WP/13/17

IMF Working Paper

A Fiscal Stimulus and Jobless Recovery

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INTERNATIONAL MONETARY FUND

 WP/13/17

IMF Working Paper

Research Department

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Authorized for distribution by Andrew Berg

January 2013

Abstract

We analyse the effects of a government spending expansion in a DSGE model with Mortensen-Pissarides labour market frictions, deep habits in private and public consumption, investment adjustment costs, a constant-elasticity-of-substitution (CES) production function, and adjustments in employment both at the intensive as well as the extensive margin. The combination of deep habits and CES technology is crucial. The presence of deep habits magnifies the responses of macroeconomic variables to a fiscal stimulus, while an elasticity of substitution between capital and labour in the range of available estimates allows the model to produce a scenario compatible with the observed jobless recovery.

JEL Classification Numbers: E24; E62

Keywords: fiscal policy; deep habits; labor market search-match frictions; unemployment; CES production function

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[1] Comments by Yunus Aksoy, Federico Di Pace, Lorenzo Forni, Alessio Moro, Stefania Villa, Roland Winkler, seminar participants at UAB, Birkbeck, 17th CEF 2011, San Francisco, 2012 RES Conference, University of Cambridge, 4th CIMS workshop at the University of Surrey are acknowledged. We acknowledge financial support from ESRC project RES-062-23-2451. The usual disclaimer applies.

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I. Introduction

In the recent financial crisis an important dimension along which many governments have taken action has been fiscal policy. The economics profession and much of the academic discussion placed emphasis on the issue of whether and to what extent a fiscal stimulus delivers the dual outcome of (i) moderating the output collapse and (ii) boosting job creation. This assumes great importance also in the light of the *jobless recovery* that the US are experiencing in the aftermath of the Great Recession.[1]

As shown in Figure 1 (left-hand-side quadrant), the cyclical component of private investment positively co-moves with that of output, exhibiting a considerably greater volatility and leading the cyclical deviations of the stock of capital, which lies well below trend in the quarters following the Great Recession. The cyclical component of hours worked per employee (right-hand-side quadrant) displays positive co-movement with the cyclical fluctuations of real output, and the cyclical component of unemployment is negatively correlated with that of output. However, while hours worked per employee and output have been on a recovery path since Q2 2009 (the trough of the great recession), the unemployment rate has persistently remained well above average while vacancy posting has remained below average. During the recovery, overtime hours per employee have also quickly increased, leading the increase of hours and recently positively deviating from trend more than in the pre-recession period.[2] In sum, the recovery of output has been accompanied by a recovery of hours worked, while for the stock of capital and unemployment it is taking much longer to return to pre-crisis levels.[3]

In this paper 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, investment adjustment costs, a constant-elasticity-of-substitution (CES) production function, and adjustments in employment both at the intensive as well as the extensive margin.[4] This model is consistent with four empirical regularities that have arisen in the literature, namely that: (a) private consumption and (b) real wage increase following a public spending expansion; (c) the mark-up is countercyclical and falls following a government spending shock; (d) factor shares are time-varying at business cycle frequencies and capital and labour are gross complements in production. The main results are that: (i) we obtain output multipliers in the high range of empirical estimates even in the absence of nominal rigidities; (ii) we can reproduce a fiscal expansion with low job creation;

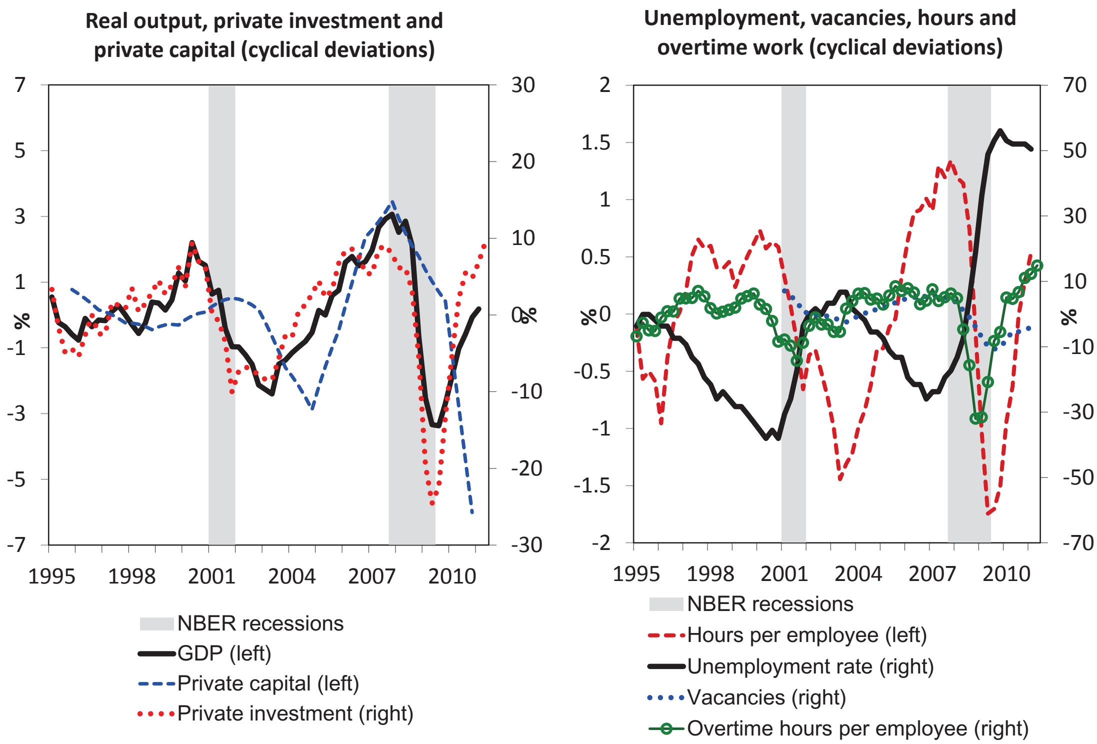
[1]In the literature there is still no consensus on whether the current recovery can be defined as *jobless* or simply *slow*, as we document in the following section.

[2]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. Overtime hours, on the contrary, display a much greater volatility. In Table A.1 in the online appendix we report standard deviations, correlations and autocorrelations of time series in Figure 1.

[3]The cyclical deviations reported in Figure 1 represent unconditional patterns, which are driven by a potentially large number of shocks. Therefore, they should not be taken as empirics regarding the effects of fiscal shocks, but rather as business cycle dynamics that motivate the analysis. In the remainder of the paper we specifically focus on the effects of fiscal shocks.

[4]For alternative approaches on the introduction of labour market frictions see Gali (2011).

Figure 1: A jobless recovery



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

and (iii) we can simulate a fiscal stimulus 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*.

The combination of deep habits and CES technology is crucial for the jobless outcome of a fiscal stimulus. In fact, 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 magnified responses of macroeconomic variables in response to a fiscal stimulus. 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. 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. Given that capital is unable to change instantaneously in response to the fiscal expansion - partly because it is a stock variable and partly because of the presence of adjustment costs to investment - firms have smaller incentives to create new jobs through vacancy posting, being this a costly process. However, both the negative wealth effect (coming from the absorption 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 per employee. In such a case, the expansion in output is driven relatively more by an increase in the hours of work of current employees rather than new job creation. Thus, the CES technology with an empirically supported elasticity of substitution proves to be a useful tool to simulate a fiscal stimulus that mitigates the output collapse in a recession but contains the rise in unemployment only marginally.

The remainder of the paper is structured as follows. Section II. places this paper in the context of the literature and discusses similarities and differences of our model with previous works. Section III describes the model. Section IV illustrates the parameter choice. Section V presents the results, isolates the effects of several features of the model and simulates a scenario compatible with the jobless recovery. Finally, Section VI concludes and sets the agenda for future research. The paper is complemented by an online appendix that provides a battery of sensitivity exercises, a sticky prices extension of the model, the symmetric equilibrium and the steady state of the baseline model.

II. Selected Literature

There is still no broad consensus about the quantitative and qualitative effects of fiscal policy shocks in the literature. The empirical literature has not provided robust stylized facts yet, hence the theoretical literature developed a set of models compatible with contrasting results. We briefly report on them[5] and then we relate this paper to the jobless recovery literature.

