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Fiscal Policy in a Business Cycle Model with Endogenous Productivity

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This paper shows that transitory demand-side fiscal policy shocks can have long-run effects. We develop a Real Business Cycle model with search and matching frictions and introduce an endogenous growth channel driven by total hours worked. We estimate the model using Bayesian methods on data for the United States. The model with the endogenous growth link generates a better fit to the data than the model without the link. Further, we find evidence for cleansing effects of recessions. Therefore, transitory demand-side shocks will have long-run effects. We stress the policy relevance of endogenous productivity in recessions and for the effects of austerity programs.

Key Words: DSGE; Endogenous productivity; Fiscal policy; Search and matching.
JEL Classification Numbers: C11, E32, E62, J63, O40.

1. INTRODUCTION

The Great Recession has resuscitated the interest in fiscal policy. Governments around the world used large fiscal policy measures trying to counter the recessionary forces and to foster economic and job growth.[1] This paradigm change follows decades during which monetary policy was considered to be sufficient to stabilize economic activity. Although the theoretical effects of fiscal shocks and the empirical evidence on fiscal policy are disputed amongst economists, it is less controversial that investment into public capital is superior to wasteful government consumption spending. According to this paradigm, demand-side fiscal policy triggers only

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[1] For example, in the United States the 2009 American Recovery and Reinvestment Act spend 831 Billion U.S. Dollars in total.

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short-run effects while supply-side fiscal policy will have effects on growth through its effect on private capital's marginal productivity.[2]

In this paper we challenge the paradigm that transitory demand-side fiscal policy shocks only have short-run effects. Put differently, we show that this result only holds in the absence of an endogenous growth channel. We develop a standard Real Business Cycle (RBC, for short) model of the business cycle which we use to generate and identify short-run fluctuations. Further, we combine this short-run model with a tractable, mainly atheoretical, and parsimonious approach to model endogenous growth, more precisely, endogenous productivity. We follow the work by Galí and Hammour (1991) modelling endogenous growth using an approach that relies on very little structural assumptions letting the data speak for itself. In this model, there are two, key estimable parameters: one driving the exogenous and one driving the endogenous component of growth. The sign of the endogenous component then allows us to infer whether learning-by-doing effects or cleansing effects of recession dominate. As a consequence, short-run fluctuations can have long-run effects.

Consider an example about the key transmission channels in our model. Suppose there is an increase in government consumption. This will, ceteris paribus, increase output in the short-run and lead to an increase in labor demand (either hours worked or employment). More employment via the endogenous productivity channel will increase productivity and, therefore, will have positive effects on output (growth) even in the long-run. Within this transmission channel there is one important link: the labor market. If we assume that the labor market is perfectly competitive, wealth effects (labor supply) and firm's demand mainly pin down the labor market equilibrium. In contrast, if we assume - more realistically - that the labor market is imperfect, an additional quantitatively important driving force is added that significantly affects the equilibrium and alters model dynamics. Therefore, we introduce search and matching frictions into the RBC model with endogenous productivity. To be precise, we allow for adjustments along the intensive (hours worked) and extensive (employment) margin. We then estimate this model on U.S. data using Bayesian methods.

We find that models with the endogenous growth channel generate a better fit to the data than the models without the link. Further, we find that the endogenous growth channel is more important if we consider labor market frictions. This supports our view that labor market dynamics are an important driving force of the endogenous growth channel.

Most importantly, we find evidence in favor of cleansing effects of recessions. Assuming a long-term growth rate of roughly 2 percent, a significant

[2]Of course, demand-side policies will only have an effect if the economy does not operate at full capacity. Supply-side fiscal policy can also have short-run effects due to expectation effects about higher long-run growth.

amount of growth is not explained by exogenous growth generating an annual growth rate of about 0.5 percent in the basic RBC and 0.2 percent in the search and matching model. Therefore, we can support our motivation that demand-side fiscal policies have long-run effects.

Further, we show that government spending increases output and employment in the short-run but decreases them over the medium-run. With cleansing effects of recessions using government spending is less beneficial than in the baseline scenario. Then, we perform several robustness checks showing that the results are robust to different specifications of the endogenous growth process. However, we find learning-by-doing effects when we consider fiscal rules or public capital. We can draw the conclusion that the design of fiscal policy has strong implications for the endogenous growth channel.

Finally, we perform two policy exercises. Due to the cleansing effects of recessions, we observe that productivity increases in a recession. This limits the effects of the recession by lowering the peak and duration. Put differently, cleansing effects of recession act as an automatic stabilizer. Second, we find that the effects of a government spending cut, as part of an austerity program, depend largely on the endogenous growth channel; while the overall effects are small. Lowering government spending creates a recession: lowering output and employment and increasing government debt. At the same time the program results in an increase in investment over the medium-run and in an increase of productivity.

Our paper relates to different streams in the literature. First, we combine the endogenous growth literature with the literature on business cycle models. Within the endogenous growth literature there are two opposing approaches.[3] First, Stadler (1990), following Arrow (1962), introduced learning-by-doing effects. In his model, aggregate demand shocks have permanent effects on productivity and, hence, on employment and output. In this model, recessions negatively affect growth due to the adverse learning-by-doing effects. Second, the "cleansing effects or recessions" by Caballero and Hammour (1994) suggest the opposite: recessions increase productivity. They argue that a selection process identifies inefficient production units and shuts them down. This increases average productivity by destroying production units that embody outdated techniques. Along this line, Hall (1991), Cooper and Haltiwanger (1993), and Saint-Paul (1997) stress that in a recession firms have an incentive to substitute productivity-enhancing activities for current production activities and, therefore, increase productivity. More recently, Lee and Mukoyama (2015) show that plant entry rather than plant exit is an important driver of plant-level dy-

[3]Lucas (1988) builds a model in which the accumulation of knowledge (human capital) depends on the current state of the economy. In this model, temporary shocks can have permanent effects as they affect the incentive structure in the economy.

namics over the business cycle. Wesselbaum (2015) estimates the Smets and Wouters (2007) New Keynesian model with this endogenous productivity channel on U.S. data. The findings point towards a dominance of reallocation effects in recessions over learning-by-doing effects. Further, the findings show that even non-technological innovations can have effects on productivity and, therefore, long-run growth.

Second, we add to the literature on fiscal policy in endogenous growth models. This literature highlights the growth-enhancing effects of public capital expenditures and tax rates. Barro (1990) considers government consumption expenditures entering the agents' utility function. He shows that they will only affect the social rate of return on investment if they are financed via a proportional income tax. Further, various papers focus on the long-run effects of public capital (such as infrastructure investment) showing that the balanced growth rate increases in public capital spending (Baier and Glomm (2001)) and that the balanced growth rate is driven by fiscal policy and, via learning-by-doing, labor supply (Barseghyan and Battaglini (2015)).[4] Taxation in endogenous growth models is studied, among others, by Barro and Sala-i-Martin (1992), King and Rebelo (1990), Rebelo (1991), Jones et al. (1993), and Jones and Manuelli (2005). In those models tax policy has significant long-run effects due to its effect on the social rate of return and, therefore, on capital accumulation. Turnovsky (2004) calculates the effects of government expenditures on public capital and government consumption in a non-scale growing economy financed via lump-sum taxation. He finds that an increase in government consumption increases the private and public capital stock and output. More closely related to our paper is Turnovsky (2000) who builds an endogenous growth model in which government consumption enters the agents' utility function. Higher government consumption therefore creates a negative effect on labor supply, lowers the growth rate, and increases leisure.

2. THE MODEL

The model we develop is a dynamic stochastic general equilibrium model with flexible prices, labor market frictions, fiscal policy, and endogenous productivity. It is populated by three different type of agents: households, firms, and a fiscal authority, i.e., the government. Given that the focus is on fiscal policy we ignore monetary policy and, therefore, limit ourselves to a flexible price model. Labor market frictions are modelled along the lines of the search and matching model by Mortensen and Pissarides (1994).

[4]Gemmell et al. (2012) and Barbiero and Cournède (2013) estimate the long-run effects of fiscal policy finding positive effects of public capital expenditures on growth.

The government uses distortionary taxes, transfers, government spending, and provides unemployment benefits.

The model combines the search and matching model by Mortensen and Pissarides (1994) with the endogenous productivity channel by Galí and Hammour (1991). In contrast to the paper by Wesselbaum (2015), this paper assumes a frictional labor market and flexible prices.

We describe our model using Prescott's narrative approach. First, we define the economy's preferences and technology. Second, we present the model's assumed market structure. Finally, we derive the optimality conditions and define the equilibrium.

2.1. Preferences and Technology

2.1.1. Households

We assume the existence of a representative household with family members distributed on the unit interval.[5] Household members can be either employed or unemployed. They perfectly insure each other against fluctuations in income (see Merz (1995)). Households like to consume, C_t, but, when employed, N_t, dislike working, H_t.

Preferences are given by the utility function

$$\mathbb{E}_t \sum_{t=0}^{\infty} \beta^t u_t^b \left[\frac{(C_t - \chi C_{t-1})^{1-\sigma}}{1-\sigma} - u_t^l \int_0^1 N_{it} \frac{H_{it}^{1+\mu}}{1+\mu} \mathbf{d}i \right], \tag{1}$$

where $\beta \in (0,1)$ is the discount factor and $\mathbb{E}_t$ is the mathematical expectation operator in period t. The degree of risk aversion is given by $\sigma > 0$ and $\mu > 0$ is the inverse of the Frisch elasticity of labor supply. Consumption shows habit persistence, $0 \leq \chi \leq 1$, where the habit stock is a fraction of previous period consumption, C_{t-1}.

