Employment Prospects and the Propagation of Fiscal Stimulus

Kopiec, Paweł

Narodowy Bank Polski

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Paweł Kopiec†

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Abstract

I study a novel channel that amplifies the effects of a rise in government purchases. Fiscal stimulus increases aggregate demand and boosts job creation. The latter improves employment prospects by reducing idiosyncratic unemployment risk faced by households. This, in turn, weakens precautionary motives and raises private consumption which strengthens the initial fiscal impulse. To explore the mechanism, I use a model with uninsured idiosyncratic risk, frictional labor market and sticky prices. Quantitative analysis indicates that magnitude of the employment prospects channel is substantial: its elimination implies that crowding out of aggregate consumption associated with higher government expenditures rises by 47%.

Keywords: Heterogeneous Agents, Frictional Markets, Fiscal Stimulus
JEL Classification: D30, E62, H23, H30, H31

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†Narodowy Bank Polski, e-mail: pawel.kopiec@nbp.pl.

1 Introduction

I study a novel channel which amplifies the macroeconomic effects of higher government purchases through improvement in employment prospects. Fiscal expansion fuels aggregate demand and, due to price rigidities, leads to adjustment in the quantity of produced goods. The latter requires larger output capacity across firms and hence increases incentives to recruit additional workers. Higher demand for labor improves employment prospects faced by households as job creation translates into higher job finding and lower job separation rates and, as a result, shorter expected unemployment spells in the future. Lower unemployment risk, in turn, weakens precautionary motives, raises consumer confidence and stimulates private consumption which amplifies the effects of fiscal stimulus. On the top of that, since changes in employment are prolonged by labor market frictions, higher employment persists over time and stimulates output, consumption and job creation in future periods which, in turn, improves job prospects and stimulates private expenditures in the current period.

Mechanism analyzed in the paper is based on a combination of two premises. First, households are not able to insure against unemployment and suffer from substantial drops in income and consumption expenditures as they lose jobs. For instance, Kolsrud et al. (2015) analyze Swedish data and find that average drop in consumption expenditures during the first year of an unemployment spell equals 32%. Therefore, as suggested by Den Haan et al. (2015), a worsening of employment prospects leads to an increase in precautionary motives across consumers and induces cuts in private consumption. Second, there is an ample evidence suggesting that fiscal packages have a large impact on job creation and employment. For example, Chodorow-Reich et al. (2012) and Serrato and Wingender (2016) find that $100,000 of additional government expenditures in the US generate 3.8 and 3.3 job-years, respectively. Moreover, using a structural VAR, Monacelli et al. (2010) show that an increase in fiscal purchases equal to 1% of GDP lowers unemployment by 0.6% and raises labor market tightness by 20%.

To quantify the employment prospects channel it is necessary to extend the standard Bewley-Huggett-Aiyagari model (BHA henceforth) along two dimensions. First ingredient that is required to analyze the problem are price rigidities, which guarantee that higher aggregate demand generated by fiscal package is not entirely absorbed by price adjustment.[1] Second, to account for the idiosyncratic, endogenous unemployment risk faced by households, I blend the BHA framework with the standard Diamond-Mortensen-Pissarides model of frictional labor market.

My paper is related to works studying the effects of higher government expenditures in models with heterogeneous households, in which a significant proportion of agents deviates from the consumption-savings behavior predicted by the permanent income hypothesis and thus exhibits relatively high levels of marginal propensity to consume (MPC).

Navarro and Ferriere (2016) study the impact of changes in government expenditures in the standard BHA model with labor indivisibility and flexible prices. They find that only an increase in government spending that is accompanied by a rise in tax progressivity is able to generate a positive response in aggregate consumption. The reason for this fact is intuitive: when tax progressivity increases, authorities are able to decrease the average tax level because they tax top incomes at higher rates. Main beneficiaries of the associated tax cuts are agents with low labor income who exhibit relatively

[1] Moreover, as it has been noticed by Hagedorn et al. (2017), a combination of price stickiness and consumer heterogeneity in the BHA model (more precisely, the presence of households with high marginal propensity to consume) gives rise to income channel through which fiscal expansions affect private consumption: an increase in government purchases stimulates aggregate demand which, if sticky prices are in place, translates into higher output which, in turn, is associated with increase in labor demand. This raises employment, imposes an upward pressure upon wages and thus leads to rise in labor income. Since high MPC households spend a significant proportion of the increase in labor income on consumption then aggregate demand grows even further triggering higher labor demand, growth in labor income etc. It is thus clear, that price rigidity is key for existence of the feedback loop which describes the traditional logic underlying the fiscal multiplier.

high MPC. In contrast to Navarro and Ferriere (2016), I consider a BHA model with frictional labor and sticky prices in which government finances expenditures with a flat-rate tax.[2]

It seems that the closest work to mine is Hagedorn et al. (2017) who study the size of fiscal multiplier using a version of the BHA model with price adjustment costs as in Rotemberg (1982) and decompose the reaction of private consumption to government purchases into several channels to get a better understanding of mechanisms that propagate fiscal stimulus. There are, however, two substantial differences between my work and the paper of Hagedorn et al. (2017). First, I consider a different specification of labor market that features search frictions. Second, in contrast to Hagedorn et al. (2017), my decomposition method of aggregate consumption, which is crucial for the isolation of employment prospects channel, is based on the total differentiation of aggregate consumption with respect to economic variables entering the household maximization problem.[3]

The remaining sections of the paper are organized as follows. Section 2 presents the BHA model with frictional product market and sticky prices. In Section 3 I study the effects of an increase in government expenditures when monetary policy is relatively responsive to changes in macroeconomic environment and stimulus is financed with taxes. Section 4 describes the employment prospects channel. In Section 5 I consider two alternative scenarios of expansion. First of them assumes that the increase in government purchases is financed with debt. Second scenario analyzes expansion during which the response of monetary policy is less aggressive than in baseline simulation. Section 6 concludes.

[2]In addition to baseline simulation, which assumes that higher government purchases are financed with taxes, I analyze the situation in which increased fiscal expenditures are financed with debt.

[3]The decomposition method used in this work can be seen as a discrete-time counterpart of the procedure applied by Kaplan et al. (2016).

2 Model

In this section, I describe the main building blocks of the model which is populated by heterogeneous households, identical retailers, representative firm and government.

2.1 Households

The model is populated by a continuum of households of measure one who face uninsurable idiosyncratic income and labor status shocks that are driven by: exogenous changes in labor productivity z and endogenous shifts in job-finding rate f. The only asset actively traded in the economy is bond b which earns nominal interest rate i.[4] Labor supply is exogenous and normalized to unity. Agents value consumption streams c only. The associated instantaneous utility function is denoted by $u(c)$ (with $u' > 0$, $u'' < 0$) and it satisfies the Inada conditions. By Π I denote the ratio between current price of consumption goods p and the price of those goods in the previous period p_{-1}:

$$\Pi = \frac{p}{p_{-1}}.$$

Employed household with productivity level z earns real wage $w \cdot z$ where w is the average real wage in the economy and the unemployed with productivity z receives unemployment benefit equal to $\nu \cdot w \cdot z$ where $\nu \in (0, 1)$ is the replacement rate. Idiosyncratic productivity shocks z follow a Markovian process that takes values in space Z. Employed households pay linear tax τ

[4] The assumption about the degenerated portfolio choice is made to preserve tractability and it can be rationalized by a situation in which government taxes capital dividends so that they are standardized to 0. Similar assumption is made by Auclert (2017). In previous versions of the paper, I have not introduced corporate tax and firm profits were redistributed according to shares entitling to dividends that were dependent on individual productivity and were estimated to match the moments from the SCF data. Results obtained in that version were almost the same as in the current variant of the paper.

on labor income.[5] Unemployed household becomes employed with probability f' at the beginning of next period.[6] Employed consumers lose jobs with probability $\sigma \cdot (1 - f')$ where $\sigma \in (0, 1)$ is exogenous separation rate. In equilibrium rate f' is endogenous and depends on the ratio between job vacancies opened by firms and the proportion of households that remains without job at the beginning of the period. The choice of next period liquid balances b' is subject to borrowing constraint:

$$b' \geq -\bar{b}$$

where $\bar{b}$ is a positive constant. Maximization problem of employed household with current balances b and productivity level z can be represented by the following Bellman equation:[7]

$$W_e(z, b) = \max_{c,\, b'} \Big\{ u(c) + \beta \cdot \mathbb{E}_{z'|z} \left[(1 - \sigma \cdot (1 - f')) \cdot W_e(z', b') \right. \tag{1}$$

$$\left. + \sigma \cdot (1 - f') \cdot W_u(z', b') \right] \Big\}$$

$$subject\ to:$$

$$\begin{cases} c + b' = \frac{1+i}{\Pi} \cdot b + (1 - \tau) \cdot w \cdot z \\ b' \geq -\bar{b} \end{cases} \tag{2}$$

where W_e and W_u are value functions associated with the dynamic problem of employed and unemployed agent, respectively. I adopt the convention that separations occur before hiring. Agents discount future utility streams with

[5]Notice, that since the number of hours worked is fixed for employed household (i.e., equal to one) then labor income tax is not distortionary, i.e., it has no effect on labor supply.