A. Empirical literature

On the size of fiscal multipliers the literature has provided a variety of results. Auerbach et al. (2010) describe the range of mainstream estimates of fiscal multipliers as “almost embarrassingly large”. Recent VAR estimates of the output multiplier are generally greater than those predicted by DSGE models with no zero-lower-bound constraints but still present values varying from 0.7 to 2.5.[6]

[5] A full literature review is behind the scope of this paper. For comprehensive reviews of the empirical effects of fiscal policy please refer to Perotti (2007), Caldara and Kamps (2008) and Hebous (2011).

[6] Pessimistic estimates of the output multiplier (around 0.7) can be found in (Barro and Redlick, 2011; Ramey, 2009); some contributions find values around one (see Hall, 2009, among others); while other authors (see Blanchard and Perotti, 2002; Monacelli et al., 2010; Blinder and Zandi, 2010; Acconcia et al., 2011; Fragetta and Melina, 2011, among others) report values above one. Auerbach and Gorodnichenko (2012) study asymmetries in the propagation of fiscal shocks in booms and downturns and report an output multiplier of up to 2.5 during recessions.

The literature is divided not only on the quantitative analysis of the fiscal multipliers but also on the qualitative responses of key macroeconomics variables to fiscal shocks. However, recently Caldara and Kamps (2008) have shown that these disagreements are mostly due to differences in the sample selection and in the specification of the reduced-form VAR models. After controlling for different identification approaches used in the literature, applied to the same reduced-form VAR, they show that private consumption and the real wage increase after a government spending shock.[7] On the size of the output multiplier, in a more recent paper, Caldara and Kamps (2012) provide further evidence in favour of the spending multiplier being larger than one. In addition, Monacelli and Perotti (2008) and Canova and Pappa (2011) have recently provided evidence on the fact that the mark-up responds in a countercyclical way to government spending shocks.

B. Theoretical literature

In models with rational expectations government spending multipliers are typically small. The main reason 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) 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 New-Keynesian (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.[8]

To analyze the effect of fiscal policy on unemployment, the common practice in the literature has been that of introducing Mortensen-Pissarides search-matching (MPMF) frictions into otherwise standard DSGE models (Campolmi et al., 2011; Faia et al., 2010; Monacelli et al., 2010). A typical problem that arises in 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) although this practice has been criticised by Pissarides (2009). Pissarides (2009) criticises 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. Di Pace and Faccini (2012) tackle the unemployment volatility puzzle via the introduction of "deep habits" in consumption as in Ravn et al. (2006). The

[7]They also show how the responses of labor market variables seem to be important to rationalize the consumption response.

[8]The results in New-Keynesian (NK) models have also been shown to be dependent on the reaction of monetary policy: 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. (2011) find that the spending multiplier may also reach 10 at the ZLB if the fiscal stimulus lasts for exactly the quarters during which the ZLB is binding.

introduction of deep habits in a DSGE model also imply 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 the context of our paper, the inclusion of deep-habits into a DSGE model featuring MPMF frictions in the labour market, in addition to magnifying the amplitude of the responses of unemployment to shocks, also delivers results in line with three of the four empirical regularities reported in the introduction: (i) that private consumption is typically crowded in by a government spending expansion as opposed to being crowded out as a canonical DSGE model predicts; (ii) the real wage increases after a government spending expansion as opposed to falling as in the canonical Real Business Cycle (RBC) model; (iii) the mark-up is typically countercyclical.[9] The introduction of a CES production function, in the spirit of Cantore et al. (2010a), completes the picture by matching (iv) the evidence of gross complementarity between capital and labour in production and time-varying factor shares[10] as well as allowing the model to reproduce a scenario compatible with the jobless recovery.

C. Jobless recovery

We do not go as far as claiming that ours is the only explanation for the jobless outcome of the fiscal stimulus during the recovery and indeed the jobless recovery itself is still a very controversial issue in the literature.[11] Possible explanations of the delay in the response of unemployment in recovery periods (observed from the 1991 recession onwards) have been associated with structural change stories such as the availability of a more flexible labour force (temporary workers and offshoring), a temporary increase in the natural rate of unemployment (Daly et al., 2011), the mismatch between job-seekers and vacancies in the labour market (Sahin et al., 2011), the increase in health benefits and a rise in the speed of sectoral reallocations (see Groshen and Potter (2003), Andolfatto and MacDonald (2004) and Schreft et al. (2005) amongst others). However, Aaronson et al. (2004a) and Aaronson et al. (2004b) find little support for the structural change hypothesis. Some other authors have also given a cyclical explanation of the jobless recovery. We contribute to this strand of the literature, although we acknowledge that structural and cyclical explanations of the jobless recovery need not be mutually exclusive. Examples of business cycle explanations are Aaronson et al. (2004a), relating the jobless recovery to a negative labour supply shock; Bernanke (2003), focusing on a sluggish aggregate demand; and Bachmann (2011), calibrating a DSGE model with adjustment costs to the extensive margin. In a recent paper, Shimer (2012) combines wage rigidities and labor market frictions. His model predicts that employment is low during a recovery because firms cut back on hiring, not because the incidence of unemployment rises. He argues that this low hiring accounts for the majority of fluctuations in

[9] Blanchard and Perotti (2002); Pappa (2005); Gali et al. (2007); Caldara and Kamps (2008); Pappa (2009); Monacelli et al. (2010); Fragetta and Melina (2011); Caldara and Kamps (2008).

[10] Blanchard (1997); Jones (2003, 2005); Klump et al. (2007); Chirinko (2008); McAdam and Willman (2008); Ríos-Rull and Santaeulália-Llopis (2010); Cantore et al. (2010b, 2012a); León-Ledesma et al. (2012).

[11] For instance, Galí et al. (2012) go as far as claiming that there are no jobless recoveries but only slow motion recoveries.

unemployment and his approach accounts for the simultaneous increase in unemployment and decline in vacancies that occurred in the past recession shown in Figure 1. In this paper we link the jobless outcome of a fiscal stimulus to factor complementarity. This of course does not exclude that other mechanisms (both cyclical and structural) may reinforce and amplify the jobless recovery mechanism presented here.

III. The Model

A. Search-match technology

The labour market is characterised by standard Mortensen-Pissarides search-match frictions in which firms fill jobs by posting vacancies. Let n_t be the number of employed workers and total population be normalised 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.

B. 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. 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 normalised to one, so that n_t^j can be interpreted as an employment rate. Let also the total time available to individuals be normalised 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 $l_t^j = 1$.[12] 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 law of motion

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

where $\rho^c \in (0,1)$ 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 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.

[12] We also assume that workers can perfectly insure themselves against idiosyncratic shocks, i.e. that income is pooled between the employed and the unemployed.

Each household j solves a two-stage problem. Letting P_{it} be the price of variety i, they first minimise 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 maximise 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 budget constraint

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

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 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

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

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:

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

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 privately efficient, as shown below.

C. Government

Deep habits are present also in government consumption. From a technical point of view this is entirely analogous to how deep habits are introduced in private consumption. From an intuitive point of view, Ravn et al. (2006) justify this choice by assuming that private households value government spending in goods in a way that is separable from private consumption and leisure and that households derive habits on consumption of government-provided goods. Alternatively, as in Ravn et al. (2012) and 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. For example, 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. Moreover, Ravn et al. (2012) also propose the idea of procurement relationships that create a tendency for the government to favour transactions with sellers that supplied public goods in the past.

In each period t, the government allocates spending P_tG_t over differentiated goods sold by retailers in a monopolistic market to maximise 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 $\int_0^1 P_{it}G_{it} \leq P_tG_t$, where η is the elasticity of substitution across varieties, S_{it-1}^g denotes the stock of habits for government expenditures, which evolves as

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

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,

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

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

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

while taxes are set according to the following feedback rule:

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

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 our benchmark scenario of lump-sum taxes and fully financed lump-sum taxation, it suffices to set the tax rates and government debts constantly equal to zero, $B_t = \tau_t^C = \tau_t^W = \tau_t^K = 0$, and $\tau_t = G_t + (1-n_t)w_u$.

