t^c)^j = \left[\int_0^1 (C_{it}^j - \theta^c S_{it-1}^c)^{1-\frac{1}{\eta}} di \right]^{\frac{1}{1-\frac{1}{\eta}}}, \tag{3}$$

parameter η is the intratemporal elasticity of substitution across varieties, $\theta^c \in (0,1)$ is the degree of deep habit formation on each variety, and S_{it-1}^c denotes the stock of external habit in the consumption of good i. The stock of external habit S_{it}^c evolves over time according to the following law of motion:

$$S_{it}^c = \varrho^c S_{it-1}^c + (1 - \varrho^c) C_{it}, \tag{4}$$

where $\varrho^c \in (0,1)$ measures the speed of adjustment of the stock of external habit in the consumption of variety i to changes in the average level of consumption of the same variety.

For household j, the Beveridge curve is given by:

$$n_{t+1}^j = (1 - \lambda) n_t^j + p(\theta_t)(1 - n_t^j). \tag{5}$$

Let us also assume that household j has K_t^j capital holdings, which evolve according to the following law of motion:

$$K_{t+1}^j = (1-\delta)K_t^j + I_t^j \left[1 - S\left(\frac{I_t^j}{I_{t-1}^j}\right)\right], \tag{6}$$

where δ is the capital depreciation rate, I_t^j is investment taking place at time t, and $S(\cdot)$ represents an investment adjustment cost satisfying $S(1) = S'(1) = 0$ and $S''(1) > 0$. We assume that investment is also a composite of differentiated goods; however it does not exhibit deep habit formation, i.e. $I_t^j = \left[\int_0^1 \left(I_{it}^j\right)^{1-\frac{1}{\eta}} di\right]^{\frac{1}{1-\frac{1}{\eta}}}$. Expenditure minimisation leads to the optimal level of demand of investment goods for each variety i:

$$I_{it}^j = \left(\frac{P_{it}}{P_t}\right)^{-\eta} I_t^j, \tag{7}$$

where $P_t \equiv \left[\int_0^1 P_{it}^{1-\eta} di\right]^{\frac{1}{1-\eta}}$ is the nominal price index.

Each household j solves a two-stage problem. Letting P_{it} be the price of variety i, they first minimize total expenditure $\int_0^1 P_{it}C_{it}^j di$ over C_{it}^j, subject to (3). This leads to the optimal level of demand for each variety i for a given composite:

$$C_{it}^j = \left(\frac{P_{it}}{P_t}\right)^{-\eta} (X_t^c)^j + \theta S_{it-1}^c, \tag{8}$$

which is characterised by a price-elastic component and a price-inelastic component.

By multiplying both sides of equation (8) by P_{it}, integrating across varieties, and using the definition of nominal price index, we obtain the nominal value of the habit-adjusted consumption composite $P_t(X_t^c)^j = \int_0^1 P_{it}\left(C_{it}^j - \theta S_{it-1}^c\right) di$, which can be rearranged to write the household's real consumption expenditure C_t^j as a function of the consumption composite and the stock of habit: $C_t^j = (X_t^c)^j + \Omega_t$, where $\Omega_t \equiv \theta^c \int_0^1 \frac{P_{it}}{P_t} S_{it-1}^c di$.

The second stage of the problem faced by household j at time t is choosing paths for the habit-adjusted consumption composite $(X_t^c)^j$, capital K_{t+1}^j, investment I_t^j, and government real bond holdings B_t^j, which pay the gross real interest rate R_{t+1} one period ahead, to maximize lifetime utility:

$$H_t^j\left(n_t^j, K_t^j, B_t^j\right) \equiv \max_{(X_t^c)^j, K_{t+1}^j, I_t^j} \left\{ \begin{array}{c} U\left((X_t^c)^j, n_t^j, 1-h_t^j\right) \\ +\beta E_t H_t^j\left(n_{t+1}^j, K_{t+1}^j, B_{t+1}^j\right) \end{array} \right\}, \tag{9}$$

where $\beta \in (0,1)$ is the discount factor, subject to the law of motion of capital (6) and the following budget constraint:

$$\left(1+\tau_t^C\right)\left((X_t^c)^j+\Omega_t\right)+I_t^j+\tau_t+B_t^j=\left(1-\tau_t^W\right)n_t^j h_t^j w_{it}+(1-n_t^j)w_u$$
$$+\left(1-\tau_t^K\right)R_t^K K_t^j+R_t B_{t-1}^j+\int_0^1 J_{it}di, \tag{10}$$

where τ_t^C, τ_t^W and τ_t^K are tax rates on consumption, labour income and the return on capital, respectively; τ_t is a lump-sum tax; R_t^K is the rental rate of capital; and $\int_0^1 J_{it}di$ represents firms' profits.

The first-order condition with respect to the consumption composite $(X_t^c)^j$ implies that the Lagrange multiplier on the household's budget constraint (10) is equal to $\Lambda_t^j=\frac{U_{x,t}^j}{1+\tau_t^C}$, where $U_{x,t}^j$ is the marginal utility of the consumption composite. Let $\Lambda_t^j Q_t^j$ be the multiplier on the capital accumulation equation (6), and Q_t^j represent Tobin's Q. Then, the first-order condition with respect to capital, K_{t+1}^j, yields the following Euler equation:

$$Q_t^j=E_t\left\{D_{t,t+1}^j\left[\left(1-\tau_{t+1}^k\right)R_{t+1}^K+(1-\delta)Q_{t+1}^j\right]\right\}, \tag{11}$$

where $D_{t,t+1}^j\equiv\beta\frac{U_{x,t+1}^j}{U_{x,t}^j}\frac{1+\tau_t^C}{1+\tau_{t+1}^c}$ is the stochastic discount factor. The first order condition with respect to investment I_t^j yields the following:

$$\left\{\begin{array}{c} Q_t^j\left(1-S\left(\frac{I_t^j}{I_{t-1}^j}\right)-S'\left(\frac{I_t^j}{I_{t-1}^j}\right)\frac{I_t^j}{I_{t-1}^j}\right) \\ +E_t\left(D_{t,t+1}^j Q_{t+1}^j S'\left(\frac{I_{t+1}^j}{I_t^j}\right)\left(\frac{I_{t+1}^j}{I_t^j}\right)^2\right)\end{array}\right\}=1; \tag{12}$$

while the first order condition with respect to real government bonds implies:

$$1=E_t\left[D_{t,t+1}^j R_{t+1}\right]. \tag{13}$$

Employment n_t^j is determined as a result of a Nash wage bargaining, as described below. The surplus of the household in the bargaining, S_t^{wj}, can be computed as the value of having an additional household member employed. By using the envelope condition for employment, we obtain:

$$(S_t^w)^j=H_{nt}^j\left(n_t^j,K_t^j,B_t^j\right)=\left(1-\tau_t^W\right)w_{kt}h_t^j-\left[w_u-\frac{U_{n,t}^j}{U_{x,t}^j}\right]$$
$$+\left(1-\lambda-p(\theta_t)\right)E_t\left[D_{t,t+1}(S_{t+1}^w)^j\right], \tag{14}$$

which implies that the surplus from employment for the household is increasing in the net labour income plus the expected value from being employed the next period and decreasing in the opportunity costs.

Finally, hours of work h_t^j are chosen in a way that makes the bargain efficient, as again shown below.

2.3 Government

Deep habits are present also in government consumption. This can be justified by assuming that households derive habits also on consumption of government provided goods which can be thought of entering additively in their instantaneous utility function. Alternatively, as in Leith et al. (2009), one can also argue that public goods are local in nature and households care about the provision of individual public goods in their constituency relative to other constituencies. Controversies over "post-code lotteries" in health care and other local services (Cummins et al., 2007) and comparisons of regional per capita government spending levels (MacKay, 2001) suggest that households care about their local government spending levels relative to those in other constituencies.

In each period t, the government allocates spending $P_t G_t$ over differentiated goods sold by retailers in a monopolistic market to maximize the quantity of a habit-adjusted composite good:

$$X_t^g = \left[\int_0^1 (G_{it} - \theta^c S_{it-1}^g)^{1-\frac{1}{\eta}} di \right]^{\frac{1}{1-\frac{1}{\eta}}}, \tag{15}$$

subject to the budget constraint $\int_0^1 P_{it} G_{it} \leq P_t G_t$, where η is the elasticity of substitution across varieties, S_{it-1}^g denotes the stock of habits for government expenditures, which evolves as:

$$S_{it}^g = \varrho^c S_{it-1}^g + (1 - \varrho^c) G_{it}. \tag{16}$$

At the optimum:

$$G_{it} = \left(\frac{P_{it}}{P_t} \right)^{-\eta} X_t^g + \theta^c S_{it-1}^g. \tag{17}$$

Aggregate real government consumption G_t is set as an exogenous process:

$$\log \left(\frac{G_t}{\bar{G}} \right) = \rho_G \log \left(\frac{G_{t-1}}{\bar{G}} \right) + \epsilon_t^g, \tag{18}$$

where $\bar{G}$ is the steady-state level of government spending, ρ_G is an autoregressive parameter and ϵ_t^g is a mean zero, i.i.d. random shock with standard deviation σ^G.

The government budget constraint will then read as follows:

$$B_t = R_t B_{t-1} + G_t + (1 - n_t) w_u - \tau_t - \tau_t^C C_t - \tau_t^W w_t n_t h_t - \tau_t^K R_t^k K_t, \tag{19}$$

while taxes are set according to the following feedback rule :

$$\log\left(\frac{X_t}{\bar{X}}\right) = \rho_X \log\left(\frac{X_{t-1}}{\bar{X}}\right) + \rho_{XB}\frac{B_{t-1}}{Y_{t-1}} + \epsilon_t^X, \quad X_t = (\tau,\ \tau^c, \tau^w, \tau^k), \tag{20}$$

where ρ_X are autoregressive coefficients; $\bar{X}$ are steady state values; ϵ_t^X are serially uncorrelated, normally distributed shocks with zero mean and standard deviations σ^X, and ρ_{XB} is the responsiveness of tax X to the debt-to-GDP ratio.

We set steady-state government debt equal to zero in steady state, implying also that the government runs a balanced budget in steady state. To explore the benchmark scenario of lump-sum taxes and fully financed lump-sum taxation, it suffices to set the tax rates and governemnt debts constantly equal to zero, $B_t = \tau_t^C = \tau_t^W = \tau_t^K = 0$, and $\tau_t = G_t + (1-n_t)w_u$.

2.4 Firms

A continuum of monopolistically competitive firms indexed by $i \in [0,1]$ uses capital, K_{it}, and labour, $N_{it} \equiv n_{it}h_{it}$ to produce differentiated goods Y_{it}, which are sold at price $p_{it} \equiv P_{it}/P_t$. The technology used in the production process is represented by $F((ZK)_t K_{it}, (ZN)_t n_{it} h_{it})$, where $(ZK)_t$ and $(ZN)_t$, are a capital-augmenting technology shock and a labour-augmenting technology shock, respectively.

Employment at firm i evolves over time according to the following law of motion:

$$n_{it+1} = (1-\lambda)n_{it} + q(\theta_t)v_{it}, \tag{21}$$

where θ_t is treated as exogenous by the firm.

In addition, the firm faces hiring costs, HC_{it}, of posting v_{it} vacancies and employing n_{it} workers given by:

$$HC_{it} = g(z_{it})n_{it}\,; \quad g', g'' \geq 0, \tag{22}$$

where $z_{it} \equiv \left(\frac{v_{it}}{n_{it}}\right)$ is the vacancy ratio.[2]

The firm rents capital services from households at a rental rate R_t^K, takes employment n_{it} as given at time t, and maximizes the following flow of discounted profits:

$$J_t(n_{it}) = E_t\left\{\sum_{s=0}^{\infty} D_{t,t+s}\left[\begin{array}{c} p_{it}\left(C_{it+s} + G_{it+s} + I_{it+s}\right) - HC_{it+s} \\ -w_{it+s}n_{it+s}h_{kt+s} - R_{t+s}^K K_{it+s}\end{array}\right]\right\}, \tag{23}$$

with respect to K_{it+s}, n_{it+s}, v_{it+s},C_{it+s}, S_{it+s}^c, G_{it+s}, S_{it+s}^g and $p_{it+s} \equiv P_{it+s}/P_{it+s}$ subject to (21), (22), the demand for good i in the form of private consumption C_{it}, (8), government consumption G_{it}, (17), and investment, (7), the laws of motion of the stocks of habit for households, (4), and the government, (16), and the firm's resource contraint:

[2]Note in the original Pissarides model $g(z_t) = cz_t$ so that hiring costs per vacancy posted are constant.

$$C_{it+s} + G_{it+s} + p_{it}^{-\eta} I_{t+s} = F((ZK)_t K_{it}, (ZN)_t n_{it} h_{it}) = Y_{it}. \tag{24}$$

The corresponding first-order conditions for this problem are:

$$R_t^K = MC_t F_{K,it}, \tag{25}$$

$$\mu_{it} = (MC_t F_{N,it} - w_{it}) h_{it} + g'(z_{it}) z_{it} - g(z_{it}) + (1-\lambda) E_t \left[D_{t,t+1} \mu_{it+1} \right], \tag{26}$$

$$g'(z_{it}) = q(\theta_t) E_t \left[D_{t,t+1} \mu_{it+1} \right], \tag{27}$$

$$\nu_t^c, = p_{it} - MC_t + (1-\varrho^c) \lambda_t^c, \tag{28}$$

$$\lambda_t^c = E_t D_{t,t+1} (\theta^c \nu_{t+1}^c + \varrho^c \lambda_{t+1}^c), \tag{29}$$

$$\nu_t^g = p_{it} - MC_t + (1-\varrho^c) \lambda_t^g, \tag{30}$$

$$\lambda_t^g = E_t D_{t,t+1} (\theta^c \nu_{t+1}^g + \varrho^c \lambda_{t+1}^g), \tag{31}$$

$$C_{it} + G_{it} + (1-\eta) p_{it}^{-\eta} I_t + \eta MC_t p_{it}^{-\eta-1} I_t - \eta \nu_t^c p_{it}^{-\eta-1} X_t^c - \eta \nu_t^g p_{it}^{-\eta-1} X_t^g = 0. \tag{32}$$

Variables MC_t, μ_{it}, ν_t^c, λ_t^c, ν_t^g, λ_t^g are the Lagrange multipliers associated to constraints (24), (21), (8), (4), (17), (16), respectively. In particular, MC_t is the shadow value of output and represents the firm's real marginal cost.

If we denote the nominal marginal cost with MC_t^n, the gross mark-up charged by final good firm i can be defined as $M_{it} \equiv P_{it}/MC_t^n = \frac{P_{it}}{P_t} / \frac{MC_t^n}{P_t} = p_{it}/MC_t$. In the symmetric equilibrium all final good firms charge the same price, $P_{it} = P_t$, hence the relative price is unity, $p_{it} = 1$. It follows that, in the symmetric equilibrium, the mark-up is simply the inverse of the marginal cost.