Utility is subject to two shocks: a preference shock, u_t^b and a labor supply shock, u_t^l. Both shocks follow AR(1) processes

$$\ln u_t^b = \rho^b \ln\left(u_{t-1}^b\right) + \varepsilon_t^b, \tag{2}$$
$$\ln u_t^l = \rho^l \ln\left(u_{t-1}^l\right) + \varepsilon_t^l, \tag{3}$$

[5]The economy begins with all households having identical financial wealth and consumption histories. Further, households make optimal use of the contingent claims market. Hence, we are able to consider the consumption and savings decisions of a representative household.

where the autocorrelation parameters are given by $\rho^b > 0$, $\rho^l > 0$ respectively. Innovations are i.i.d. over time and normally distributed,

$$\varepsilon_t^b \sim \mathcal{N}(0, \sigma_b), \quad (4)$$
$$\varepsilon_t^l \sim \mathcal{N}(0, \sigma_l). \quad (5)$$

2.1.2. Technology

Firms in our economy use capital and labor to produce differentiated goods. Firms share the same technology represented by a Cobb-Douglas production function

$$Y_{it} = Z_t \Xi_t \left(\kappa_{it} K_{it-1}\right)^{1-\alpha} \left(H_{it} N_{it}\right)^{\alpha}, \quad (6)$$

where $0 < \alpha < 1$ and $i \in [0, 1]$ represents the continuum of different firm names. Total labor services used are given by $H_{it}N_{it}$ while capital, K_{it}, is subject to capital utilization, $\varkappa_{it}$. We assume that the capital stock is owned by households and firms rent it on a frictionless capital market (see Pissarides (2000)) at the rate R_t^K. Capital accumulates according to

$$K_t = (1 - \delta(\varkappa_t))K_{t-1} + \left(1 - S\left(\frac{u_t^i I_t}{I_{t-1}}\right)\right) I_{t,} \quad (7)$$

where I_t is investment and $S(\cdot)$ captures investment adjustment costs as in Christiano et al. (2005).[6] Adjustment costs are subject to an efficiency shock u_t^i which follows and AR(1) process

$$\ln u_t^i = \rho^i \ln\left(u_{t-1}^i\right) + \varepsilon_t^i, \ \varepsilon_t^i \sim \mathcal{N}(0, \sigma_i), \quad (8)$$

here the autocorrelation of the shock is governed by $\rho^i > 0$.

Firms have control over the intensity with which the capital stock is utilized, κ_{it}. Christiano et al. (2005) assume that a higher utilization rate comes at the cost of a faster depreciation $\delta(\cdot)$, which is modelled as in Schmitt-Grohé and Uribe (2008), i.e.

$$\delta(\kappa_{it}) = \delta_0 + \delta_1(\varkappa_{it} - 1) + \frac{\delta_2}{2}(\varkappa_{it} - 1)^2, \quad (9)$$

where $\delta_0, \delta_1, \delta_2 > 0$.

[6]In steady state: $S = 0$, $S' = 0$, and $S'' > 0$

The model is augmented by an endogenous growth component, Ξ_t

$$\Xi_t = [\vartheta + \psi H_t N_t]\, \Xi_{t-1}, \tag{10}$$

where $\vartheta \geq 0$ is the exogenous growth rate and $\psi \in \mathbb{R}$ governs the endogenous growth component. The growth rate of productivity is $\Delta s_t = s_t - s_{t-1}$, where $s_t = \log(Z_t \Xi_t)$.

Following Galí and Hammour (1991), there are three possible cases for the value of the endogenous growth component, ψ. First, setting $\psi = 0$ the endogenous growth component vanishes and growth is purely exogenously determined. The growth rate of the economy is then simply given by $\vartheta + Z_t$. Second, if we assume that $\psi > 0$ the model features learning-by-doing effects and the growth rate of the economy is $\log(Z_t \Xi_t)$. Third, the value can be negative $\psi < 0$ in which case the model accounts for cleansing effects of recessions.

Finally, Z_t is a Hicks-neutral aggregate technology shock following a first-order autoregressive process,

$$\ln Z_t = \rho^Z \ln (Z_{t-1}) + \varepsilon_t^Z,\ \varepsilon_t^Z \sim \mathcal{N}(0, \sigma_Z), \tag{11}$$

where the autocorrelation is driven by $\rho^Z > 0$ and the error term is i.i.d. and normally distributed.

2.2. Market Structure

The model features two perfectly competitive markets and one imperfect one. Goods and capital market are perfectly competitive, while the labor market is imperfect.

According to Mehra and Prescott (1980) and Pissarides (2000), we assume that households own capital between quarters. At the beginning of each quarter, households' sell capital to the representative firm. At the quarter's end, the firm sells all capital available back to the households.

Search takes place on a discrete and closed market. Workers can be either employed or unemployed. Each firm has one job that is either filled or vacant. If it is filled the probability of being exogenously destructed is given by $\rho > 0$. Firms create jobs at the rate $M(U_t, V_t)$ at the cost of $c > 0$ units of output per vacancy, V_t. Matches, M_t, are created using the matching technology

$$M(U_t, V_t) = m U_t^{\varsigma} V_t^{1-\varsigma}, \tag{12}$$

where $m > 0$ gives the match efficiency and $\varsigma > 0$ is the elasticity of the matching function with respect to unemployment.

Labor market tightness is given by $\theta_t = V_t/U_t$, such that the vacancy filling probability is $q(\theta_t) = M(U_t, V_t)/V_t = m\theta_t^{\varsigma}$. Using the definition of entry and exit in the labor market gives the evolution of employment

$$N_t = (1-\rho)(N_{t-1} + M_{t-1}). \tag{13}$$

The evolution of aggregate unemployment, given constant population, is $U_t = 1 - N_t$.

2.3. Optimization and Equilibrium

Optimization of all agents but the fiscal authority defines equilibrium. First, we solve the households utility maximization problem and, then, solve the firms profit maximization problem. We proceed by solving the bargaining problem between firm and worker to pin down the optimal combination of wages and hours. We conclude with a definition of fiscal policy and define the equilibrium.

2.3.1. Households

The representative household maximizes utility and faces the following intertemporal budget constraint

$$\begin{aligned} & \left(1+\tau_t^C\right) C_t + I_t + B_t = R_{t-1} B_{t-1} \qquad (14) \\ + \quad & \left(1-\tau_t^W\right) \int_0^1 W_{it} N_{it} H_{it} \mathbf{d}i + bU_t + T_t + \left(1-\tau_t^K\right) R_t^K \kappa_t K_{t-1}. \end{aligned}$$

There are three types of taxes: consumption, τ_t^C, labor income, τ_t^W, and capital income, τ_t^K. The household holds bonds, B_t, that pay a gross interest rate R_t. Lump-sum transfers from the government are denoted by T_t and b denotes unemployment benefits. Firms pay the real wage W_{it}.

Then, the representative household maximizes the utility function subject to the budget constraint, the law of motion of capital together with equation (9). The first-order necessary conditions are given by

$$\frac{u_t^b \left(C_t - \chi C_{t-1}\right)^{-\sigma}}{1+\tau_t^c} = \beta R_t \mathbb{E}_t \left[u_{t+1}^b \frac{\left(C_{t+1} - \chi C_t\right)^{-\sigma}}{1+\tau_{t+1}^c}\right], \tag{15}$$

$$1 = \left[1 - S\left(\frac{u_t^i I_t}{I_{t-1}}\right) - S'(\cdot)\frac{u_t^i I_t}{I_{t-1}}\right] q_t + \mathbb{E}_t\left[\beta q_{t+1} \frac{\lambda_{t+1}}{\lambda_t} S'(\cdot) \frac{u_{t+1}^i I_{t+1}^2}{I_t^2}\right], \tag{16}$$

$$q_t = \mathbb{E}_t\left\{\beta \frac{\lambda_{t+1}}{\lambda_t}\left[q_{t+1}\left(1-\delta(\kappa_{t+1})\right) + \left(1-\tau_{t+1}^K\right) R_{t+1}^K \kappa_{t+1}\right]\right\}, \tag{17}$$

$$\left(1-\tau_t^K\right) R_t^K = q_t\left(\delta_1 + (\kappa_t - 1)\delta_2\right), \tag{18}$$

where λ_t is the Lagrange multiplier on the budget constraint. Further, $\lambda_t = u_t^b (C_t - \chi C_{t-1})^{-\sigma}$ is marginal utility and Tobin's q is given by $q_t = \frac{\varrho_t}{\lambda_t}$, where ϱ_t is the Lagrange multiplier on the capital accumulation technology.

2.3.2. *Firms*

The representative firm solves its profit maximization problem by choosing the optimal path for $\{N_{it}, V_{it}, k_{it} = \kappa_{it} K_{it-1}\}_{t=0}^{\infty}$. The firm maximizes profits

$$\Pi_{i0} = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \frac{\lambda_t}{\lambda_0} \left[Y_{it} - W_{it} H_{it} N_{it} - cV_{it} - R_t^K \kappa_{it} K_{it-1}\right], \tag{19}$$

subject to the production function eq. (6) and the law of motion for employment eq. (13).[7]

The first-order necessary conditions are given by[8]

$$\begin{aligned} \xi_t &= \varphi_t \alpha Z_t \Xi_t (\kappa_t K_{t-1})^{1-\alpha} (H_t N_t)^{\alpha-1} H_t \\ &- W_t H_t + \mathbb{E}_t \left[\beta \frac{\lambda_{t+1}}{\lambda_t} (1-\rho) \xi_{t+1}\right], \qquad (20) \\ \frac{c}{q(\theta_t)} &= \mathbb{E}_t \left[\beta \frac{\lambda_{t+1}}{\lambda_t} (1-\rho)\, \xi_{t+1}\right], \qquad (21) \\ R_t^k &= (1-\alpha) Z_t \Xi_t (\kappa_t K_{t-1})^{-\alpha} (H_t N_t)^{\alpha}. \qquad (22) \end{aligned}$$

The Lagrangian multiplier on the law of motion for employment is ξ_t. Using eq. (20) and eq. (21) gives the job creation condition

$$\frac{c}{q(\theta_t)} = \mathbb{E}_t \left\{\beta (1-\rho) \frac{\lambda_{t+1}}{\lambda_t} \left[\alpha Z_{t+1} \Xi_{t+1} (\kappa_{t+1} K_t)^{1-\alpha} (H_{t+1} N_{t+1})^{\alpha-1} H_{t+1} - W_{t+1} H_{t+1} + \frac{c}{q(\theta_{t+1})}\right]\right\}. \tag{23}$$

This equation determines vacancy posting activities. The right-hand side gives the expected, discounted profits of hiring a worker. It is equal to the output produced by the new worker reduced by his wage costs and increased by the saved hiring costs in the next period, iff the worker is not laid-off. In equilibrium, the profits from hiring a new worker need to be equal to the costs of the hiring (the left-hand side).