D. 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 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.[13]

The firm rents capital services from households at a rental rate R_t^K, takes employment n_{it} as given at time t, and maximises the 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 constraint

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

The corresponding first-order conditions for this problem are:

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

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

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

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

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

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

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

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

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

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 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

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

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*:

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

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

E. Wage bargaining and hours worked

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

$$\max_{w_{it}} (S^w_{it})^{1-\varepsilon} \left(S^f_{it}\right)^{\varepsilon} \tag{36}$$

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

$$S^w_{it} = \frac{1-\varepsilon}{\varepsilon}\left(1-\tau^w_t\right) S^f_{it}. \tag{37}$$

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

$$w_{it}h_{it} = (1-\varepsilon)\left[MC_t F_{N,it} h_{it} - g(z_{it}) + g'(z_{it})z_{it} + \theta_t g'(z_{it})\right] + \varepsilon \left[\frac{w_u - \frac{U_{n,t}}{U_{x,t}}}{1-\tau^w_t}\right]. \tag{38}$$

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, we follow Thomas (2008) in modelling hours per worker as being determined by firms and workers in a privately efficient way, i.e. in order to maximize the joint surplus of their employment relationship. The joint surplus is in turn the sum of the firm's surplus, S^f_{it}, and the worker's surplus, S^w_{it}. By maximizing the joint surplus with respect to h_{it}, we obtain the hours-determination condition

$$MC_t F_{N,it} = -\frac{U_{nh,it}}{U_{x,it}} + \tau^w_t w_t, \tag{39}$$

according to which the marginal revenue product of labour is equal to the marginal rate of substitution between consumption and leisure and the labour income tax paid on each hour of work. In the absence of distortionary taxes, with $\tau^w_t = 0, \forall t$ (i.e. in the vast majority of experiments conducted in this paper), hours are independent of the hourly wage.

F. 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 summarised in the online appendix, Section D, while the steady state is outlined in Section E.

G. CES production function and "re-parametrization"

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

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

where K_t is capital, n_t is the number of employees, h_t are hours worked per employee, $(ZK)_t$ and $(ZN)_t$ are capital and labour-augmenting technology shocks, 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 (2012). 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 (2012).

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 characterised 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, $S^{SM} \equiv \frac{g(z)n}{Y}$, where $g(z)n$ represents total hiring costs, which are a function of the vacancy rate z. In equilibrium, $S^K + S^N + S^{SM} = 1$.

H. Additional functional forms

Equation (2) specialises as a non-additively-separable utility function:

$$U(X_t^c, n_t, 1-h_t) = n_t \frac{\left[X_t^{c(1-\rho)} (1-h_t)^\rho \right]^{1-\sigma_c} - 1}{1-\sigma_c} + (1-n_t) \frac{X_t^{c(1-\rho)(1-\sigma_c)} - 1}{1-\sigma_c}, \tag{47}$$

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,

$$S\left(\frac{I_t}{I_{t-1}} \right) = \frac{\gamma}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2, \ \mu > 0, \tag{48}$$

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	0
Elasticity of subst leisure/consumption	ρ	set to target $\bar{h} = 0.33$
Scaling factor in hiring cost function	χ	set to target $\bar{p} = 0.95$
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 1: Baseline calibration

while the model allows for a possibly convex hiring cost function, i.e. $g(z_t)$ specialises as

$$g(z_t) = \frac{\chi}{1+\psi} z_t^{1+\psi}, \ \psi \geq 0. \tag{49}$$

IV. Parameter Choice

We assign numerical values to parameters in order to match either a number of stylised facts for the US economy in the post-WWII era or according to available empirical estimates or conventions. The time period in our model corresponds to one quarter in the data. Table 1 summarises the parameter choice.

A set of parameters are simply set equal 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 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 mark-up 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. (2012). We obtain the Cobb-Douglas as a limiting case, by setting $\sigma \to 1$. 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, ψ, in the hiring cost function to 0, which makes it linear as the assumption of convex hiring costs made by Gertler and Trigari (2006) and Thomas (2008) is not needed in the absence of the Calvo wage setting. 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 33%; (b) a steady-state job finding probability, $\bar{p}$, equal to 95% as in Gertler et al. (2008); (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 online appendix, Section B.2.

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 9.5%, a value close to that of Hall (2005).

V. 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. First, we present the well known results that in the baseline RBC model the output multiplier is well below the range of available empirical estimates. We 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. Second, we show how, even in the absence of price stickiness, the introduction of deep habits magnifies the responses of macroeconomic variables to a fiscal stimulus. At the same time, in line with Ravn et al. (2006), the mark-up falls, real wages rise and consumption is crowded in after an expenditure expansion. Furthermore, by introducing the CES production function, 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. Last, we explore the effects of a fiscal stimulus at a recession time, which fosters a *jobless recovery*. In the online appendix we show that an accommodative monetary policy with respect to the output gap alongside sticky prices plays an important role for the stabilisation properties of the fiscal stimulus.

A. Neoclassical benchmark with search-match frictions

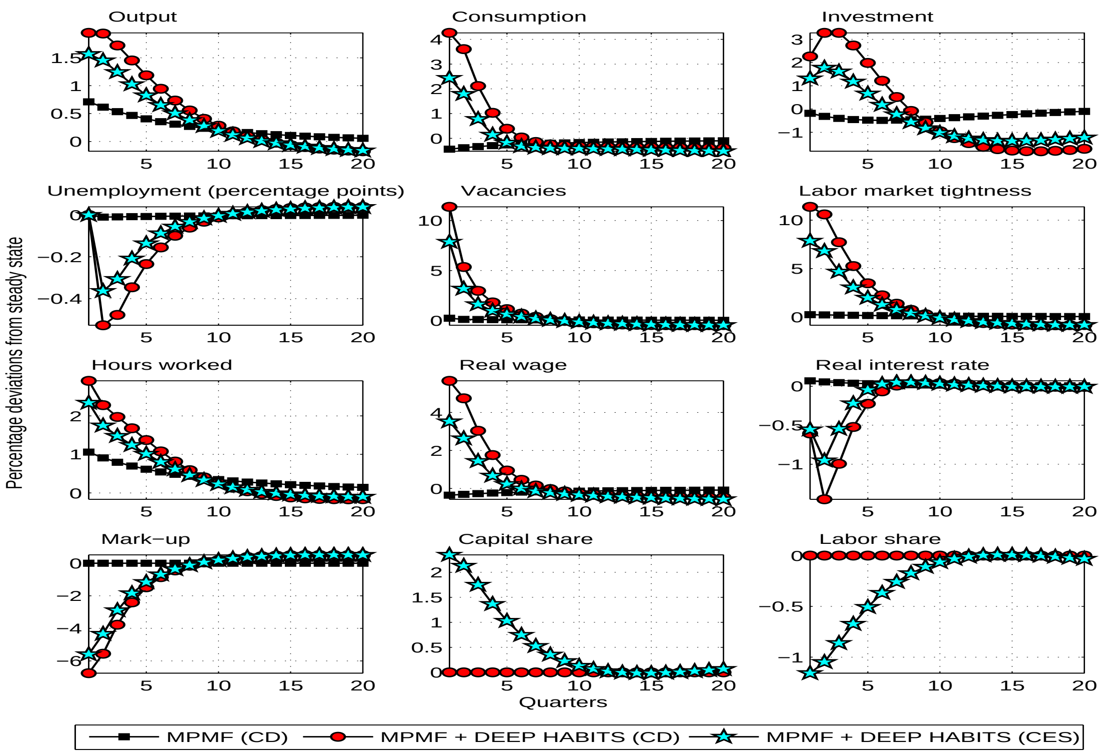
In Figure 2 we plot the impulse responses of a number of fundamental macroeconomic variables to a government spending expansion of size 1% of output. Normalising the size of the fiscal shock as such allows us to interpret the output responses as fiscal multipliers. For unemployment, we report the absolute 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.

As a benchmark, we consider the effects of a government spending expansion in a model where the production function is Cobb-Douglas, and 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. This 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 private investment is also 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 the 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 similar to existing contributions such as Campolmi et al. (2011) and Monacelli et al. (2010): government spending expansions yield output multipliers well below one (slightly above 0.5 for our calibration) and almost negligible negative effects on unemployment.

Figure 2: 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 ($\theta^c = \rho^c = 0$). Line marked by circles: MPMF, CD production function, and deep habits in consumption ($\theta^c = 0.86$ and $\rho^c = 0.85$). 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.

These results 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. 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.

