UCD CENTRE FOR ECONOMIC RESEARCH

WORKING PAPER SERIES

2019

**Investment Tax Incentives and
Their Big Time-to-Build Fiscal Multiplier**

Dimitrios Bermperoglou, Kiel Institute of the World Economy
Yota Deli, University College Dublin
Sarantis Kalyvitis, Athens University of Economics and Business

WP19/27

November 2019

**UCD SCHOOL OF ECONOMICS
UNIVERSITY COLLEGE DUBLIN
BELFIELD DUBLIN 4**

Investment Tax Incentives and Their Big Time-to-Build Fiscal Multiplier*

Dimitrios Bermperoglou† Yota Deli‡
Sarantis Kalyvvitis§

November 4, 2019

Abstract

This paper studies how investment tax incentives stimulate output in a medium-scale DSGE model, which allows for a variety of fiscal financing mechanisms. We find that the horizon following a positive shock in investment tax incentives is crucial. The shock is highly expansionary in the long run, with the relevant fiscal multiplier substantially exceeding 1, but this effect only becomes visible after two to three years. Our analysis indicates that a rise in the marginal product of labor and the demand for labor trigger this expansion, which is an effect that partial equilibrium studies ignore. Our analysis also contributes to the time-to-build profile of the fiscal multiplier. The results suggest that investment tax incentives are even more effective when nominal wages adjust faster.

JEL classification: E32, E60, E62.

Keywords: private investment incentives, investment tax credit, fiscal multiplier.

*An appendix is available at http://www2.aueb.gr/users/kalyvitis/. We would like to thank Michael Oywang and seminar participants at UCD, ESRI, University of Manchester, Kent University, IMAEF, IEA, University of Limerick, and University of Glasgow for many helpful comments and suggestions.

†Kiel Institute of the World Economy, Germany. Email: demitrios.bermperoglou@ifw-kiel.de

‡UCD School of Economics, Ireland. Email: yota.deli@ucd.ie

§Athens University of Economics and Business, Greece. Email: skalyvitis@aueb.gr

1 Introduction

Governments use a variety of tax incentives to stimulate private investment. These incentives take the form of traditional subsidies for the purchase of new investments, investment allowances (e.g., bonus depreciation) that reduce taxable income, and tax credits that directly reduce tax liability.[1] Investment allowances and investment tax credits (henceforth, ITC) historically have been a policy instrument implemented in many countries, including the United States, United Kingdom, Canada, France, and Italy.[2] Each country might provide these incentives to all firms or to specific industries (for example, R&D or energy). Despite the appealing nature of such policies in terms of boosting output, opinions in the literature range from irrelevance to the belief that the impacts of these policies on the macroeconomy are, at best, moderate. These opinions are mainly based on partial equilibrium theoretical and empirical specifications that do not address the behavior of forward-looking policy or the interactions with other markets.

This paper quantifies and explains the general equilibrium effects of investment tax incentives. To assess the size and significance of these incentives on output and other key aggregates, we examine the magnitude and time profile of the fiscal multiplier in an estimated medium-scale Dynamic Stochastic General Equilibrium (DSGE) model with nominal rigidities based on U.S. data, along the lines of Smets and Wouters (2007) and Justiniano et al. (2010). Our main analysis is based on the impact of a

[1] We stress that private investment incentives provide tax benefits over and above the depreciation allowed for the asset. Hence they differ from standard depreciation allowances, which permit investors or businesses to deduct a specified percentage of certain capital costs, based on their book value, from taxable income.

[2] Also, bonus deprecation schemes are currently in use in the United States (50% rate at the federal level), among other countries. A detailed description of all types of investment tax incentives used globally is in *Worldwide Corporate Tax Guide* (2018). An analytical description of the investment tax incentives implemented in the United States and their changes is in table 2 of House et al. (2019). The European Commission (2014) report describes the implementation of these incentives in EU countries.

temporary shock in investment tax incentives (captured by an ITC shock), which permit firms to deduct a percentage of their current investment costs from their tax liability. The model features a rich fiscal policy sector in which ITC and other spending and tax policies interact endogenously, whereas the availability of ITC series permits us to estimate a policy rule for the ITC rate.

Our main finding is that a temporary increase in the ITC rate has a pronounced and persistent, yet delayed, effect on output. In particular, we find that the *long-run* multiplier of ITC is above unity, significantly exceeding the corresponding government consumption, labor tax, or capital tax multipliers. In our benchmark model, the median fiscal multiplier reaches 1.42 five years after the ITC shock, while the respective multipliers for government consumption and income tax shocks are always below 1. This means that an unexpected rise in investment-related tax credits equal to 1% of GDP increases aggregate output by 1.42%. On the flip side, this effect takes time to materialize; our estimates indicate that the positive impact becomes visible two to three years following the ITC shock. Notably, our results hold when private investment incentives take the form of investment allowances rather than tax credits.

To put these numbers into perspective from a policy point of view, consider a change in the temporary ITC rate from 0% to 10% in the United States. Our estimates imply that, on average, output will be 1.8% higher after five years compared to the baseline output. A surge in private investment will fuel this rise, which will be higher by 13.2% after five years compared to the baseline and will outweigh the adverse effects of the rise in distortionary taxation needed to maintain fiscal solvency.