2.3.3. *Bargaining*

[7]Perfect capital markets imply that firms use the same discount factor as households.
[8]Notice that we drop subscript indices due to symmetry.

In this section we find expressions for the wage and hours worked. Once a firm and a worker match, the match shares an economic rent which is splitted in individual Nash bargaining.

Worker and firm by maximize the Nash product

$$W_t = \arg\max_{\{W_t\}} \left[\left(\mathcal{S}_t^H\right)^\eta \left(\mathcal{S}_t^F\right)^{1-\eta} \right], \tag{24}$$

where $\mathcal{S}_t^H$ and $\mathcal{S}_t^F$ are households and firms surplus. The worker's relative bargaining power is given by $\eta \in (0,1)$.

Now, we define the asset value functions. Household surplus, $\mathcal{S}_t^H$, is given by

$$\mathcal{S}_t^H = (1-\tau_t^W) W_t H_t - \frac{u_t^l}{\lambda_t} \frac{H_t^{1+\mu}}{1+\mu} - b + \mathbb{E}_t \left\{ \beta \frac{\lambda_{t+1}}{\lambda_t} \left[(1-\rho) - \theta_{t+1} q(\theta_{t+1}) \right] \mathcal{S}_{t+1}^H \right\}, \tag{25}$$

while firm surplus, $\mathcal{S}_t^F$, is

$$\mathcal{S}_t^F = \alpha Z_t \Xi_t \left(\varkappa_t K_{t-1}\right)^{1-\alpha} \left(N_t\right)^{\alpha-1} H_t^\alpha - W_t H_t + \mathbb{E}_t \left[\beta \frac{\lambda_{t+1}}{\lambda_t} (1-\rho) \mathcal{S}_{t+1}^F \right]. \tag{26}$$

Households receive a wage, suffer from working (and from not receiving unemployment benefits when employed), and benefit from a continuation value of being employed, if the job is not destructed. Otherwise, they receive the value of being unemployed. Firms surplus is driven by the output produced reduced by the wage, and the continuation value of the match.

After some algebra, the individual real wage solves

$$\mathcal{S}_t^H = \frac{\eta}{1-\eta} \mathcal{S}_t^F. \tag{27}$$

Substituting the asset value function into this condition gives the hourly real wage

$$W_t = \frac{(1-\eta)\left(b + \frac{u_t^l}{\lambda_t} \frac{H_t^{1+\mu}}{1+\mu}\right) + \eta \alpha Z_t \Xi_t \left(\kappa_t K_{t-1}\right)^{1-\alpha} \left(H_t N_t\right)^{\alpha-1} H_t + \mathbb{E}_t \left[\eta \beta \frac{\lambda_{t+1}}{\lambda_t} c \theta_{t+1} \right]}{\left((1-\tau_t^W)(1-\eta) + \eta\right) H_t}. \tag{28}$$

Finally, we need to find a condition for the optimal supply of hours. Hours need to maximize joint surplus $S_t = \mathcal{S}_t^H + \mathcal{S}_t^F$. Then,

$$\begin{aligned} &(1-\tau_t^W) W_t - \frac{u_t^l}{\lambda_t} H_t^\mu + \alpha^2 Z_t \Xi_t \left(\kappa_t K_{t-1}\right)^{1-\alpha} \left(H_t N_t\right)^{\alpha-1} \\ + \;& \psi \Xi_{t-1} \alpha Z_t \left(\kappa_t K_{t-1}\right)^{1-\alpha} \left(N_t\right)^{\alpha-1} H_t^\alpha - W_t = 0, \end{aligned} \tag{29}$$

which gives

$$\underbrace{\alpha^2 Z_t \Xi_t \left(\kappa_t K_{t-1}\right)^{1-\alpha} \left(H_t N_t\right)^{\alpha-1}}_{\text{Marginal Productivity of Hours}} + \underbrace{\psi \Xi_{t-1} \alpha Z_t \left(\kappa_t K_{t-1}\right)^{1-\alpha} \left(N_t\right)^{\alpha-1} H_t^{\alpha}}_{\text{Effect of Hours on Productivity}}$$

$$= \underbrace{\frac{u_t^l}{\lambda_t} H_t^{\mu} + \tau_t^W W_t}_{\text{Marg. Rate of Subst.}} . \tag{30}$$

The left-hand side gives the marginal productivity of labor hours which has to be equal to the right-hand side: the marginal rate of substitution net of taxes. Here, we find a significant difference between the model with and without an endogenous growth channel. If the channel is present ($\psi \neq 0$) then hours have an effect on productivity and, therefore, have an effect on the optimal choice of hours. If the channel is not present ($\psi = 0$), then we are back to the standard result that the marginal productivity of hours is equal to the marginal rate of substitution (net of taxes).

2.3.4. Fiscal Policy and Equilibrium

The government in our model has various instruments under its control. It issues bonds, B_t, provides government spending, G_t, and provides social security payments such as unemployment benefits, b, and transfers, T_t. Expenditures are financed using distortionary taxes, $\left(\tau_t^K, \tau_t^w, \tau_t^C\right)$. Therefore, Ricardian equivalence is broken in our model. Overall six of those instruments can be set independently, while the seventh follows from the government's budget constraint

$$B_t + \tau_t^K R_t^K \kappa_t K_{t-1} + \tau_t^w W_t N_t H_t + \tau_t^C C_t = R_{t-1} B_{t-1} + G_t + bU_t + T_t. \tag{31}$$

We assume that all instruments are exogenously determined by first-order autoregressive processes

$$\ln G_t = \rho^G \ln\left(G_{t-1}\right) + \varepsilon_t^G, \tag{32}$$
$$\ln \tau_t^K = \rho^{\tau_K} \ln\left(\tau_{t-1}^K\right) + \varepsilon_t^{\tau_K}, \tag{33}$$
$$\ln \tau_t^W = \rho^{\tau_W} \ln\left(\tau_{t-1}^W\right) + \varepsilon_t^{\tau_W}, \tag{34}$$
$$\ln \tau_t^C = \rho^{\tau_C} \ln\left(\tau_{t-1}^C\right) + \varepsilon_t^{\tau_C}, \tag{35}$$
$$\ln T_t = \rho^T \ln\left(T_{t-1}^T\right) + \varepsilon_t^T, \tag{36}$$

where

$$\varepsilon_t^X \sim \mathcal{N}\left(0, \sigma_X\right), \tag{37}$$

and $0 < \rho_X < 1$, for all $X \in \{G, \tau_K, \tau_W, \tau_C, T\}$.

Then, an equilibrium for given initial conditions, the nine stochastic processes, and a set of prices $\{W_t, R_t^k, R_t\}_{t=0}^{\infty}$ is a state-contingent sequence of

$$\left\{C_t, I_t, Y_t, V_t, M_t, H_t, N_t, U_t, \theta_t, B_t, G_t, \tau_t^K, \tau_t^w, \tau_t^C, T_t, \delta_t, \varkappa_t, K_{t-1}, q_t, \Xi_t\right\}_{t=0}^{\infty}$$

such that

1. *Household optimality*

Given $\{W_t, R_t^k, R_t\}_{t=0}^{\infty}$ the household solves its optimization problem, maximizing (1) s.t. (14).

2. *Profit maximization*

The processes for $\{N_t, V_t, \varkappa_t, K_{t-1}\}_{t=0}^{\infty}$ maximize (24) s.t. (6) and (13).

3. *Fiscal policy*

The government budget constraint (36) holds with equality and the processes for $\{G_t, \tau_t^K, \tau_t^w, \tau_t^C, T_t\}_{t=0}^{\infty}$ are determined by (37) to (41).

4. *Market clearing*

In the symmetric equilibrium, factor and goods market clear and the resource constraint is

$$Y_t = C_t + I_t + G_t + cV_t. \tag{38}$$

Finally, the set of equations forming the equilibrium is log-linearized around the non-stochastic steady-state.

3. ESTIMATION STRATEGY

In this section we discuss our strategy to estimate the model. We use five chains of 100.000 draw each for our MCMC chains. We need nine time series for the nine shocks in the model. We use time series for the United States from 1960:Q1 to 2004:Q3 (173 observations). The time series are: private consumption, private investment, output, output growth rate, hours worked, wages, government debt, government spending, and transfers. Most time series are constructed as in Smets and Wouters (2007). For the time series of government debt, government spending, and transfers we use data from the Bureau of Economic Analysis' NIPA. The nominal values are converted into real values by dividing by the GDP deflator. Then, we take the logarithm and detrend them using - as usual in the literature estimating DSGE models - a Hodrick-Prescott filter with $\lambda = 1600$.

We assume that the autocorrelation of all shocks is beta distributed with mean 0.5 and standard deviation 0.2 as in Smets and Wouters (2007). For the standard errors we assume that they belong to the inverse gamma family with mean 0.1 and standard error 2, which is a quite loose prior.