[6]The prime symbol denotes the next period value of a variable.

[7]Observe that all quantities entering the maximization problem are expressed in real terms.

factor $\beta \in (0,1)$. The maximization problem of unemployed household reads:

$$W_u(z,b) = \max_{c,\,b'} \left\{ u(c) + \beta \cdot \mathbb{E}_{z'|z} \left[f' \cdot W_e(z',b') \right.\right. \tag{3}$$

$$\left.\left. + (1-f') \cdot W_u(z',b') \right] \right\}$$

$$subject\ to:$$

$$\begin{cases} c + b' = \frac{1+i}{\Pi} \cdot b + \nu \cdot w \cdot z \\ b' \geq -\bar{b} \end{cases}$$

Euler inequalities associated with dynamic problems of employed and unemployed households are:

$$\begin{cases} u'(c_e) \geq \frac{1+i'}{\Pi'} \cdot \beta \cdot \mathbb{E}_{z'|z} \left[(1-\sigma \cdot (1-f')) \cdot u'(c_e') + \sigma \cdot (1-f') \cdot u'(c_u') \right] \\ u'(c_u) \geq \frac{1+i'}{\Pi'} \cdot \beta \cdot \mathbb{E}_{z'|z} \left[f' \cdot u'(c_e') + (1-f') \cdot u'(c_u') \right] \end{cases} \tag{4}$$

where c_e is consumption policy conditional on being employed and c_u corresponds to policy of the unemployed consumer.

2.2 Retailers

The model is populated by perfectly competitive retailers who pack differentiated goods y_j, where $j \in [0,1]$, produced by firms into baskets of consumption goods y using technology described by the Dixit-Stiglitz aggregator:

$$y = \left(\int_0^1 y_j^{1-\frac{1}{\gamma}} dj \right)^{\frac{1}{1-\frac{1}{\gamma}}}$$

where $\gamma > 1$ is the elasticity of substitution between intermediate goods generated by firms. Retailers choose $\{y_j\}$ to maximize profits:

$$p \cdot y - \int_0^1 p_j y_j dj$$

where p_j is price of variety produced by firm j. The following equation describes first order condition of the retailer:

$$y_j = \left(\frac{p_j}{p}\right)^{-\gamma} \cdot y \tag{5}$$

where p reads:

$$p = \left(\int_0^1 p_j^{1-\gamma} dj\right)^{\frac{1}{1-\gamma}}.$$

2.3 Firms

There is measure one of firms owned by households and indexed with $j \in [0,1]$ that produce intermediate goods using linear technology with labor n as the only input and hire workers in the frictional labor market by posting vacancies v_j. The probability that vacancy is filled equals q which, similarly to f, is endogenous and depends on the ratio between job vacancies opened by firms and the proportion of households that remains without job at the beginning of the period. Proportion σ of existing job is destroyed between periods.

For tractability, it is assumed that firms are not able to distinguish between more productive and less productive workers while recruiting them. Once the worker is hired, firm learns about his productivity and pays wage that is proportional to his productivity level. The assumption about unobservability of z during the recruitment process enables to blend together the idiosyncratic income risk captured by changes in z with the Diamond-Mortensen-Pissarides specification of labor market.

Firms are monopolistically competitive and set prices subject to quadratic price adjustment costs as in Rotemberg (1982) and subject to demand for their products given by equation 5. Future profit streams are discounted with real interest rate $\frac{\Pi'}{1+i'}$ where Π is the ratio between the current price level and the one from the previous period.[8]

[8] Observe that firms discount future profits with the real interest rate and not with the standard stochastic discount factor that is dependent on agents marginal utilities. The

Firms solve a dynamic problem of maximizing the discounted sum of real profits:

$$F\left(p_{j,-1}, n_{j,-1}\right) = \max_{p_j, v_j, n_j, y_j} \left\{ \frac{p_j}{p} \cdot y_j - \mathbb{E}_z\left(w \cdot z \cdot n_j\right) - \kappa \cdot v_j \right.$$

$$\left. - \frac{\phi}{2}\left(\frac{p_j - p_{j,-1}}{p_{j,-1}}\right)^2 \cdot y + \frac{\Pi'}{1+i'} \cdot F\left(p_j, n_j\right) \right\} \tag{6}$$

$$subject\,to:$$

$$y_j = \mathbb{E}_z\left(z \cdot n_j\right)$$

$$y_j = \left(\frac{p_j}{p}\right)^{-\gamma} \cdot y$$

$$n_j = (1-\sigma) \cdot n_{j,-1} + q \cdot v_j. \tag{7}$$

where $\phi > 0$ is a parameter, F is value function associated with the firm

maximization problem, $p_{j,-1}$ is price set in the previous period, $n_{j,-1}$ is the number of workers employed in the previous period. First constraint describes production technology, second constraint captures the demand for goods produced by firm j and third describes the law of motion for employment in firm j. Moreover, it is assumed that $\mathbb{E}_z z = 1$.

In the symmetric equilibrium, in which all firms are identical and hence subscripts j can be omitted, first order condition that characterizes the optimal solution to problem 6 reads:

$$1 - \gamma + w \cdot \gamma + \gamma \cdot \frac{\kappa}{q} - \frac{\Pi'}{1+i'} \cdot \frac{\kappa \cdot (1-\sigma) \cdot \gamma}{q'} \tag{8}$$

latter becomes problematic if agents exhibit heterogeneous asset holdings and consumption rates (see Gornemann et al. (2016) and Den Haan et al. (2015)). The simplification applied here makes the calibration exercise tractable and was used, for example, by Kaplan et al. (2016) and Hagedorn et al. (2017).

$$= \phi \cdot (\Pi - 1) \cdot \Pi - \frac{\Pi'}{1 + i'} \cdot \phi \cdot (\Pi' - 1) \cdot \Pi' \cdot \frac{y'}{y}.$$

Finally, let us define the real value of firm's profits d:

$$d \equiv n - w \cdot n - \kappa \cdot v - \frac{\phi}{2} \cdot (\Pi - 1)^2 \cdot n. \tag{9}$$

2.4 Government

Government consists of two branches: fiscal authority and monetary authority. In stationary equilibrium, fiscal branch is assumed to run a balanced budget - i.e., it adjusts tax rate τ to finance purchases of manufactured goods G, expenditures on unemployment benefits and the cost of debt service net of firms' profits that are transferred directly to government:

$$n \cdot \tau \cdot w + d = (1 - n) \cdot \nu \cdot w + \frac{1 + i}{\Pi} \cdot B - B' + G \tag{10}$$

where B is the real value of bonds issued by government in the previous period. It is assumed that the level of government purchases in stationary equilibrium is equal to zero:

$$G_{ss} = 0.$$

Central bank sets the value of nominal interest rate $i \geq 0$ according to the following Taylor-type monetary policy rule:

$$i = \bar{i} + \phi_y \cdot \frac{y - y_{ss}}{y_{ss}} + \phi_\Pi \cdot (\Pi - \Pi_{ss})$$

where Π_{ss} and y_{ss} are values of Π and y in stationary equilibrium and $\bar{i}$, ϕ_y and ϕ_Π are parameters.

2.5 Wage-setting

Since there is no universal theory that would pin down wages in labor market featuring search frictions then, while analyzing stationary equilibrium, I assume that w is parameter that is set to match the calibration target presented in Section 3.[9]

2.6 Consistency Conditions

Market clearing condition for manufactured goods reads:

$$\int c_e\left(b,z\right)d\pi_e(b,z)+\int c_u\left(b,z\right)d\pi_u(b,z)+\kappa\cdot v \tag{11}$$

$$+\frac{\phi}{2}\cdot\left(\Pi-1\right)^2\cdot y+G=y$$

where $c_e\left(b,z\right)$ and $c_u\left(b,z\right)$ are policy functions associated with dynamic problems of employed and unemployed households, respectively and by $\pi_e(b,z)$ I denote the measure of employed agents with asset holdings b and productivity z. An analogous object associated with unemployed households is denoted by $\pi_u(b,z)$. Market clearing condition for liquid assets is:

$$\int b_e'\left(b,z\right)d\pi_e(b,z)+\int b_u'\left(b,z\right)d\pi_u(b,z)=B'.$$

Labor market tightness satisfies:

$$x=\frac{v}{1-(1-\sigma)\cdot n_{-1}} \tag{12}$$

Observe that the pool of workers available to firms during the recruitment process (given by the denominator of 12) consists of workers who were unemployed in the previous period $1-n_{-1}$ and those who worked but were fired at the beginning of the current period: σn_{-1}.