The mechanism that drives this result passes through what we call a *labor demand effect.* In particular, the marginal product of labor rises following the ITC shock and the induced rise in capital accumulation. This goes beyond the standard negative wealth effect triggered by shocks to government spending or taxes, which crowds out private consumption and investment, along with a rise in labor supply that lowers the real wage rate (see e.g., Ramey, 2011). On the contrary, there is a gradual and persistent increase in investment and output, as the fall in the after-tax price of investment and the induced increase in capital accumulation create a positive shift in labor demand and increase employment and the real wage rate. This channel is strong enough to offset the aforementioned negative wealth effect. Notably, a partial equilibrium approach does not capture this mechanism, because it would identify only the standard decline of the after-tax price of investment and the subsequent rise in the demand for investment. Our results are robust to nominal and real frictions that propagate shocks to investment tax incentives and to a two-sector model specification in which the relative price of investment is allowed to vary. Investment tax incentives are even more effective when nominal wages adjust faster.

Our paper contributes to two strands of the literature: that which analyzes how private investment incentives affect output and that which assesses the size of the fiscal multiplier. First, our paper follows Edge and Rudd (2011), who examine the macroeconomic effects of temporary partial expensing allowances on business investment in a calibrated new-Keynesian model. In a model with nominal rigidities, they find a large investment response, which exceeds that of a partial equilibrium model. Recently, House et al. (2019) assess the responses to investment tax incentives in an open economy model and find that they increase investment, employment, real wage rates and output, with about half of the rise coming from increased domestic production. Also, in an empirical study, Zwick and Mahon (2017) estimate the effects of bonus depreciation on firm investments and find that investment increases affect mainly smaller firms, especially when these incentives generate immediate cash flows. Our results extend the evidence in two ways. First, by showing how these incentives operate in the macroeconomy, namely through the rise in labor demand that raises hours worked, the real wage, and output, and eliminates the crowding out of private investment. Second, by assessing the quantitative implications of this channel based on a full-information Bayesian approach. This *labor demand effect* contributes to the time-to-build profile of the estimated ITC multiplier. Thus, we are able to quantify and explain structurally the general equilibrium effects of fiscal policy in the form of investment tax incentives in the context of the estimated fiscal multipliers over the short and long run.

In addition, in its analysis on the size of the fiscal multiplier, our paper builds on Uhlig (2010), Leeper et al. (2010), and Zubairy (2014), who address the effects of fiscal policy in the context of the American Recovery and Reinvestment Act (ARRA) of 2009. The assessment is based on the net present fiscal multiplier, which stresses the importance of the long-run consequences of fiscal stimuli. Uhlig (2010) finds that the multiplier for government spending turns negative as the horizon increases. Leeper et al. (2010) use a frictionless real business cycle model to estimate the multipliers for tax and government spending shocks, and they investigate the role of fiscal financing, which allows for responses to output and government debt as "automatic stabilizers," for the size of the multiplier. They find that short-run multipliers can differ markedly from long-run multipliers, even in their signs. Zubairy (2014) estimates a medium-scale new-Keynesian model with nominal rigidities and deep habits in private consumption. That study reports multipliers for income taxes and government spending. Our fiscal policy environment builds on Leeper et al. (2010) and Zubairy (2014) using a rich fiscal policy block with endogenous policy rules. As a starting point in our analysis, we show that our estimates of the multipliers for income tax and government spending shocks are in line with the aforementioned papers. Our analysis further reveals an important policy trade-off between the modest short-run effects of the ITC shocks on output and their long-run effectiveness when compared to traditional fiscal instruments.

The rest of the paper is organized as follows. Section 2 outlines the existing literature on the effectiveness of ITC policies. Section 3 briefly discusses the theoretical model. Section 4 introduces the data, the estimation methodology, and the results from the Bayesian estimation. Section 5 presents the main results on impulse responses and fiscal multipliers. Section 6 inspects the mechanism, and section 7 concludes.

2 Evaluating the effectiveness of investment tax incentives

The debate in the literature on the effectiveness of investment tax incentive policies is based on the contrast between the theoretical literature that suggests these policies can increase total output under specific circumstances through increased investment, and the majority of empirical literature that finds little or no impact of such policies. The literature that examines the effects of such policies goes back to Auerbach and Summers (1979), who suggest that ITC and other forms of tax incentives on investment tend to destabilize the economy, whereas their quantitative effects are much smaller than anticipated.

From a theoretical perspective, Abel (1982) shows that a temporary ITC might reduce investment when it takes the form of accelerated depreciation allowances in an inflationary environment. In a model with discrimination between new and old investment, Lyon (1989) argues that if tax incentives apply only to new investment, the value of the existing capital assets may decline and therefore the ITC may have ambiguous results. Huffman (2008) considers a model with endogenous investment-specific technological change, in which the changing relative price of capital is driven by research activity undertaken by labor effort as increased spending on research lowers the future cost of producing capital. That study finds it optimal to impose both a capital tax and an ITC, whereas labor taxation should equal zero. Altug et al. (2009) study the effects of a temporary ITC and its persistence on the decisions of a monopolistically competitive firms; it finds that it does not always lead to higher investment but always leads to more volatile investment.

When it comes to empirical studies, some papers estimate the partial effects of the implementation of ITC policies on economic activity but find no significant effects.[3] Bronzini et al. (2008) and Caiumi (2011) examine the effects of an ITC-related program in Italy and find mixed evidence on its effectiveness. Kato et al. (2009) consider a 100% tax credit established in 2001 in Hawaii and show that, albeit generous, the tax cut was inefficiently used. Klemm and Van Parys (2012) use a data-set of tax incentives for over 40 developing countries covering 1985-2004 and find that investment tax incentives do not boost private investment. Zwick and Mahon (2017) use micro-level data from the United States to examine the effects of changes in bonus depreciation and find a positive impact on investment, especially for smaller firms, whereas the effect on long-term capital stock is ambiguous. Notably, firms only respond to investment incentives when the policy immediately generates cash flows. Finally, Chen et al. (2018) examine how the implementation of ITC affects Chinese companies and find a positive effect on fixed investment, especially when these companies are less financially constrained.