By combining equations (28), (30) and (32), substituting for for the demands for C_{it} and G_{it}, (8) and (17), and rearranging, the optimal pricing decision in the symmetric equilibrium can be written as follows:

$$\left\{ \begin{array}{c} (X_t^c + X_t^g + I_t) \left[1 - \frac{\eta}{\eta-1} MC_t \right] \\ + \frac{\eta}{\eta-1} (1-\varrho^c) \left[\lambda_t^c X_t^c + \lambda_t^g X_t^g \right] - \frac{\theta^c}{\eta-1} \left(S_{t-1}^c + S_{t-1}^g \right) \end{array} \right\} = 0. \tag{33}$$

The surplus of the firm from employment at the margin is represented by μ_{it}:

$$S_{it}^f = \mu_{it}, \tag{34}$$

while $F_{K,it}$ represents the marginal product of capital, and $F_{N,it}$ represents the marginal product of labour. Note that (26) uses the fact that the product of an employee is given by $F_{n,it} = F_{N,it} h_{it}$ at the margin.

Iterating (26) one period forward and combining it with (27) yields the following *vacancy* *equation* or *job creation condition*:

$$\begin{aligned} \frac{g'(z_{it})}{q(\theta_t)} &= E_t\left[D_{t,t+1}\mu_{it+1})\right] \\ &= E_t\left\{D_{t,t+1}\left[\begin{array}{c}(MC_tF_{N,it+1} - w_{it+1})h_{it+1} + g'(z_{it+1})\,z_{it+1} \\ -g(z_{it+1}) + (1-\lambda)\frac{g'(z_{it+1})}{q(\theta_{t+1})}\end{array}\right]\right\}. \end{aligned} \quad (35)$$

Clearly, in the absence of hiring costs, $g(z_{it+1}) = g'(z_{it+1}) = 0$, (35) becomes $MC_tF_{N,it} = w_{it}$, the competitive labour market outcome.

2.5 Wage bargaining and hours worked

Let $\epsilon \in [0,1]$ denote the firm's bargaining power and S_{it}^w be the surplus of a household negotiating with firm i. Then, Nash bargaining implies that the real wage maximise the weighted product of the worker's and the firm's surpluses from employment:

$$\max_{w_{it}} (S_{it}^w)^{1-\epsilon}\left(S_{it}^f\right)^{\epsilon} \quad (36)$$

The solution to problem (36) yields the following surplus-splitting rule:

$$S_{it}^w = \frac{1-\epsilon}{\epsilon}\left(1-\tau_t^w\right)S_{it}^f. \quad (37)$$

. The introduction of the distiortionary labour tax makes the workers actual bargaining power fluctuate along the business cycle and reduces the share of the workers in the barganing itself. Substituting for (14), (34), and (26) into (37) and rearranging yields the following *wage equation*:

$$w_{it}h_{it} = (1-\epsilon)\left[MC_tF_{N,it}h_{it} - g(z_{it}) + g'(z_{it})z_{it} + \theta_t g'(z_{it})\right] + \epsilon\left[\frac{w_u - \frac{U_{n,t}}{U_{x,t}}}{1-\tau_t^w}\right]. \quad (38)$$

Condition (38) implies that the wage paid to the employee is a weighted average of the marginal product of the employee plus the savings from job continuation, net of the cost of posting vacancies, and the opportunity cost of working, which is increasing in the unemployment benefits, the disutility of working activities and the labour income tax.

Finally, hours are chosen to achieve an efficient bargain. This means that in equilibrium the marginal product of labour must be equal to the marginal rate of substitution between leisure and the consumption composite:

$$F_{N,it} = -\frac{U_{nh,t}}{U_{x,t}}. \quad (39)$$

2.6 Equilibrium

In equilibrium all markets clear. The resource constraint completes the model:

$$Y_t = C_t + I_t + G_t + g(z_t)n_t. \tag{40}$$

The system of equations describing the full equilibrium is summarized in Appendix B.

3 Functional forms and calibration

3.1 Utility function, investment adjustment costs and hiring costs

In what follows, equation (2) specializes as a non-additively-separable utility function:

$$U(X_t^c, n_t, 1-h_t) = n_t \frac{\left[X_t^{c(1-\varrho)}(1-h_t)^{\varrho}\right]^{1-\sigma_c} - 1}{1-\sigma_c} + (1-n_t)\frac{X_t^{c(1-\varrho)(1-\sigma_c)} - 1}{1-\sigma_c},$$

where $\sigma_c > 0$ is the coefficient of relative risk aversion, and ϱ is the elasticity of substitution between leisure and consumption. When $\sigma_c \to 1$, preferences are represented by an additively separable utility function; while in the case of full employment, i.e. $n_t \to 1$, the equation reads as a standard utility function in consumption and leisure compatible with balanced growth.

Investment adjustment costs take the form of a quadratic function:

$$S\left(\frac{I_t}{I_{t-1}}\right) = \frac{\gamma}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2, \ \mu > 0,$$

while we allow for a convex hiring cost function, i.e. $g(z_t)$ specializes as follows :

$$g(z_t) = \frac{\chi}{1+\psi} z_t^{1+\psi}, \ \psi > 0.$$

3.2 CES production function and "re-parametrization"

We specialize the production function $F((ZK)_t K_t, (ZN)_t n_t h_t)$ as a constant-elasticity-of-substitution (CES) production function:

$$F((ZK)_t K_t, (ZN)_t n_t h_t) = \left[\alpha_K \left((ZK)_t K_t\right)^{\frac{\sigma-1}{\sigma}} + \alpha_N ((ZN)_t n_t h_t)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}} \tag{41}$$

where σ is the elasticity of substitution between capital and labour, and α_K and α_N are the so-called distribution parameters. Note that, unlike in the Cobb-Douglas case, the distribution parameters do not represent factor shares of income and are not dimensionless. In other words, these have dimensions that depend on the measurement units of capital and labour as discussed in Cantore and Levine (2011). As such, the distribution parameters are meaningless and cannot be calibrated. In this subsection, we show that once the capital share of income has been calibrated, α_K and α_N can be "re-parameterized", i.e. expressed as functions of this share and of endogenous variables of the model, which in turn depend on the deep parameters. This procedure is conducted in the spirit of Cantore and Levine (2011).

As $\sigma \to 1$, the CES production function collapses to a Cobb-Douglas (CD) if and only if $\alpha_K + \alpha_N = 1$. While $\sigma \to 0$ leads to the Leontief case.

In the CES case, marginal products of capital and labour take the following forms:

$$F_{K,t} = \alpha_K (ZK)_t^{\frac{\sigma-1}{\sigma}} \left(\frac{Y_t}{K_t} \right)^{\frac{1}{\sigma}}, \tag{42}$$

$$F_{N,t} = \alpha_N (ZN)_t^{\frac{\sigma-1}{\sigma}} \left(\frac{Y_t}{n_t h_t} \right)^{\frac{1}{\sigma}}. \tag{43}$$

Let variables without time subscript denote steady-state values and $S^K \equiv \frac{F_K K}{Y} \in (0,1)$ be the calibrated capital share of income. Combining equation (42) with the definition of capital share and rearranging yields α_K as a function of the capital share and endogenous variables:

$$\alpha_K = S^K \left(\frac{Y}{(ZK) \cdot K} \right)^{\frac{\sigma-1}{\sigma}}. \tag{44}$$

As $\sigma \to 1$, i.e. the production function tends to a CD, $\alpha_K \to S^K$. As the total products of capital and labour have to add up to total output, the following holds:

$$\frac{F_N nh}{Y} = 1 - \frac{F_K K}{Y} = 1 - S^K. \tag{45}$$

Combining equations (43) and (45) allows us to recover α_N:

$$\alpha_N = (1 - S^K) \left(\frac{Y}{(ZN)nh} \right)^{\frac{\sigma-1}{\sigma}}. \tag{46}$$

As $\sigma \to 1$, $\alpha_N \to (1 - S^K)$. Note that if the labour market is not Walrasian, i.e. it is characterized by wage bargaining and hiring costs, $(1 - S^K)$ does not represent the labour share, S^N, but it also includes the share of income that is wasted in the search-matching and bargaining process, $S^{SM} \equiv \frac{g(z)n}{Y}$, such that $S^K + S^N + S^{SM} = 1$.

3.3 Parameter choice and calibration

To calibrate the model we assign numerical values to parameters in order to match a number stylized facts for the US economy in the post-WWII era. The time period in our model corresponds to one quarter in the data. Table 1 summarises the calibration exercise.

A set of parameters are simply set to values that are widely used in the literature. Namely we set the subjective discount factor, β, equal to 0.99, which implies a quarterly real interest

Parameter		Value
Discount factor	β	0.99
Capital share of income	S^K	$1/3$
Capital depreciation rate	δ	0.025
Relative risk aversion	σ_c	2
Elasticity of substitution in production function	σ	0.4
Elasticity of substitution across varieties	η	6
Investment adjustment cost parameter	γ	3.24
Degree of deep habit formation	θ^c	0.86
Habit persistence	ϱ^c	0.85
Job separation rate	λ	0.103
Elasticity of matching to unemployment	ω	0.5
Firms' bargaining power	ϵ	0.5
Share of government spending in output	$\bar{g}/\bar{y}$	0.2
Persistence of government spending shock	ρ_g	0.90
Persistence of tax shocks	ρ_X	0.90
Convexity in hiring cost	ψ	1
Elasticity of subst leisure/consumption	ϱ	set to target $\bar{h} = 0.40$
Scaling factor in hiring cost function	χ	set to target $\bar{p} = 0.83$
Scaling factor in matching function	κ	set to target $\bar{q} = 0.70$
Unemployment benefit	w_u	set to target $\bar{\Theta} = 0.70$

Table 2: Baseline calibration

rate of about 1%. The capital depreciation rate, δ, and the coefficient of relative risk aversion, σ_c, are set equal to 0.025 and 2, respectively, while the capital share of income, S^K, takes the conventional value of $1/3$. The elasticity of substitution across varieties, is set to a rather standard value of 6, which implies a steady state markup of around 20% in the absence of deep habits.

When the production function takes the general CES form, we set the elasticity of substitution, σ, equal to 0.40, a value close to the empirical estimates in León-Ledesma et al. (2010). We obtain the Cobb-Douglas as a limiting case, by setting $\sigma \to 1$. In that case $\alpha_K \to 1/3$ and $\alpha_N \to 2/3$. The investment adjustment cost parameter is set equal to 3.24, the value estimated by Christiano et al. (2005). The degree of deep habit formation, θ^c, and the habit persistence, ϱ^c, are set equal to 0.86 and 0.85, respectively. These are the same estimated values used in Ravn et al. (2006). We then set the convexity parameter in the hiring cost function to 1, which makes it quadratic as in Gertler and Trigari (2006) and Thomas (2008). The firms' bargaining power, ϵ, and the elasticity of matching to unemployment, ω, are both set equal to 0.5. This choice satisfies the Hosios condition for the efficiency of the equilibrium. There is no reason to believe that this condition holds in practice, however this parameter choice is shared by most of the existing literature and hence allows comparability of the results. The value for the job separation rate, λ, is set equal to 0.103 to imply that jobs last on average 2 years and a half.

This is in line with the calculations made by Shimer (2005). The persistence of fiscal shocks is set equal to 0.90, which is approximately the value observed in the data (see Monacelli et al., 2010, among others).

Finally, we set (i) the elasticity of substitution between leisure and consumption, ϱ; (ii) the scaling factor in the hiring cost function, χ; (iii) the scaling factor in the matching function, κ, and (iv) the unemployment benefit, w_u, in order to match: (a) a steady-state share of hours worked over total hours, $\bar{h}$, of 40%; (b) a steady-state job finding probability, $\bar{p}$, equal to 83%, as estimated by Shimer (2005);[3] (c) a value for the vacancy filling probability, $\bar{q}$, equal to 70%, as in Trigari (2009); and (d) a ratio for the value of non-work to work activities (*replacement ratio*), $\bar{\Theta} \equiv \frac{w_u - \bar{U}_n/\bar{U}_c}{\bar{F}_n}$ (i.e. the sum of unemployment benefits and the disutility of work over the marginal product of employment), equal to 70%, a value very close to the point estimate of 72% by Sala et al. (2008). As the value for the replacement ratio is debated in the literature and is an important determinant of the unemployment multiplier, we show sensitivity of our results to different magnitudes for this parameter in the Appendix A.

In addition to the explicitly-targeted steady-state values, this calibration implies reasonable "great ratios"; namely a consumption/output ratio of 61%, an investment/output ratio of 18% and a hiring costs/output ratio of 1%. The choice of the job separation rate, coupled with the job finding probability implies, through the Beveridge curve, a steady-state unemployment rate of approximately 11%.

4 Results

We present the results starting from a standard neoclassical (RBC) model with search and matching frictions in the labour market and adding deep habits and the CES technology one at a time. Subsection 4.1 presents the well known results that in the baseline RBC model output and unemployment multipliers are well below the range of available empirical estimates. It also show some features at odds with the data, namely constant price mark-up and factor shares, a negative response of the real wage and a negative response of consumption following a government spending shock. Subsection 4.2 shows how, even in the absence of price stickiness and the imposition of a ZLB, the introduction of deep habits magnifies both output and unemployment multipliers. At the same time, in line with Ravn et al. (2006), now the mark-up falls, real wages rise and consumption is crowded in after an expenditure expansion. By introducing the CES production function in Subsection 4.3 we show that, as capital and labour became more complementary, the growth of output fostered by a government spending expansion is sustained relatively more by an increase in the intensive margin (current employees work longer hours) than an increase in the extensive margin (new job creation). Factor shares now present cyclical fluctuations. Subsection 4.4 shows how the magnitude of the responses

[3]Shimer (2005) estimated a monthly job finding probability of 0.45, which corresponds to a quarterly value of approximately 0.83.

of output and unemploymen is altered by distortionary taxation. Finally, in Subsection 4.5, we explore the effects of a fiscal stimulus at a recession time, which fosters a *jobless recovery.*

4.1 Neoclassical benchmark with search-match frictions

In Figure 3 we plot the impulse responses of a number of fundamental macroeconomic variables to a government spending expansion of size 1% of output. Normalising the size of the fiscal shock as such allows us to interpret the output responses as fiscal multipliers. For unemployment, we report the absolute changes in percentage points that the increase in spending by 1% of output triggers. This can be regarded as a measure of the unemployment multiplier. This exercise is conducted under the assumption that the fiscal measure is fully financed by lump-sum taxes, i.e. $\tau_t^C = \tau_t^W = \tau_t^K = 0$, and $\tau_t = G_t$.[4]

As a benchmark, we consider the effects of a government spending expansion in the neoclassical flexible-price benchmark with MPMF under the assumption that the production function is Cobb-Douglas, and that no deep habits in private and government consumption are formed. The results are in line with most of the recent theoretical fiscal stimulus literature: a fiscal expansion triggers a negative wealth effect, via an increase in tax obligations, that curbs consumption and boosts labour supply. In the context of MPMF, this has a negative effect on households' reservation wage and a smaller positive effect on firms' reservation wage. As a result, the share of the firms in the surplus from wage bargaining increases, which translates into more vacancies being posted, a tighter labour market, a reduction in equilibrium unemployment, and a fall in the real wage. The absorption of resources by the government is such that also private investment is crowded out and the real interest rate rises. As standard in flexible-price neoclassical models with imperfect competition, the price mark-up over the marginal cost remains constant. Another standard result – coming instead from use of the Cobb-Douglas production function – is that capital and labour shares of income are also constant.

From a quantitative point of view, results are also similar to existing contributions such as Campolmi et al. (2010) and Monacelli et al. (2010): government spending expansions yield output multipliers well below one (around 0.5 for our calibration) and almost negligible negative effects on unemployment.