We continue with the household parameters. The risk aversion σ is set to a value of 2 with a standard deviation of 0.1 and belongs to the normal density family. The disutility of working, μ, is assumed to be normally distributed with mean 2 and standard deviation 0.1. Further, habit formation is beta distributed with mean 0.7 and standard deviation 0.1.

For the labor market parameters we assume the following. The elasticity of the matching function w.r.t. unemployment, ς, follows a beta distribution with mean 0.7 and standard deviation 0.1. The separation rate belongs to the beta family with mean 0.08 and standard deviation 0.01. Both values are in line with the usually assumed calibration of search and matching values for the United States.

On the firm side of our model, we assume a mean value of 5 for the capital ajdustment costs with a standard deviation of 0.5, belonging to the normal family. This value is in line with the value assumed in Christiano et al. (2005). The capital depreciation rate is assumed to be beta distributed with mean 0.03 and standard deviation 0.1. This value is in line with the commonly assumed value of 0.025 percent per quarter or 10 percent per year.

Finally, our exogenous growth parameter, ϑ, is assumed to follow a gamma distribution with mean 0.2 and standard deviation 0.1. This implies an annual growth rate of 0.8 percent. The endogenous growth parameter, ψ, belongs to the normal family withmean 0.2 and standard deviation 0.5. Here, we selected a particularly wide prior and assume the presence of learning-by-doing effects. As Wesselbaum (2015) finds cleansing effects of recessions ($\psi < 0$) a similar result given a prior on learning-by-doing would be stronger evidence compared to a prior on cleansing effects on recessions.

We begin with calibrating household preferences. The discount factor is set to $\beta = 0.99$, which corresponds to an annual interest rate of 4 percent. The steady state interest rate is $R = 1/\beta$.

Unemployment benefits (as share of wages) are set to 60 percent. This value is an average between the values assumed by Shimer (2005) and Hagedorn and Manovskii (2008). The steady state unemployment rate is 10 percent. This higher value is higher than the observed unemployment rate over the sample period to control for workers that are searching but who are not reported as unemployed (effectively out-of-labor force search).

Vacancy posting costs are 0.025. Matches in steady state are computed from $M = (\rho/(1-\rho))N$. The vacancy filling probability is calibrated to be $q = 0.9$. Vacancies in steady state are $V = M/q$, labor market tightness is $\theta = V/U$, and the match efficiency is $m = q\theta^{\varsigma}$. Assuming symmetric bargaining power gives $\eta = 0.5$.

The production function is assumed to be Cobb-Douglas and the elasticity of output w.r.t. labor is 1/3. The depreciation rates are set to $\delta_2 = 0.029$, while $\delta_1 = R^K(1-\tau^K)$ is inferred from the steady state.

The steady state fiscal policy parameters are calibrated to match the empirically observed values: the steady state capital tax rate is 0.184, the consumption tax rate is 0.028, and government consumption is equal to 9.22 percent of total output. The steady state level of government debt is 33.96 percent of output on an annual level. Then, the remaining steady state values are found by solving a linear system of nine equations using Matlab's fsolve function. Then, investment in steady state is given by $I = \delta_0 K$.

4. ESTIMATION RESULTS

4.1. Model Comparison

In this section we want to discuss the implications of endogenous growth with and without equilibrium unemployment. Table 1 presents the log-likelihood values for the four models estimated. We find that the models with the endogenous growth channel ($\psi \neq 0$) generate a better fit to the data than the models without this link. This shows the relevance of the endogenous growth link.

4.1.1. Posterior Estimates

In this section we want to highlight the differences in the posterior estimates across the four estimated models.[9] Again, table 1 presents the posterior estimates while table 2 presents the estimates for the standard deviations of the nine shocks in our models.

We begin by comparing the posterior estimates for the basic RBC model without search and matching frictions. The exogenous growth rate in the model with the endogenous growth link is smaller compared to the model without the link (0.12 vs. 0.33). This shouldn't come at a surprise as the introduction of a second growth channel leaves the overall observed growth

[9]Those four models are: the basic RBC model with and without the endogenous productivity channel and the search and matching model with and without this channel.

TABLE 1.

Posterior estimates for the models with and without search and matching frictions and with and without the endogenous growth link (Endo. Gr.), ψ.

	RBC		Search and Matching	
	No Endo. Gr.	Endo. Gr.	No Endo. Gr.	Endo. Gr.
ϑ Exogenous growth	0.33 (0.33,0.33)	0.12 (0.07,0.18)	0.19 (0.18,0.20)	0.05 (0.03,0.06)
ψ Endogenous growth	–	−0.05 (−0.09,−0.0004)	–	−0.08 (−0.11,−0.05)
σ Risk aversion	2.13 (2.13,2.13)	1.61 (1.57,1.67)	1.92 (1.92,1.92)	1.82 (1.77,1.88)
μ Inverse of Frisch el.	2.04 (2.04,2.04)	2.29 (2.23,2.36)	2.21 (2.20,2.21)	1.84 (1.81,1.86)
χ Habit persistence	0.76 (0.76,0.76)	0.75 (0.72,0.78)	0.44 (0.43,0.44)	0.3 (0.28,0.33)
ς El. of match. fct.	–	–	0.99 (0.99,0.99)	0.99 (0.99,0.99)
ρ Separation rate	–	–	0.06 (0.06,0.06)	0.04 (0.04,0.04)
s Capital adjustment costs	6.39 (6.39,6.4)	5.74 (5.34,6.09)	5.41 (5.4,5.43)	7.27 (7.2,7.33)
δ_0 Capital depreciation rate	0.03 (0.03,0.03)	0.02 (0.02,0.03)	0.07 (0.07,0.07)	0.09 (0.09,0.1)
ρ^Z Technology AR(1)	0.97 (0.97,0.97)	0.96 (0.95,0.96)	0.001 (0,0.002)	0.25 (0.2,0.3)
ρ^i Investment AR(1)	0.97 (0.97,0.97)	0.54 (0.46,0.61)	0.86 (0.85,0.86)	0.91 (0.9,0.92)
ρ^b Preference AR(1)	0.55 (0.55,0.55)	0.99 (0.99,0.99)	0.98 (0.98,0.98)	0.99 (0.99,0.99)
ρ^l Labor supply AR(1)	0.81 (0.81,0.81)	0.78 (0.74,0.83)	0.38 (0.37,0.39)	0.45 (0.41,0.47)
ρ^G Government Spend. AR(1)	0.94 (0.94,0.94)	0.9 (0.89,0.91)	0.81 (0.80,0.82)	0.73 (0.69,0.77)
$\rho^{\tau K}$ Capital tax. AR(1)	0.97 (0.97,0.97)	0.38 (0.23,0.52)	0.8 (0.79,0.81)	0.98 (0.97,0.99)
$\rho^{\tau W}$ Income tax AR(1)	0.58 (0.58,0.58)	0.8 (0.77,0.84)	0.99 (0.99,0.99)	0.91 (0.9,0.91)
$\rho^{\tau C}$ Consumption tax AR(1)	0.56 (0.56,0.56)	0.74 (0.59,0.87)	0.99 (0.99,0.99)	0.99 (0.99,0.99)
ρ^T Transfer AR(1)	0.59 (0.59,0.59)	0.77 (0.74,0.81)	0.001 (0,0.002)	0.4 (0.34,0.44)
LLN	-3335.28	-3072.56	-7514.59	-5479.34

rate unchanged. It does, however, introduce an alternative to exogenous growth, namely the endogenous component. Therefore, if the endogenous growth component is significant, a lower exogenous growth rate should be expected. Further, we find that the value on the endogenous growth link is -0.05 which implies the presence of cleansing effects of recessions.

TABLE 2.

Posterior estimates for the standard deviations for the models with and without search and matching frictions and with and without the endogenous growth link, ψ.

	RBC		Search and Matching	
	No Endo. Gr.	Endo. Gr.	No Endo. Gr.	Endo. Gr.
σ^Z	1.03 (1.03,1.03)	12.86 (11.87,13.96)	9.95 (9.84,10.06)	9.14 (8.45,9.64)
σ^i	8.41 (8.38,8.45)	2.63 (2.35,2.89)	13.1 (13.01,13.19)	29.99 (29.16,30.78)
σ^b	5.5 (5.49,5.52)	6.54 (5.61,7.58)	14.64 (14.6,14.69)	20.49 (19.63,21.71)
σ^l	8.53 (8.53,8.53)	6.64 (6,7.15)	23.46 (23.28,23.67)	85.23 (84.8,85.63)
σ^G	22.8 (22.76,22.84)	27.53 (25.31,29.59)	2.27 (2.24,2.3)	4.82 (3.96,5.78)
$\sigma^{\tau K}$	9.13 (9.11,9.15)	0.09 (0.02,0.17)	15.59 (15.52,15.66)	25.28 (24.59,26.04)
$\sigma^{\tau W}$	16.47 (16.45,16.49)	18.55 (17.36,19.77)	7.95 (7.85,8.02)	33.33 (32.73,33.91)
$\sigma^{\tau C}$	8.34 (8.32,8.36)	0.07 (0.02,0.13)	12 (11.92,12.07)	21.64 (21.01,22.22)
σ^T	13.17 (13.16,13.17)	12.86 (11.87,13.96)	10.73 (10.67,10.8)	8.22 (7.88,8.56)

On the household side of the model we find that agents are less risk averse with endogenous growth (1.61 vs. 2.13) while the inverse of the Frisch elasticity is larger (2.29 vs. 2.04) with endogenous growth. The latter implies a stronger substitution effect of wages on hours worked while the former implies a larger wealth effect on labor supply. In the endogenous growth model, lower wages will lead to an even stronger drop in hours supplied as this will create a positive effect on output through the endogenous growth channel. Habit persistence is unaffected by the introduction of endogenous growth.