[3] For an overview, see Holland and Vann (1998).

3 The model

This section briefly describes the details of a general equilibrium model introducing investment tax incentives (the full version of the model is in the online appendix). The model follows Christiano et al. (2005), Smets and Wouters (2007), and Justiniano et al. (2010), and it features nominal rigidities and frictions in the consumption and investment decisions of households and firms, a public sector that conducts fiscal policy, and a monetary policy authority. It is also characterized by several exogenous shocks in order to fit U.S. business cycles as much as possible. In particular, following Justiniano et al. (2010) we include a price and wage mark-up shock, a TFP shock, a preference shock in the consumers' utility, an investment-specific shock, and shocks to fiscal and monetary policy rules.

The economy is populated by six types of agents: (a) monopolistically competitive intermediate firms that use capital and labor to produce an intermediate good; (b) perfectly competitive retailers that use a technology that transforms one unit of intermediate good to one unit of final good for consumption or investment; (c) households that own and accumulate capital, consume the final good, and supply differentiated labor; (d) monopolistically competitive labor agencies that combine differentiated labor services and sell them to firms; (e) a government sector that conducts fiscal policy using government spending, labor, and capital taxes, as well as investment tax credits as policy instruments; and (f) an independent monetary policy authority that sets the interest rate according to a Taylor rule, which corrects inflation and output deviations from the steady state.

Also, we assume that wages are sticky in the short run, with wage rigidities arising at the household level. Price rigidities arise at the retail level, so as to generate a demand effect after a fiscal shock. We consider a rich fiscal policy structure where the fiscal instruments endogenously adjust for output and government debt deviations from the steady state, as in Leeper et al. (2010) and Zubairy (2014). Investment tax incentives enter the household sector either as an investment tax credit (ITC) rate formed as a subsidy on the purchase of investment goods (price subsidy) or as investment allowances (bonus depreciation) that alter the tax base. In the benchmark model description that follows, we consider investment tax incentives in the form of ITC.

3.1 Equations affected by the ITC

The household derives utility from consumption, c_t and is a monopolistic supplier of labor, l_t. It owns capital stock, $\bar{k}_{t-1}$, uses it at a utilization rate, u_t, and spends on new investment, i_t. Also, it receives income from renting capital to the intermediate firm at a real rate, r_t, from the firms' profits, Π_t, and also from working at a real wage rate, w_t. The nominal wage rate is optimally set by the labor agencies. The household holds its financial wealth in bonds, B_{t-1}, and chooses sequences $\{c_t, B_t, \bar{k}_t, i_t, u_t, l_t, w_t\}$ so as to maximize its expected lifetime utility subject to the intertemporal budget constraint:

$$c_t+(1-itc_t)i_t+B_t = (1-\tau_t^k)r_t u_t \bar{k}_{t-1}+(1-\tau_t^l)w_t l_t+T_t+\Pi_t+R_{t-1}\frac{B_{t-1}}{\pi_t}-\kappa(u_t)\bar{k}_{t-1}, \tag{1}$$

where R_t is the gross interest rate, π_t is the gross price inflation rate, τ_t^k and τ_t^l denote the tax rates on capital income and labor income, and T_t are lump-sum transfers. The variable itc_t stands for the ITC expressed as a subsidy rate to investment.[4]

[4] Investment tax incentives in the United States have historically taken the form of either a tax credit (savings per unit of investment) as modelled here, or the form of investment allowances (tax base deductions) as described in section 5.3. We also estimate models where firms own the capital of the economy and the investment tax

From the fiscal policy side, the government finances its expenditures by taxing income on labor and capital with tax rates τ_t^l and τ_t^k respectively, and by issuing new debt, which in real terms is denoted by B_t. Government expenditures consist of government spending on goods and services, g_t, investment tax incentives (here formed as ITC, itc_t), lump-sum transfers T_t, and debt repayment. The government budget constraint is:

$$g_t + itc_t i_t + T_t + R_{t-1}\frac{B_{t-1}}{\pi_t} = \tau_t^l w_t l_t + \tau_t^k r_t k_t + B_t. \tag{2}$$

The five fiscal policy instruments $g_t, itc_t, \tau_t^k, \tau_t^l, T_t$ are modelled as simple policy rules that react endogenously to the state of the economy, captured by output deviations from its steady state, and to the government debt in order to ensure fiscal solvency. In particular, the ITC rate, the income tax rates $x_t \in \{\tau_t^k, \tau_t^l\}$, and spending and transfers $m_t \in \{g_t, T_t\}$ follow the processes:

$$\begin{aligned} \widehat{itc}_t &= -\rho_{itc,y}\widehat{y}_t - \rho_{itc,b}\hat{b}_{t-1} + \widehat{e}_t^{itc}, \\ \widehat{e}_t^{itc} &= \rho_{itc}\widehat{e}_{t-1}^{itc} + \varepsilon_t^{itc}, \\ \varepsilon_t^{itc} &\sim i.i.d.N(0, \sigma_{itc}^2), \end{aligned} \tag{3}$$

$$\begin{aligned} \widehat{x}_t &= \rho_{x,y}\widehat{y}_t + \rho_{x,b}\hat{b}_{t-1} + \widehat{e}_t^x, \\ \widehat{e}_t^x &= \rho_x\widehat{e}_{t-1}^x + \varepsilon_t^x, \\ \varepsilon_t^x &\sim i.i.d.N(0, \sigma_x^2), \end{aligned} \tag{4}$$

incentive is either a tax credit or an investment allowance for corporate profits. They produce very similar results.

$$
\begin{aligned}
\widehat{m}_t &= \rho_{m,y}\widehat{y}_t - \rho_{m,b}\hat{b}_{t-1} + \widehat{e}_t^m, \\
\widehat{e}_t^m &= \rho_m \widehat{e}_{t-1}^m + \varepsilon_t^m, \\
\varepsilon_t^m &\sim i.i.d.N(0, \sigma_m^2),
\end{aligned} \tag{5}
$$

where hats denote log-deviations from steady-state values. The innovations $\varepsilon_t^{itc}, \varepsilon_t^x, \varepsilon_t^m$ are white noise processes, uncorrelated among them. The three policy rules for the various instruments presented above only differ in the signs of the output and debt terms in order to assign prior distributions conveniently for the adjustment parameters ρ later in the estimation part.