[9]Of course, w must be an element of bargaining set (see Hall (2005)) which is the case in the calibrated version of the model.

Probabilities f and q are induced by a constant returns to scale matching technology M and satisfy:

$$f = \frac{M\left(v, 1-(1-\sigma)\cdot n_{-1}\right)}{1-(1-\sigma)\cdot n_{-1}} = M\left(x, 1\right) \tag{13}$$

$$q = \frac{M\left(v, 1-(1-\sigma)\cdot n_{-1}\right)}{v} = M\left(1, \frac{1}{x}\right). \tag{14}$$

The law of motion of agents across states is characterized by two equations:

$$\pi_e\left(\mathcal{B}', z'\right) = \left(1-\sigma\cdot(1-f')\right)\cdot\int_{Z\times\{b: b'_e(b,z)\in\mathcal{B}'\}} \mathbb{P}(z'|z)d\pi_e(b,z) \tag{15}$$

$$+f'\cdot\int_{Z\times\{b: b'_u(b,z)\in\mathcal{B}'\}} \mathbb{P}(z'|z)d\pi_u(b,z)$$

$$\pi_u\left(\mathcal{B}', z'\right) = \sigma\cdot(1-f')\cdot\int_{Z\times\{b: b'_e(b,z)\in\mathcal{B}'\}} \mathbb{P}(z'|z)d\pi_e(b,z) \tag{16}$$

$$+\left(1-f'\right)\cdot\int_{Z\times\{b: b'_u(b,z)\in\mathcal{B}'\}} \mathbb{P}(z'|z)d\pi_u(b,z)$$

where $\mathcal{B}'$ is a Borel subset of $[-\bar{b}, +\infty)$, $\mathbb{P}(z'|z)$ is transition probability between states z and z' determined by the Markovian process which takes values in space Z. Finally, it is required that:

$$\int d\pi_e(b,z) + \int d\pi_u(b,z) = 1, \tag{17}$$

i.e., the total measure of households equals one.

2.7 Stationary Equilibrium

Having defined maximization problems of households and firms, government budget constraints, price-setting mechanisms and market clearing (and consistency) conditions, we are in position to define the stationary equilibrium of the model:

Definition. *A stationary equilibrium is: positive numbers* x*, value functions* W_e *and* W_u*, policy functions* c_e*,* c_u*,* b'_e*,* b'_u *and probability distributions* π_e*,* π_u *such that given* τ*,* $\bar{b}$*,* i*,* Π*,* w*,* d *and* B*:*

(a) Value functions solve household maximization problems given x*,* τ*,* Π*,* w*,* i *and* c_e*,* c_u*,* b'_e*,* b'_u *are the associated policy functions,*

(b) Numbers x*,* Π*,* w*,* v*,* n*,* d *satisfy equations 6-9 associated with firm's problem,*

(c) Government budget constraint holds, $G = 0$*,* $B = B'$ *and* $i = \bar{i}$*,*

(d) Measures π_e *and* π_u *are a fixed point of the dynamical system described by equations 15-17,*

(e) Consistency conditions and market clearing conditions hold.

In the Appendix, I present an algorithm that computes the stationary equilibrium of the model.

3 Increase in Fiscal Purchases: Baseline Simulation

In this section, I calibrate the model and simulate the transitional path of main economic aggregates resulting from an unexpected, transitory change in government purchases.

3.1 Calibration

3.1.1 Functional Forms

First, let us specify the functional form of utility function u. It is assumed that it takes the following form:

$$u(c) = \frac{c^{1-\theta}}{1-\theta}$$

where θ is the rate of relative risk aversion. Second, let us concentrate on matching technology M. Following Ramey et al. (2000), I assume that M is specified as:

$$M\left(v, 1-(1-\sigma)\cdot n_{-1}\right) = \frac{v\cdot\left(1-(1-\sigma)\cdot n_{-1}\right)}{\left(v^{\alpha}+\left(1-(1-\sigma)\cdot n_{-1}\right)^{\alpha}\right)^{\frac{1}{\alpha}}}$$

where $\alpha > 1$.

3.1.2 Parameter Values

The time period is a quarter. Targets of my calibration are moments characterizing US economy. Model parameters can be divided into two groups. First of them contains parameters that are set with reference to the literature and second group is calibrated using the model to match moments observed in the data.

Parameters taken from the literature are: relative risk aversion θ, separation rate σ, replacement rate ν, parameters associated with the process governing exogenous productivity shocks, elasticity of substitution between intermediate goods γ, parameters associated with Taylor rule - ϕ_{Π} and ϕ_y and lower bound on asset holdings $\bar{b}$. I set $\theta = 2$ which is a standard value in the literature. Following Shimer (2005), I set $\sigma = 0.057$ and $\nu = 0.4$. Similarly to Guerrieri and Lorenzoni (2011), I assume that the evolution of logs of idiosyncratic productivity z follows an AR(1) process with autocorrelation $\rho_z = 0.9674$ and variance $\epsilon_z = 0.0172$ chosen to match evidence documented by Floden and Lindé (2001). Next, I use the procedure constructed by Tauchen (1986) to approximate the AR(1) process by a discrete Markov chain and the associated space Z of its values consists of 12 points. I set $\gamma = 11$ to match the monopolistic markup equal to 10%. I follow the textbook of Galí and I assume that parameters associated with Taylor rule are $\phi_{\Pi} = 1.5$ and $\phi_y = 0.125$. Finally, I follow McKay and Reis (2016) and standardize the liquidity constraint $\bar{b}$ to 0. Calibrated parameter values of θ,

Table 1: Parameters set with reference to the literature

Parameter	Description	Value	Source
θ	Relative risk aversion	2	Standard value
σ	Separation rate	0.057	Shimer (2005)
ν	Replacement rate	0.4	Shimer (2005)
ρ_z	Persistence of productivity shock	0.9674	Floden and Lindé (2001)
ϵ_z	Variance of productivity shock	0.0172	Floden and Lindé (2001)
γ	Elasticity of substitution between intermediate goods	11	Standard value
ϕ_Π	Taylor rule parameter (inflation)	1.5	Galí (2008)
ϕ_y	Taylor rule parameter (output gap)	0.125	Galí (2008)
$\bar{b}$	Liquidity constraint	0	McKay and Reis (2016)

σ, μ, ρ_z, ϵ_z, γ, ϕ_Π, ϕ_y, $\bar{b}$ are summarized in Table 1.

Let us turn to parameters that are calibrated by matching the moments generated by the model with their empirical counterparts. As in Guerrieri and Lorenzoni (2011), I assume that the steady state value of the annual real interest rate equals 2.5% and is targeted by β. Real interest rate, in turn, is induced by the annual nominal interest rate equal to 4.5% and annual inflation rate of 2% (inflation target of the Fed). The first value becomes the calibration target for $\bar{i}$ which equals $(1+0.045)^{\frac{1}{4}}-1$. The latter implies that $\Pi_{ss}=(1+0.02)^{\frac{1}{4}}-1$. Real wage w is adjusted to match the unemployment rate u equal to 5% where:

$$u \equiv 1-n.$$

As in Hagedorn and Manovskii (2008), parameter α characterizing matching in labor market is calibrated so that quarterly vacancy filling rate in the model q equals 97.6%. Parameter κ is chosen to match the ratio between recruitment costs spent on each hired and worker's wage reported by Silva and Toledo (2009) that equals 0.14 for quarterly labor earnings. I follow Guerrieri and Lorenzoni (2011) in setting the steady state value of government bonds

Table 2: Parameters calibrated with the model

Parameter	Description	Value	Target
β	Discount factor	0.96	Proportion of indebted agents
$\bar{i}$	Nominal interest rate in s.s.	$(1+0.045)^{\frac{1}{4}}-1$	Annual nominal rate of 4.5%
w	Nominal wage	0.76	Unemployment rate
α	Parameter associated with function M	3.74	Quarterly vacancy filling rate 97.6%
κ	Vacancy posting cost	0.12	Ratio between recruitment costs and wages as in Silva and Toledo (2009)
B	Aggregate supply of bonds	6.76	Ratio between liquid assets and GDP
ϕ	Parameter of price adjustment costs	61.0	Evidence by Zbaracki et al. (2004)

B to match the ratio between liquid asset holdings of households and annual GDP equal to 1.78. Tax rate τ is set to balance government budget. Finally, I calibrate the parameter associated with price adjustment costs ϕ to match the evidence documented by Zbaracki et al. (2004) who find that the physical, managerial, and customer costs of changing prices amount to 1.22 percent of the firm's revenue in a given year.