B. Deep habits

As shown in Figure 2, the introduction of deep habits in consumption yields a substantial improvement on the performance of the DSGE model in matching these empirical findings.[14]

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 coexistence 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:

$$AD_{it} = C_{it} + G_{it} + I_{it} = \left(\frac{P_{it}}{P_t}\right)^{-\eta}\left(X_t^c + X_t^g + I_t\right) + \theta^c\left(S_{it-1}^c + S_{it-1}^g\right), \tag{50}$$

where G_{it} is public consumption of variety i, I_{it} is the component entering the investment aggregator I_t (which is not subject to deep habits) and X_t^g and S_{it}^g are the public counterparts of the habit-adjusted consumption composite and the stock of habit for variety i. 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 $\left(X_t^c + X_t^g + I_t\right)$ rises, the "weight" of the price-elastic component of demand grows and the effective price elasticity of demand, $\tilde{\eta}_{it} \equiv -\frac{\partial AD_{it}}{\partial p_{it}}\frac{p_{it}}{AD_{it}} = \eta\left(1 - \theta^c\frac{\left(S_{it-1}^c + S_{it-1}^g\right)}{AD_{it}}\right)$, 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 relatively 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, which 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-

[14]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 (2012) 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.

Douglas production function and our baseline calibration the resulting output multiplier is almost 2, while the peak unemployment multiplier is almost -0.6 percentage points.

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). Although the zero-lower-bound for the nominal interest rate has been found to be a determinant for higher output multipliers, we see this more as a special circumstance rather than a feature able to explain business cycle patterns in general.

C. 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 expenditure 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.[15]

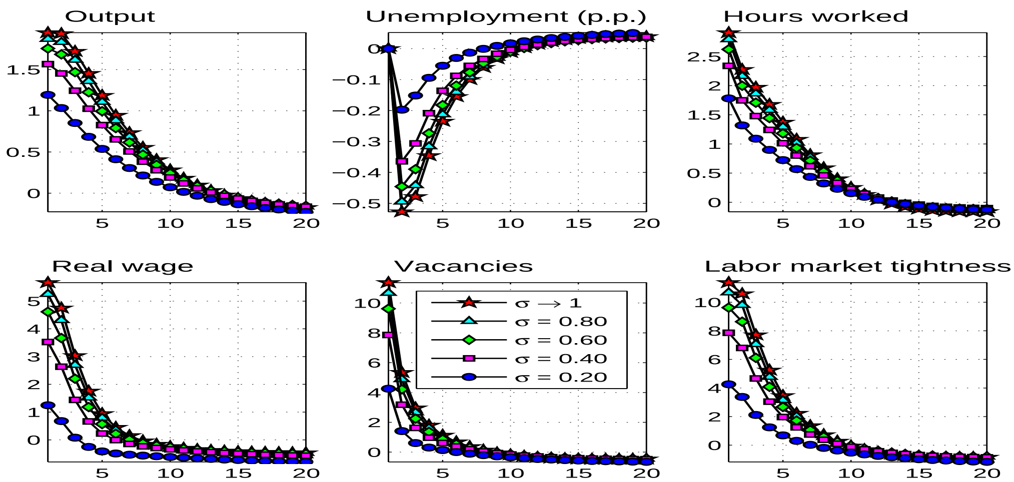
In this subsection we show that if the elasticity of substitution between capital and labour, σ, is allowed to drop from 1 (CD case) to values in the range of estimated values, the unemployment multiplier drops considerably more than the output multiplier. Estimates of σ are between 0.3 and 0.6 (Klump et al., 2007; Chirinko, 2008; Cantore et al., 2012a, 2010b; León-Ledesma et al., 2012).

In Figure 2 we show that a value of $\sigma = 0.4$ makes the output multiplier diminish to almost 1.6 (that is 81% of the value obtained in the CD case), while the unemployment multiplier drops to -0.35 percentage points (about 66% of the value obtained in the CD case). In addition, factor shares react to the government spending expansion.

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 gross complements. In Figure 3 we show that, with a smaller σ, given that capital is unable to change instantaneously in response to the fiscal

[15]For OECD countries Holden and Sparrman (2012) find a multiplier of -0.30 percentage points while Brückner and Pappa (2012) show that the effect may even be negative.

Figure 3: 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 $\rho^c = 0.85$).

expansion, firms have smaller incentives to create new jobs through vacancy posting. However, both the negative wealth effect (coming from the absorption 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. From a quantitative perspective, this effect is stronger in the presence of investment adjustment costs, as shown in the online appendix, Section B.4.[16]

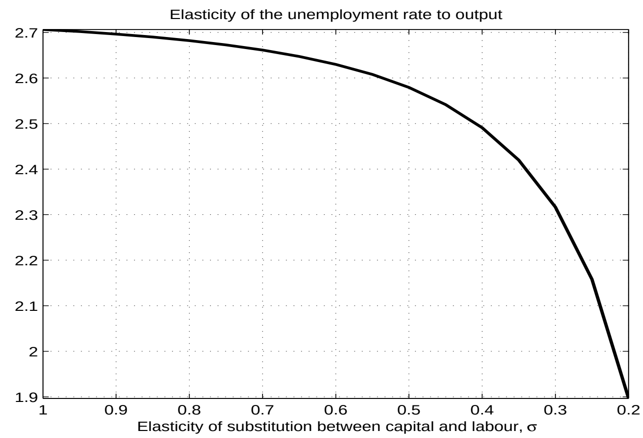
In Figure 4 we plot the peak elasticity of the unemployment rate to output in response to a government spending expansion at different levels of the elasticity of substitution between capital and labour. When σ drops from 1 (CD case) to the lower bound of the range of empirical estimates ($\sigma = 0.3$), the peak elasticity of the unemployment rate to output drops by around 15%.

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 an increase in the intensive margin (current employees work longer hours) than an increase in the extensive margin (new job creation).[17]

[16] Another additional possible venue in modelling capital is the introduction of variable capital utilization. Such a feature may be used as a device to soften the *jobless* outcome of a fiscal stimulus. In fact if firms have an adequate capital buffer, they may use it in response to a fiscal stimulus. This, together with some complementarity between capital and labour may yield to higher vacancy posting and hence higher unemployment multipliers.

[17] In the online appendix, Section B.1, we also show that, as the technology tends to Leontief, the calibration of the bargaining parameter becomes increasingly less important for the equilibrium outcome. Rowthorn (1999) also emphasises the role of CES technology with an elasticity σ below unity in explaining European unemployment persistence despite

Figure 4: 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 $\rho^c = 0.85$).

D. Jobless recovery

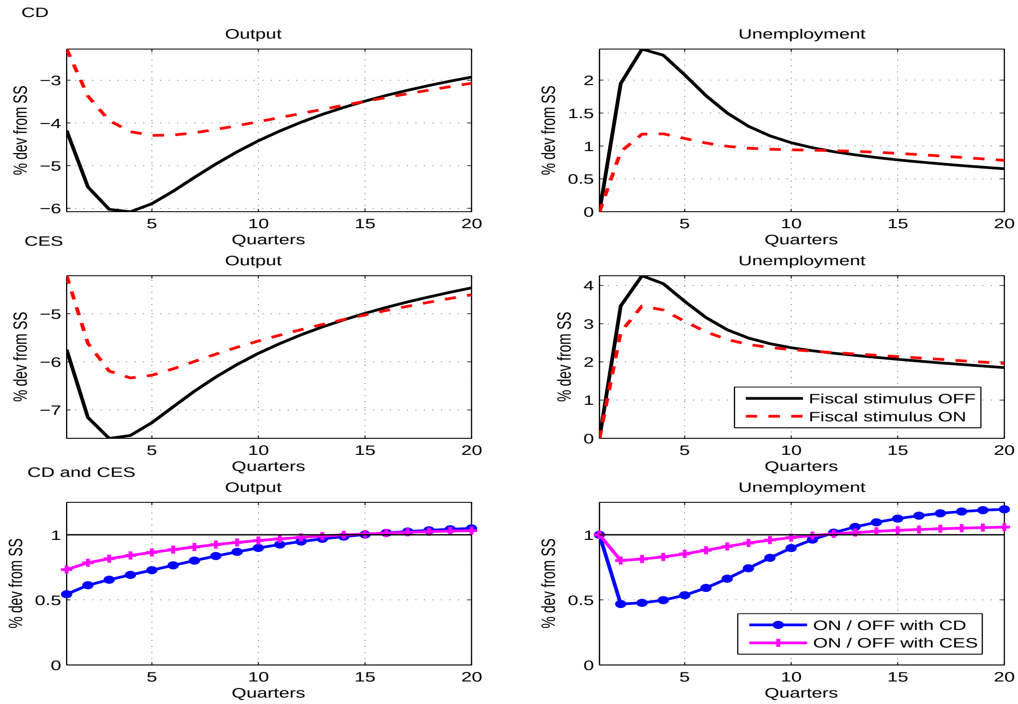
In this subsection we investigate the low-job-creation feature of the fiscal stimulus in a case in which the latter takes place at a recession time.