The results in the flexible-price benchmark model contrast with much of the recent empirical literature, both from a quantitative and from a qualitative point of view. On the quantitative side, recent empirical estimates of the output multiplier are generally greater than those predicted by DSGE models with no zero-lower-bound constraints. More pessimistic estimates of the output multiplier are around 0.7 (Barro and Redlick, 2011; Ramey, 2009); some contributions find values around one (see Hall, 2009, among others); while in

[4]When lump-sum taxes are in place the timing of tax collection does not matter as the Ricardian equivalence holds. In other words, debt-financed fiscal expansions would yield the same effects.

other contributions these are greater than one (see Blanchard and Perotti, 2002; Monacelli et al., 2010; Blinder and Zandi, 2010; Fragetta and Melina, 2011, among others). On the size of the unemployment multiplier Monacelli et al. (2010) provide an estimate at peak of -0.6 percentage points after ten quarters, which *per se* may be regarded to be small, but it is an order of magnitude bigger than the multiplier predicted by the flexible-price benchmark with MPMF.[5] On the qualitative side, there is also empirical evidence that government spending expansions crowd in private consumption and boost *both* hours worked *and* the real wage (see Pappa, 2005; Gali et al., 2007; Pappa, 2009; Fragetta and Melina, 2011, among others). In addition, Monacelli and Perotti (2008) and Canova and Pappa (2011) find evidence for a fall in the price mark-up following a fiscal expansion.

4.2 Deep habits in consumption

The introduction of deep habits in consumption yields a substantial improvement on the performance of the DSGE model in matching these empirical findings, even in the absence of price and/or wage rigidities and the zero-lower bound. In the seminal work by Ravn et al. (2006), they already illustrate that a government spending expansion yields a crowding-in of private consumption as opposed to a crowding-out, when deep habits in private and public consumption are introduced into an otherwise standard flexible-price model with imperfect competition. In addition, Di Pace and Faccini (2011) find that deep habits in consumption have the property of considerably magnifying unemployment volatility also in a model with flexible wages, proposing a solution to Pissarides (2009)'s unemployment puzzle.

In Figure 3 we show that by introducing deep habits in our model, not only are we able to match a number of empirical facts from a qualitative point of view, but we are also able to obtain output and unemployment multipliers closer to those computed in the SVAR literature, under a plausible calibration.

The differences in the transmission mechanism of a fiscal shock in a model with deep habits in consumption work through the fact that the mark-up is counter-cyclical under deep habits even if the model features fully flexible prices. Under deep habits the mark-up is counter-cyclical due to the co-existence of two effects: an *intra-temporal effect* (or *price-elasticity effect*) and an *inter-temporal effect*. The intra-temporal effect can easily be understood by looking at the demand faced by an individual firm i:

$$AD_{it} = C_{it} + G_{it} + I_{it} = p_{it}^{-\eta} \left(X_t^c + X_t^g + I_t \right) + \theta^c \left(S_{it-1}^c + S_{it-1}^g \right).$$

The right-hand side of the demand curve is given by the sum of a *price-elastic* term and a *price-inelastic* term. When the habit-adjusted aggregate demand $(X_t^c + X_t^g + I_t)$ rises, the "weight"

[5] Brückner and Pappa (2010) report evidence according to which unemployment may also rise in response to a government spending shock and match this finding by including the labour-force participation rate into a New-Keynesian model through an insider/outsider mechanism.

of the price-elastic component of demand grows and the effective price elasticity of demand $\tilde{\eta}_{it} \equiv -\frac{\partial AD_{it}}{\partial p_{it}} \frac{p_{it}}{AD_{it}} = \eta - \theta^c \frac{\left(S^c_{it-1} + S^g_{it-1}\right)}{AD_{it}}$ increases, as opposed to remaining constant and equal to η as in the standard case ($\theta^c = 0$). The fact that the elasticity of demand is pro-cyclical is one determinant for the price mark-up being counter-cyclical. The other determinant comes from the inter-temporal effect: the awareness of higher future sales coupled with the notion that consumers form habit at the variety level, makes firms inclined to give up some of the current profits – by temporarily lowering their mark-up – in order to lock-in new consumers into customer/firm relationships and charge them higher mark-ups in the future.

A government spending expansion, also under deep habits, causes a negative wealth effect. However, the drop in the mark-up, which in turn implies higher future sales, translates into more vacancy posting through the job creation condition. The higher labour market tightness implies a greater fall in the unemployment rate. This coexists not only with an increase in the intensive margin (hours worked) but also with an increase in the real wage. The increase in the real wage is made possible by the greater increase in the firm's reservation wage, which induces a rise in the bargained wage. The increase in equilibrium wage makes leisure relatively more expensive and causes a substitution effect towards consumption that more than compensate the negative wealth effect. As a result, consumption rises.

With a Cobb-Douglas production function and our baseline calibration the resulting output multiplier is around 1.7, a number in the high range of empirical estimates. The peak unemployment multiplier is -0.27 percentage points, which is of the same order of magnitude of the estimates reported by Monacelli et al. (2010), as opposed to the model without deep habits.

In sum, deep habits in private and public consumption are a useful addition to the DSGE model because through them – even in the absence of any sources of nominal stickiness and without the imposition of the ZLB – (i) the output multiplier of government spending can be considerably magnified up to values in the range of empirical estimates; (ii) the unemployment multiplier can be brought from near-zero to values of the same order of magnitude found in the data; (iii) private consumption is crowded in by government spending; (iv) the price mark-up drops; and (v) the real wage rises together with hours worked.

In the NK literature the fall in the mark-up and the increase in the real wage are matched to a certain extent by including price and/or wage stickiness. However, NK models manage to get only an initial positive response in the real wage – while the empirical literature finds a persistent positive increase – and the fall in the mark-up is not generally enough to push aggregate supply upward to such an extent that the fiscal multiplier is dramatically magnified. Consumption is still crowded out unless either (i) a non-additively separable utility function is adopted and the intertemporal elasticity of substitution of consumption is set to be low (i.e. σ_c, its inverse, is high) entailing strong intratemporal substitution effects between consumption and leisure (see for example Linnemann, 2006; Monacelli et al., 2010) or (ii) it has to be assumed that an implausibly high share of consumers show a “rule-of-thumb” non-optimising behaviour (Gali et al., 2007).

4.3 CES production function

The empirical literature has not reached a consensus on the macroeconomic effects of fiscal policy. Nonetheless, if one wants to operate a synthesis of available empirical estimates on output and unemployment expenditures multipliers, it seems fair to conclude that, when the government purchases more goods and services from the private sector, this may yield a sizeable increase in real output, while the effect on new job creation is likely to be small (Brückner and Pappa (2010) claim that the effect may even be negative).

In this subsection we show that if the elasticity of substitution between capital and labour, σ, is allowed to drop from 1 (CD case) to values in the range of estimated values, this empirical regularity can be explained within a DSGE model with MPMF and deep habits in private and government consumption. Estimates of σ are between 0.3 and 0.6 (Klump et al., 2007; Chirinko, 2008; Cantore et al., 2011, 2010a; León-Ledesma et al., 2010).

In Figure 4 we show that the introduction of the CES production function – obtained by setting $\sigma = 0.4$ – marginally diminishes the output multiplier to almost 1.4 (which is about 83% of the value obtained in the CD case), while the unemployment multiplier drops to -0.18 percentage points (about 67% of the value obtained in the CD case). In addition, factor shares react to the government spending expansion.[6]

The unequal effects on the output and unemployment multipliers depend on the fact that lowering the elasticity of substitution in the CES production function is equivalent to assuming that the technology is closer to the Leontief case, i.e. capital and labour are more complements than substitutes. In Figure 4 we show that, as σ is allowed to assume values lower than one, given that capital is unable to change instantaneously in response to the fiscal expansion, firms have smaller incentives to create new jobs through vacancy posting. However, both the negative wealth effect (coming from the absorbtion of resources by the government) and the substitution of leisure with consumption (coming from the decline in the mark-up due to the presence of deep habits) still act in the same direction of causing a substantial increase in the supply of hours of work.

Similarly to the comparison made above for the fiscal multipliers, we can quantitatively compare the impact responses of equilibrium hours worked, wage and vacancies obtained in the CD case ($\sigma \to 1$) with the CES case, i.e. the case in which σ takes a value in the range of empirical estimates ($\sigma = 0.4$). With a CES the response of hours worked is around 80% of

[6] In the exercises we perform in this subsection and the rest of the paper, different responses of unemployment in absolute deviations, obtained by changing some parameter values, are comparable as we ensure that steady-state unemployment is the same across calibrations. This is allowed by the calibration strategy itself, which entails targeting a specific job finding probability $\bar{p}$ and setting the job separation rate λ. In fact, steady-state unemployment, through the Beveridge curve, is a function of only $\bar{p}$ and λ, i.e. $\bar{n} = \bar{p}/(\lambda + \bar{p})$.

the response obtained with a CD, while the responses of the real wage and vacancies with a CES are around 62% and 67% of the responses delivered by a CD, respectively.

In Figure 5 we plot the peak elasticity of the unemployment rate to output in response to a government spending expansion at different levels of the elasticity of substitution between capital and labour. When σ drops from 1 (CD case) to the lower bound of the range of empirical estimates ($\sigma = 0.3$), the peak elasticity of the unemployment rate to output drops by around 20%.

In sum, if the technology operating in the economy is represented by a CES production function, as σ falls, the growth of output fostered by a government spending expansion is sustained relatively more by the an increase in the intensive margin (current employees work longer hours) than an increase in the extensive margin (new job creation).

4.4 Debt-financed fiscal policy and distortionary taxation

In order to introduce government debt and distortionary taxes we set the steady-state tax rates to the values reported by Christiano et al. (2010), i.e. $\overline{\tau}^c = 0.05$, $\overline{\tau}^w = 0.24$, and $\overline{\tau}^k = 0.32$, and the response of the tax rates to government debt $\rho_{XB} = 0.02$, the value used by Monacelli et al. (2010). In addition, we let the government accumulate public debt according to law of motion (19). Figure 6 shows that the introduction of distortionary taxes alters the magnitude of the responses of output and unemployment, but unemployment is affected more. Such reductions in the multipliers are (i) due to the distortion on equilibrium employment triggered by the increase in the tax rates following the fiscal expansion and (ii) to the dynamics of the fiscal instruments implied by feedback rule (20). In fact, as consumption and the sources of income are taxed more, the tax-adjusted value of non-work activity increases. This reduces the total surplus of employment. In addition, as the imposed feedback rule implies a gradual return of the tax instruments to their steady state value, this implies also postponement of work activities.

4.5 Jobless recovery

In this subsection we investigate the low-job-creation feature of the fiscal stimulus in a case in which the latter takes place at a recession time. In accordance with the findings of subsection 4.3, we show that a lower-than-one factor elasticity of substitution delivers a more jobless outcome as the output contraction is mitigated more by an increase in the hours of work than by vacancy posting and job creation.

For illustrative purposes, we simulate a recession by means of a negative technology shock. Figure 7 shows the responses of output and unemployment in the cases in which the production function is a CD and a CES with $\sigma = 0.4$ (bold lines in the first and second row of Figure 7). The size of the shock is chosen in order to make output contract by around 7.5% from steady state at peak when the production function is a CES. This is approximately the size of the deviation of US output from potential in the second quarter of 2009 (the trough of the *great recession* according to the National Bureau of Economic Research), using the series available in ALFRED (Federal Reserve Bank of St. Louis). The same shock makes output contract less (6%) when the production function is CD. In addition the model predict that unemployment increases at peak by more than 4 percentage points in the CES case and by 2.5 percentage points in the CD case.

In the same charts, we show the mitigatory effects of a fiscal stimulus (dashed lines). In particular, we proxy the fiscal stimulus with a government spending expansion of 5% of output, approximately the expenditure expansion foreseen by the ARRA.[7] It is evident that while the fiscal stimulus has similar effects in terms of output stabilization, unemployment stabilization is considerably less pronounced under the CES production function. The third row of Figure 7 plots the ratios of the impulse responses with the fiscal stimulus activated with respect to the impulse responses with no fiscal stimulus, in the two alternative cases of CD and CES. In the experiment proposed here, the output contraction in the presence of the fiscal stimulus is around 40% of the contraction in the no-fiscal policy scenario under CD and around 25% under CES. The rise in unemployment in the presence of the fiscal stimulus is instead 50% less pronounced under CD and around 20% under CES. In other words, at a recession time, the model with a CES production function predicts that a government spending expansion fosters a considerably more *jobless recovery.*

5 The fiscal stimulus in a NK extension of the model

This section offers a new-Keynesian (NK) extension of the model that includes sticky prices and monetary policy. Price stickiness is introduced as in Rotemberg (1982), i.e. by assuming that changing prices costs resources while monetary policy is set by imposing a Taylor rule.[8]

5.1 Introducing sticky prices

The introduction of sticky prices changes the problem of final good firms $i \in (0,1)$ presented in Section 2.4 in that they now choose the price level, P_{it}, instead of the relative price, p_{it}, and they face quadratic price adjustment costs $\frac{\xi}{2}\left(\frac{P_{it}}{P_{it-1}}-1\right)^2$, where parameter ξ measures the degree of price stickiness. Thus, the profit function now reads as follows:

[7]Blinder and Zandi (2010, table 10) report that the total more-than \$ 1-trillion 2009 stimulus package in the US was split into a total of \$ 682 billion for spending increases and \$ 383 billion for tax cuts. Given that the 2009 US GDP at current prices was \$ 14 trillion, the spending increases were 4.9% of GDP.

[8]The use of price-adjustment costs as in Rotemberg (1982) is shared by virtually all papers featuring deep habits in consumption as it is a rather straight-forward addition from a technical point of view. By contrast using Calvo-type contracts introduces firm-specific habit effects which are more difficult to handle.

$$J_t(n_{it}) = E_t \left\{ \sum_{s=0}^{\infty} D_{t,t+s} \left[\begin{array}{c} \frac{P_{it+s}}{P_{t+s}} \left(C_{it+s} + G_{it+s} + I_{it+s} \right) - HC_{it+s} \\ -w_{it+s} n_{it+s} h_{kt+s} - R^K_{t+s} K_{it+s} - \frac{\xi}{2} \left(\frac{P_{it+s}}{P_{it+s-1}} - 1 \right)^2 \end{array} \right] \right\}, \quad (47)$$

The first-order conditions with respect to K_{it+s}, n_{it+s}, v_{kt+s},C_{it+s}, S^c_{it+s}, G_{it+s}, S^g_{it+s} remain unaltered relative to the flexible-price case, while taking the first-order condition with respect to the price level P_{it+s} leads to the following:

$$\left\{ \begin{array}{c} \frac{P_{it}}{P_t} \left(C_{it} + G_{it} \right) - \xi \left(\frac{P_{it}}{P_{it+s}} - 1 \right) \frac{P_{it}}{P_{it-1}} + (1-\eta) \left(\frac{P_{it}}{P_t} \right)^{1-\eta} I_t \\ +\eta MC_t \left(\frac{P_{it}}{P_t} \right)^{-\eta} I_t - \eta \nu^c_t \left(\frac{P_{it}}{P_t} \right)^{-\eta} X^c_t - \eta \nu^g_t \left(\frac{P_{it}}{P_t} \right)^{-\eta} X^g_t \\ +\xi \Lambda_{t,t+1} \left[\left(\frac{P_{it+1}}{P_{it}} - 1 \right) \frac{P_{it+1}}{P_{it}} \right] \end{array} \right\} = 0. \quad (48)$$

Similar algebraic manipulations to those described in Section 2.4 lead to the following optimal pricing decision in the symmetric equilibrium:[9]

$$\left\{ \begin{array}{c} \left(X^c_t + X^g_t + I_t \right) \left[1 - \frac{\eta}{\eta-1} MC_t \right] \\ +\frac{\eta}{\eta-1} (1-\varrho^c) \left[\lambda^c_t X^c_t + \lambda^g_t X^g_t \right] - \frac{\theta^c}{\eta-1} \left(S^c_{t-1} + S^g_{t-1} \right) \\ +\xi E_t \Lambda_{t,t+1} \left[\Pi_{t+1} \left(\Pi_{t+1} - 1 \right) \right] - \xi \Pi_t \left(\Pi_t - 1 \right) \end{array} \right\} = 0, \quad (49)$$

where $\Pi_t \equiv \frac{P_t}{P_{t-1}}$ is the gross inflation rate. Note that the pricing equation (49) collapses to the analogous flexible-price equation (32) when $\xi = 0$. Furthermore, when $\xi > 0$, real cost $\frac{\xi}{2} \left(\frac{P_t}{P_{t-1}} - 1 \right)^2$ enters the economy's resource constraint.