4 Estimation methodology

4.1 Data

The estimation uses a standard Bayesian approach (Smets and Wouters, 2003) and U.S. quarterly data for 1964-2006. We consider eleven observable variables to match exactly the number of the shocks in the model. The observable variables are: private consumption (c_t), private investment (i_t), government spending (g_t), hours worked (l_t), the average labor income tax rate (τ_t^l), the average capital tax rate (τ_t^k), the investment tax credit rate (itc_t), government debt (b_t), price inflation (π_t^p), the wage rate (w_t), and the interest rate (R_t). Consumption, investment, government spending, and government debt are transformed into real per capita terms by dividing them by the GDP deflator and the U.S. population. Hours worked are also expressed in per capita terms by dividing by the population. The wage rate is transformed into real terms by dividing it by the GDP deflator. Price inflation is the quarterly growth rate of the GDP deflator. The average labor income and capital income tax rates are based on the national accounts (NIPA tables) following Jones (2002). All fiscal policy variables account for both the federal and state government by appropriately merging the original series of the two government levels.

Chirinko and Wilson (2008) provide the historical legislated investment tax credit rates for the U.S. federal and the state governments for 1964-2006.[5] It is important to take into account both the federal and state variation in the ITC rates as these policies are implemented at both levels.[6] These rates measure the credit against state and federal corporate income tax liabilities. We construct the average (federal and state) ITC rate by dividing total (federal and state) credits by the tax base (total investment expenditures):

$$\overline{itc} = \frac{\sum_i \left(itc^F + itc_i^S\right) \times I_i}{\sum_i I_i} \tag{6}$$

where itc^F and itc_i^S are the legislated federal and state ITC rates, and I_i is investment expenditures of state i.[7]

Since the model is log-linearized around a nonstochastic steady state, the price inflation, the interest rate, and the ITC rate are expressed in log-deviations from their sample means. The logarithms of all the rest of the variables are detrended with a linear trend. The data definitions and

[5] We would like to thank Robert Chirinko and Daniel Wilson for kindly providing us with the ITC data.

[6] In particular, several types of ITC at the federal level givew participating taxpayers a dollar-for-dollar reduction in tax liabilities for new investment projects. Varying renewable energy ITCs depend on the type of project (i.e., solar and wind projects receive subsidies for 30% of the cost of investment; geothermal projects are subsidized by 10%). New York was the first to implement a similar state-level investment policy (see Office of Tax Policy Analysis, 1996). Other states also have long histories of using tax incentives to encourage economic development. For example, 35 States use ITC in general, and 22 states use an ITC for R&D. For general descriptions of these policies in the United States, see Karier (1998), Joint Committee on Taxation (2011), House et al. (2019, table 2).

[7] A valid critique of our approach is that we use legislated ITC data to capture the effect of unanticipated ITC shocks. The state governments legislate and announce the rates to the public in the previous fiscal year. This could prompt firms to postpone their investments until the higher ITC rates take effect. The results remain robust to the exclusion of ITC series from the estimation of the structural model. The results of this exercise are available upon request.

sources, as well as the details on the construction of the variables are in the online appendix.

4.2 Priors and calibrated parameters

Some of the model's parameters are calibrated in line with the literature. Specifically, the utility discount factor is set at 0.99. The depreciation rate of capital is set at 0.025, and the capital share in the production function is 0.33. The steady states of variables are calibrated based on averages over the sample period. The steady states of capital income and labor income tax rates are set at 0.44 and 0.22, respectively. The steady states of public spending and public-debt-to-output ratios are set at 0.21 and 0.46, respectively. Finally, the steady states of the preference and investment-specific shocks, as well as the steady state of the gross inflation rate, are set to unity. Based on the historical mean of the ITC rate series, we set the steady-state ITC rate to 5%.

The prior distributions for the estimated parameters are set as follows. The inter-temporal elasticity of substitution parameter and the inverse of labor supply parameter that appear in the utility function are set according to Leeper et al. (2010). Parameters related to investment adjustment costs, capital utilization, price and wage markups, and wage and price stickiness are set in line with Justiniano et al. (2010). Finally, parameters related to fiscal and monetary policy rules are set according to Zubairy (2014).

4.3 Bayesian estimation

This subsection describes the algorithm used to estimate the model. We use Dynare software for the estimation process. The likelihood is computed using the Kalman filter, and the posterior distribution of the parameters is obtained by combining the priors and the likelihood of the data. We use

Sims' optimization algorithm for the computation of the posterior mode. Next, we use the Metropolis–Hastings algorithm to generate draws from the posterior distributions. We ensure an acceptance rate close to 25%-30%, by appropriately adjusting the step size (variance) of the jumping distribution in the MH algorithm. We generate 500,000 draws and discard the first half in order to avoid correlation in the draws. Diagnostic tests (i.e., trace plots, Geweke test) ensure the convergence of the MCMC chain of draws of the parameters. We also ensure the model fits the data by comparing second moments (i.e., autocorrelations and cross-correlations) resulted from the data and the model. All post-estimation checks, as well as the prior and posterior distribution graphs, are presented in the online appendix.