For illustrative purposes, we simulate a recession by means of a negative technology shock. Figure 5 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 5, respectively). 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 the 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 predicts 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.[18] It is evident that while the fiscal stimulus has similar effects in terms of output stabilisation, unemployment stabilisation is considerably less pronounced under the CES production function. The third row of Figure 5 plots the ratios of the impulse responses with the fiscal stimulus

moves towards greater labour market flexibility as captured by an increase in the firm's bargaining power in our model.

[18] 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.

Figure 5: 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 $\rho^c = 0.85$). 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 CD and CES technologies.

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 50% of the contraction in the no-fiscal policy scenario under CD and around 30% 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*.

VI. Concluding Remarks

We have analysed 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, capital adjustment costs, a constant-elasticity-of-substitution (CES) production function, and adjustments in employment both at the intensive as well as the extensive margin.

The combination of deep habits and CES technology is crucial. The presence of deep habits magnifies the responses of macroeconomic variables to a fiscal stimulus, while an elasticity of substitution between capital and labour in the range of available estimates allows the model to produce a scenario compatible with the jobless recovery. In other words, factor complementarity proves to be a determinant of the jobless outcome of a fiscal stimulus. In fact, setting the elasticity of substitution in the CES production function equal to a value smaller than one – as found in the empirical literature – is equivalent to assuming that the technology is closer to a Leontief specification in which capital and labour are gross complements. 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, the trasmission mechanism of the fiscal shock is characterized by a negative wealth effect and a substitution of leisure with consumption, both acting in the same direction of a substantial increase in the supply of the hours of work. Therefore, the expansion in output is driven relatively more by the intensive margin rather than by the extensive one.

From a policy perspective, this result implies that, for a fiscal stimulus to have a stronger impact on reducing the rate of unemployment, it should prioritize measures enhancing the economy's stock of capital, such as incentives for private investments but also direct government investment in public infrastructure.

The results presented in this paper are also an important starting point for future research. More specifically, 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, as shown by Cantore et al. (2012b), examining optimised Taylor rules as e.g. in Levine et al. (2008) would be a useful exercise.

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Appendix

A Business Cycle Statistics

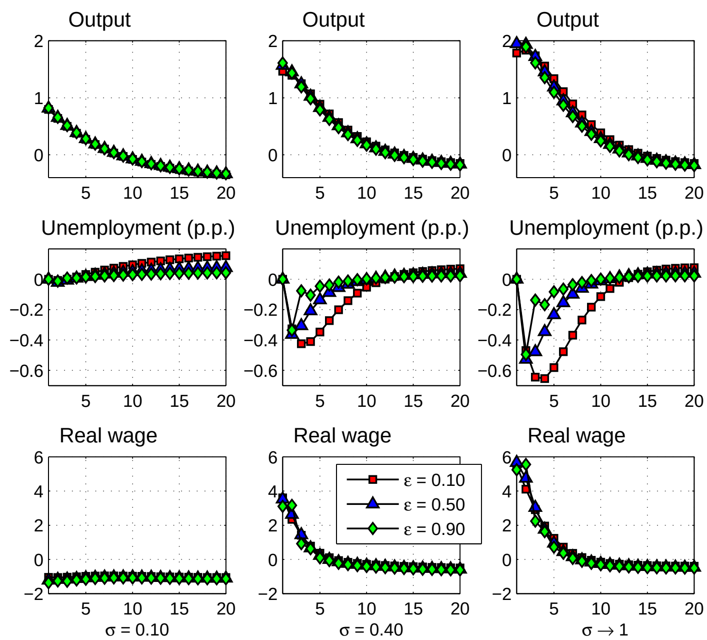
Table A.1: Business cycle properties of selected macroeconomic series.

	Standard deviations relative to real output	
	1995 - 2007	1995 - 2011
GDP	–	–
Private investment	4.16	4.90
Private capital	1.04	1.14
Hours per employee	0.55	0.53
Overtime hours per employee	4.20	5.84
Job openings	3.72	3.19
Unemployment rate	10.06	17.38
	Autocorrelations	
	1995 - 2007	1995 - 2011
GDP	0.93	0.91
Private investment	0.89	0.87
Private capital	0.97	0.96
Hours per employee	0.95	0.92
Overtime hours per employee	0.87	0.87
Job openings	0.94	0.96
Unemployment rate	0.96	0.98
	Correlations with real output	
	1995 - 2007	1995 - 2011
GDP	–	–
Private investment	0.88	0.86
Private capital	0.59	0.41
Hours per employee	0.88	0.91
Overtime hours per employee	0.34	0.35
Job openings	0.88	0.75
Unemployment rate	-0.74	-0.60

Note: The series of job openings starts from 2001.

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

Figure B.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 $\rho^c = 0.85$). 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.

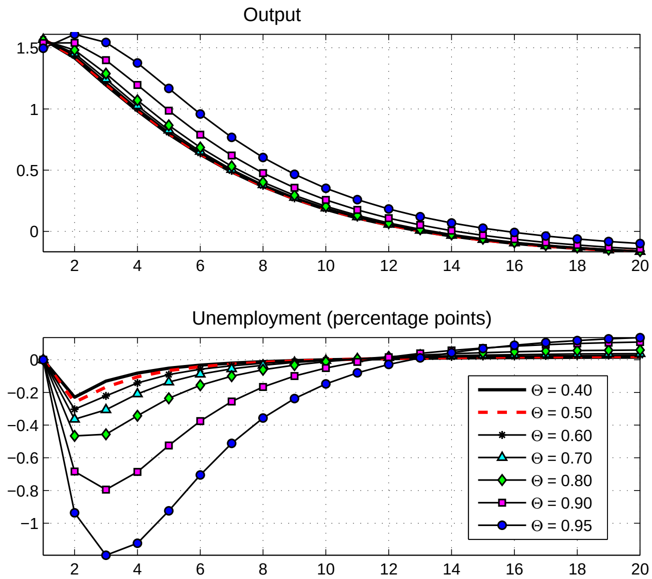
B Sensitivity exercises

A. Bargaining power

In Figure B.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 $\varepsilon = \{0.10, 0.50, 0.90\}$.

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.

Figure B.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 $\rho^c = 0.85$), 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.

If the technology is sufficiently away from Leontief, the greater firms' share in the wage bargaining, 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.

B. 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 the steady-state value of non-work to work activities, the higher 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 B.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, however the output multiplier changes only marginally. Even

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

			(A)	(B)	
			$\sigma \to 1$	$\sigma = 0.4$	(B)/(A)
$\Theta = 0.7$	$\varepsilon = 0.1$	$\frac{\Delta Y}{\Delta G}$	1.78	1.46	0.82
		$\frac{\Delta u}{\Delta G}$	-0.65	-0.42	0.65
	$\varepsilon = 0.5$	$\frac{\Delta Y}{\Delta G}$	1.95	1.57	0.81
		$\frac{\Delta u}{\Delta G}$	-0.53	-0.35	0.66
	$\varepsilon = 0.9$	$\frac{\Delta Y}{\Delta G}$	2.02	1.61	0.80
		$\frac{\Delta u}{\Delta G}$	-0.49	-0.33	0.67
$\Theta = 0.9$	$\varepsilon = 0.1$	$\frac{\Delta Y}{\Delta G}$	1.63	1.38	0.85
		$\frac{\Delta u}{\Delta G}$	-1.27	-0.75	0.59
	$\varepsilon = 0.5$	$\frac{\Delta Y}{\Delta G}$	1.91	1.54	0.81
		$\frac{\Delta u}{\Delta G}$	-1.29	-0.79	0.61
	$\varepsilon = 0.9$	$\frac{\Delta Y}{\Delta G}$	2.05	1.62	0.79
		$\frac{\Delta u}{\Delta G}$	-1.01	-0.65	0.64

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

when using the CES production function (with $\sigma = 0.4$) – and hence incorporating a mechanism that moderates the unemployment multiplier *per se* – if the replacement ratio is calibrated in the high range of plausible values the flexible-price model augmented with MPMF and deep habits in consumption is able to reproduce a considerably higher unemployment multiplier. As a result, the Hagedorn and Manovskii effect proves to be a powerful tool if the goal is just to obtain higher unemployment multipliers. Additional model features, such as deep habits, are needed to obtain higher output multipliers and impulse responses of the real wage, consumption and the mark-up featuring signs consistent with much of the empirical literature.