5.2 Monetary policy

The model with price stickiness is closed with a monetary policy following the following Taylor rule

$$\log \left(\frac{R^n_t}{\bar{R}^n} \right) = \varrho_\pi \log \left(\frac{\Pi_{t-1,t}}{\bar{\Pi}} \right) + \varrho_y \log \left(\frac{Y_t}{\bar{Y}} \right), \quad (50)$$

and a Fisher equation:

$$R_{t+1} = E_t \left[\frac{R^n_t}{\Pi_{t,t+1}} \right]. \quad (51)$$

5.3 Results

Woodford (2011) shows that adding sticky prices into an otherwise standard DSGE model enhances the effects of a government spending expansion. Jacob (2010) argues that if price stickiness is added into a model with deep habit formation the countercyclical movement that

[9] Equation (49) is obtained by combining equations (28), (30) and (48), substituting for for the demands for C_{it} and G_{it}, (8) and (17), and rearranging.

the government spending shock induces in the mark-up is milder, that private consumption and investment are still crowded out as in traditional RBC and NK models and, consequently, the output multiplier becomes small. We show that for a sufficiently high degree of deep habit formation the addition of price stickiness may indeed soften the effects of a government spending expansion. However, we also find that (i) for an empirically plausible degree of deep habit formation and price stickiness the effects of a fiscal stimulus in terms of consumption and investment crowding-ins, the decline in the mark-up, the increase in the real wage, and the sizes of the output and unemployment multipliers are quite robust to the introduction of price stickiness; and (ii) Jacob's result is heavily dependent on the assumption that the Taylor rule implies a monetary response to the output gap that makes the nominal interest rate counteract the output expansion to an extent that the effects of the fiscal expansion are almost completely offset. As a result, it is not price stickiness *per se* that subverts the effects of a government spending expansion, but an aggressive monetary response that goes exactly in the opposite direction of output growth, which is the primary goal of the fiscal stimulus itself.

Figure 8 shows the effects of an expansion of government expenditures at different degrees of price stickiness in three alternative scenarios. First, in the top panel of Figure 8, we set the degree of deep habits in consumption to a considerable lower level than the baseline calibration ($\theta^c = 0.55$) and we assume that the monetary authority reacts only to inflation ($\rho_\pi = 1.5$) and not to the output gap ($\rho_y = 0$). In this case, when prices are fully flexible, deep habits alone are not strong enough to induce a decrease in the mark-up sufficient to boost output in a more-than-proportional way to the government spending expansion. Accordingly, consumption and investment are crowded out, the real wage falls, the real interest rate rises, and the output and unemployment multipliers are small. As we increase the degree of price stickiness, ξ, the decline in the mark-up become more pronounced and at $\xi = 29.41$, which corresponds to a Calvo contract average duration of around 3 quarters for our calibration,[10] the effects of a government spending expansion become very similar to those obtained in the flexible-price case with a higher degree of deep habits. In other words, price stickiness allows matching empirics also at a substantially lower level of deep habit formation.

Second, in the middle panel of Figure 8, we set the degree of deep habits in consumption to the baseline level ($\theta^c = 0.86$) and we again assume that the monetary authority reacts only to inflation. In this case, when prices are fully flexible, the decline in the mark-up is strong enough to push the real wage, consumption and investment upward and the real interest rate

[10] Jacob (2010) shows that for a given value of Rotemberg adjustment costs, the introduction of deep habits reduces the response of prices to the marginal cost and hence it is impossible to compare the deep habits New-Keynesian Phillips Curve (NKPC) slope to the Calvo analogue. Hence, following Jacob (2010), we interpret the slope of the standard forward-looking NKPC in quarterly terms. Namely, the log-linearized NKPC assumes the following form: $\hat{\Pi}_t = \beta E_t \hat{\Pi}_{t+1} + \kappa \hat{MC}_t$, where $\kappa = \frac{\eta - 1}{\xi}$ under Rotemberg pricing and $\kappa = \frac{(1-\beta\xi^c)(1-\xi^c)}{\xi^c}$ under Calvo contracts, where ξ^c is the Calvo parameter that determines the average quarterly duration of contracts $\frac{1}{1-\xi^c}$. Given a certain ξ, it is straightforward to induce the implied analogous contract duration in the Calvo world.

downward. When we introduce price stickiness, the effects of the fiscal expansion become softened by the decrease in the rate of inflation. This may occur if the shift in the aggregate supply due to the presence of a high level of deep habits is relatively strong given the shift in the aggregate demand due to the government spending expansion.

Third, in the lower panel of Figure 8, we leave the degree of deep habits in consumption at the baseline level ($\theta^c = 0.86$) and we set the same Taylor rule as Jacob (2010) i.e. $\rho_\pi = 1.5$ and $\rho_y = 0.5$, i.e. we add the monetary response to the output gap. In this case, Jacob's result is replicated: if prices are sticky, the nominal interest rate reacts positively to the output growth despite the fall in inflation, the real interest rate reacts positively and offsets the effects of the fiscal expansion.

5.4 Sensitivity to the Taylor rule parameters

Figure 9 shows the impact responses (peak responses for unemployment) (i) at different levels of monetary policy response to inflation and (ii) at different degrees of deep habit formation. In general the higher the degree of deep habit formation and the smaller the reaction of monetary policy to a government spending expansion, the stronger the effects of fiscal policy. In particular if the degree of deep habit formation is very high, the output multiplier is greater than one also if monetary policy responds more aggressively. However, the unemployment multiplier and vacancies are more sensitive to the monetary policy response to inflation.

Figure 10 shows that the impact responses (peak responses for unemployment) (i) at different levels of monetary policy response to the output gap and (ii) at different degrees of deep habit formation. As explained in the previous subsection, surfaces show that, even at high degrees of deep habit formation, even a mild monetary policy response to the output gap may offset the expansionary effects of a government spending expansion. In particular, unemployment may also rise if ρ_y is above 0.4, while the output multiplier falls below one even with a ρ_y above 0.2.

6 Concluding remarks

We have analyzed the effects of a government spending expansion in a DSGE model with Mortensen-Pissarides labour market frictions, deep habits in private and public consumption and a constant-elasticity-of-substitution (CES) production function.

The combination of deep habits and CES technology is crucial. If the elasticity of substitution between capital and labour approaches one, i.e. the production function approximates a Cobb-Douglas, the presence of deep habits in consumption enables the model to deliver output and unemployment multipliers in the range of recent empirical estimates, and to match a number of empirical regularities even under flexible prices and without the imposition of the zero lower bound (ZLB) on the nominal interest rate. As the elasticity of substitution is allowed to drop to values in the range of available estimates – i.e. the degree of complementarity between capital and labour increases – while the output multiplier falls only marginally, the unemployment multiplier experiences a sizeable contraction. In fact, in response to a fiscal stimulus and for a given level of capital, the smaller the elasticity of substitution, the smaller the number of vacancies posted. In such a case, the expansion in output is driven relatively more by an increase in the hours of work rather than new job creation. To the best of our knowledge, ours is the first contribution showing that incorporating a CES production function, as in Cantore and Levine (2011), with an empirically supported factor elasticity of substitution, coupled with deep habits, makes the model able to deliver a scenario compatible with the observed jobless recovery.

Further, adding sticky prices into the DSGE model augmented with deep habits in private and public consumption in general enhances the effects of a government spending expansion similarly to what happens in more standard models. However, if the degree of deep habit formation is sufficiently high the reverse may be true. In this respect, an accommodative monetary policy with respect to the output gap, alongside sticky prices, plays an important role for the size of fiscal multipliers and, more generally, for the expansionary effects of the fiscal stimulus.

The results presented in this paper represent also an important starting point for future research. In particular, first it would be interesting to empirically evaluate the building blocks of the model via the comparison of the marginal likelihood in a Bayesian estimation setting. Second, given the binding ZLB for the monetary policy rate in the latest recession, it would be worth investigating to what extent this features affect our results.[11] Third, the model is well-suited for the design of optimal fiscal and monetary rules. In particular, given the sensitivity of the results to the monetary response, examining optimised Taylor rules would be a useful exercise.[12]

[11] These are basically two ways of introducing a nominal interest rate ZLB. In the deterministic setting of this paper the Taylor rule is allowed to remain in force as long as the ZLB is not reached. When this does happen a residual adjustment is added to the rule that avoids a negative interest rate (see, for example, Christiano et al. (2010)). In a stochastic setting a Monte-Carlo approach is needed that uses the previous technique for each stochastic draw (see Coenen et al. (2004)). When it comes to optimal policy a desirable property of a monetary rule is the ZLB is only reached very infrequently. This outcome is achieved by raising the steady-state inflation rate and penalizing the interest rate variability in an optimal fashion – see Levine et al. (2008).

[12] For a study of optimal monetary and fiscal policy in a new Keynesian model with deep habit see Leith et al. (2009).

References

Auerbach, A. J., Gale, W. G., and Harris, B. H. (2010). Activist fiscal policy. *Journal of Economic Perspectives*, 24(4):141–64.

Auerbach, A. J. and Gorodnichenko, Y. (2011). Measuring the output responses to fiscal policy. *American Economic Journal: Economic Policy*, forthcoming.

Barro, R. J. and Redlick, C. J. (2011). Macroeconomic effects from government purchases and taxes. *The Quarterly Journal of Economics*, 126:51–102.

Bernstein, J. and Romer, C. (2009). *The Job Impact of the American Recovery and Reinvestment Plan.* Council of Economic Advisers, Washington, DC, USA.

Blanchard, O. and Perotti, R. (2002). An empirical characterization of the dynamic effects of changes in government spending and taxes on output. *The Quarterly Journal of Economics*, 117(4):1329–1368.

Blanchard, O. J. (1997). The Medium Run. *Brookings Papers on Economic Activity*, 2:89–158.

Blinder, A. and Zandi, M. (2010). How the great recession was brought to an end. Technical report, Moody's Analytics.

Brückner, M. and Pappa, E. (2010). Fiscal expansions affect unemployment, but they may increase it. CEPR Discussion Papers 7766, C.E.P.R. Discussion Papers.

Caldara, D. and Kamps, C. (2008). What are the effects of fiscal shocks? a VAR-based comparative analysis. Working Paper Series 877, European Central Bank.

Campolmi, A., Faia, E., and Winkler, R. C. (2010). Fiscal calculus in a New Keynesian model with matching frictions. Mimeo, University of Frankfurt.

Canova, F. and Pappa, E. (2011). Fiscal policy, pricing frictions and monetary accommodation. Working paper, CREI.

Cantore, C., Ferroni, F., and León-Ledesma, M. (2011). Interpreting the hours-technology time-varying relationship. Mimeo, University of Surrey.

Cantore, C., Ferroni, F., Levine, P., and Yang, B. (2010a). CES technology and business cycle fluctuations. Mimeo, University of Surrey. Presented to a MONFISPOL Conference, 4–5 December, 2010 at London Metropolitan University.

Cantore, C., León-Ledesma, M. A., McAdam, P., and Willman, A. (2010b). Shocking stuff: technology, hours, and factor substitution. Working Paper Series 1278, European Central Bank.

Cantore, C. and Levine, P. (2011). Getting normalization right: dealing with 'dimensional constants' in macroeconomics. Mimeo, University of Surrey .

Chirinko, R. S. (2008). Sigma: The Long and Short of It. *Journal of Macroeconomics*, 30(2):671–686.

Christiano, L., Eichenbaum, M., and Rebelo, S. (2009). *When is the government spending multiplier large?* National Bureau of Economic Research Cambridge, Mass., USA.

Christiano, L., Motto, R., and Rostagno, M. (2010). Financial factors in economic fluctuations. *ECB Working Paper*, 1192.

Christiano, L. J., Eichenbaum, M., and Evans, C. L. (2005). Nominal rigidities and the dynamic effects of a shock to monetary policy. *Journal of Political Economy*, 113(1):1–45.

Coenen, G., Orthanides, A., and Wieland, V. (2004). Price stability and monetary policy effectiveness when nominal interest rates are bounded at zero. *Advances in Macroeconomics*, 4(1).

Cogan, J., Cwik, T., Taylor, J., and Wieland, V. (2010). New Keynesian versus old Keynesian government spending multipliers. *Journal of Economic Dynamics and Control*, 34(3):281–295.

Cummins, J., Francis, R., and Coffey, R. (2007). Local solutions or postcode lotteries. *Office of Public Management*, May.

Di Pace, F. and Faccini, R. (2011). Deep habits and the cyclical behaviour of equilibrium unemployment and vacancies. *Journal of Economic Dynamics and Control*, forthcoming.

Faia, E., Lechthaler, W., and Merkl, C. (2010). Fiscal multipliers and the labour market in the open economy. *Kiel Working Papers*, 1592.

Fragetta, M. and Melina, G. (2011). The effects of fiscal shocks in SVAR models: a graphical modelling approach. *Scottish Journal of Political Economy*, 58(4):537–566.

Gali, J., Lopez-Salido, J. D., and Valles, J. (2007). Understanding the effects of government spending on consumption. *Journal of the European Economic Association*, 5(1):227–270.

Gertler, M. and Trigari, A. (2006). Unemployment fluctuations with staggered Nash wage bargaining. Mimeo.

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

Hall, R. E. (2009). By how much does GDP rise if the government buys more output? NBER Working Papers 15496, National Bureau of Economic Research, Inc.

Jacob, P. (2010). Deep habits, nominal rigidities and the response of consumption to fiscal expansions. *Working Papers of Faculty of Economics and Business Administration, Ghent University, Belgium*, 10/641.

Jones, C. I. (2003). Growth, capital shares, and a new perspective on production functions. mimeo, Stanford University.

Jones, C. I. (2005). The shape of production functions and the direction of technical change. *Quarterly Journal of Economics*, 120(2):517–549.

Klump, R., McAdam, P., and Willman, A. (2007). Factor Substitution and Factor Augmenting Technical Progress in the US. *Review of Economics and Statistics*, 89(1):183–92.

Krause, M., Lopez-Salido, D., and Lubik, T. (2008). Inflation dynamics with search frictions: A structural econometric analysis. *Journal of Monetary Economics*, 55(5):892–916.