3.2 Increase in Government Purchases

In this section I study the effects of an unexpected, transitory increase in government purchases G. First, I discuss the modifications that need to be introduced into the model to study the dynamic impact of the rise in fiscal consumption. Second, I present simulation results.

3.2.1 Transitional Dynamics: Technical Issues

It is assumed that economy is in stationary equilibrium in period $t = 0$. In period $t = 1$ there is an unexpected increase in government purchases which rise from zero at $t = 0$ to 1% of the stationary equilibrium level of GDP at $t = 1$. For $t > 1$, government spending is governed by autoregressive process and decays at rate 0.8. I assume that for $t > 1$ agents have perfect foresight about evolution of aggregate variables. As $t \to +\infty$, economy converges back to its initial allocation from period $t = 0$. In practice, it is assumed that economy is back in the stationary equilibrium in period $t = \bar{T}$ where $\bar{T}$ is sufficiently large.

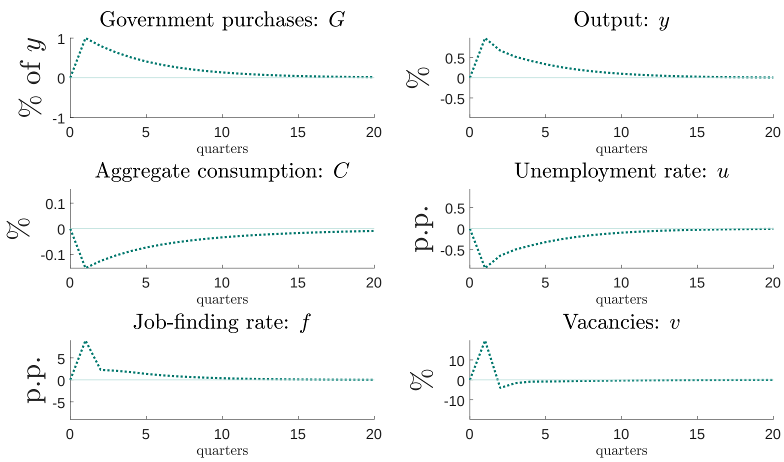
As it has been mentioned, as there is no universal theory of price-setting in frictional markets then we have some freedom in specifying the behavior of wages. While analyzing the transitional dynamics, I assume a perfect degree of indexation of nominal wages to the price level associated with manufactured goods which implies that real wages are constant over time. This formulation resembles the specification of the process governing real wages in works by Michaillat (2012) and Blanchard and Galí (2010) who assume that w co-moves with aggregate productivity. As the latter remains unchanged in my simulation then it implies that the average real wage does not change, too. Finally, in the baseline simulation I assume that increase in G is financed with taxes τ and hence B remains constant over time. I will analyze the situation in which higher government purchases are covered with a rise in B in Section 5.

Endogenous Grid Method (see Carroll (2006)) is applied to solve the model and to compute transitional dynamics. More details on the solution algorithm are provided in the Appendix.

3.2.2 Simulation Results

First, let us define a new variable - aggregate consumption, which is the main object of interest in my analysis:

Figure 1: Impulse response functions, main aggregate variables, deviations from stationary equilibrium values, baseline simulation.



$$C \equiv \int c_e\,(b,z)\,d\pi_e(b,z) + \int c_u\,(b,z)\,d\pi_u(b,z).$$

Figure 1 displays the impact of the rise in government purchases on main economic variables. First, notice that output increases less than one-for-one with G - the multiplier in period $t = 1$ is equal to 0.98. It does not exceed unity because aggregate consumption C drops by about 0.14% at $t = 1$ and this negative impact is not mitigated by the rise in job creating activities $\kappa \cdot v$ and in price adjustment cost which contribute to the economy-wide aggregate demand according to equation 11. Observe that higher government expenditures lead to a substantial decrease in unemployment rate which drops by almost 0.8 percentage points - a value that is not very far from the VAR estimates reported by Monacelli et al. (2010).

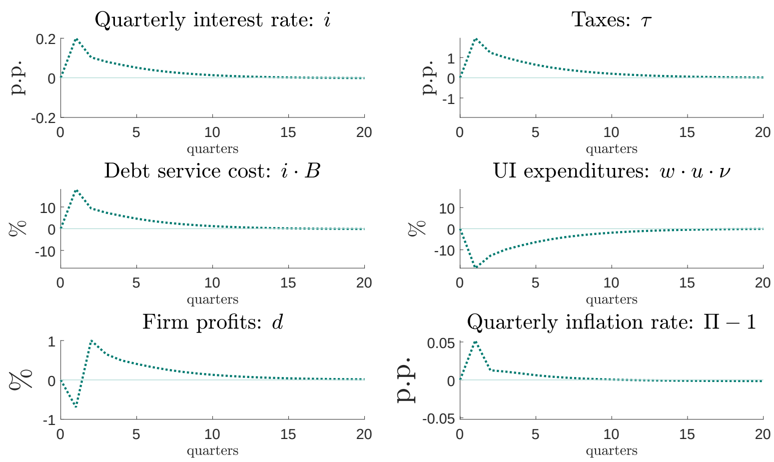
Let us analyze the behavior of two additional variables associated with labor market: v and f that are reported in the bottom row of Figure 1. Intuitively, transitory fiscal expansion raises current and future aggregate demand which spurs job creation across firms when price rigidities are in place. This process is particularly intense at the beginning of fiscal expansion as rational firms anticipate the future drop in the pool of jobless workers and the associated rise in effective recruitment costs, which is captured by lower vacancy filling rate q (which mirrors the behavior of f), and hence they choose to intensify hiring activities in period $t = 1$ when this pool is relatively large.[10] The rapid increase in vacancy posting at the beginning of fiscal intervention explains the spike in the job-finding rate at $t = 1$.

Variables associated with monetary and fiscal policy are presented in Figure 2. Fiscal intervention leads to a sharp increase in nominal interest rates (by about 0.8 percentage points in annual terms). This reflects the reaction of monetary authority to the rise in output which is determined by Taylor rule. Higher nominal interest rates elevate real rates and thus strengthen incentives to save and to cut consumption. Additionally, fiscal stimulus leads to a 1.9 percentage point growth in tax rate τ.

It is instructive to study the determinants of changes in τ. Except for adjusting to higher level of G, there are several additional forces that shape the response of labor tax. On the one hand, observe that higher quarterly nominal interest rate, raises debt service cost $i \cdot B$. This reflects an interaction between fiscal and monetary policy during which the latter leans against the former and, as a result, decreases its effectiveness. Higher debt service costs impose an upward pressure on tax rate τ - see equation 10. On the other hand, however, fiscal expansion decreases employment which has two effects that tend to decrease rate τ: i) higher employment means that labor tax base $w \cdot n$ is larger which induces lower rates τ ii) at the same time, the increase in n lowers government expenditures associated with unemployment benefits which, again, imposes a downward pressure on τ. On the top of that, labor tax depends on corporate tax which is equal to firm profits in the

[10]Putting differently, firms intensify recruitment when labor market tightness is relatively low.

Figure 2: Impulse response functions, fiscal and monetary variables, deviations from stationary equilibrium values, baseline simulation.



model. Observe that d drops in period $t = 1$: this occurs because, as it has been mentioned above, firms invest lots of resources in posting vacancies v to create new jobs at $t = 1$ which, by 9, translates into lower profits. As the job creation decays, monopolistic firms generate higher profits when faced by higher aggregate demand associated with larger G. All this means, that the effects of corporate tax on labor income tax τ is non-monotonic over time.

Since the rise in government purchases stimulates aggregate demand then we observe higher inflation that grows by 0.2 percentage points at the peak.

4 Employment Prospects Channel

Let us turn to the main exercise of the paper which aims at isolating the employment prospects channel from the impulse response function of aggregate consumption.