Table 1 reports the priors, the mean, and 5^{th} and 95^{th} percentiles of the posterior distributions for the estimated parameters. The investment adjustment cost parameter γ, which could be a key factor in the transmission of investment-related policies, has a value close to those reported in Leeper et al. (2010) and Justiniano et al. (2010), and is close to the average magnitude of adjustments costs in the DSGE literature. In our sensitivity analysis, we experiment with a wide range of values for this parameter to explore the robustness of our findings regarding the multiplier of ITC. In accordance with Leeper et al. (2010), σ is significantly higher than unity, indicating a relatively low inter-temporal elasticity of substitution for consumption. Similarly, the estimated external habits in consumption, ν, are moderate, very close to the estimates of Leeper et al. (2010), and somewhat lower than the estimates in Smets and Wouters (2007) and Zubairy (2014). The estimated model also indicates high price and wage stickiness and a relatively aggressive monetary policy when correcting for inflation and output growth. Looking at the autocorrelation coefficients, ϱ, most fiscal instruments are quite persistent. Finally, the fiscal policy corrects for public debt deviations mainly based on ITC and transfers, but output growth deviations are mainly corrected via income taxation and ITC.

5 Results

5.1 Impulse responses

Figure 1 presents the model variables' responses to an ITC shock.[8] The shock is normalized to a one percentage point increase in the ITC rate. The x-axis shows quarters after the shock, and the y-axis shows percentage deviations from the steady state (with the exception of the y-axis for tax rates, which measures absolute changes in percentage points). The solid lines denote the median response, and the dashed lines correspond to the 5^{th} and 95^{th} percentiles of the posterior distribution of the responses.

Following a temporary increase in the ITC rate, output and hours rise. Their intervals are reasonably tight, reflecting the tight posterior distribution on the parameters and the model restrictions. As in the case of a rise in government spending, the standard negative wealth effect is present, which induces households to increase labor supply and cut their demand for consumption. However, in contrast to a government spending shock, the rise in the ITC rate leads to a decline in the after-tax price of investment and, in the presence of investment adjustment costs, induces a hump-shaped and persistent rise in investment, which lowers the price markup and shifts labor demand upward. In turn, as capital accumulates the marginal product of labor gradually increases, which further shifts labor demand and leads to a rise in hours worked, the real wage rate, and output. This *labor demand effect* reinforces the initial expansion of investment and output.

[8] We randomly draw a set of values from the posterior distribution (MCMC chains) of the model parameters, solve the model, and compute impulse responses. We then obtain a distribution of posterior impulse responses by repeating the aforementioned process 500 times.

At the same time, the increase in wages leads households to substitute away from leisure to consumption. In the first periods after the shock, the negative wealth effect outweighs this substitution effect, and it crowds out consumption. However, as the *labor demand effect* comes into play, the increase in investment is partly met by expanded hours and output, and less by crowding out other demand components. As the crowding out becomes less necessary and gradually phases out, private consumption starts rising in the medium and long run.

Overall, the increase in investment is large enough to dominate the initial drop in consumption and induces a significant and persistent rise in output, with its qualitative pattern closely following that of investment. In particular, following a one percentage point rise in the ITC rate, output rises by 0.18% after five years compared to the steady-state output, with an estimated 95% confidence interval of [0.13%, 0.21%]. The corresponding estimated rise in private investment amounts to 1.32% with a confidence interval of [0.77%, 1.70%], whereas the rise in consumption is 0.05% with a confidence interval of [0.02%, 0.08%].

Regarding the public-financing effects of the ITC shock, although both labor and capital taxes take the main burden of adjustment, as they increase to finance the rise in the ITC expenditures, any distortionary effects are outweighed by the positive impacts on capital accumulation and labor. These render the effects of the ITC shock on output, consumption, and investment long-lived.[9]

Our analysis stresses the crucial role of the *labor demand channel* for reinforcing the expansionary effects ITC shocks have in the medium and long run. We note that partial equilibrium studies do not capture this

[9]The responses to the rest of the fiscal shocks are in the online appendix and are similar to the estimates in the existing literature (see, e.g., Leeper et al., 2010; Zubairy, 2014). As a general note, we find that a shock to government expenses and to the tax on capital is mostly financed by higher taxes on labor, making those instruments more distortive than the ITC for the household wealth.

mechanism and its implications. Moreover, compared to other simulation-based general equilibrium studies, our Bayesian approach enables us to use data to theory and consistently quantify the combined effect of the various propagation mechanisms.

5.2 Fiscal multipliers

To highlight the quantitative differences in how various fiscal policies affect output, we present the output multipliers of our four fiscal instruments, namely government spending, labor and capital tax rates, and the ITC rate. Specifically, the government spending and ITC multipliers measure the change in the value of output (in currency units, e.g., dollars) due to a one-currency-unit increase in government consumption and investment tax credits, respectively. Similarly, the labor tax and capital tax multipliers measure the change in the value of output (in currency units) due to a one-currency-unit *decrease* in labor tax and capital tax revenues, respectively.[10]

Following Leeper et al. (2010) and Zubairy (2014), we report the *present-value cumulative multipliers*, which are computed by dividing the present-value cumulative response of output by the present-value cumulative response of the expenditure (or revenue) implied by each fiscal instrument.

$$\text{Present-value multiplier at horizon } h = \frac{\sum_{j=0}^{h}(1+R)^{-j}\Delta Y_{t+h}}{\sum_{j=0}^{h}(1+R)^{-j}\Delta F_{t+h}}, \tag{7}$$

where ΔY_{t+h} denotes the change in output h periods ahead and ΔF_{t+h} denotes the change in investment tax credits, government consumption, labor income tax revenue, or capital income tax revenue h periods ahead. The discounting is based on the steady-state value of the nominal interest