Leith, C., Moldovan, I., and Rossi, R. (2009). Monetary and fiscal policy under deep habits. CDMA Conference Paper Series 0905, Centre for Dynamic Macroeconomic Analysis.

León-Ledesma, M. A., McAdam, P., and Willman, A. (2010). In dubio pro CES: supply estimation with mis-specified technical change. Working Paper Series 1175, European Central Bank.

Levine, P., McAdam, P., and Pearlman, J. (2008). Quantifying and sustaining welfare gains from monetary commitment. *Journal of Monetary Economics*, 55(7):1253–1276.

Linnemann, L. (2006). The effect of government spending on private consumption: A puzzle? *Journal of Money Credit and Banking*, 38(7):1715–1736.

MacKay, R. R. (2001). Regional taxing and spending: The search for balance. *Regional Studies*, 35(6):563–575.

McAdam, P. and Willman, A. (2008). Medium Run Redux. Working Paper No. 915, European Central Bank.

Monacelli, T. and Perotti, R. (2008). Fiscal policy, wealth effects, and markups. NBER Working Papers 14584, National Bureau of Economic Research, Inc.

Monacelli, T., Perotti, R., and Trigari, A. (2010). Unemployment fiscal multipliers. *Journal of Monetary Economics*, 57(5).

Pappa, E. (2005). New keynesian or RBC transmission? The effects of fiscal policy in labor markets. Working Papers 293, IGIER (Innocenzo Gasparini Institute for Economic Research), Bocconi University.

Pappa, E. (2009). The effects of fiscal shocks on employment and the real wage. *International Economic Review*, 50(1):217–244.

Pissarides, C. (2009). The unemployment volatility puzzle: is wage stickiness the answer? *Econometrica*, 77(5):1339–1369.

Ramey, V. A. (2009). Identifying government spending shocks: It's all in the timing. NBER Working Papers 15464, National Bureau of Economic Research, Inc.

Ravn, M., Schmitt-Grohé, S., and Uribe, M. (2006). Deep habits. *Review of Economic Studies*, 73(1):195–218.

Ríos-Rull, J.-V. and Santaeulália-Llopis, R. (2010). Redistributive shocks and productivity shocks. *Journal of Monetary Economics*, 57(8):931 – 948.

Rotemberg, J. J. (1982). Monopolistic price adjustment and aggregate output. *Review of Economic Studies*, 49(4):517–31.

Rowthorn, R. (1999). Unemployment, wage bargaining and capital-labour substitution. *Cambridge Journal of Economics*, 23(4):413.

Sala, L., Söderström, U., and Trigari, A. (2008). Monetary policy under uncertainty in an estimated model with labor market frictions. *Journal of Monetary Economics*, 55(5):983–1006.

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

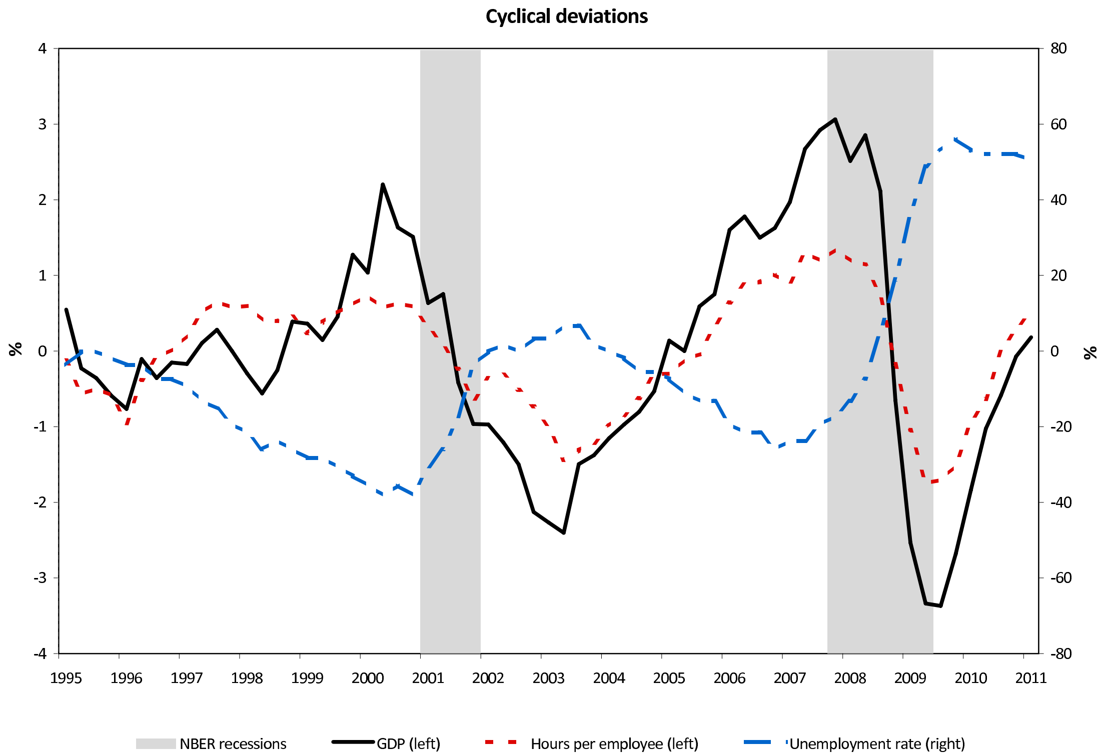
Smets, F. and Wouters, R. (2007). Shocks and frictions in us business cycles: A bayesian DSGE approach. *American Economic Review*, 97(3):586–606.

Thomas, C. (2008). Search and matching frictions and optimal monetary policy. *Journal of Monetary Economics*, 55(5):936–956.

Trigari, A. (2009). Equilibrium unemployment, job flows, and inflation dynamics. *Journal of Money, Credit and Banking*, 41(1):1–33.

Woodford, M. (2011). Simple analytics of the government expenditure multiplier. *American Economic Journal: Macroeconomics*, 3(1):1–35.

Figures



Source: ALFRED, Federal Reserve Bank of St. Louis and authors' calculations. Percentage deviations from HP-trend for GDP and hours per employee, percentage deviations from the sample mean for the unemployment rate.

Figure 1: A jobless recovery

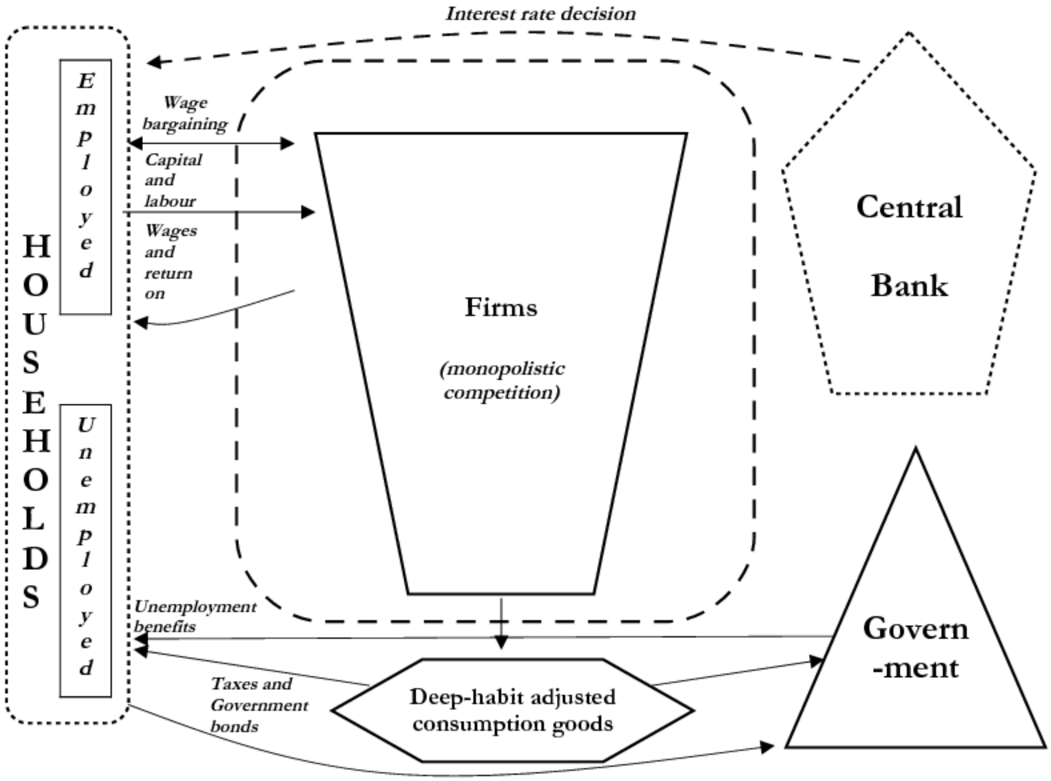


Figure 2: The model

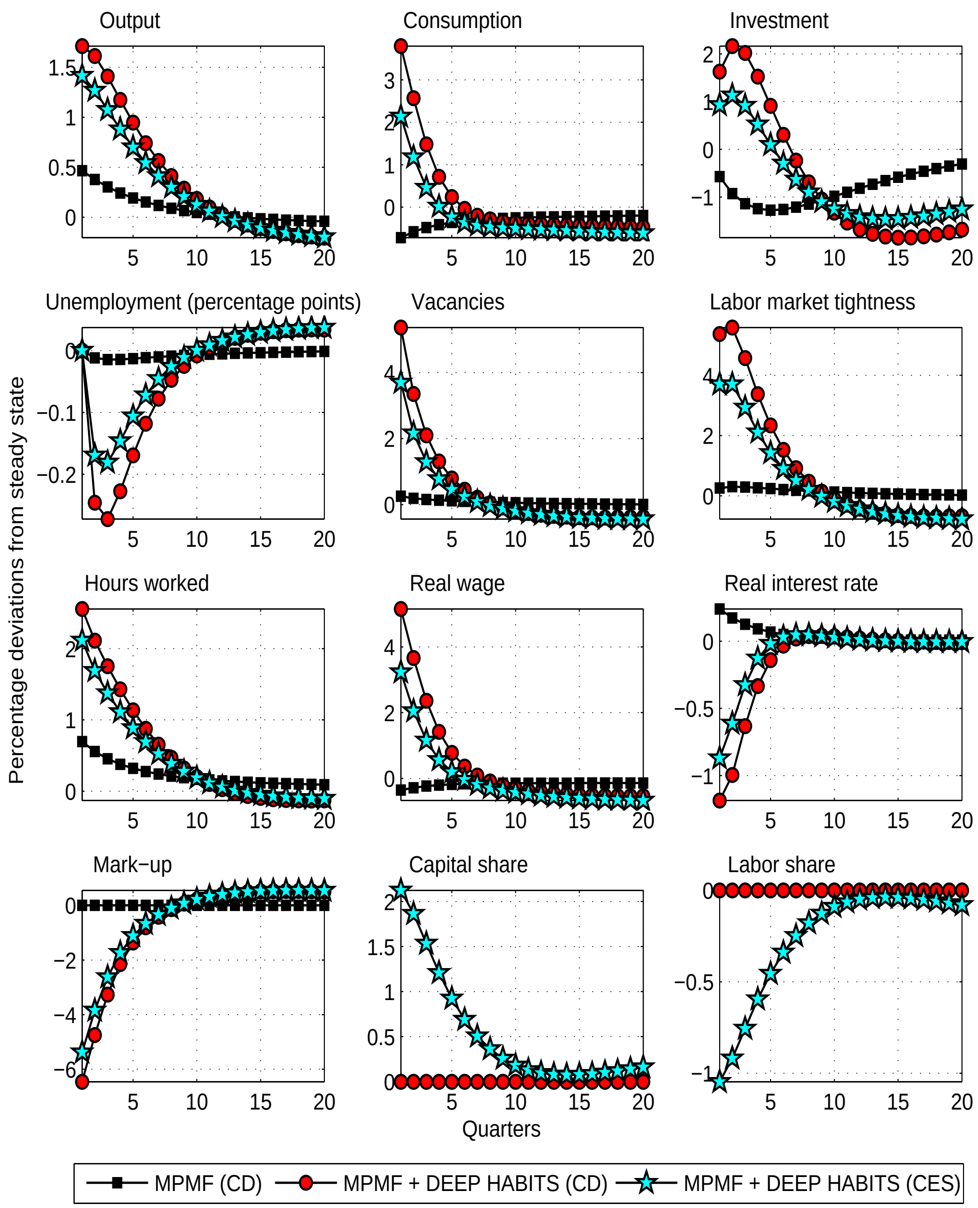


Figure 3: A government spending expansion (1% of output, lump-sum taxes, balanced budget) in an RBC model augmented with Mortensen-Pissarides Matching Frictions: the effects of deep habits in consumption.

Note: Line marked by squares: RBC model with Mortensen-Pissarides Matching Friction (MPMF), Cobb-Douglas (CD) production function ($\sigma \to 1$) and no habits in consumption ($\theta^c = \varrho^c = 0$). Line marked by circles: MPMF, CD production function, and deep habits in consumption ($\theta^c = 0.86$ and $\varrho^c = 0.85$). Line marked by stars: MPMF, CES production function ($\sigma = 0.40$) and deep habits in consumption. Responses of all variables but the unemployment rate are in percentage deviations from steady state. For the unemployment rate, absolute changes in percentage points are reported.

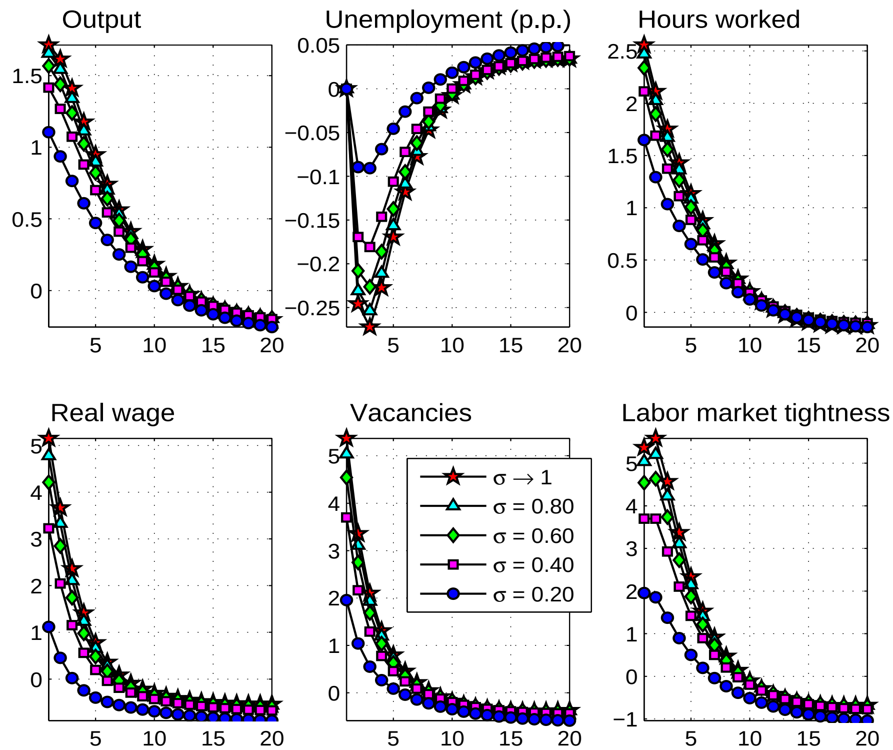


Figure 4: Sensitivity of the results to different values of the elasticity of substitution between capital and labour, σ.