C. Quantitative implications of the choice of the replacement ratio and the bargaining power

In Table B.1 we report the impact output multipliers and the unemployment peak multipliers obtained with different parametrisations: (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 ($\varepsilon = 0.5$) versus two extreme cases in which either the workers or the firms get almost the whole surplus ($\varepsilon = 0.1$ or $\varepsilon = 0.9$, 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 increases, the unemployment multiplier drops.

In relative terms (last column), almost irrespective of how the surplus is split between workers and firms (ε) 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.

D. Sensitivity to investment adjustment costs and the elasticity of substitution between leisure and consumption

In Table B.2 we report the impact output multiplier and the peak unemployment multiplier obtained using the CD production function ($\sigma \to 1$) and the CES production function ($\sigma = 0.4$) under the baseline parametrisation vis-a-vis two alternative scenarios: (i) with different calibrations of the elasticity of substitution between leisure and consumption, which are set to target a lower (greater)-than-baseline steady-state proportion of working time, i.e. $\bar{h} = 0.25$ ($\bar{h} = 0.40$); and (ii) in the absence of investment adjustment costs (obtained by setting $\gamma = 0$).

A progressively lower elasticity of substitution between leisure and consumption, ρ, which implies a progressively greater steady-state proportion of working time, causes a *ceteris paribus* fall in the output multiplier, while the unemployment multiplier is almost insensitive to such a choice. In relative terms, when σ drops from 1 to 0.4, both the output and the unemployment multipliers fall by approximately the same proportion as in the baseline parametrisation. In other words, the increasingly *jobless* stimulus obtainable as σ drops is robust to the choice of ρ or, equivalently, to the calibration of hours worked.

Compared to baseline results, the absence of investment adjustment costs generates a *ceteris paribus* increase in the output multiplier and a fall in the unemployment multiplier. This is due to the fact that investment is allowed to respond more quickly to the fiscal stimulus and firms find it optimal to post relatively less vacancies. Compared to the baseline specification, when σ drops from 1 to 0.4, especially the output multiplier experiences a bigger reduction. The unemployment multiplier, however, is still reduced to a greater extent. From a quantitative perspective, investment adjustment costs prove important in delivering a *jobless* stimulus.

Another additional possible venue in modelling capital is the introduction of variable capital utilization. Such a feature may be used as a device to soften the *jobless* outcome of a fiscal stimulus. In fact if firms have an adequate capital buffer, they may use it in response to a fiscal stimulus. This, together with some complementarity between capital and labour may lead to higher vacancy posting and hence higher unemployment multipliers.

Table B.2: The impact of the fiscal stimulus in different scenarios

		(A)	(B)	
		$\sigma \to 1$	$\sigma = 0.4$	(B)/(A)
Baseline	$\frac{\Delta Y}{\Delta G}$	1.95	1.57	0.81
	$\frac{\Delta u}{\Delta G}$	-0.53	-0.35	0.66
ρ s.t. $\bar{h} = 0.25$	$\frac{\Delta Y}{\Delta G}$	2.18	1.74	0.80
	$\frac{\Delta u}{\Delta G}$	-0.52	-0.35	0.67
ρ s.t. $\bar{h} = 0.40$	$\frac{\Delta Y}{\Delta G}$	1.74	1.43	0.82
	$\frac{\Delta u}{\Delta G}$	-0.51	-0.34	0.67
No invest. adj. costs	$\frac{\Delta Y}{\Delta G}$	2.50	1.81	0.72
	$\frac{\Delta u}{\Delta G}$	-0.40	-0.25	0.63

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

E. Debt-financed fiscal policy and distortionary taxation

In order to introduce government debt and distortionary taxes we set the steady-state tax rates on consumption, the labour income and the return on capital to the values reported by Christiano et al. (2010), i.e. $\overline{\tau}^c = 0.05$, $\overline{\tau}^w = 0.24$, and $\overline{\tau}^k = 0.32$. In addition, we let the government accumulate public debt, while tax rates react to government debt according to a feedback rule:

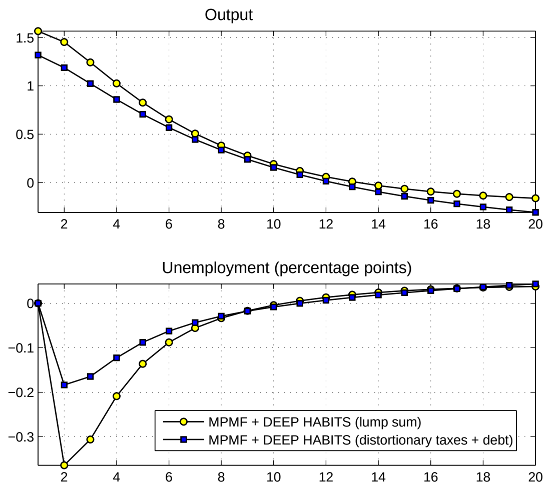
$$\log\left(\frac{X_t}{\bar{X}}\right) = \rho_X \log\left(\frac{X_{t-1}}{\bar{X}}\right) + \rho_{XB}\frac{B_{t-1}}{y_{t-1}}, \;\; X_t = (\tau,\ \tau^c, \tau^w, \tau^k) \tag{B.1}$$

We set the response coefficient of the tax rates to government debt $\rho_{XB} = 0.02$, the value used by Monacelli et al. (2010). Figure B.3 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 absolute value) in the multipliers are due (i) 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 the feedback rule. 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.

F. Sensitivity to tax persistence and the tax responsiveness to government debt.

In the previous subsection we report output and unemployment multipliers in the case of distortionary taxes and in the presence of government debt. Results may be potentially affected by the assumed

Figure B.3: 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 $\rho^c = 0.85$), 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.

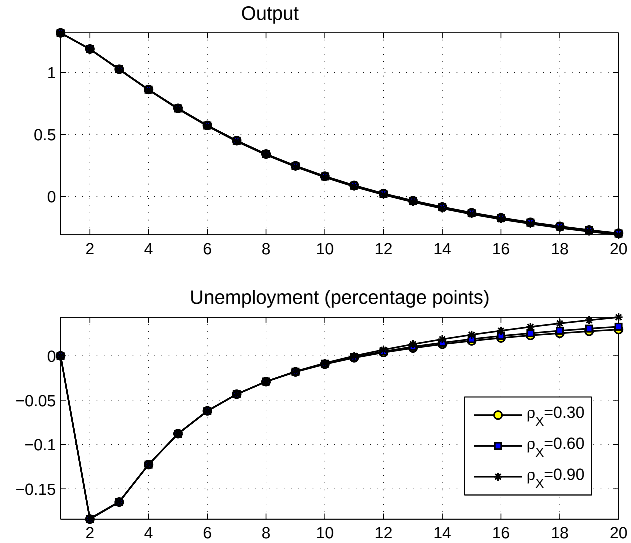
persistence of tax instruments or by the responsiveness of tax instruments to government debt. Hence, in this subsection, we show the sensitivity of the results to the choice of the two parameter values. Figure B.4 shows that both the output and the unemployment multipliers are very robust to the choice of the persistence of the tax instruments. When the persistence changes from low ($\rho_X = 0.30$) to high ($\rho_X = 0.90$), our baseline value, close to some empirical estimates, the plots of the output and the unemployment multipliers are almost indistinguishable. Figure B.5 shows that the output and the unemployment multipliers are quite robust also to the choice of the responsiveness of the tax instruments to government debt, especially up to a horizon of around two years. Starting from two years after the fiscal stimulus has occurred, a more aggressive responsiveness of the tax instruments of government debt (from $\rho_{XB} = 0.005$ to $\rho_{XB} = 0.10$) results into a progressively faster fall of output and a more pronounced rise in unemployment.

C 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.[19]

[19]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

Figure B.4: Sensitivity of output and unemployment multipliers to changes in the persistence of tax instruments.