[10] Equivalently, the fiscal multiplier can be interpreted as the percentage change in output due to a 1% GDP change in the respective fiscal expenditure or revenue component.

rate, R.[11]

Table 2 presents the median and the 5^{th} and 95^{th} percentiles of the posterior distribution of the output multipliers for the four fiscal shocks. Similarly, figure 2A depicts the median cumulative multipliers of output for the four shocks. The time profile of the government spending multiplier decreases across the horizon. On impact, the government spending multiplier amounts to 0.75, and the estimated values over the horizon are very close to Leeper et al. (2010). Given, however, that our model does not account for deep habits in consumption, the magnitude of the multiplier is somewhat smaller than in Zubairy (2014), as it is dominated by the negative wealth effect on consumption. The labor tax cut has only modest effects on output. The capital tax cut results in multipliers comparable to those of government spending shocks in terms of magnitude, but with the opposite time profile. Capital tax cuts stimulate capital accumulation, which in turn takes time to build, causing the multiplier to rise gradually over the horizon. Over a five-year horizon the government spending multiplier amounts to 0.31, while the income tax and capital tax multipliers amount to 0.10 and 0.76, respectively.

Turning to the ITC shocks, the respective multiplier equals 0.15 on impact, which is smaller than that of government spending and capital tax shocks. However, it builds over time, gradually outperforming in magnitude the multipliers of the other fiscal shocks and reaching 1.42 after five years. The multiplier remains statistically significant throughout the whole horizon.

[11] In particular, the multiplier is calculated based on the formula:

$$\frac{\sum_{j=0}^{h}(1+R)^{-j}\Delta\ln Y_{t+h}}{\sum_{j=0}^{h}(1+R)^{-j}\Delta\ln F_{t+h}}\frac{1}{\overline{F}/\overline{Y}}$$

where $\Delta\ln Y_{t+h}$ and $\Delta\ln F_{t+h}$ are the impulse responses of output and the fiscal variable obtained in the previous section, while $\overline{Y}$ and $\overline{F}$ are the steady-state values. The multipliers of labor and capital income taxes are multiplied by -1, so that they correspond to 1% of GDP *cut* in the respective tax revenues.

A policy trade-off emerges when we compare the effects of ITC shocks with those of government spending and capital tax shocks. Government spending induces higher output multipliers than ITC shocks over short horizons (on impact and in the first quarter after the shock), whereas the ITC multipliers take their highest values over longer horizons (after the second quarter). An increase in government consumption raises aggregate demand for goods and services and affects output immediately after the shock, but an ITC shock stimulates aggregate demand only gradually through the increase in private investment, the marginal product of labor, and labor demand. This is a sluggish and persistent process due to investment adjustment costs. Similarly, the capital tax multiplier is higher than the ITC multiplier on impact, but it follows behind thereafter. Although both a cut in the capital tax rate and an increase in the ITC rate encourage capital accumulation, the ITC shock further crowds out private consumption in the short run, which renders it less effective than the capital tax cut on impact.

From a policy perspective, it is important to quantify the effects of fiscal policy on key variables, namely the components of output (consumption and investment) and hours worked, as the response of these variables can shed light on the transmission of ITC shocks. To this end, similar to the definition of the multiplier, in panels A, B, and C of table 3 and in panels A, B, C and D of figure 2 we present the present-value cumulative multipliers for output, private consumption, private investment, and hours worked, respectively, for the four types of shocks. The government spending multipliers for consumption and investment are negative across all periods, which implies that the typical negative wealth effect and the crowding out effect are significant and strong. These negative multipliers also explain why the spending multiplier for total output is below 1. Looking at labor tax shocks, only the tax multiplier for consumption is significant and positive, but small, whereas for capital tax shocks only the multiplier of investment is significantly positive and sizeable. Not surprisingly, the expansionary effect of capital tax cuts is mainly driven by their stimulative effect on private investment. The multipliers of hours worked (panel C in table 3 and panel D of figure 2) are positive and slowly decaying for spending shocks, and also positive but much smaller for labor tax shocks. These findings corroborate with earlier studies (see e.g. Smets and Wouters, 2007; Leeper et al., 2010; Zubairy, 2014).

With regard to the ITC shocks, figure 2 offers a direct comparison of the ITC multipliers with those of the rest fiscal instruments for any of the key variables. The last column in each panel of table 3 presents the corresponding ITC multipliers. The ITC multiplier for private consumption is negative throughout the horizon and somewhat smaller than the respective government spending multiplier in the first years, highlighting consumption reductions needed to accommodate the increase in investment in the case of ITC shocks. However, consumption recovers earlier after ITC shocks than after spending shocks due to the delayed *labor demand effect* that raises employment and wages. The ITC multiplier of investment, albeit modest on impact, becomes large one year after the shock and exceeds in magnitude the respective multipliers for the other shocks throughout the horizon. In particular, over a five-year horizon, a $1 increase in the investment tax credits raises private investment by $1.73. The increased capital accumulation and the expansion of labor demand after an ITC shock results in a stable increase in hours worked that is evident two years following the shock (panel D of figure 2). Moreover, the ITC multiplier of hours worked exceeds the multipliers for the other fiscal instruments at any horizon after the first year, once again indicating the labor demand expansion effect that follows ITC shocks. In particular, over a five-year horizon, a $1 increase in the investment tax credits raises hours by 0.42 units, whereas a $1 increase in government spending raises hours by 0.31 units, and an equivalent cut in labor taxes results in a much smaller increase in hours.

Overall, ITC shocks have modest short-run effects on output, but they turn out to be the most effective instruments in stimulating employment, private investment, and output in the medium and long run.