First, let us discuss the consumption decomposition method more generally. Observe that aggregate consumption in period $t > 0$ can be totally differentiated with respect to elements of set $\mathcal{X}_s$ of all endogenous variables which appear in the maximization problems 1 and 3 in period $s > 0$:[11]

$$dC_t = \sum_{s=1}^{+\infty} \sum_{x_s \in \mathcal{X}_s} \frac{\partial C_t}{\partial x_s} \cdot dx_s \tag{18}$$

where:

$$\mathcal{X}_s = \{w_s, \Pi_s, \tau_s, f_{s+1}, i_s\}.$$

Thus, formula 18 allows to decompose the response of aggregate consumption into channels which have a clear, model-based interpretation. In particular, element $\sum_{s=1}^{+\infty} \frac{\partial C_t}{\partial f_{s+1}} df_{s+1}$ is given by:

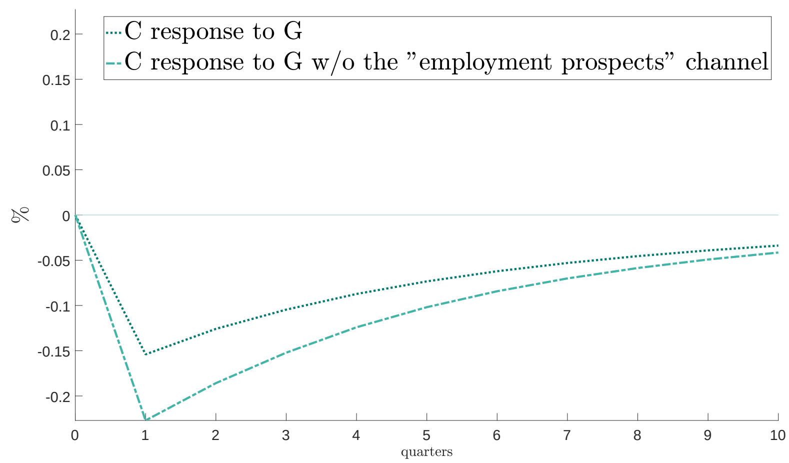
$$\sum_{s=1}^{+\infty} \frac{\partial C_t}{\partial f_{s+1}} df_{s+1} = \sum_{s=1}^{+\infty} \frac{\partial}{\partial f_{s+1}} \left\{ \sum_{a \in \{e,u\}} \int c_{a,t}(b,z)\, d\pi_{a,t}(b,z) \right\} df_{s+1}.$$

and can be interpreted as the accumulated effect of variation in elements of transition path $\{f_{s+1}\}_{s=1}^{+\infty}$ on aggregate consumption in period t. Notice that the formula above does not isolate the impact of employment prospects on aggregate consumption in a proper way. It is because it fails to eliminate the effect of job-finding rate f on the composition of agents (employed and unemployed workers) which works through the evolution of the aggregate distribution of households captured by equations 15 and 16. Nevertheless, $\sum_{s=1}^{+\infty} \frac{\partial C_t}{\partial f_{s+1}} df_{s+1}$ can be decomposed further into two parts:

$$\sum_{s=1}^{+\infty} \frac{\partial C_t}{\partial f_{s+1}} \cdot df_{s+1} = \underbrace{\sum_{s=1}^{+\infty} \sum_{a \in \{e,u\}} \left(\int c_{a,t}(b,z) \cdot \left\{ \frac{\partial}{\partial f_{s+1}} \tilde{\pi}_{a,t}(b,z) \right\} dbdz \right) \cdot df_{s+1}}_{\text{"Compositional" channel}}$$

[11]This is a discrete time version of the procedure described in Kaplan et al. (2016).

Figure 3: Employment prospects channel, baseline simulation.



$$+\underbrace{\sum_{s=1}^{+\infty}\sum_{a\in\{e,u\}}\left(\int\left\{\frac{\partial}{\partial f_{s+1}}c_{a,t}\left(b,z\right)\right\}\cdot\tilde{\pi}_{a,t}\left(b,z\right)dbdz\right)\cdot df_{s+1}}_{\text{"Employment prospects" channel}}. \tag{19}$$

where $\tilde{\pi}$ is the density function associated with measure π.[12] Since formula 19 does not exclude a possibility that $t > s$ then it may appear that the second component captures the impact of past job finding rates on current aggregate consumption which, in turn, would mean that its name - "employment prospects" channel is not adequate. To see why it is not the case, observe that since the optimization problems are forward looking then:[13]

$$\frac{\partial}{\partial f_{s+1}}c_{a,t}\left(b,z\right)=0 \quad for \;\; s<t.$$

[12]For tractability and for notational purposes, I assume than $\tilde{\pi}$ exists.

[13]Formally, policy function $c_{a,t}$ depends on individual state variables b, z and the vector of aggregate state variables π_e, π_u, p_{-1} and n_{-1}. Dependence on the latter is omitted in the text for clarity.

This implies that:

$$\sum_{s=1}^{+\infty} \sum_{a\in\{e,u\}} \left(\int \left\{ \frac{\partial}{\partial f_{s+1}} c_{a,t}\left(b,z\right) \right\} \cdot \tilde{\pi}_{a,t}\left(b,z\right) dbdz \right) \cdot df_{s+1}$$

$$= \sum_{s\geq t}^{+\infty} \sum_{a\in\{e,u\}} \left(\int \left\{ \frac{\partial}{\partial f_{s+1}} c_{a,t}\left(b,z\right) \right\} \cdot \tilde{\pi}_{a,t}\left(b,z\right) dbdz \right) \cdot df_{s+1}$$

which shows that second component in formula 19 captures solely the impact of future job-finding rates on private consumption. This means that its name - "employment prospects channel" - is justified.

From the numerical point of view, the "unemployment prospects" component is calculated by performing the "backward iteration" with all variables from set $\mathcal{X}_s$ taking their steady state values - except for the path of job finding rates which takes values calculated in Section 3. Then, using calculated policies, I perform the "forward iteration" and, at the same time, I keep the distribution of agents equal to its stationary equilibrium value. Procedures of "backward" and "forward" iterations are described in the Appendix.

Figure 3 displays the response of aggregate consumption which has been already presented in Figure 1 together with the hypothetical path of household spending when employment prospects channel is closed. More precisely, elements of the latter are defined as:

$$C_t - \sum_{s\geq t}^{+\infty} \sum_{a\in\{e,u\}} \left(\int \left\{ \frac{\partial}{\partial f_{s+1}} c_{a,t}\left(b,z\right) \right\} \cdot \tilde{\pi}_{a,t}\left(b,z\right) dbdz \right) \cdot df_{s+1}.$$

Figure 3 indicates, that the magnitude of the analyzed channel is significant. In particular, a drop in aggregate consumption associated with fiscal stimulus in period $t = 1$ is 47% larger when the role of employment prospects is ignored.

5 Increase in Fiscal Purchases: two alternative scenarios

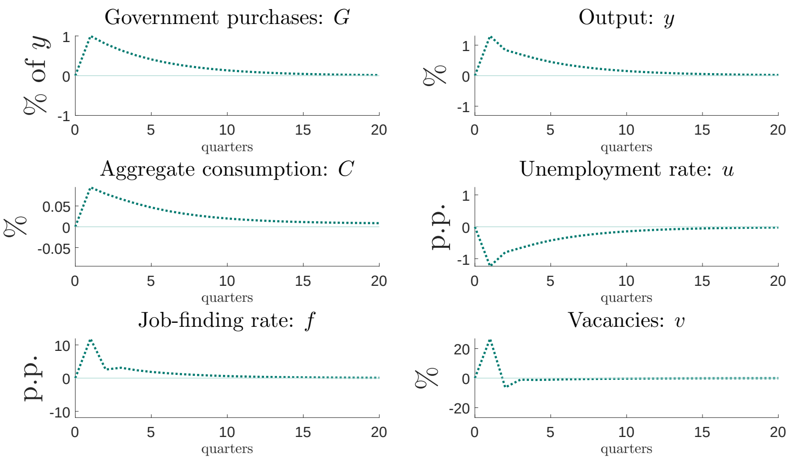
In this part, I verify the robustness of the finding concerning the magnitude of the employment prospects channel by analyzing its importance under two additional scenarios. First of them assumes that monetary policy is less responsive to changes in macroeconomic environment which is formalized by changing the value of parameter ϕ_y from 0.125 to 0. This variant is motivated partly by a large literature studying the effects of government purchases when monetary policy is constrained by the zero lower bound on nominal interest rates which, automatically, makes monetary policy less responsive to changes in G (see, e.g., Eggertsson (2011) and Woodford (2011)). Second scenario studies an alternative way of financing fiscal expansion which is based on an increase in government debt B instead of the rise in taxes τ during the first year of intervention.

5.1 Less aggressive monetary policy

Figure 4 shows the effects of an increase in government expenditures on main economic variables when monetary policy rule is modified by setting $\phi_y = 0$. The resulting multiplier value in period $t = 1$ amounts to 1.30 and it exceeds unity mainly due to the fact that, in contrast to baseline scenario, aggregate consumption grows during fiscal expansion. The resulting drop in unemployment is deeper and it equals 1.1 percentage points. Notice that the rise in aggregate demand that is driven by both higher G and C creates stronger incentives to expand output capacity by creating new jobs than in the baseline case which is captured by a more dynamic increase in posted vacancies v and in job finding rate f.

To understand the behavior of aggregate consumption, it is useful to analyze changes in nominal interest rates and taxes which are displayed in Figure 5.