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

A. Introducing sticky prices

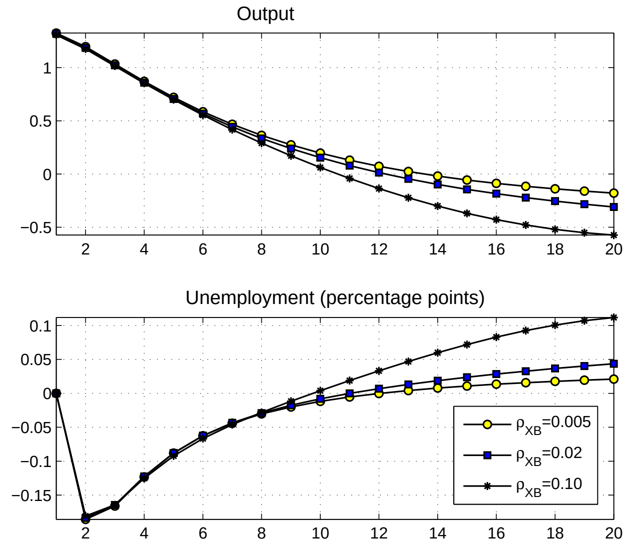
The introduction of sticky prices changes the problem of firms $i \in (0,1)$ in that they now choose the price level, P_{it}, instead of the relative price, p_{it}, and they face quadratic price adjustment costs $\frac{\xi}{2}\left(\frac{P_{it}}{P_{it-1}}-1\right)^2$, where parameter ξ measures the degree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

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

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:

introduces firm-specific habit effects which are more difficult to handle.

Figure B.5: Sensitivity of output and unemployment multipliers to changes in the tax responsiveness to government debt.



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

$$\left\{ \begin{array}{c} \frac{P_{it}}{P_t}(C_{it}+G_{it}) - \xi\left(\frac{P_{it}}{P_{it+s}}-1\right)\frac{P_{it}}{P_{it-1}} + (1-\eta)\left(\frac{P_{it}}{P_t}\right)^{1-\eta} I_t \\ +\eta MC_t\left(\frac{P_{it}}{P_t}\right)^{-\eta} I_t - \eta\nu_t^c\left(\frac{P_{it}}{P_t}\right)^{-\eta} X_t^c - \eta\nu_t^g\left(\frac{P_{it}}{P_t}\right)^{-\eta} X_t^g \\ +\xi\Lambda_{t,t+1}\left[\left(\frac{P_{it+1}}{P_{it}}-1\right)\frac{P_{it+1}}{P_{it}}\right] \end{array} \right\} = 0. \tag{C.2}$$

Similar algebraic manipulations to those described in Section 2.4 lead to the following optimal pricing decision in the symmetric equilibrium:[20]

$$\left\{ \begin{array}{c} \left(X_t^c + X_t^g + I_t\right)\left[1 - \frac{\eta}{\eta-1}MC_t\right] \\ +\frac{\eta}{\eta-1}(1-\rho^c)\left[\lambda_t^c X_t^c + \lambda_t^g X_t^g\right] - \frac{\theta^c}{\eta-1}\left(S_{t-1}^c + S_{t-1}^g\right) \\ +\xi E_t\Lambda_{t,t+1}\left[\Pi_{t+1}\left(\Pi_{t+1}-1\right)\right] - \xi\Pi_t\left(\Pi_t - 1\right) \end{array} \right\} = 0, \tag{C.3}$$

where $\Pi_t \equiv \frac{P_t}{P_{t-1}}$ is the gross inflation rate. Note that the pricing equation (C.3) collapses to the

[20]Equation (C.3) is obtained by combining equations (28), (30) and (C.2), substituting for the demands for C_{it} and G_{it}, (8) and (17), and rearranging.

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.

The NK model is closed by the monetary policy, which is set by imposing a Taylor rule

$$\log\left(\frac{R_t^n}{\bar{R}^n}\right) = \rho_r \log\left(\frac{R_{t-1}^n}{\bar{R}^n}\right) + (1-\rho_r)\left[\rho_\pi \log\left(\frac{\Pi_t}{\bar{\Pi}}\right) + \rho_y \log\left(\frac{Y_t}{\bar{Y}}\right)\right], \tag{C.4}$$

where R_t^n is the nominal interest rate, Π_t is the gross inflation rate, and ρ_r, ρ_π and ρ_y are parameters. A Fisher equation links the ex-post real interest rate R_{t+1} to the nominal interest rate:

$$R_{t+1} = E_t\left[\frac{R_t^n}{\Pi_{t+1}}\right]. \tag{C.5}$$

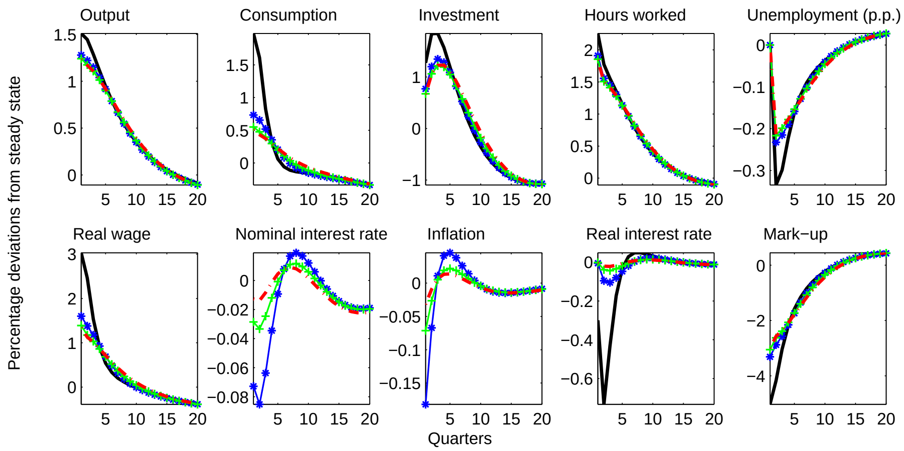
B. Results

Woodford (2011) shows that adding sticky prices into an otherwise standard DSGE model enhances the effects of a government spending expansion. Jacob (2011) argues that if price stickiness is added into a model with deep habit formation the countercyclical movement that the government spending shock induces in the mark-up is milder, that private consumption may still be crowded out as in traditional RBC and NK models and, consequently, the output multiplier becomes small. We show that, with 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 (as evident also in the robustness exercises of his paper) is dependent on the assumption that the Taylor rule has a strong 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 offset.

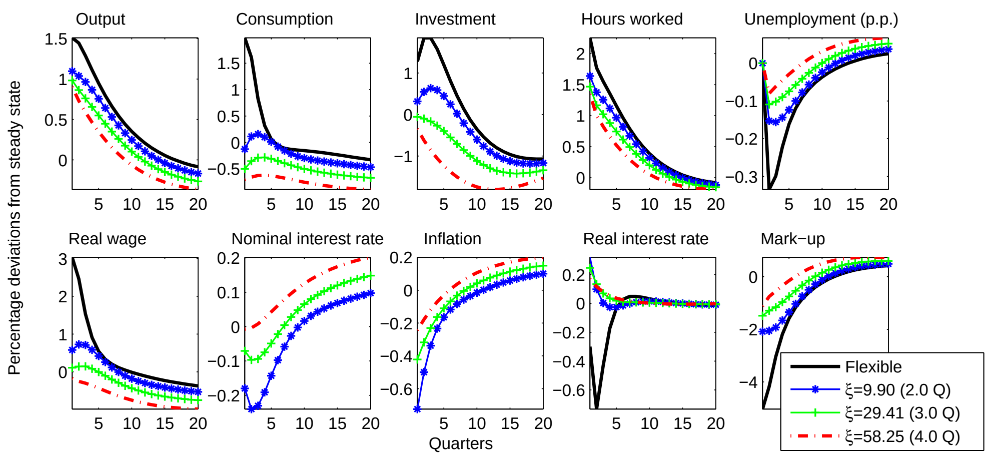
As a result, it is not price stickiness *per se* that subverts the effects of a government spending expansion, but an aggressive monetary response that goes exactly in the opposite direction of output growth, which is the primary goal of the fiscal stimulus itself. We explore these issues also in the context of a model with optimal monetary policy but without unemployment in Cantore et al. (2012b).

Figure C.1 shows the effects of an expansion of government expenditures at different degrees of price stickiness in two alternative scenarios. First, in the top panel of Figure C.1, we assume that the nominal interest rate exhibits persistence in line with the data ($\rho_r = 0.8$) and that the monetary authority reacts only to inflation ($\rho_\pi = 2$)[21] and not to the output gap ($\rho_y = 0$). We explore increasing degrees of price stickiness, ξ. A $\xi = 29.41$ corresponds to a Calvo contract average duration of around 3 quarters for

[21] Both parameter values are the posterior estimates found by Smets and Wouters (2007).



(a) No monetary response to the output gap ($\rho_y = 0$).