5.3 Investment allowances

Tax-based investment incentives can take various forms when implemented. The investment tax credits, examined in the previous section, refer to a reduction in tax liabilities that amounts to a certain fraction of investment expenditures. Another popular form of investment tax incentives are *investment allowances* (e.g., bonus depreciations), which permit firms to deduct a percentage of their capital purchases from their taxable income. Investment allowances have been popular in past years and there is an emerging interest in the macroeconomic implications of such policies.[12] Edge and Rudd (2011), for example, examine a model with investment allowances modelled in the production side and simulate the effects of historical episodes of such policies (2003 and 2008 U.S. stimulus bills). House et al. (2019) approximate tax deductions with a comprehensive investment tax subsidy, defined as the sum of investment tax credits and the present discounted value of depreciation allowances.

Our aim here is to verify whether our benchmark results remain robust to the alternative modeling of investment tax incentives in the related lit-

[12] For example, bonus depreciations are a relatively new and popular policy measure introduced for the first time in the U.S. in 2002 through the Job Creation and Worker Assistance Act. It allows firms to immediately deduct a large percentage of the purchase cost of capital assets rather than write them off over their useful lives. Initially, it permitted firms to deduct 30% of the capital purchase costs. Subsequently, a bonus depreciation rate of 50% was applied through the 2003 Jobs and Growth Tax Relief Reconciliation Act, the 2008 Economic Stimulus Act, and the 2015 Protecting Americans from Tax Hikes Act. The U.S. Tax Cuts and Jobs Act of 2017 doubled the bonus depreciation deduction from 50% to 100%.

erature. To this end, we modify the benchmark model by assuming that a deduction in capital taxes that households pay, namely an investment allowance, replaces the ITC rate. In particular, the households' budget constraint is now given by:

$$c_t+i_t+B_t = r_t u_t \bar{k}_{t-1} - \tau_t^k (r_t u_t \bar{k}_{t-1} - s_t i_t) + (1-\tau_t^l) w_t l_t - T_t + \Pi_t + R_{t-1}\frac{B_{t-1}}{\pi_t} - \kappa(u_t)\bar{k}_{t-1}, \tag{8}$$

where $s_t i_t$ denotes the total amount of capital tax deductions (investment allowances), and s_t denotes the investment allowance rate.[13]

The economic responses to a temporary investment allowance shock are shown in figure 3. They look similar to those of an ITC shock in our benchmark analysis (figure 1), though somewhat weaker, especially for private investment, output, and hours worked. The estimated multipliers for output for the present model setup are in table 4. The investment allowance multipliers (fourth column) have a similar time profile to the ITC multipliers of the benchmark model (fourth column in table 2), but they are somewhat higher. The investment allowance multipliers outperform the multipliers of the other fiscal shocks. These results indicate that our main conclusions about the performance of investment tax incentive policies remain robust regardless of the form these incentives take (namely, tax credits or tax deductions).

We note that, by definition, investment tax credits directly reduce households' tax liabilities, and investment allowances reduce their tax base. Therefore, the change (increase) in forgone tax revenue triggered by a one percentage point increase in the ITC rate is always greater than the change (increase) in the forgone revenue implied by an equal-sized (one percentage

[13]In Edge and Rudd (2011), investment allowances are modelled in the production side (firms). Because households own the firms in this class of models, this alternative setup yields almost identical results. The equivalence of the two versions of the model is presented in the online appendix.

point) increase in the investment allowance rate. Because the fiscal multiplier accounts for the change in tax revenue related to the two policies, the investment allowance multiplier might exceed the ITC multiplier, which is exactly what we obtain from our estimations. In practice, this means investment allowances may be slightly better than investment tax credits because, for a given amount of forgone tax revenue, investment allowances raise output more than tax credits do. An alternative (inverse) interpretation of the multipliers is that investment allowances are as effective in raising output as investment tax credits but do so at a lower cost, measured by the sacrificed tax revenue.

In summary, both investment tax credits and investment allowances are both effective tools for stimulating private investment and output, and both outperform traditional instruments in the medium and long run. Yet, investment allowances may be less costly for the government than investment tax credits. Our analysis reveals the importance of evaluating investment tax incentives in a multiplier context, because impulse responses fail to account for the induced change in the foregone tax revenue and thus can be an inaccurate measure of the impact of such policies.

6 Inspecting the mechanism

6.1 The role of price and wage inertia

In their analysis on the effects of expensing allowances, Edge and Rudd (2011) point out the role of wage and price flexibility. They find that following a 50% three-year increase in investment allowances, private investment peaks at over 30% in a sticky-price model, but the rise remains below 10% in a flexible-price model. In the flexible-price model, higher investment allowances lead to a sharp increase in the real interest rate, a contained fall in the shadow rental rate of capital, and a modest rise in investment. On the contrary, a positive aggregate demand shock in the sticky-price model is partly met by increased supply, which causes a smaller rise in the real interest rate and a higher response of investment after the stimulus.

Gali et al. (2007) argue that the size of the government spending multiplier on impact increases as price rigidity increases. This comes as a result of the increase in real wages even in the face of a drop in the marginal product of labor. The combined effect of a higher real wages and higher employment raises current labor income and hence stimulates consumption. Similarly, Pappa (2009) highlights the importance of the labor market in a canonical RBC model and a model with price and wage rigidities. In particular, in a flexible price and wage environment, a government spending shock increases labor supply due to the standard negative wealth effect, shifting the labor supply curve to the right. Given the unchanged labor demand arising from the flexible price/wages assumption, this increase reduces wages and increases output. On the other hand, in the sticky price/wage model, a government spending shock still induces a negative wealth effect, but now the increase in government spending increases labor demand as well, with the latter being stronger in general, thereby pushing wages up.