Along the firm side of our model we find that capital adjustment costs are sizably smaller (5.74 vs. 6.39) which implies that capital reacts stronger to exogenous disturbances under endogenous growth. Finally, capital depreciates at almost the same rate in both models (0.03 vs. 0.02).

The nine shocks in our model show a fairly high degree of persistence. The main differences are obtained for the investment-specific technology shock, the preference shock which is more, less autocorrelated in the endogenous growth version of the model respectively. Further, we find that the shock to the capital tax rate is less autocorrelated while the other shocks to the two remaining tax rates and transfers show a higher autocorrelation. For the standard deviations we observe that the technology shock is much more volatile in the endogenous growth model, while the investment-specific technology shock is sizably less volatile. Along this line, the shock to the capital and the consumption tax rates are less volatile if we consider endogenous growth.

Next, we discuss the differences across the posterior estimates when we introduce search and matching frictions. As for the RBC model we find that the exogenous growth parameter ϑ is smaller if we add endogenous growth (0.19 vs. 0.05). The endogenous growth component is estimated at a value of -0.08 implying cleansing effects of recessions as the main driver of endogenous growth.

Households are slightly less risk averse (1.82 vs. 1.92) in the endogenous growth model, which also implies a stronger wealth effect in the endogenous growth model which drives down labor supply even further. In contrast, we find that the inverse of the Frisch elasticity is smaller in the model with endogenous growth (1.84 vs. 2.21), which results in a smaller substitution effect on labor supply. Interestingly, habit persistence is smaller in the model with endogenous growth: 0.3 vs. 0.44. Hence, past levels of consumption play a less significant role in the dynamics of consumption over the cycle. Search and matching frictions should increase the persistence of the model, therefore, reducing the need of "ad-hoc" persistence. Capital adjustment costs are sizably higher in the model with endogenous separations (7.27 vs. 5.41) and the capital depreciation rate is higher as well (0.09 vs. 0.07). The labor market is characterized by a high elasticity of the matching function w.r.t. to unemployment and a fairly low separation rate (0.06 and 0.04). In the endogenous growth model we find an even smaller separation rate compared to the basic RBC model which highlights the additional costs of the endogenous growth channel. Optimizing firms affect productivity through the number of workers and the number of hours supplied. Separating from workers is costly due to the time it requires for employment to adjust and because this will affect the ability of firms to steer productivity.

The autocorrelation of the shocks in the search and matching model with endogenous growth tend to be slightly higher compared to the model without endogenous growth. This particularly holds true for the technology shock, the labor supply shock, and the transfer shock. While the autocorrelation are fairly stable across the model the standard deviations are much higher for most of the nine shocks in the model.

Finally, let us compare the posterior estimates with the endogenous growth link but with and without search and matching frictions. We find that the model with search and matching frictions puts a larger emphasis on the endogenous growth component. Assuming a long-term growth rate of roughly 2 percent per annum, we find that there is a significant amount of growth that is not captured by the exogenous growth channel with an annual growth rate of about 0.5 percent in the basic RBC and 0.2 percent in the search and matching model. This further supports the importance of endogenous growth and the relevance of labor market dynamics. Compared to the results by Wesselbaum (2015) found in the endogenous growth augmented Smets and Wouters (2007) model the exogenous growth rate is sizably smaller (0.45 vs. 0.12). This finding might be explained by the absence of two rigidities in our model: price and wage stickiness. The endogenous growth component, ψ, is estimated at a value of -0.08, about 50 percent larger as in the basic RBC model. Again, given that we impose almost no structural assumptions on the endogenous growth channel (apart from being driven by total hours) the data clearly prefers cleansing effects of recessions over learning-by-doing. The values found are in line with the estimates of Wesselbaum (2014) for various versions of the augmented Smets and Wouters (2007) model.

In the search and matching model with endogenous growth households are slightly more risk averse and have a lower inverse of the Frisch elasticity. This implies a stronger wealth effect and a smaller substitution effect in the model with endogenous growth. Firms face higher capital adjustment costs and a higher capital depreciation rate.

Overall, given that our estimations find that $\psi \neq 0$ transitory shocks will have long-run effects through the endogenous growth channel. Hence, transitory demand-side fiscal policy shocks will not just only create short-run effects but will also affect economic growth.

4.1.2. Variance Decomposition

The purpose of this section is to explain the main driving forces of key variables in the models with and without the endogenous growth link and with and without search and matching frictions. Figure 1 presents the unconditional variance decomposition for the basic RBC model with and without the endogenous growth link.

The main driving forces of output in the model without endogenous growth are the labor tax, government spending, and preference shocks. In contrast, for the model without the link, we find that consumption and capital tax shocks as well as the government spending shock are main drivers of fluctuations in output. For hours worked, we find that the preference shock, the labor supply shock, and the government spending shock dominate fluctuations in the model with the endogenous growth link. Without the link, we find that labor supply, investment, and technology shocks drive the fluctuations. For investment, variations are mainly driven by preference and investment-specific technology shocks with the link in place. Without the link, consumption tax shocks and technology shocks explain most of the variations. Consumption is mainly influenced by disturbances to the labor tax, preferences, and government spending. In the model without the link, we find that many shocks drive non-negligible shares of the fluctuations in consumption.

Overall, labor supply shocks (labor tax and labor supply) and preference shocks are main drivers of fluctuations in the key variables in the basic RBC model.

FIG. 1. Variance decomposition for the basic RBC model without search and matching frictions.

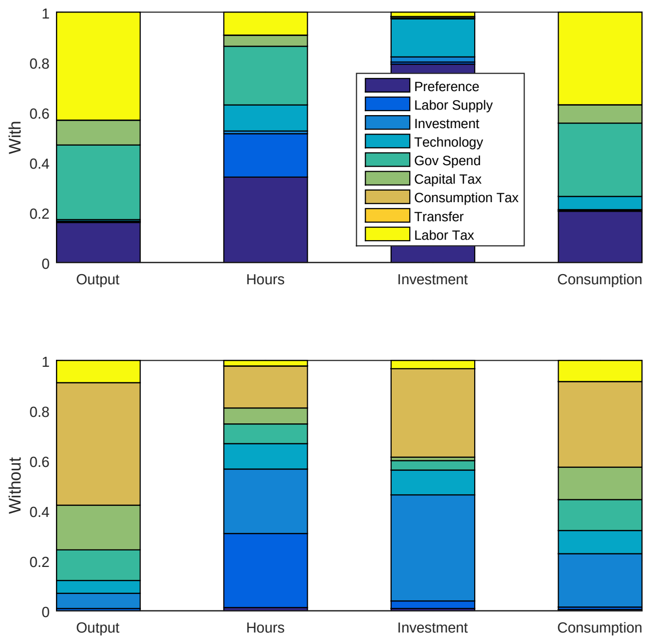
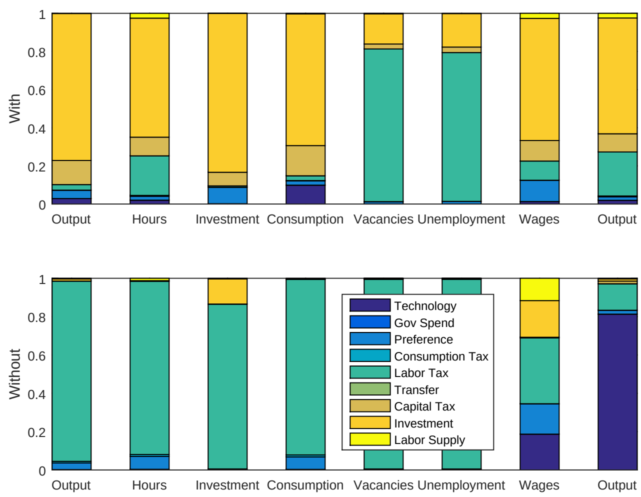


Figure 2 presents the unconditional variance decomposition for the search and matching model with and without the endogenous growth link. In the model without the endogenous growth link the labor tax shock, as a labor supply shock, is the main driver of fluctuations in key variables. Only wages are influenced by several shocks, specifically the labor tax, technology, investment-specific technology, and government spending shocks. The growth rate is driven by technology and labor tax shocks. In the model version with endogenous growth, the investment-specific technology shock explains more than 50 percent of the variation in most variables. Only the two labor market variables vacancies and unemployment are predominantly driven by innovations to the labor tax rate, again, as a labor supply shock. The growth rate, in contrast to the model without the link, is driven by the investment-specific technology shock and, to a lesser extent, by the labor tax shock.

Again, we find that the investment-specific technology shock and the labor tax shock (as a labor supply shock) are the main driving forces of fluctuations in key macroeconomic and labor market variables.

FIG. 2. Variance decomposition for the model with search and matching frictions.

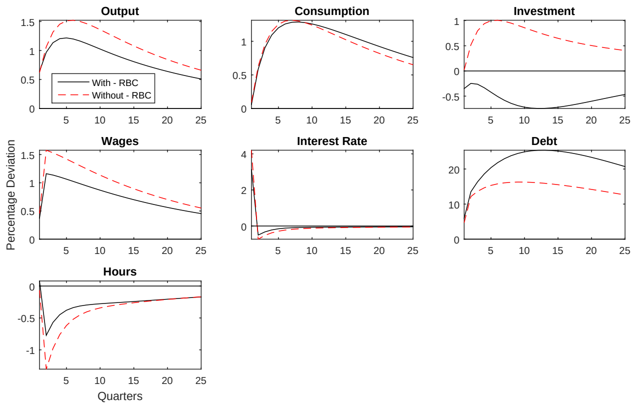


Comparing the main driving forces across models shows that the family of labor supply shocks and investment-specific technology shocks are key drivers of fluctuations. While preference shocks are important in the basic RBC model, they do not play an important role in the search and matching model. Our findings are in line with the results obtained by Wesselbaum (2014) finding that technology shocks and labor supply shocks are key drivers in the augmented Smets and Wouters (2007) model. Further, our findings are in line with the results by Chang and Schorfheide (2007), Smets and Wouters (2007), and Galí et al. (2012) showing that the family of labor supply shocks (labor tax, labor supply, and wage mark-up shocks) is a key driver of variations in output.