(b) Monetary response to the output gap ($\rho_y = 0.5$)

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

our calibration.[22]

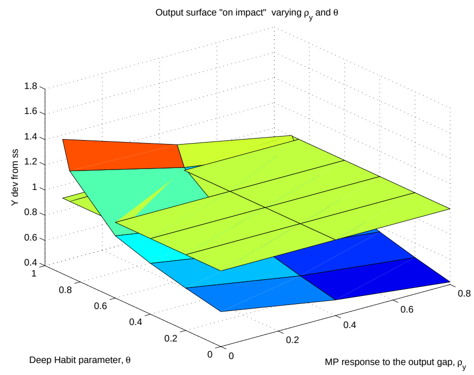
When we introduce price stickiness, the effects of the fiscal expansion become softened by the decrease in the rate of inflation. This occurs if the shift in the aggregate supply, due to the presence of a high level of deep habits, is relatively strong given the shift in the aggregate demand due to the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

[22] Jacob (2011) 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 (2011), we interpret the slope of the standard forward-looking NKPC in quarterly terms. Namely, the log-linearised 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.

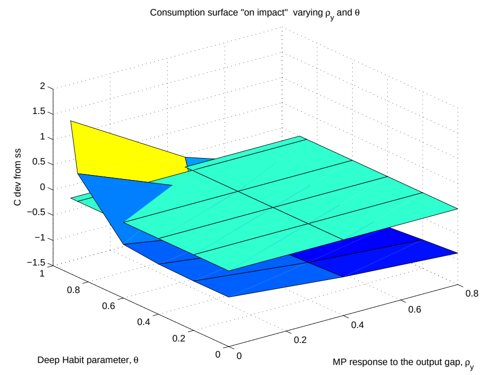
obtained in the flexible-price case. In the lower panel of Figure C.1, we set a Taylor rule featuring a strong response to the output gap ($\rho_y = 0.5$). In this case if prices are sticky, the nominal interest rate reacts positively to the rise in output despite the fall in inflation, the real interest rate reaction becomes positive and offsets the effects of the fiscal expansion.

Figure C.2 shows 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. Surfaces show that, even at high degrees of deep habit formation, a substantial monetary policy response to the output gap may offset the expansionary effects of a government spending expansion. In particular, unemployment may also rise and consumption may be crowded out if ρ_y is above 0.4, while the output multiplier falls below one with a ρ_y above 0.6. Is the observed response parameter ρ_y so high and should it be so from an optimal policy perspective? In the empirical DSGE model literature, estimates of the value of ρ_y are typically low. For example in Smets and Wouters (2007) in a standard NK model with superficial habit, no unemployment and Cobb-Douglas production, estimated using US data by Bayesian methods over 1984:1-2004:1, a posterior mean corresponding to $\rho_y = 0.08$ is obtained. These findings are typical of this literature. In the optimal policy literature optimised interest rate rules using a welfare criterion also find a weak long-run response of the interest rate to the output gap; for example, Schmitt-Grohe and Uribe (2007) find $\rho_y = 0.1$ and Levin et al. (2006), Levine et al. (2008) and Levine et al. (2012) all find its welfare-improving contribution to be so small as to be ignored in their optimised rules.[23]

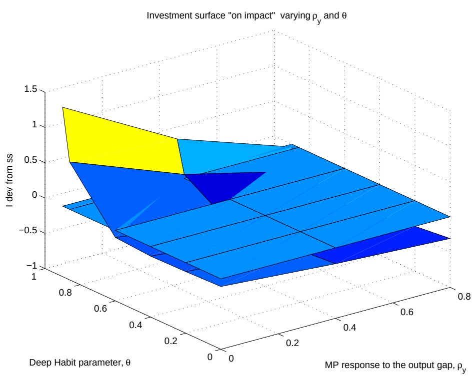
[23] These results abstract from active fiscal stabilisation policy. Our findings suggest that when fiscal rules are added, their efficacy would require an even weaker response of interest rates to the output gap. This is confirmed in Schmitt-Grohe and Uribe (2007). Indeed they devote a whole subsection to "the importance of (monetary policy) not responding to output". For a study of optimal monetary and fiscal policy in a new Keynesian model with deep habit see Leith et al. (2009). In both these models, there is no unemployment and Cobb-Douglas production is assumed, so important features of our set-up are missing. Nonetheless their optimised interest rate rules in conjunction with fiscal stabilisation of debt also feature a weak long-run response to the output gap.



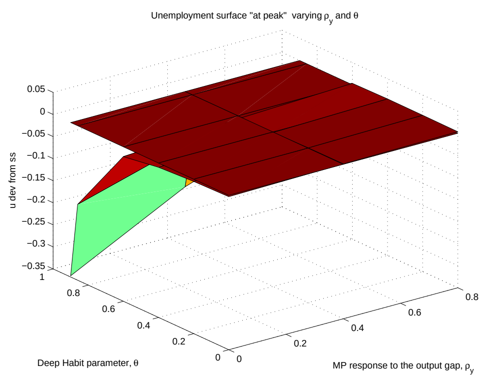
(a) Output



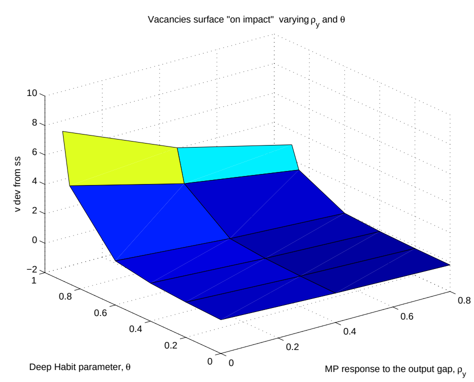
(b) Consumption



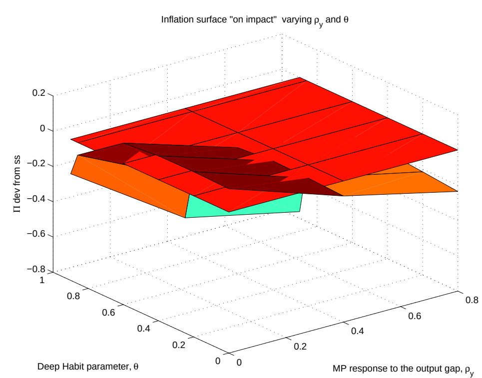
(c) Investment



(d) Unemployment



(e) Vacancies



(f) Inflation

Figure C.2: Sensitivity of impact responses to the deep habit parameter θ^c and the monetary response to the output gap ρ_y.

D Symmetric equilibrium

Production function and marginal products:

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

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

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

Utility function, marginal utilities and deep habits in consumption:

$$U(X_t^c, n_t, 1-h_t) = n_t \frac{\left[(X_t^c)^{(1-\rho)}(1-h_t)^{\rho}\right]^{1-\sigma_c} - 1}{1-\sigma_c} + (1-n_t)\frac{(X_t^c)^{(1-\rho)(1-\sigma_c)} - 1}{1-\sigma_c} \quad \text{(D.4)}$$

$$U_{x,t} = (1-\rho)(X_t^c)^{(1-\rho)(1-\sigma)-1}\left[1 + n_t\left(((1-h_t)^{\rho(1-\sigma)} - 1\right)\right] \quad \text{(D.5)}$$

$$U_{n,t} = \frac{(X_t^c)^{(1-\rho)(1-\sigma)}\left[(1-h_t)^{\rho(1-\sigma)} - 1\right]}{1-\sigma} \quad \text{(D.6)}$$

$$U_{hn,t} = -\rho\,(X_t^c)^{(1-\rho)(1-\sigma)}(1-h_t)^{\rho(1-\sigma)-1} \quad \text{(D.7)}$$

$$S_t^c = \rho^c S_{t-1}^c + (1-\rho^c) C_t \quad \text{(D.8)}$$

$$C_t = X_t^c + \theta^c S_{t-1}^c \quad \text{(D.9)}$$

Intertemporal investment/consumption decisions:

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

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

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

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

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

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

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

Hiring decisions and wage bargaining:

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

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

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

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

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

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

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

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

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

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

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

Further firms' decisions:

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

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

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

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

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

Government budget constraint and fiscal rules:

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

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

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

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

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

Resource constraint:

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

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

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

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

E Steady state

Steady-state values of the employment rate, n, hours worked, h, and the marginal cost, MC, solve simultaneously the wage equation, (D.21), the economy's resource constraint, (D.38), and the pricing equation, (D.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:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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