Note: Fiscal policy: government spending expansion (1% of output, lump-sum taxes, balanced budget). Model: RBC with Mortensen-Pissarides Matching Friction (MPMF), deep habits in consumption ($\theta^c = 0.86$ and $\varrho^c = 0.85$).

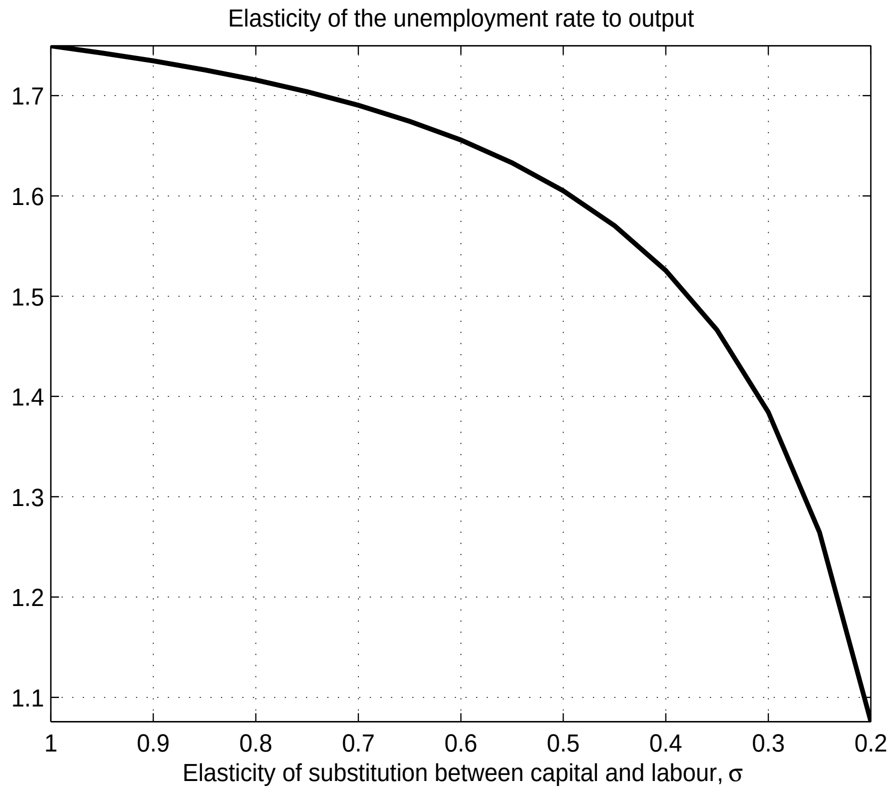


Figure 5: Peak elasticity of the unemployment rate to real output changes in response to a government spending expansion at different levels of the elasticity of substitution between capital and labour.

Note: Fiscal policy: government spending expansion (1% of output, lump-sum taxes, balanced budget). Model: RBC with Mortensen-Pissarides Matching Friction (MPMF), deep habits in consumption ($\theta^c = 0.86$ and $\varrho^c = 0.85$).

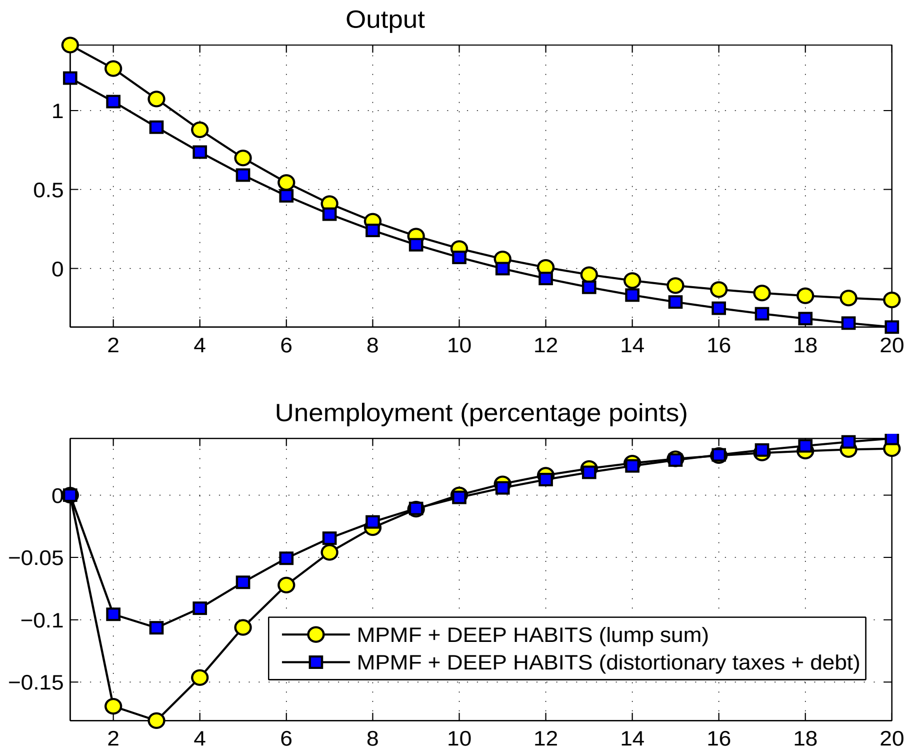


Figure 6: Sensitivity of output and unemployment multipliers to the introduction of distortionary taxation and government debt.

Note: Fiscal policy: government spending expansion (1% of output, distortionary taxes, partially debt-financed fiscal policy). Model: RBC with Mortensen-Pissarides Matching Friction (MPMF), deep habits in consumption ($\theta^c = 0.86$ and $\varrho^c = 0.85$), and CES production function ($\sigma = 0.40$). Responses of output are in percentage deviations from steady state. For the unemployment rate, absolute changes in percentage points are reported.

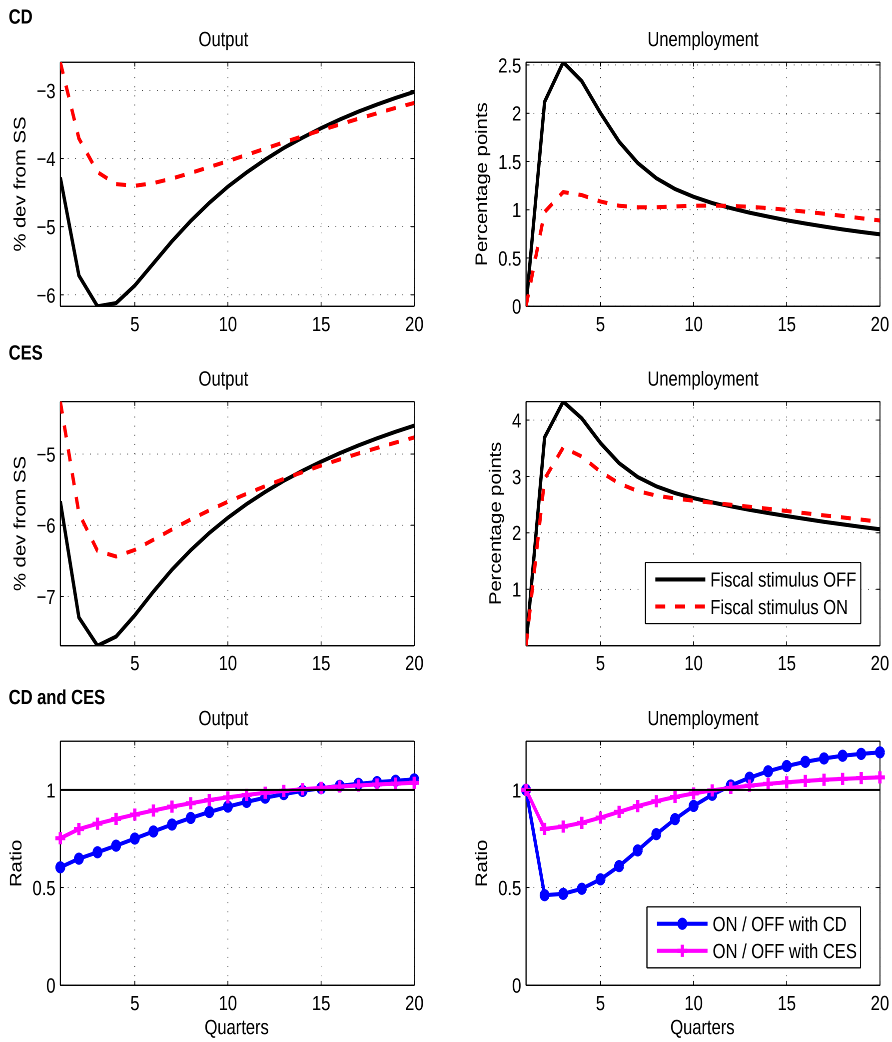
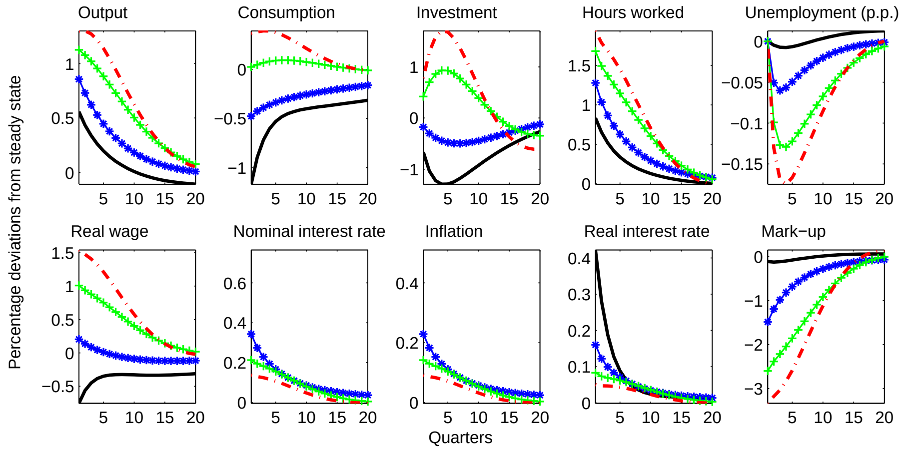
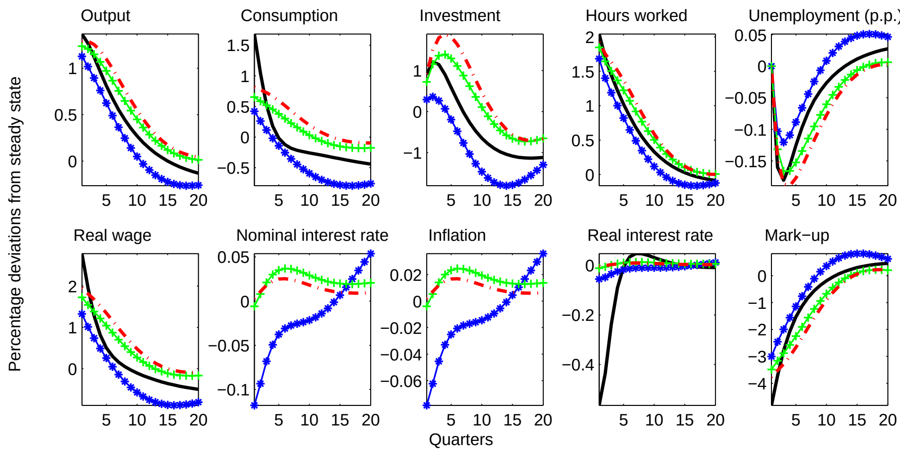


Figure 7: A fiscal stimulus in a recession.

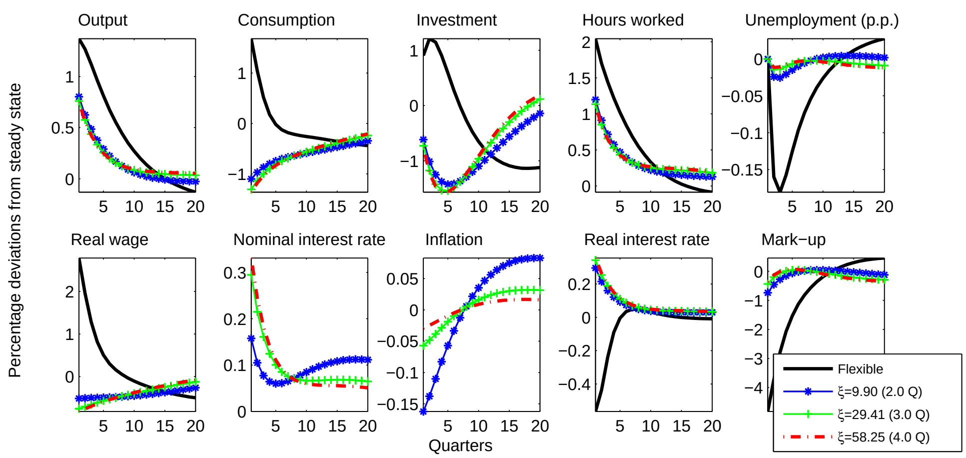
Note: Model: RBC with Mortensen-Pissarides Matching Friction (MPMF) and deep habits in consumption ($\theta^c = 0.86$ and $\varrho^c = 0.85$). Recession driven by a negative technology shock that leads to a peak output contraction of around 7.5 % from steady state with a CES production function. Fiscal stimulus: government spending expansion of 5% of output; lump-sum taxes; balanced budget. First row (CD): simulated output and unemployment responses in the absence and with the fiscal stimulus under a Cobb-Douglas technology ($\sigma \rightarrow 1$). Second row (CES): responses under a CES technology ($\sigma = 0.40$). Third row (CD and CES): ratios of impulse responses with and without the fiscal stimulus under CE and CES technologies.



(a) Mild deep habits, no monetary response to the output gap ($\theta^c = 0.55$, $\rho_\pi = 1.5$, $\rho_y = 0$).

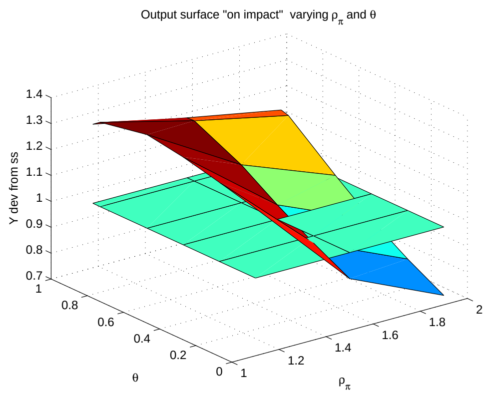


(b) Baseline deep habits, no monetary response to the output gap ($\theta^c = 0.86$, $\rho_\pi = 1.5$, $\rho_y = 0$).