4.2. Demand-Side Fiscal Policy

In this section we want to discuss the impulse response functions for a positive government spending shock and highlight the effects of the endogenous growth channel. Figure 3 presents the estimated impulse response functions in the basic RBC model while figure 4 presents the dynamics in the search and matching model.[10]

FIG. 3. Impulse response functions to a government spending shock for the basic RBC model with and without the endogenous growth link.



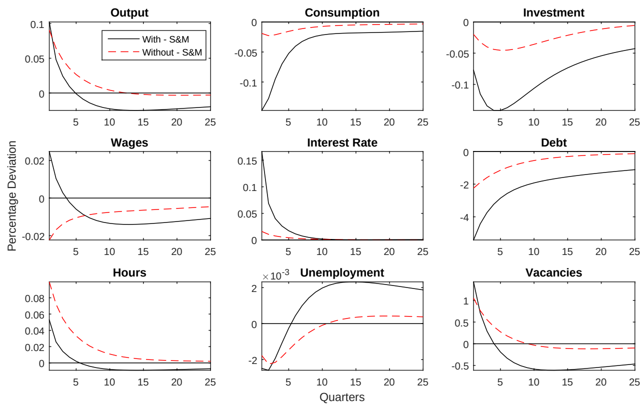
In the basic RBC model a temporary increase in government consumption, for example to counter recessionary effects, will lead to an increase in output. This is the standard demand-side effect of government spending. Then, with higher output wages and the interest rate will increase. The latter puts upward pressure on government debt. Higher wages, given the estimated utility function parameters, will lead to less hours worked and more consumption. Therefore, households consume and invest more.

If we consider the endogenous growth channel and the cleansing effects of recessions found in the estimation, we observe that the output response is amplified. This is the additional endogenous growth channel not present in the standard RBC model. As hours worked decrease, and in the absence of equilibrium unemployment, this create a positive effect on productivity

[10]The size of the estimated shocks can be inferred from table 2.

which boosts output. With higher output wages increase even more. The only qualitative difference is the response of investment. With higher productivity, output increases and hours decrease even further. At the same time, higher productivity reduces the demand (and the return) on new investment projects. Hence, firms can produce a higher output level even with lower investment.

FIG. 4. Impulse response functions to a government spending shock for the search and matching model with and without the endogenous growth link.



In figure 4 we present the estimated impulse response functions for the search and matching model. An increase in government spending, again, increases output. With higher output produced, firms start to post more vacancies in order to increase employment. Consequentially, unemployment decreases and hours worked increase. This puts downward pressure on wages. Due to the higher interest rate and given the estimated parameters in the utility function, consumption and investment decrease. If we consider the endogenous growth channel, we find a much larger response of our economy to the spending shock. Because hours worked and employment increase there is a negative effect on productivity which leads to lower output over the cycle. The difference in the adjustment path for output influences the interest rate and the wage. Wages increase in the model with the endogenous growth channel while they decrease without the negative effect on productivity. The main reason for this finding is the smaller increase in hours worked which puts less upward pressure on wages. Further, firms adjust less along the intensive margin but more along the extensive margin. We find that the adjustment process is much more persistent in the model with the endogenous growth link. Notice that the persistence in this model is less driven by habit persistence as in the basic RBC model.

A key difference between the two models is that government debt increases in the RBC version while it decreases in the search and matching version. The intution for this difference is twofold. First, unemployment, and therefore unemployment benefit payments, decrease in the search and matching model putting downward pressure on debt. Second, and most important, the increase in the interest rate paid on government bonds increases less sizably in the search and matching model. Therefore, the increase in tax revenue outweighs the increase in re-financing costs and debt decreases in the search and matching model.

Overall, we can conclude that government spending will increase output and employment in the short-run but may lead to a decrease in output and employment over the medium-run. Further, our findings show that the effects of demand-side fiscal policies do depend on the endogenous growth channel. Due to the cleansing effects of recessions we find that using government spending is less beneficial than in the baseline scenario.

5. POLICY SCENARIOS

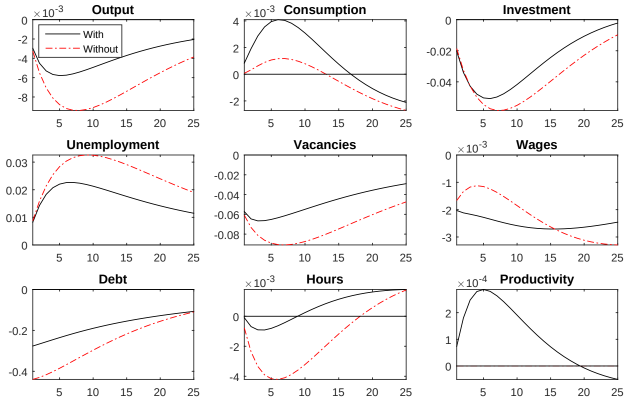
5.1. Recessions

In this section we want to discuss the role of endogenous growth if the economy is driven into a recession. Because we find evidence for cleansing effects of recessions, the endogenous growth channel should be particularly important during recessions; times during which average productivity in the economy should increase because firms engage in productivity-enhancing activities. Figure 5 presents the impulse responses to a negative investment-specific technology shock. Here, in order to isolate the effect of the endogenous growth channel, we keep all parameters except ψ on their respective prior values.[11] The qualitative effects of our model are in line with the estimated impulse response functions by Justiniano et al. (2011).

In response to a decrease in the efficiency of investment, output, investment, hours, and wages fall persistently in a hump-shaped pattern. Lower investment efficiency makes investment activities less profitable and households start to consume more and save (invest) less. Therefore, output decreases which lowers wages. With lower output firms stop posting vacancies and unemployment increases. Through the cleansing effects of

[11] The impulse responses based upon all estimated parameters are available upon request.

FIG. 5. Recession simulation: impulse response functions to a negative investment-technology shock. In this figure we keep all parameter at their prior values except the value for the endogenous growth channel.



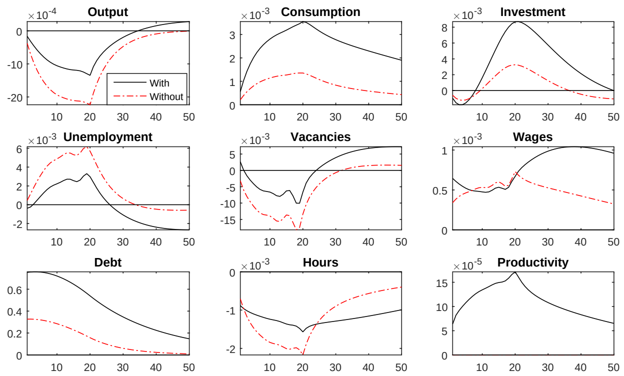
recessions, we observe that productivity increases. Overall, this leads to a less severe recession in terms of peak and duration. Due to the faster recovery of the economy in the endogenous growth model firms start to invest earlier (the investment minimum is reached earlier) and even increase hours worked after two years. The latter has a negative effect on productivity and even turns it negative after five years. We can conclude that the endogenous growth channel plays an important role in the propagation of (negative) shocks to the economy. The cleansing effects of recession act as an automatic stabilizer and limit the adverse effects of recessions.

5.2. Austerity

Since the American Recovery and Reinvestment Act in 2009 fiscal policy in the United States changed dramatically. Since the midterm election in 2010 and the two debt-ceiling crisis in 2011 and 2013 policy makers are on a path of fiscal consolidation. In Europe, the European debt crisis forced many countries into large austerity programs. Spain and Italy, amongst other policy actions, cut government spending by 15 and 13 Billion Euro while Greece was forced to cut government spending by 10 percent.

In this section, we want to highlight the role of endogenous growth for the effects of an austerity program. We consider a 10 percent cut in government spending for 20 quarters. We therefore assume that after five years the economy recovers and allows a gradual increase in government expenditures. Again, we keep the parameters at their respective prior values in order to isolate the effect of the endogenous growth link. Further, this exercise is a counterfactual and not a forecast.

FIG. 6. Austerity: impulse response functions to a negative government spending shock. Government consumption is ten percent lower for five years, then returns back to its steady state value. In this example, we keep all parameters at their prior values except the parameter on endogenous growth.



As shown in figure 6 the cut in government spending generates a recession and an increase in government debt and, therefore, in the debt-to-GDP ratio. Less government spending will lower output. Firms respond by posting fewer vacancies and unemployment increases. With hours going down, workers demand a higher hourly wage. Households consume more due to the income effect of higher wages. Consumption is financed by higher wages and lower investment. However, investment does increase after about 10 quarters when expectation effects start to emerge about the end of the austerity program. With cleansing effects of recessions the decrease in employment and hours worked creates a positive effect on productivity (or growth). This effect dampens the adverse effects of lower government spending on output and unemployment. However, it leads to a stronger build up of government debt due to its effect on the interest rate. We find that in this model, due to the higher productivity, output will overshoot and we observe higher employment after about 6 years.

We can conclude that the effects of the government spending cut, our austerity program, depend on the endogenous growth channel. However, the overall effects of the spending cut are small. Further, given that austerity programs usually are used by countries who already are in a recession we tend to underestimate the effect on productivity. In addition, notice that austerity programs are usually not only related to spending cuts but are a combination of, for example, higher taxes, lower wages for government employees, labor market regulations, and changes in the pension system. Therefore, the overall effect of an austerity program will be different from our results focusing on demand-side fiscal policy measures and should be treated as a lower bound.