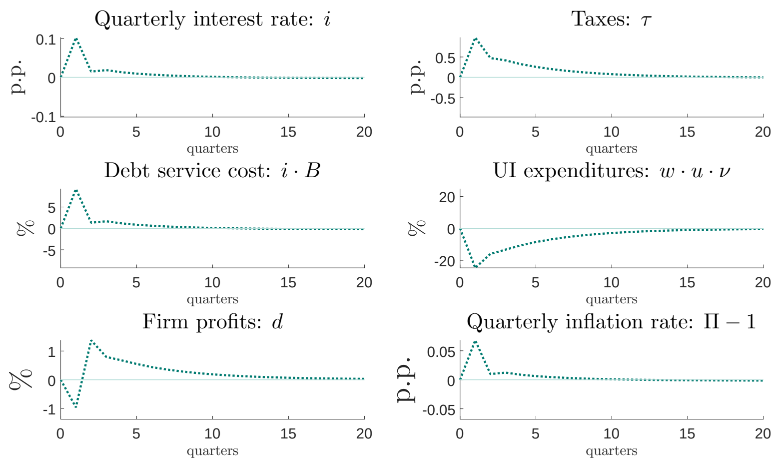
Figure 4: Impulse response functions, main aggregate variables, deviations from stationary equilibrium values, simulation assumes $\phi_y = 0$.



Observe, that since monetary policy does not react to the positive change in output gap, then the overall response of nominal rates is much more moderate than in the baseline case. More precisely, i grows by 0.1 percentage points at $t = 1$ in comparison to almost 0.2 percentage points before. This implies, that intertemporal substitution effects spurred by monetary policy, which strengthen saving incentives, are two times smaller when $\phi_y = 0$. This, in turn, mitigates the downward pressure of higher nominal rates on aggregate consumption.

Let us turn to the behavior of tax rate τ. Again, its value grows only by a half of the rise in τ calculated in the previous scenario. To understand this difference, observe that in contrast to the case in which monetary policy follows the Taylor Rule that is affected by output gap, a version of the monetary rule that assumes $\phi_y = 0$ implies lower growth in nominal which results in a more moderate growth in debt service costs which, in turn, substantially reduces an upward pressure on tax τ. On the top of that, due to a

Figure 5: Impulse response functions, fiscal and monetary variables, deviations from stationary equilibrium values, simulation assumes $\phi_y = 0$.

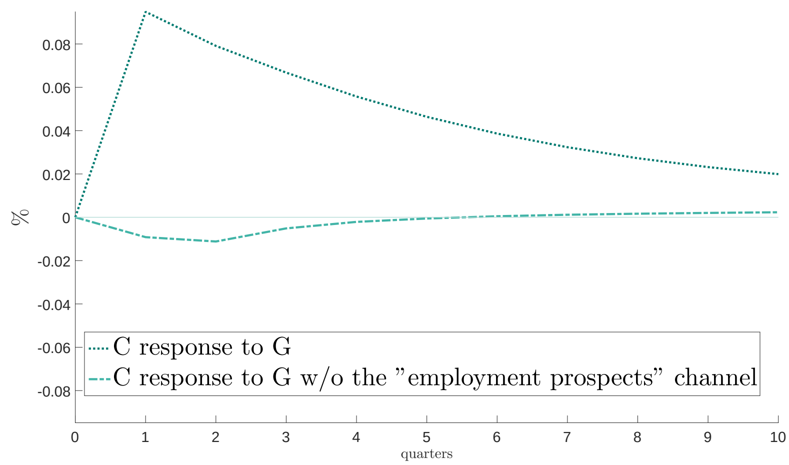


more pronounced decrease in unemployment, transfers to jobless households drop and the labor tax base expands, which reduces the rise in rates τ even further.

Summing up, a less intensive increase in i and τ when $\phi_y = 0$ is the main cause of the switch in the sign of aggregate consumption response to fiscal expansion with respect to baseline scenario. Notice that higher private demand stimulates output, job creation, improves employment prospects which, in turn, boosts private consumption even further, etc. Thus, a reduction in growth of i and τ sets in motion a feedback loop of general equilibrium effects which generate a substantial difference between the results of fiscal policy under different monetary regimes.

Finally, let us investigate the role of employment prospects channel when $\phi_y = 0$. Results of the simulation are presented in Figure 6. It turns out that once the improvement in job prospects is ignored, response of aggregate consumption to higher government purchases switches its sign and becomes negative. This outcome underscores a prominent role of job prospects in the propagation of fiscal stimulus packages and shows that the analyzed channel

Figure 6: Employment prospects channel, simulation assumes $\phi_y = 0$.



is robust to changes in assumption about monetary policy rule.

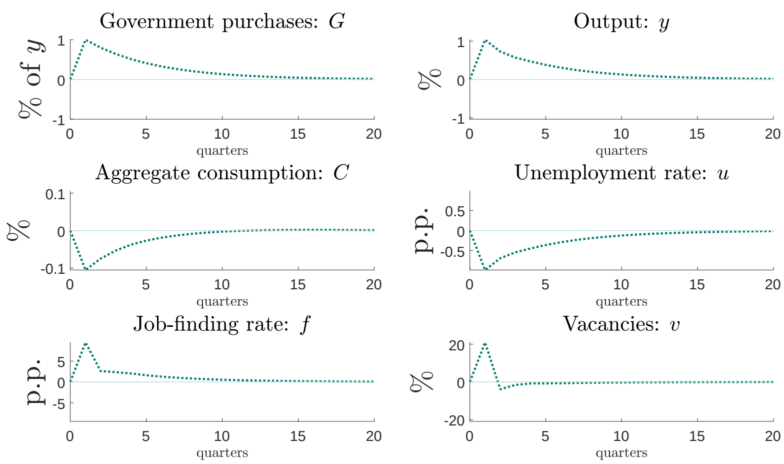
5.2 Debt-financed stimulus

Let us study the effects of the stimulus financed with an increase in government debt. Using the same, autoregressive path of government spending $\{G_t\}_{t=1}^{\bar{T}}$ as in two previous cases, I set the path of real public debt $\{B_t\}_{t=1}^{\bar{T}}$ so that it satisfies:

$$\begin{cases} B_{t+1} = B_{ss} + \sum_{s=1}^{t} G_s & for\ \ 0 < t \leq t' \\ B_{t+1} = B_{ss} + \left(1 - \frac{t-t'}{t''-t'}\right) \cdot \sum_{s=1}^{t'} G_s & for\ \ t' < t \leq t'' \\ B_{t+1} = B_{ss} & for\ \ t'' < t \leq \bar{T}. \end{cases}$$

In other words, from period $t = 1$ to period $t = t'$, increase in government expenditures is completely absorbed by public debt. Next, between periods t' and t'', the initial increase in government debt is reduced to its steady state level (I assume a linear pace of downward adjustment). For periods $t > t''$ onward, the real value of public debt is identical to B_{ss}.

Figure 7: Impulse response functions, main aggregate variables, deviations from stationary equilibrium values, debt financed government purchases.

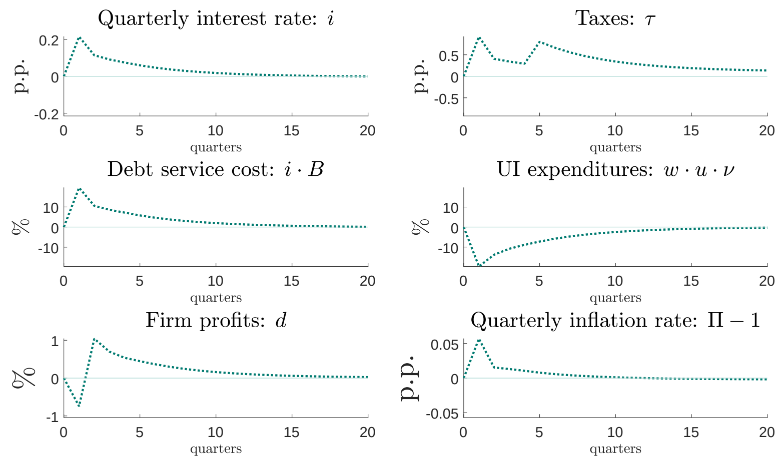


In the simulations, I set $t' = 4$ and $t'' = 40$: the stimulus is financed entirely with public debt during the first year and then, the additional debt issued at the beginning is repaid within 10 years from the onset of expansion. Clearly, we need to guarantee that government budget constraint is satisfied for each period $t \in \left\{1, 2, ..., \bar{T}\right\}$ and hence τ adjusts to balance the budget.

Figure 7 displays the impact of a rise in government purchases on main economic aggregates when B follows the path described above. The fiscal spending multiplier value in period $t = 1$ amounts to 1.03 and it is larger than in the baseline scenario mainly because the crowding out of private consumption drops by about a half. The resulting drop in unemployment is more pronounced and it is equal to 0.9 percentage points.