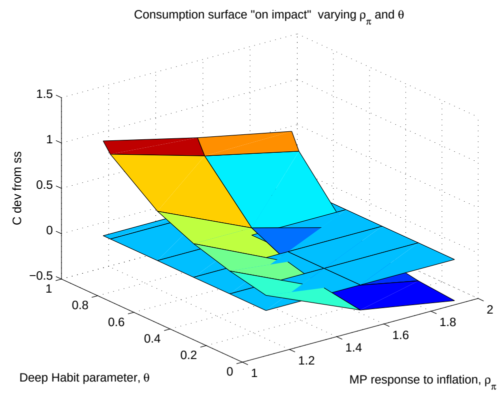


(c) Baseline deep habits, monetary response to the output gap ($\theta^c = 0.86$, $\rho_\pi = 1.5$, $\rho_y = 0.5$)

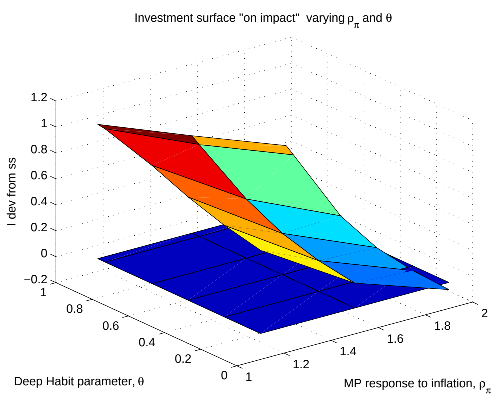
Figure 8: A government spending expansion (1% of output, lump-sum taxes, balanced budget) in a model augmented with Mortensen-Pissarides Matching and deep habits in consumption: flexible vs. sticky prices.



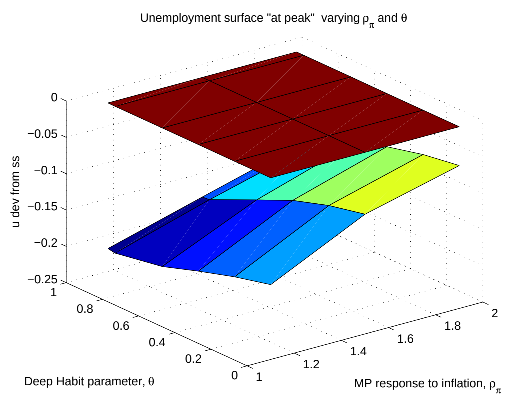
(a) Output



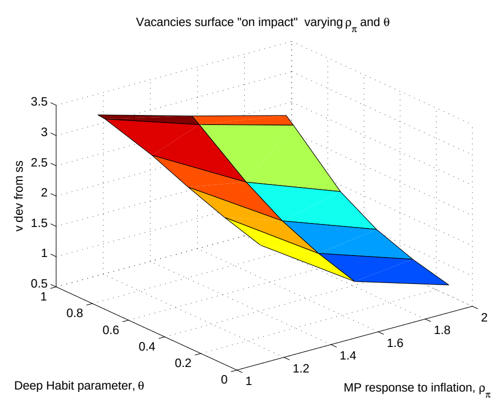
(b) Consumption



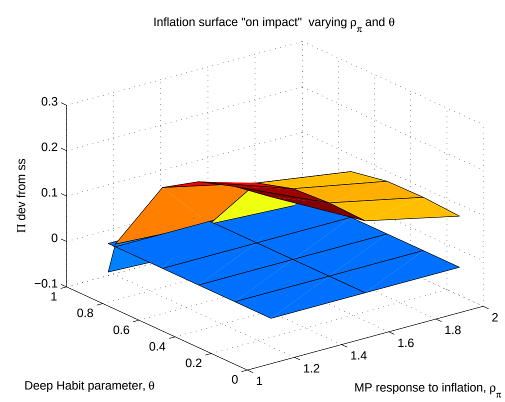
(c) Investment



(d) Unemployment

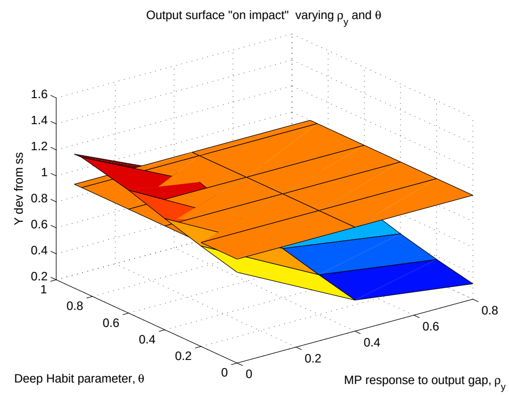


(e) Vacancies

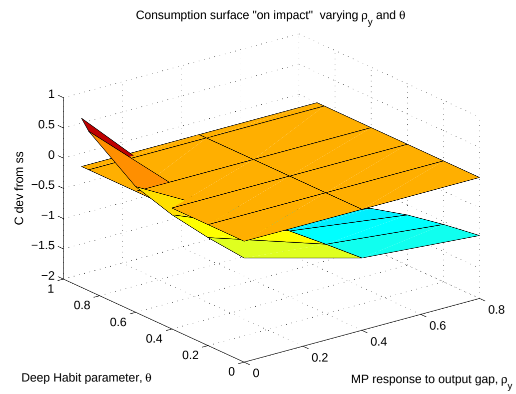


(f) Inflation

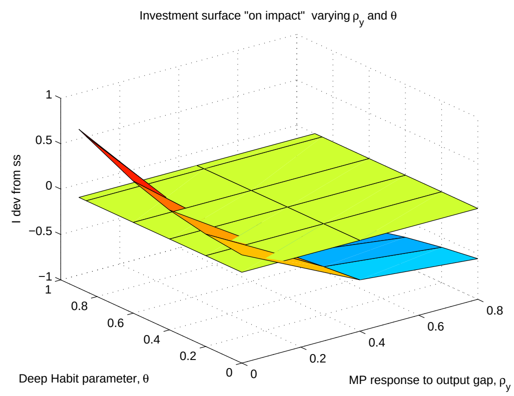
Figure 9: Sensitivity of impact responses to the deep habit parameter θ^c and the monetary response to inflation ρ_π.



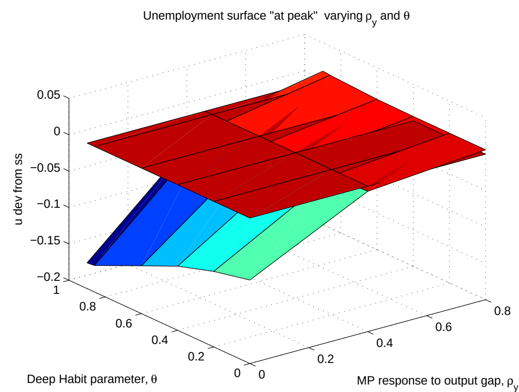
(a) Output



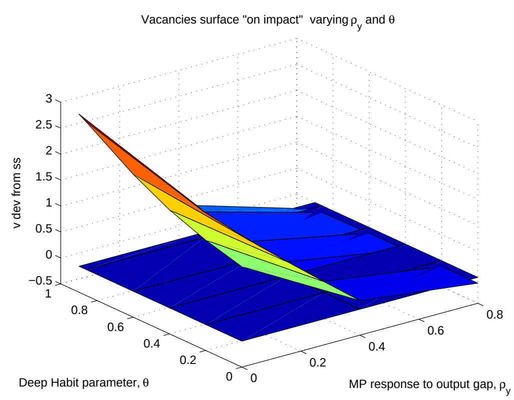
(b) Consumption



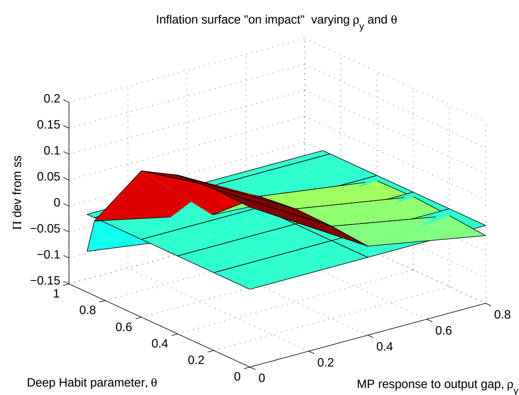
(c) Investment



(d) Unemployment



(e) Vacancies



(f) Inflation

Figure 10: Sensitivity of impact responses to the deep habit parameter θ^c and the monetary response to the output gap ρ_y.

Appendix

A Sensitivity exercises

A.1 Bargaining power

In Figure A.1 we show how the combination of different elasticities of substitutions (σ) and different levels of firms' bargaining power (ϵ) affect the response of output, unemployment and the real wage to a government spending shock. In the left column, the technology is almost Leontief ($\sigma = 0.10$), in the right column it approximates a Cobb-Douglas ($\sigma \to 1$), while the central column features an intermediate elasticity of substitution in the range of empirical estimates ($\sigma = 0.40$). Impulse responses are drawn with $\epsilon = \{0.10, 0.50, 0.90\}$.

If $\sigma = 0.10$, despite the use of deep habits in consumption, by which the mark-up responds negatively to a government spending shock, the real wage declines as the strong complementarity between capital and labour induces firms to post relatively less vacancies and to a lower reservation wage for them. In other words labour demand (through vacancy posting) "shifts" less than labour supply. This scenario predicts an output multiplier less than unity and a small or even positive response of unemployment (if firms get 90% of total surplus in the wage bargaining).

If the technology is sufficiently away from Leontief, the greater firms' share in the wage bargaining, the the smaller the increase in the real wage and the reduction in unemployment, given the smaller incentive for households to sign labour contracts, keeping how they value non-work activities relative to work activities (replacement ratio) constant. While output is not greatly affected by the calibration of the factor elasticity of substitution and the bargaining parameter, the unemployment response is considerably affected by both choices. In addition, as the technology tends to Leontief, the calibration of the bargaining parameter becomes increasingly less important for the equilibrium outcome.[13]

A.2 Hagedorn and Manovskii effect

A common result in the MPMF literature is that unemployment volatility importantly depends on the calibration of the replacement ratio, $\bar{\Theta}$, i.e. the value of non-work to work activities. The higher is the steady-state value of non-work to work activities, the higher is the volatility of unemployment. In the literature $\bar{\Theta}$ ranges between Shimer (2005)'s 0.40 and Hagedorn and Manovskii (2008)'s 0.95. In Figure A.2 we show the sensitivity of the output and unemployment multipliers to the replacement ratio in the model with deep habits in consumption and the CES production function. Increasing $\bar{\Theta}$ increases the magnitudes of both multipliers, how-

[13] Rowthorn (1999) also emphasizes the role of CES technology with an elasticity σ below unity for explaining European unemployment persistence despite moves towards greater labour market flexibility as captured by an increase in the firm's bargaining power in our model.

			(A)	(B)	
			$\sigma \to 1$	$\sigma = 0.4$	(B)/(A)
$\Theta = 0.7$	$\epsilon = 0.1$	$\frac{\Delta Y}{\Delta G}$	1.69	1.40	0.83
		$\frac{\Delta u}{\Delta G}$	-0.31	-0.21	0.68
	$\epsilon = 0.5$	$\frac{\Delta Y}{\Delta G}$	1.71	1.42	0.83
		$\frac{\Delta u}{\Delta G}$	-0.27	-0.18	0.67
	$\epsilon = 0.9$	$\frac{\Delta Y}{\Delta G}$	1.79	1.46	0.82
		$\frac{\Delta u}{\Delta G}$	-0.14	-0.08	0.57
$\Theta = 0.9$	$\epsilon = 0.1$	$\frac{\Delta Y}{\Delta G}$	1.68	1.39	0.83
		$\frac{\Delta u}{\Delta G}$	-0.82	-0.53	0.65
	$\epsilon = 0.5$	$\frac{\Delta Y}{\Delta G}$	1.71	1.41	0.82
		$\frac{\Delta u}{\Delta G}$	-0.70	-0.44	0.63
	$\epsilon = 0.9$	$\frac{\Delta Y}{\Delta G}$	1.78	1.45	0.81
		$\frac{\Delta u}{\Delta G}$	-0.30	-0.19	0.63

Table A.1: The impact of the fiscal stimulus in different scenarios

Note: Government spending expansion (1% of output, lump-sum taxes, balanced budget) in a model augmented with Mortenses-Pissarides Matching Frictions and deep habit formation. Impact output multipliers and peak unemployment multipliers are reported).

ever the output multiplier changes only marginally. Even using the CES production function (with $\sigma = 0.4$) – and hence incorporating a mechanism that moderates the unemployment multiplier *per se*, as explained above – if the replacement ratio is calibrated in the high range of plausible values, i.e. between 0.90 and 0.95, the flexible-price model augmented with MPMF and deep habits in consumption is able to reproduce the unemployment multiplier estimated by Monacelli et al. (2010).

A.3 Quantitative implications of the choice of the replacement ratio and the bargaining power

In Table 2 we report the impact output multipliers and the unemployment peak multipliers obtained with different parameterizations: (i) our baseline value of the replacement ratio ($\Theta = 0.7$), which is close to the estimate of 0.72 of Sala et al. (2008) versus the value used in the baseline calibration of Monacelli et al. (2010) ($\Theta = 0.9$), which is in the high range of empirical estimates; (ii) our baseline value for the firms' bargaining power ($\epsilon = 0.5$) versus two extreme cases in which either the workers or the firms get almost the whole surplus ($\epsilon = 0.1$ or $\epsilon = 0.9$, respectively); (iii) the CD production function ($\sigma \to 1$) versus a CES with $\sigma = 0.4$ (our baseline value).

As noted above, while the unemployment multiplier is very sensitive to the choice of the replacement ratio, the output multiplier barely changes. Keeping σ constant, as firms gain a bigger share of the surplus from employment, while the output multiplier slightly increases, the unemployment multiplier significantly drops.

In relative terms (last column), almost irrespective of how the surplus is split between workers (ϵ) and firms and how workers value non-work activities with respect to work activities (Θ), when σ drops from 1 (CD case) to 0.4, while the output multiplier is around 4/5 of the value obtained in the CD case; the unemployment multiplier is around or even below 2/3 of the value delivered by the CD case. In sum, the increasingly *jobless* stimulus obtainable as σ drops is robust to the calibration of the replacement ratio and the bargaining power parameter.

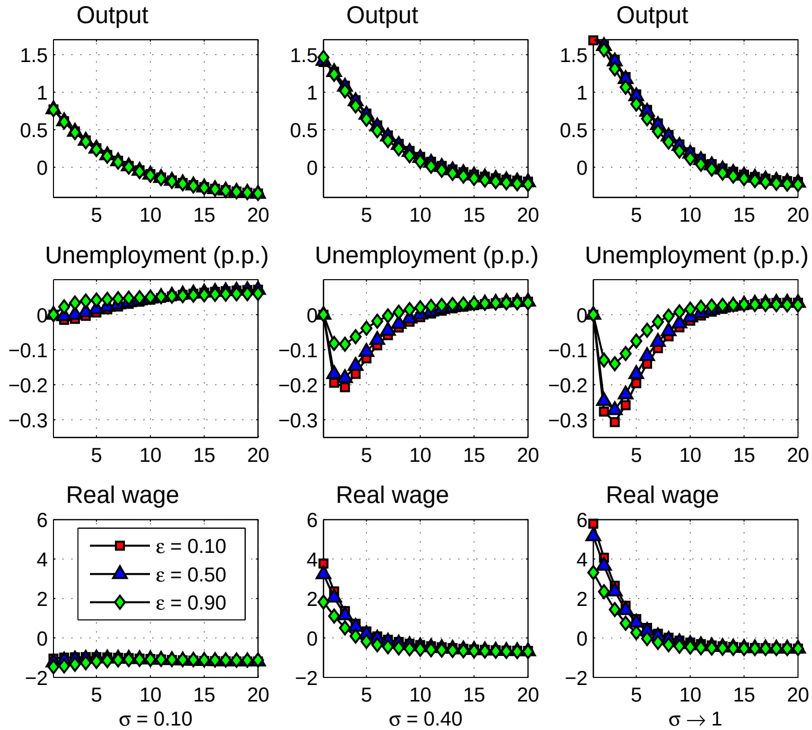


Figure A.1: Sensitivity of output and unemployment multipliers to changes in the firms' bargaining power.