Our results are related to, for example, Turnovsky (2000) showing that an increase in government spending would increase the growth rate and employment but decreases consumption. Our results are similar as we show that consumption increases and hours worked decrease: agents substitute away from labor towards consumption. However, Turnovsky's (2000) model, for a cut in government spending, implies a negative effect on growth while our model yields a positive effect on growth. The reason is that in our model an additional channel is present that is absent in Turnovsky's (2000) model: cleansing effects of recessions. They dominate the negative effect of less labor and create positive, although small, effects on growth.

6. ROBUSTNESS

In this section we present four important robustness checks. First, we assess whether different assumptions on the endogenous growth process affect our results. Then, we introduce fiscal rules to allow for an automatic stabilization of economic activity. Finally, we consider productive government spending and introduce government (public) capital.

6.1. Endogenous Growth Process

In this first robustness check we assess the effects of different processes for endogenous growth. So far, we assumed that endogenous growth is driven by total hours worked, the product of individual hours worked, H_t, and employment, N_t

$$\Xi_t = [\vartheta + \psi H_t N_t] \, \Xi_{t-1}.$$

There are at least two different specifications that should be considered: endogenous growth might only be driven by individual hours or might only be driven by employment. Table 3 presents the posterior estimates for those two specifications. We begin with the case that endogenous growth is only driven by employment. We find that the exogenous growth component is much larger compared to the model with total hours worked (0.69 vs. 0.05). Further, we find much stronger cleansing effects of recessions (-1.8 vs. -0.08). Households are more risk averse and reveal a lower inverse of

TABLE 3.

Posterior estimates for the robustness checks.

	With Endo. Gr.	With Empl.	With Hours	Gov. Capital	Fiscal Rules
ϑ Exogenous growth	0.05 (0.03,0.06)	0.69 (0.69,0.69)	0.09 (0.09,0.09)	0.2 (0.20,0.21)	0.04 (0.04,0.04)
ψ Endogenous growth	−0.08 (−0.11,−0.05)	−1.8 (−1.8,−1.8)	−0.01 (−0.01,−0.01)	0.74 (0.7,1.78)	0.27 (0.26,0.27)
σ Risk aversion	1.82 (1.77,1.88)	2.57 (2.57,2.58)	0.67 (0.67,0.67)	1.7 (1.67,1.73)	1.92 (1.92,1.92)
μ Inverse of Frisch el.	1.84 (1.81,1.86)	1.05 (1.04,1.05)	1.28 (1.28,1.28)	2.04 (1.99,2.12)	2.15 (2.15,2.15)
χ Habit persistence	0.3 (0.28,0.33)	0.49 (0.49,0.49)	0.59 (0.59,0.59)	0.83 (0.81,0.85)	0.39 (0.39,0.39)
ς El. of match. fct.	0.99 (0.99,0.99)	1 (1,1)	0.98 (0.98,0.98)	0.99 (0.99,0.99)	0.99 (0.99,0.99)
ρ Separation rate	0.04 (0.04,0.04)	0.08 (0.08,0.08)	0.06 (0.06,0.06)	0.11 (0.11,0.11)	0.08 (0.08,0.08)
s Capital adjustment costs	7.27 (7.2,7.33)	6.73 (6.73,6.74)	6.69 (6.69,6.69)	3.12 (2.98,3.28)	5.88 (5.87,5.88)
δ_0 Capital depreciation rate	0.09 (0.09,0.1)	0.01 (0.01,0.01)	0.04 (0.04,0.04)	0.07 (0.07,0.07)	0.04 (0.04,0.04)
ρ^Z Technology AR(1)	0.25 (0.2,0.3)	0.22 (0.22,0.23)	0.57 (0.57,0.57)	0.53 (0.41,0.65)	0.51 (0.51,0.51)
ρ^i Investment AR(1)	0.91 (0.9,0.92)	0.04 (0.04,0.04)	0.62 (0.62,0.62)	0.92 (0.92,0.93)	0.44 (0.44,0.44)
ρ^b Preference AR(1)	0.99 (0.99,0.99)	0.88 (0.87,0.88)	0.96 (0.96,0.96)	0.84 (0.82,0.86)	0.79 (0.79,0.79)
ρ^l Labor supply AR(1)	0.45 (0.41,0.47)	0.76 (0.76,0.76)	0.56 (0.56,0.56)	0.01 (0.002,0.02)	0.85 (0.85,0.85)
ρ^G Government Spend. AR(1)	0.73 (0.69,0.77)	0.99 (0.99,0.99)	0.52 (0.52,0.52)	0.78 (0.73,0.83)	0.65 (0.64,0.65)
$\rho^{\tau K}$ Capital tax. AR(1)	0.98 (0.97,0.99)	0.52 (0.52,0.52)	0.56 (0.56,0.56)	0.82 (0.81,0.84)	0.99 (0.99,0.99)
$\rho^{\tau W}$ Income tax AR(1)	0.91 (0.9,0.91)	0.95 (0.95,0.95)	0.93 (0.93,0.93)	0.84 (0.82,0.85)	0.86 (0.86,0.86)
$\rho^{\tau C}$ Consumption tax AR(1)	0.99 (0.99,0.99)	0.99 (0.99,0.99)	0.99 (0.99,0.99)	0.34 (0.30,0.38)	0.99 (0.99,0.99)
ρ^T Transfer AR(1)	0.4 (0.34,0.44)	0.0001 (0.0001,0.0002)	0.52 (0.52,0.52)	0.83 (0.81,0.84)	0 (0,0)

the Frisch elasticity. Habit persistence is higher (0.49 vs. 0.3) and firms face lower capital adjustment costs and a lower capital depreciation rate.

Next, we consider the alternative that endogenous growth is driven only by individual hours worked. In this scenario, we obtain values closer to the ones with total hours worked. Exogenous growth is roughly twice as larger (0.09 vs. 0.05) while the endogenous growth component is much smaller (-0.01 vs. -0.08). Again, we obtain cleansing effects of recessions. Households are less risk averse (0.67 vs. 1.82) and face a lower inverse of the Frisch elasticity (1.28 vs. 1.84). Firms face roughly the same capital adjustment costs but deal with a higher depreciation rate. Labor markets in both specifications are characterized by a higher job separation rate.

We can conclude that the endogenous growth parameter, ψ, is robust to changes in the specification of the endogenous growth process.

6.2. Fiscal Rules

Up to this point we considered fiscal policy to be purely exogenous (or discretionary). A more realistic modelling approach takes into account automatic stabilization, i.e. endogenous fiscal policy. To do so, we assume fiscal rules for our five fiscal instruments following Leeper et al. (2010)

$$\ln G_t = \varphi_G \ln Y_{t-1} + \gamma_G \ln B_{t-1} + u_t^G, \tag{39}$$
$$\ln \tau_t^K = \varphi_K \ln Y_{t-1} + \gamma_K \ln B_{t-1} + u_t^K, \tag{40}$$
$$\ln \tau_t^W = \varphi_W \ln Y_{t-1} + \gamma_W \ln B_{t-1} + u_t^W, \tag{41}$$
$$\ln \tau_t^C = \varphi_C \ln Y_{t-1} + \gamma_C \ln B_{t-1} + u_t^C, \tag{42}$$
$$\ln T_t = \varphi_T u_t^W + \gamma_T u_t^K + u_t^T, \tag{43}$$

where the shocks u_t are all AR(1). Those rules have a short-run target, output, and a long-run target, debt. The estimation results are again presented in table 3 while the estimates for the fiscal rule parameters are shown in table 4.

TABLE 4.

Fiscal rule parameters.

	Fiscal Rules		Fiscal Rules
φ_G Spending output coeff.	−0.11	γ_G Spending debt coeff.	0.21
φ_K Capital tax output coeff.	2.15	γ_K Capital tax output coeff.	0.46
φ_W Labor tax output coeff.	0.74	γ_W Labor tax output coeff.	−0.2
φ_C Consumption tax Labor tax coeff..	0.1	γ_C Consumption tax capital tax coeff..	0.44
φ_T Transfer output coeff.	0.4	γ_T Transfer output coeff.	0.17

We find that while the exogenous growth parameter is unaffected (0.04 vs. 0.05) we obtain a positive endogenous growth parameter (0.27). This implies that in this model learning-by-doing effects dominate. Households are less affected by the introduction of fiscal rules with a slightly higher inverse of the Frisch elasticity such that the substitution effect on labor supply is larger with fiscal rules. Habit persistence is slightly larger (0.39

vs. 0.3) while firms face lower capital adjustment costs (5.88 vs. 7.27) and a lower capital depreciation rate (0.04 vs. 0.09). Finally, we find a higher job separation rate with fiscal rules compared to our baseline search and matching estimation.

The fiscal rule parameters reveal procyclicality for most instruments. Only the reaction of government spending to output and the reaction of labor taxes to government debt are negative, implying countercyclicality in those targets. The fiscal policy maker responds strongly to changes in output by adjusting capital taxes and labor taxes but the consumption tax and the transfer are less responsive to changes in the short-run target. In response to changes to the long-run target, debt, the largest response is found for the capital tax and the consumption tax.

We can conclude that the design of fiscal policy has strong implications for the endogenous growth channel. With fiscal rules in place we should expect a smoother business cycle and less discretionary adjustments in the fiscal instruments. Therefore, there are less (discretionary) shocks to those instruments which affects labor market dynamics, especially unemployment and vacancies. With different underlying driving forces (labor supply is now a key driver besides the labor tax) optimizing firms behave differently and the estimation picks learning-by-doing over cleansing effects of recessions.

6.3. Government Capital

A different, important extension to the model is to consider productive government expenditures. The model so far only considers wasteful government consumption that only generates demand-side effects in the model without the endogenous growth link. In the data, however, governments allocate spending between wasteful and productive expenditures (infrastructure investment, for example). By adding government capital to the model we control for the positive growth effects from productive government spending.