It is crucial to understand the reasons for which the downturn in aggregate consumption is more moderate when fiscal stimulus is financed with debt in the first year of expansion. As it has been observed by Hagedorn et al. (2017), such reaction is not very surprising given the fact that the rise in G first boosts aggregate demand but, at the same time, this stimulating effect is then offset through raising taxes τ which affects income of all

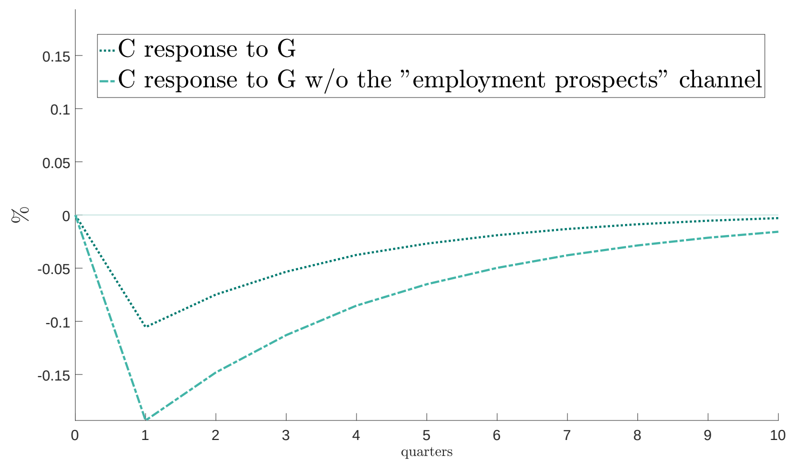
Figure 8: Impulse response functions, fiscal and monetary variables, deviations from stationary equilibrium values, debt financed government purchases.



workers. In particular, it has an impact on those with low levels of wealth who exhibit high MPC and thus larger τ decreases their consumption significantly. The situation is very different when higher G is financed with a rise in B. First, higher debt enables to reduce tax rate τ (see the top right panel of Figure 8) and hence the adverse effects of τ on incomes of high MPC workers is mitigated. Second, the newly issued debt is mainly bought by low MPC workers whereas high MPC households consume additional income generated by the stimulus. In other words, deficit financed expansion leads to an implicit redistribution from asset-rich workers, who exhibit low MPC and whose main source of financing expenditures is asset income, to low-asset households with high MPC who rely more on labor income that, through changes in labor market status, is highly dependent on job creation that takes place during fiscal expansion.

Notice that, similarly to baseline scenario, the response of monetary policy is relatively aggressive and leads to a rise in nominal interest rates by 0.8 percentage points (in annual terms) at the peak. First, this process results in stronger incentives to save which imposes a downward pressure on consump-

Figure 9: Employment prospects channel, debt financed government purchases.



tion. Second, it elevates the cost of debt service cost and leads to higher taxes. This explains why τ rises despite the fact that higher G is financed with debt. Independently of that, debt service costs increase automatically because B is raised in this scenario.

Observe that higher C in comparison to the baseline simulation leads to higher job creation and larger reduction in unemployment risk captured with the inverse of f. This, in turn, leads to additional multiplier effects between better employment prospects and private demand which reduce the drop in C and raise f even further in comparison to the benchmark.

Figure 9 displays the role of employment prospects channel when G is financed with debt. It turns out that crowding out of private consumption increases by almost 95% if the mechanism is ignored. The magnitude of the channel is larger than in baseline scenario because the reaction of job finding probability to change in G is stronger.

6 Conclusions

This paper has analyzed and quantified a channel which propagates the effects of fiscal purchases through improvement in job prospects. To this end, I have used an extended version of the Bewley-Huggett-Aiyagari (BHA) with frictional labor and sticky prices. Baseline simulation indicates that that the role of employment prospects channel for the effectiveness of fiscal expenditures is substantial: a hypothetical scenario in which the channel is shut off predicts a rise crowding out of private consumption by 47%.

To verify the robustness of this finding, I have analyzed two additional scenarios: the one in which monetary policy is less responsive to changes in output gap and the second in which expansion in fiscal purchases is financed with debt. The results of those simulations corroborate the finding from the baseline scenario: the role of employment prospects is a crucial force shaping the aggregate consumption response to change in government purchases.

References

Auclert, A. (2017). Monetary Policy and the Redistribution Channel. NBER Working Papers 23451, National Bureau of Economic Research, Inc.

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

Carroll, C. D. (2006). The method of endogenous gridpoints for solving dynamic stochastic optimization problems. *Economics Letters*, 91(3):312–320.

Chodorow-Reich, G., Feiveson, L., Liscow, Z., and Woolston, W. G. (2012). Does State Fiscal Relief during Recessions Increase Employment? Evidence from the American Recovery and Reinvestment Act. *American Economic Journal: Economic Policy*, 4(3):118–145.

Den Haan, W., Rendahl, P., and Riegler, M. (2015). Unemployment (Fears) and Deflationary Spirals. CEPR Discussion Papers 10814, C.E.P.R. Discussion Papers.

Eggertsson, G. B. (2011). What Fiscal Policy is Effective at Zero Interest Rates? In *NBER Macroeconomics Annual 2010, Volume 25*, NBER Chapters, pages 59–112. National Bureau of Economic Research, Inc.

Floden, M. and Lindé, J. (2001). Idiosyncratic Risk in the United States and Sweden: Is There a Role for Government Insurance? *Review of Economic Dynamics*, 4(2):406–437.

Galí, J. (2008). Introduction to Monetary Policy, Inflation, and the Business Cycle: An Introduction to the New Keynesian Framework. In *Monetary Policy, Inflation, and the Business Cycle: An Introduction to the*

New Keynesian Framework, Introductory Chapters. Princeton University Press.

Gornemann, N., Kuester, K., and Nakajima, M. (2016). Doves for the Rich, Hawks for the Poor? Distributional Consequences of Monetary Policy. International Finance Discussion Papers 1167, Board of Governors of the Federal Reserve System (U.S.).

Guerrieri, V. and Lorenzoni, G. (2011). Credit Crises, Precautionary Savings, and the Liquidity Trap. NBER Working Papers 17583, National Bureau of Economic Research, Inc.

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

Hagedorn, M., Manovskii, I., and Mitman, K. (2017). The Fiscal Multiplier. 2017 meeting papers, Society for Economic Dynamics.

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

Kaplan, G., Moll, B., and Violante, G. L. (2016). Monetary Policy According to HANK. NBER Working Papers 21897, National Bureau of Economic Research, Inc.

Kolsrud, J., Landais, C., Nilsson, P., and Spinnewijn, J. (2015). The Optimal Timing of UI Benefits: Theory and Evidence from Sweden. CEPR Discussion Papers 10701, C.E.P.R. Discussion Papers.

McKay, A. and Reis, R. (2016). The Role of Automatic Stabilizers in the U.S. Business Cycle. *Econometrica*, 84:141–194.

Michaillat, P. (2012). Do Matching Frictions Explain Unemployment? Not in Bad Times. *American Economic Review*, 102(4):1721–1750.

Monacelli, T., Perotti, R., and Trigari, A. (2010). Unemployment fiscal multipliers. *Journal of Monetary Economics*, 57(5):531–553.

Navarro, G. and Ferriere, A. (2016). The Heterogeneous Effects of Government Spending: It's All About Taxes. 2016 Meeting Papers 1286, Society for Economic Dynamics.

Ramey, G., den Haan, W. J., and Watson, J. (2000). Job Destruction and Propagation of Shocks. *American Economic Review*, 90(3):482–498.

Rotemberg, J. J. (1982). Sticky Prices in the United States. *Journal of Political Economy*, 90(6):1187–1211.

Serrato, J. C. S. and Wingender, P. (2016). Estimating Local Fiscal Multipliers. NBER Working Papers 22425, National Bureau of Economic Research, Inc.

Shimer, R. (2005). The Cyclical Behavior of Equilibrium Unemployment and Vacancies. *American Economic Review*, 95(1):25–49.

Silva, J. I. and Toledo, M. (2009). Labor Turnover Costs And The Cyclical Behavior Of Vacancies And Unemployment. *Macroeconomic Dynamics*, 13(S1):76–96.

Tauchen, G. (1986). Finite state markov-chain approximations to univariate and vector autoregressions. *Economics Letters*, 20(2):177–181.

Woodford, M. (2011). Simple Analytics of the Government Expenditure Multiplier. *American Economic Journal: Macroeconomics*, 3(1):1–35.

Zbaracki, M. J., Ritson, M., Levy, D., Dutta, S., and Bergen, M. (2004). Managerial and Customer Costs of Price Adjustment: Direct Evidence from Industrial Markets. *The Review of Economics and Statistics*, 86(2):514–533.