Note: Fiscal policy: government spending expansion (1% of output, lump-sum taxes, balanced budget). Model: RBC with Mortensen-Pissarides Matching Friction (MPMF) and deep habits in consumption ($\theta^c = 0.86$ and $\varrho^c = 0.85$). Responses of output and the real wage are in percentage deviations from steady state. For the unemployment rate, absolute changes in percentage points are reported. ϵ = firms' bargaining power; σ = elasticity of substitution between labour and capital.

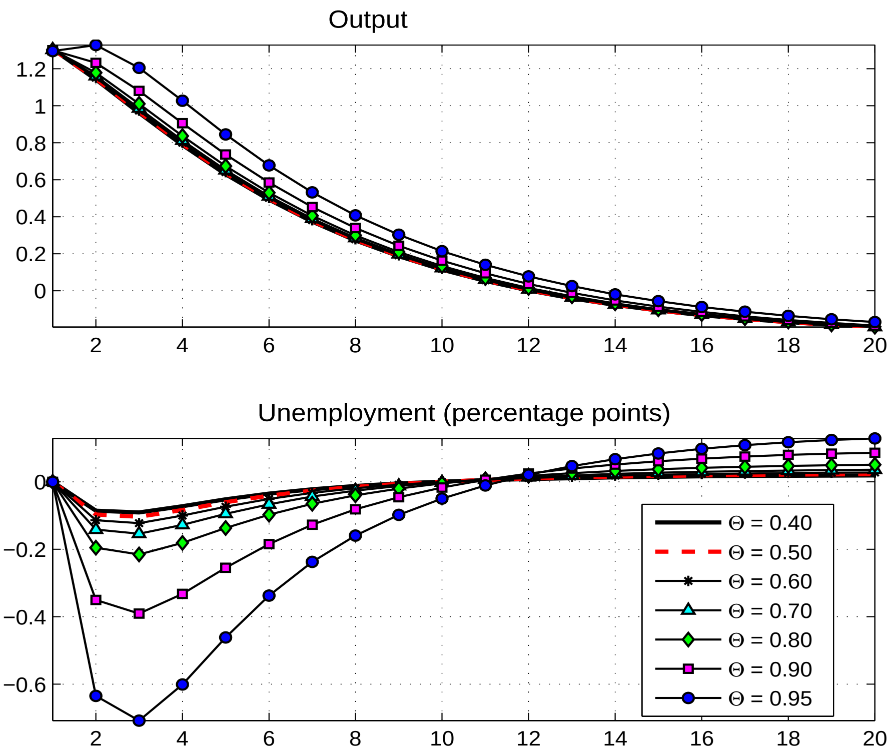


Figure A.2: Sensitivity of output and unemployment multipliers to changes in the magnitude of the replacement ratio.

Note: Fiscal policy: government spending expansion (1% of output, lump-sum taxes, balanced budget). Model: RBC with Mortensen-Pissarides Matching Friction (MPMF), deep habits in consumption ($\theta^c = 0.86$ and $\varrho^c = 0.85$), and CES production function ($\sigma = 0.40$). Responses of output are in percentage deviations from steady state. For the unemployment rate, absolute changes in percentage points are reported. Θ =replacement ratio.

B Symmetric equilibrium

Production function and marginal products:

$$F((ZK)_t K_t, (ZN)_t n_t h_t) = \left[\alpha_K \left((ZK)_t K_t\right)^{\frac{\sigma-1}{\sigma}} + \alpha_N \left((ZN)_t n_t h_t\right)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}} \tag{B.1}$$

$$F_{K,t} = \alpha_K (ZK)_t^{\frac{\sigma-1}{\sigma}} \left(\frac{Y_t}{K_t}\right)^{\frac{1}{\sigma}} \tag{B.2}$$

$$F_{N,t} = \alpha_N (ZN)_t^{\frac{\sigma-1}{\sigma}} \left(\frac{Y_t}{n_t h_t}\right)^{\frac{1}{\sigma}} \tag{B.3}$$

Utility function, marginal utilities and deep habits in consumption:

$$U(X_t^c, n_t, 1-h_t) = n_t \frac{\left[(X_t^c)^{(1-\varrho)}(1-h_t)^{\varrho}\right]^{1-\sigma_c} - 1}{1-\sigma_c} + (1-n_t)\frac{(X_t^c)^{(1-\varrho)(1-\sigma_c)} - 1}{1-\sigma_c} \tag{B.4}$$

$$U_{x,t} = (1-\varrho)\,(X_t^c)^{(1-\varrho)(1-\sigma)-1}\left[1 + n_t\left((1-h_t)^{\varrho(1-\sigma)} - 1\right)\right] \tag{B.5}$$

$$U_{n,t} = \frac{(X_t^c)^{(1-\varrho)(1-\sigma)}\left[(1-h_t)^{\varrho(1-\sigma)} - 1\right]}{1-\sigma} \tag{B.6}$$

$$U_{hn,t} = -\varrho\,(X_t^c)^{(1-\varrho)(1-\sigma)}\,(1-h_t)^{\varrho(1-\sigma)-1} \tag{B.7}$$

$$S_t^c = \varrho^c S_{t-1}^c + (1-\varrho^c) C_t \tag{B.8}$$

$$C_t = X_t^c + \theta^c S_{t-1}^c \tag{B.9}$$

Intertemporal investment/consumption decisions:

$$K_{t+1} = (1-\delta)K_t + I_t\left[1 - S\left(\frac{I_t}{I_{t-1}}\right)\right] \tag{B.10}$$

$$S\left(\frac{I_t}{I_{t-1}}\right) = \frac{\gamma}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2 \tag{B.11}$$

$$Q_t = E_t\left\{D_{t,t+1}\left[\left(1-\tau_{t+1}^k\right)R_{t+1}^K + (1-\delta)Q_{t+1}\right]\right\} \tag{B.12}$$

$$1 = Q_t\left[1 - S\left(\frac{I_t}{I_{t-1}}\right) - S'\left(\frac{I_t}{I_{t-1}}\right)\frac{I_t}{I_{t-1}}\right] + E_t\left\{D_{t,t+1}Q_{t+1}S'\left(\frac{I_{t+1}}{I_t}\right)\left(\frac{I_{t+1}}{I_t}\right)^2\right\} \tag{B.13}$$

$$D_{t,t+1} = \beta \frac{U_{x,t+1}}{U_{x,t}} \frac{1+\tau_t^C}{1+\tau_{t+1}^c} \tag{B.14}$$

$$1 = E_t \left[D_{t,t+1}^j R_{t+1} \right] \tag{B.15}$$

$$MC_t F_{K,t} = R_t^K \tag{B.16}$$

Hiring decisions and wage bargaining:

$$g_t = \frac{\chi}{1+\psi} z_t^{1+\psi} \tag{B.17}$$

$$g_{z,t} = \chi z_t^{\psi} \tag{B.18}$$

$$n_{it+1} = (1-\lambda) n_{it} + q(\theta_t) v_{it} \tag{B.19}$$

$$\frac{g'(z_t)}{q(\theta_t)} = E_t \left\{ D_{t,t+1} \left[\begin{array}{c} (MC_t F_{N,t+1} - w_{t+1}) h_{t+1} + g'(z_{t+1}) z_{t+1} \\ -g(z_{t+1}) + (1-\lambda) \frac{g'(z_{t+1})}{q(\theta_{t+1})} \end{array} \right] \right\} \tag{B.20}$$

$$w_t h_t = (1-\epsilon) \left[MC_t F_{N,t} h_t - g(z_t) + g'(z_t) z_t + \theta_t g'(z_t) \right] + \epsilon \left[\frac{w_u - \frac{U_{n,t}}{U_{x,t}}}{1-\tau_t^w} \right] \tag{B.21}$$

$$F_{N,t} = -\frac{U_{nh,t}}{U_{C,t}} \tag{B.22}$$

$$z_t = \frac{v_t}{n_t} \tag{B.23}$$

$$\theta_t = \frac{v_t}{u_t} \tag{B.24}$$

$$u_t = 1 - n_t \tag{B.25}$$

$$q_t = k \theta_t^{-\omega} \tag{B.26}$$

$$p_t = \theta_t q_t \tag{B.27}$$

Further firms' decisions:

$$1 - MC_t + (1-\varrho^c) \lambda_t^c = \nu_t^c \tag{B.28}$$

$$E_t D_{t,t+1} (\theta^c \nu_{t+1}^c + \varrho^c \lambda_{t+1}^c) = \lambda_t^c \tag{B.29}$$

$$1 - MC_t + (1-\varrho^c)\lambda_t^g = \nu_t^g \tag{B.30}$$

$$E_t D_{t,t+1}(\theta^c \nu_{t+1}^g + \varrho^c \lambda_{t+1}^g) = \lambda_t^g \tag{B.31}$$

$$\left\{ \begin{array}{c} (X_t^c + X_t^g + I_t)\left[1 - \frac{\eta}{\eta-1} MC_t\right] \\ +\frac{\eta}{\eta-1}(1-\varrho^c)\left[\lambda_t^c X_t^c + \lambda_t^g X_t^g\right] - \frac{\theta^c}{\eta-1}\left(S_{t-1}^c + S_{t-1}^g\right) \\ +\xi E_t \Lambda_{t,t+1}\left[\Pi_{t+1}\left(\Pi_{t+1}-1\right) - \Pi_t\left(\Pi_t - 1\right)\right] \end{array} \right\} = 0 \tag{B.32}$$

Government budget constraint and fiscal rules:

$$B_t = R_t B_{t-1} + G_t + (1-n_t)w_u - \tau_t - \tau_t^C C_t - \tau_t^W w_t n_t h_t - \tau_t^K R_t^k K_t \tag{B.33}$$

$$S_t^g = \varrho^c S_{t-1}^g + (1-\varrho^c) G_t \tag{B.34}$$

$$G_t = X_t^g + \theta^c S_{t-1}^g \tag{B.35}$$

$$\log\left(\frac{G_t}{\bar{G}}\right) = \rho_G \log\left(\frac{G_{t-1}}{\bar{G}}\right) + \epsilon_t^g \tag{B.36}$$

$$\log\left(\frac{X_t}{\bar{X}}\right) = \rho_X \log\left(\frac{X_{t-1}}{\bar{X}}\right) + \rho_{XB}\frac{B_{t-1}}{y_{t-1}} + \epsilon_t^X, \quad X_t = (\tau,\ \tau^c, \tau^w, \tau^k) \tag{B.37}$$

Resource constraint:

$$Y_t = C_t + I_t + G_t + g_t n_t + \frac{\xi}{2}\left(\frac{P_t}{P_{t-1}} - 1\right)^2 \tag{B.38}$$

Taylor rule and Fisher equation (sticky-price model):

$$\log\left(\frac{R_t^n}{\bar{R}^n}\right) = \varrho_\pi \log\left(\frac{\Pi_t}{\bar{\Pi}}\right) + \varrho_y \log\left(\frac{Y_t}{\bar{Y}}\right) \tag{B.39}$$

$$R_{t+1} = E_t\left[\frac{R_t^n}{\Pi_{t,t+1}}\right] \tag{B.40}$$

C Steady state

Steady-state values of the employment rate, n, hours worked, h, and the marginal cost, MC, solve simultanously the wage equation, (B.21), the economy's resource constraint, (B.38), and the pricing equation, (B.32), while the value of the remaining unknowns in the system of equations reported in Appendix A can be found recursively by using the following relationships:

$$\overline{ZN} = (ZN)_0 \tag{C.1}$$

$$\overline{ZK} = (ZK)_0 \tag{C.2}$$

$$\overline{Y} = Y_0 \tag{C.3}$$

$$\overline{D} = \beta \tag{C.4}$$

$$\overline{Q} = 1 \tag{C.5}$$

$$\overline{\Pi} = 1 \tag{C.6}$$

$$\overline{R^K} = \frac{\overline{R} + \delta}{1 - \overline{\tau^K}} \tag{C.7}$$

$$\overline{\left(\frac{K}{Y}\right)} = \overline{MC}\frac{S^K}{\overline{R^K}} \tag{C.8}$$

$$\overline{K} = \overline{\left(\frac{K}{Y}\right)}\overline{Y} \tag{C.9}$$

$$\overline{I} = \delta\overline{K} \tag{C.10}$$

$$\overline{G} = \overline{\left(\frac{G}{Y}\right)}\overline{Y} \tag{C.11}$$

$$\overline{S^g} = \overline{G} \tag{C.12}$$

$$\overline{X^g} = (1 - \theta^c)\overline{G} \tag{C.13}$$

$$\overline{u} = 1 - \overline{n} \tag{C.14}$$

$$\overline{p} = \frac{\lambda\overline{n}}{1 - \overline{n}} \tag{C.15}$$

$$\bar{\theta} = \left(\frac{\overline{p}}{\kappa}\right)^{\frac{1}{1-\omega}} \tag{C.16}$$

$$\overline{q} = \kappa\overline{\theta}^{-\omega} \tag{C.17}$$

$$\overline{v} = \overline{u}\overline{\theta} \tag{C.18}$$

$$\overline{z} = \frac{\overline{v}}{\overline{n}} \tag{C.19}$$

$$\overline{g} = \frac{\chi}{1 + \psi}\overline{z}^{1+\psi} \tag{C.20}$$

$$\overline{g_z} = \chi \overline{z}^{\psi} \tag{C.21}$$

$$\overline{FN} = \alpha_N \overline{MC} \left(\overline{ZN}\right)^{\frac{\sigma-1}{\sigma}} \left(\frac{\overline{Y}}{\overline{n}\overline{h}}\right)^{\frac{1}{\sigma}} \tag{C.22}$$

$$\overline{F}_n = \overline{F}_N \overline{h} \tag{C.23}$$

$$\overline{X}^c = \frac{1-\varrho}{\varrho} \overline{F}_N \frac{1 + \overline{n}\left(\left(1-\overline{h}\right)^{\varrho(1-\sigma_c)} - 1\right)}{\left(1-\overline{h}\right)^{\varrho(1-\sigma_c)-1}} \tag{C.24}$$

$$\overline{C} = \frac{\overline{X^c}}{1-\theta^c} \tag{C.25}$$

$$\overline{S^c} = \overline{C} \tag{C.26}$$

$$\overline{U}_n = \frac{\left(\overline{X}^c\right)^{(1-\varrho)(1-\sigma_c)} \left(\left(1-\overline{h}\right)^{\varrho(1-\sigma_c)} - 1\right)}{1-\sigma_c} \tag{C.27}$$

$$\overline{U_x} = (1-\varrho) \left(\overline{X}^c\right)^{(1-\varrho)(1-\sigma_c)-1} \left(1 + \overline{n}\left(\left(1-\overline{h}\right)^{\varrho(1-\sigma_c)} - 1\right)\right) \tag{C.28}$$

$$\overline{w} = \frac{1}{\overline{D}\overline{h}} \left[-\frac{\overline{g_z}}{\overline{q}} + \overline{D}\left(\overline{F}_n - \overline{g} + \overline{z g_z} + (1-\lambda)\frac{\overline{g_z}}{\overline{q}}\right)\right] \tag{C.29}$$