In this model extension, the production function is given by

$$Y_{it} = Z_t \Xi_t \left(\kappa_{it} K_{it-1}\right)^{\alpha_0} \left(H_{it} N_{it}\right)^{\alpha_1} \left(K_t^G\right)^{\alpha_2}, \tag{44}$$

where K_t^G is the public capital stock and α_2 is the elasticity of the production function w.r.t. the capital stock. The depreciation rate of the public capital stock is given by $\delta_G > 0$.

We find that the exogenous growth component is four times larger as in the baseline search and matching model (0.2 vs. 0.05). In contrast to the cleansing effects of recessions controlling for public capital gives a positive coefficient (0.74) for the endogenous growth link and, hence, we find learning-by-doing effects. Overall, the endogenous growth component is less important in this model as a larger share of the roughly 2 percent annual growth rate is explained by the exogenous growth component (0.8 percent annually). Still, according to this rough calculation, more than 50 percent of the annual growth rate is explained by endogenous growth.

Households are slightly less risk averse and feature a slightly higher inverse of the Frisch elasticity. Firms face much lower capital adjustment costs (3.12 vs. 7.27) and a lower capital depreciation rate. The labor market is characterized by a much larger separation rate (0.11 vs. 0.04). The elasticity of the production function w.r.t. public capital is estimated at a low value of 0.02 which is much lower compared to the usually found values of about 0.15 (see Bom and Ligthart (2009)). Public capital depreciates at a rate of 0.05 which is twice as large as the value reported by the BEA of roughly 0.02.

7. CONCLUSION

This paper considers permanent effects of transitory demand-side fiscal policy shocks. Short-run fluctuations are generated by an RBC model with a rich fiscal policy specification. Those short-run fluctuations can have long-run effects due to an endogenous growth channel. Following Galí and Hammour (1991), the model features a mainly atheoretical and parsimonious approach to model this link. The main advantage of this approach is that it allows to distinguish between learning-by-doing effects and cleansing effects of recessions.

Further, we emphasize that this link between short- and long-run fluctuations - which is usually ignored in DSGE models - is influenced by labor market dynamics. Because productivity depends on total hours worked, labor market dynamics have an effect on productivity. Therefore, we include search and matching frictions in our model and discuss the importance of labor market frictions. Then, we estimate the model using Bayesian methods on U.S. data.

Several findings stand out. The model with the endogenous growth channel generates a better fit to the data compared to the model without the link. The endogenous growth channel is more important if we consider labor market frictions. In our baseline scenario, the endogenous growth component is estimated at a value of -0.08 implying the presence of cleansing effects of recessions. Assuming a long-term growth rate of roughly 2 percent, a significant amount of growth is not explained by exogenous growth generating an annual growth rate of about 0.5 percent in the basic

RBC and 0.2 percent in the search and matching model. The main driving forces of fluctuations are labor supply shocks and investment-specific technology shocks.

We can therefore support our initial claim that demand-side fiscal policies can have long-run effects. Overall government spending will increase output and employment in the short-run but lead to a decrease in output and employment over the medium-run. The effects crucially depend on the endogenous growth channel. Due to the cleansing effects of recessions we find that using government spending is less beneficial than in the baseline scenario.

Further, we perform several robustness checks showing that the results are robust to different specifications of the endogenous growth process. In contrast, we find learning-by-doing effects if we introduce automatic stabilizers via fiscal rules and public capital. We can draw the conclusion that the design of fiscal policy has strong implications for the endogenous growth channel.

Finally, we perform two policy exercises: simulating a recession and an austerity program. Due to the cleansing effects of recessions, we observe that productivity increases in a recession. This limits the effects of the recession by lowering the peak and duration. Put differently, cleansing effects of recession act as an automatic stabilizer.

The second policy experiment is an austerity program. We find that the effects of a government spending cut depend largely on the endogenous growth channel while the overall effects are small. Lowering government spending creates a recession, lowering output and employment and increasing government debt. Positive effects are the increase in investment and the positive effect on productivity.

Further research will look at the effects of tax policies and the effects of changes to the policy mix between spending and revenues.

REFERENCES

Arrow, Kenneth, 1962. The Economic Implications of Learning by Doing. *Review of Economic Studies* **29**, 155-173.

Baier, Scott and Gerhard Glomm, 2001. Long-run Growth and Welfare Effects of Public Policies with Distortionary Taxation. *Journal of Economic Dynamics and Control* **25**, 2007-2042.

Barbiero, Omar and Boris Cournède, 2013. New Econometric Estimates of Long-term Growth Effects of Different Areas of Public Spending. OECD Economics Department Working Papers, No. 1100.

Barro, Robert, 1990. Government Spending in a Simple Model of Endogeneous Growth. *Journal of Political Economy* **98** 103-125.

Barro, Robert and Xavier Sala-i-Martin, 1992. Public Finance in Models of Economic Growth. *Review of Economic Studies* **59**, 645-661.

Barseghyan, Levon and Marco Battaglini, 2015. Political Economy of Debt and Growth. NBER Working Papers 21660.

Bom, Pedro and Jenny Ligthart, 2009. How Productive is Public Capital? A Meta-Regression Analysis. International Center for Public Policy Working Paper Series, No. 0912.

Caballero, Ricardo and Mohamad Hammour, 1994. The Cleansing Effect of Recessions. *American Economic Review* **84**, 1350-1368.

Chang, Yongsung and Frank Schorfheide, 2007. Labor Supply Shifts and Economic Fluctuations. Richmond FED Working Paper, No. 03-07.

Christiano, Lawrence, Martin Eichenbaum, and Charles Evans, 2005. Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy. *Journal of Political Economy* **113**, 1-45.

Cooper, Russell and John Haltiwanger, 1993. The Aggregate Implications of Machine Replacement: Theory and Evidence. *American Economic Review* **83**, 181-186.

Galí, Jordí and Mohamad Hammour, 1991. Long Run Effects of Business Cycles. First Boston Working Paper Series FB-92-26, Columbia Graduate School of Business.

Galí, Jordí, Frank Smets, and Rafael Wouters, 2012. Unemployment in an Estimated New Keynesian Model. NBER Macroeconomics Annual 26: 329-360.

Gemmell, Norman, Florian Misch, and Blanca Moreno-Dodson, 2012. Public Spending for Long-Run Growth: A Practitioners' View. World Bank, Economic Premise, No. 99.

Hagedorn, Marcus and Iourii Manovskii, 2008. The Cyclical Behavior of Equilibrium Unemployment and Vacancies Revisited. *American Economic Review* **98**, 1692-1706.

Hall, Robert, 1991. Labor Demand, Labor Supply, and Employment Volatility. In NBER Macroeconomics Annual, 17-47.

Jones, Larry and Rodolfo Manuelli, 2005. Neoclassical Models of Endogenous Growth: The Effects of Fiscal Policy, Innovation, and Fluctuations. *Handbook of Economic Growth* **1**, 13-65.

Jones, Larry, Rodolfo Manuelli, and Peter Rossi, 1993. Optimal Taxation in Models of Endogenous Growth. *Journal of Political Economy* **101**, 485-517.

Justiniano, Alejandro, Giorgio Primiceri, and Andrea Tambalotti, 2011. Investment Shocks and the Relative Price of Investment. *Review of Economic Dynamics* **14**, 101-121.

King, Robert and Sergio Rebelo, 1990. Public Policy and Economic Growth: Developing Neoclassical Implications. *Journal of Political Economy* **98**, 126-150.

Lee, Yoonsoo and Toshihiko Mukoyama, 2015. Entry and Exit of Manufacturing Plants over the Business Cycle. *European Economic Review* **77**, 20-27.

Leeper, Eric, Michael Plante, and Nora Traum, 2010. Dynamics of Fiscal Financing in the United States. *Journal of Econometrics* **156**, 304-321.

Lucas, Robert, 1988. On the Mechanics of Economic Development. *Journal of Monetary Economics* **22**, 3-42.

Mehra, Rajnish and Edward Prescott, 1980. Recursive Competitive Equilibrium: The Case of Homogeneous Households. *Econometrica* **48**, 1365-1379.

Merz, Monika, 1995. Search in the Labor Market and the Real Business Cycle. *Journal of Monetary Economics* **36**, 269-300.

Mortensen, Dale and Christopher Pissarides, 1994. Job Creation and Job Destruction in the Theory of Unemployment. *Review of Economic Studies* **61**, 397-415.

Pissarides, Christoper, 2000. Equilibrium Unemployment Theory. MIT Press.

Rebelo, Sergio, 1991. Long-Run Policy Analysis and Long-Run Growth. *Journal of Political Economy* **99**, 500-521.

Saint-Paul, Gilles, 1997. Business Cycles and Long-Run Growth. *Oxford Review of Economic Policy* **13**, 145-153.

Schmitt-Grohé, Stephanie and Martín Uribe, 2008. What's 'News' in Business Cycles? NBER Working Paper, No. 14215.

Shimer, Robert, 2005. The Cyclical Behavior of Equilibrium Unemployment and Vacancies. *American Economic Review* **95**, 24-49.

Smets, Frank and Rafael Wouters, 2007. Shocks and Frictions in U.S. Business Cycles: A Bayesian DSGE Approach. *American Economic Review* **97**, 586-606.

Stadler, George, 1990. Business Cycle Models with Endogenous Technology. *American Economic Review* **80**, 763-778.

Turnovsky, Stephen, 2004. The Transitional Dynamics of Fiscal Policy: Long-Run Capital Accumulation and Growth. *Journal of Money, Credit, and Banking* **36**, 883-910.

Turnovsky, Stephen, 2000. Fiscal Policy, Elastic Labor Supply and Endogenous Growth. *Journal of Monetary Economics* **45**, 185-210.

Wesselbaum, Dennis, 2015. What Drives Endogenous Growth in the United States? B.E. *Journal of Macroeconomics* **15**, 183-221.