Appendix

Solution Algorithm: Stationary Equilibrium

Steps:

1. Guess Π. Given $\bar{i}$ it defines the steady state value of real interest rate.

2. For a given Π:

   (a) Compute q from 8.

   (b) Given q compute x from 14 and f from 13 given x. Then, use the fact that $q \cdot v = M(v, 1 - (1 - \sigma) \cdot n)$ (equation 14) to reformulate the stationary version of equation 7 to get:

   $$\sigma \cdot n = M(v, 1 - (1 - \sigma) \cdot n)$$

   and divide by $1 - (1 - \sigma) n$ to get (the CRS property of M works here):

   $$\frac{\sigma \cdot n}{1 - (1 - \sigma) n} = M(x, 1)$$

   so given x we are able to obtain n. Take n, q to derive v from the equilibrium condition concerning the job market flows:

   $$\sigma \cdot n = q \cdot v.$$

   (c) Given Π, n and v compute firm's profits d.

   (d) Given n, d, Π, $G = 0$ and parameters B_{ss}, $\bar{i}$ derive τ from 10.

   (e) We are in position to use the EGM method to obtain policy functions $\{c_u(b, z)\}_{b,z}$ and $\{c_e(b, z)\}_{b,z}$ as we have already calculated all endogenous variables that are taken as given by households: $f' = f$, Π, τ and $i = \bar{i}$.

(f) Use $\{c_u(b,z)\}_{b,z}$, $\{c_e(b,z)\}_{b,z}$ and household budget constraints to derive $\{b_u'(b,z)\}_{b,z}$ and $\{b_e'(b,z)\}_{b,z}$. Use them together with $f' = f$ to compute the fixed point of the dynamical system that consists of 15 and 16: measures $\{\pi_e(b,z)\}_{b,z}$, $\{\pi_u(b,z)\}_{b,z}$.

(g) Given $\{b_u'(b,z)\}_{b,z}$ and $\{b_e'(b,z)\}_{b,z}$ and $\{\pi_e(b,z)\}_{b,z}$, $\{\pi_u(b,z)\}_{b,z}$ calculate households' demand for liquid assets:

$$B_{demand} = \int b_e'(b,z)\,d\pi_e(b,z) + \int b_u'(b,z)\,d\pi_u(b,z).$$

3. Use the following formula:

$$\Pi^{new} = \Pi + \epsilon \cdot (B_{demand} - B)$$

where ϵ is a small positive number. The idea is that if demand for liquid assets calculated for Π exceeded the number B then to move towards equilibrium in which $B_{demand} = B$ we need to disincentivize households from saving. This is done by increasing Π which reduces the real interest rate. Finally, replace Π with Π^{new}. Iterate until convergence - i.e. when $|B_{demand} - B|$ is sufficiently small.

Solution Algorithm: Transition

I will discuss the procedure which is used to compute the transitional dynamics of the model.

1. Set a sufficiently large number $\bar{T}$ (the end of the transition - economy is assumed to be back in the stationary equilibrium in period $\bar{T}$) and set $\left\{c_{u,\bar{T}}(b,z)\right\}_{b,z} = \{c_u(b,z)\}_{b,z}$, $\left\{c_{e,\bar{T}}(b,z)\right\}_{b,z} = \{c_e(b,z)\}_{b,z}$,$\Pi_{\bar{T}} = \Pi_{ss}$, $f_{\bar{T}} = f_{ss}$, $q_{\bar{T}} = q_{ss}$. Set the initial distribution of agents across nominal wealth and productivity $\{\pi_{e,1}(b,z)\}_{b,z} = \{\pi_e(b,z)\}_{b,z}$ and $\{\pi_{u,1}(b,z)\}_{b,z} = \{\pi_u(b,z)\}_{b,z}$. Guess the paths of: price ratios $\{\Pi_t\}_{t=1}^{\bar{T}-1}$, interest rates $\{i_t\}_{t=1}^{\bar{T}}$, employment $\{n_t\}_{t=1}^{\bar{T}}$ and auxiliary path of objects

$\{\tilde{p}_t\}_{t=1}^{\bar{T}}$ which satisfies $\Pi_t = \Pi_{ss} \cdot \frac{\tilde{p}_t}{\tilde{p}_{t-1}}$. It is introduced to improve the convergence properties of the algorithm as guessing the path $\{\Pi_t\}_{t=1}^{\bar{T}-1}$ did not lead to successful calculations. The idea is that $\tilde{p}_t$ affects both the rate Π_t that determines the value of households wealth via holdings b_t and the real interest rate $\frac{1+i'}{\Pi'}$ that governs consumption/savings decisions in period t. Using the postulated AR(1) process and the initial value $G_1 = 0.01 \cdot y_{ss}$ compute the path of real government expenditures $\{G_t\}_{t=1}^{\bar{T}}$.

2. For $t = \bar{T} - 1$ back to $t = 1$:

   (a) Given Π_{t+1}, Π_t, q_{t+1}, i_{t+1}, $y_{t+1} = n_{t+1}$ and $y_t = n_t$ compute q_t from 8.

   (b) Given q_t compute x_t from 14 and f_t from 13 given x_t. Use q_t and the guessed values of n_t and n_{t-1} to obtain v_t from 7.

   (c) Use 9 and v_t and guessed values of n_t and Π_t to compute d_t.

   (d) Use guessed values of n_t, i_t, Π_t and computed d_t to get τ_t from 10.

   (e) BACKWARD ITERATION: We are in position to use equations/inequalities 4 and budget constraints from 1 and 3 and to apply the EGM procedure to derive $\{c_{u,t}(b,z)\}_{b,z}$ and $\{c_{e,t}(b,z)\}_{b,z}$. It is because we have either derived or guessed all endogenous variables that are taken as given by households: i_t, f_{t+1}, Π_t, τ_t and we know $\{c_{u,t+1}(b,z)\}_{b,z}$ and $\{c_{e,t+1}(b,z)\}_{b,z}$.

3. For $t = 1$ to $t = \bar{T} - 1$ (FORWARD ITERATION):

   (a) Given $\{\pi_{e,t}(b,z)\}_{b,z}$, $\{\pi_{u,t}(b,z)\}_{b,z}$ and f_t compute the distribution of agents after labor market shocks (i.e., after separations and job finding) which take place at the beginning of the period and before agents make their consumption/saving choices. Denote those distributions by $\{\tilde{\pi}_{e,t}(b,z)\}_{b,z}$, $\{\tilde{\pi}_{u,t}(b,z)\}_{b,z}$. Integrate to obtain n_t:

$$n_t = \sum_{b,z} \left\{\tilde{\pi}_{e,t}(b,z)\right\}_{b,z}.$$

It becomes the new guess for n_t in further iterations.

(b) Given $\left\{c_{u,t}(b,z)\right\}_{b,z}$ and $\left\{c_{e,t}(b,z)\right\}_{b,z}$ and budget constraints derive $\left\{b_{u,t+1}(b,z)\right\}_{b,z}$ and $\left\{b_{e,t+1}(b,z)\right\}_{b,z}$. Combine them with $\left\{\tilde{\pi}_{e,t}(b,z)\right\}_{b,z}$, $\left\{\tilde{\pi}_{u,t}(b,z)\right\}_{b,z}$ to derive $\left\{\pi_{e,t+1}(b,z)\right\}_{b,z}$, $\left\{\pi_{u,t+1}(b,z)\right\}_{b,z}$ and to obtain the aggregate demand for liquid assets in period t:

$$B_{demand,t} = \int b_{e,t+1}(b,z)\, d\tilde{\pi}_{e,t}(b,z) + \int b_{u,t+1}(b,z)\, d\tilde{\pi}_{u,t}(b,z).$$

4. For each $t \in \left\{1, 2, ..., \bar{T} - 1\right\}$ calculate:

   (a) An new guess of the artificial and auxiliary object $\tilde{p}_t$:

   $$\tilde{p}_t^{new} = \tilde{p}_t - \epsilon \cdot \left(B_{demand,t} - B\right) \cdot$$

   The idea is that if demand for liquid assets is to large in comparison to supply B then we need to discourage agents from saving by lowering the quasi price level $\tilde{p}_t$ so that they consume more. Replace $\tilde{p}_t$ with $\tilde{p}_t^{new}$.

   (b) Use $\Pi_t = \Pi_{ss} \cdot \frac{\tilde{p}_t}{\tilde{p}_{t-1}}$ to derive the new guess for the price ratio in period t.

   (c) Use Taylor rule to modify the guess for i_t.

5. Repeat steps 2-4 until the value $\left|B_{demand,t} - B\right|$ is sufficiently small for all t.