Following the discussion, this section considers more closely how the associated frictions included in our model (i.e., wage and price rigidities), contribute to the *labor demand effect* and to our estimated effect of the ITC shock on output. To this end, following Justiniano et al. (2010) we re-estimate two restricted versions of the baseline model: a model with flexible prices and (nearly) competitive goods sector, and a model with flexible wages and (nearly) competitive labor market. Figure 4 shows the median impulse responses of the benchmark model and the two alternative models following an ITC shock. The black solid lines correspond to the benchmark model, the red dotted lines stand for the model with flexible prices and the dashed blue lines correspond to the model with flexible wages. In turn, table 5 shows the size of the cumulative ITC multipliers for each model.

We expect the ITC multiplier to fall as price flexibility and competition in the production sector increase, capturing the fact that the crowding out of consumption is stronger as prices readjust and that the investment response is less persistent. On impact the multiplier is 0.13, and in the long run it reaches 1.29, which is within the confidence bands of the benchmark multiplier. Interestingly, the latter suggests that the *labor demand effect* still drives the big time-to-build ITC multiplier when prices are flexible and price markups are zero. The ITC multiplier is the largest compared to the other fiscal shocks in the medium run and long run (table 5).

Next, we focus on the labor market. Eliminating wage inertia is an important test for our proposed *labor demand effect* as a main transmission mechanism of investment tax incentives. The impact of wage flexibility depends on the relative size of the *labor demand effect* and the *labor supply effect* following an ITC shock. The ITC shock triggers the *labor demand effect*, which shifts the labor demand curve to the right and tends to increase hours worked and the real wage. In addition, the standard negative wealth effect shifts the labor supply curve to the right (l*abor supply effect*). When wages are flexible, the shift of labor supply is larger compared to the benchmark model. This causes the real wage to fall on impact, and hours and output to further increase compared to the benchmark model (figure 4).

When wages adjust faster, the increase in investment, although less persistent, is more pronounced thus causing a stronger positive effect on output, both on impact and in the long run, and resulting to a larger cumulative ITC multiplier that reaches 1.96 in the flexible wage model (table 5). This result also stems from the fact that the crowding out of private consumption is smaller in the flexible wage model, and although consumption initially falls, it starts increasing at a faster pace compared to the benchmark. Taken together, when wages adjust faster the combined *labor demand effect* and *labor supply effect* are reinforced, and they result to higher equilibrium hours, investment, output, and smaller crowding out of consumption.[14]

6.2 The relative price of investment

Our benchmark analysis finds that ITC policies are quite effective in stimulating output and private investment in the medium and long run. However, investment-enhancing policies do not exist in a vacuum and there is an ongoing debate on whether investment tax incentives pass through capital goods prices, thus raising the pre-tax prices of investment goods and offsetting any beneficial effects of such policies. Goolsbee (1998) estimates a model and finds that a 10% investment tax credit increases equipment prices 3.5-7.0% in the United States, thus showing that these incentives benefit capital suppliers rather than firms. Similarly, Miao and Wang (2014) show that a permanent increase in ITC raises the steady-state tax-adjusted price of capital, but reduces the steady state adjustment rate. On the contrary, House et al. (2019), based on an updated vintage and longer sample than that used by Goolsbee (1998), find that business equipment prices hardly react to an investment tax subsidy.

Because theory predicts that a pass-through price channel might crit-

[14] We also conduct alternative experiments that vary the parameters of the investment adjustment costs, capital utilization, habits, intertemporal elasticity of substitution, and labor elasticity. The results are in the appendix and show that the size of the ITC multiplier always stays strong in the long-run, whereas the size on impact can vary or even become negative, suggesting that under different environments time reveals the effectiveness of such policies.

ically undermine the effectiveness of ITC policies and the empirical work remains inconclusive, we test for this channel within our theoretical framework and precisely quantify its contribution to the transmission of ITC shocks. To this end, similarly to Edge and Rudd (2011), we modify our benchmark model by assuming that the production of the final good takes place in three stages. In the first stage, perfectly competitive firms produce an undifferentiated preliminary good using capital and labor inputs. In the second stage, two types of firms use preliminary goods as inputs and produce either intermediate consumption goods or intermediate investment goods. Firms in both sectors at this stage act in a monopolistically competitive way and face price rigidities. In the last stage, there are two types of perfectly competitive retailers that buy either consumption or investment goods and transform them into a final bundle of consumption or investment goods ready to be purchased by households. At all other aspects the model remains the same, so we present only the modified portion.[15]

Let c and k denote the consumption goods and investment goods sectors respectively. The optimal pricing decision of a firm i in the intermediate goods sector $j \in \{c, k\}$ will be given by the first-order condition of their respective maximization problem,

$$p_{it}^{j*} = (1 + \eta_{p,t}^{j}) \frac{E_t \sum_{s=0}^{\infty} (\beta \chi_p^j)^s \Lambda_{t,t+s} mc_{t+s} y_{it+s}^{j}}{E_t \sum_{s=0}^{\infty} (\beta \chi_p^j)^s \Lambda_{t,t+s} y_{it+s}^{j}}, \tag{9}$$

where χ_p^j is the probability that intermediate goods firms in sector $j \in \{c, k\}$ keep their price unchanged at the current period, and $\eta_{p,t}^{j}$ is the

[15] Such a model specification would be equivalent to a model with two production technologies (two preliminary good sectors) that produce either consumption or investment preliminary goods and perfectly mobile factors of production between sectors. Both model specifications would then imply that the two intermediate good sectors face identical marginal costs. The model with single-production technology used here yields similar results.

price markup in sector $j \in \{c, k\}$.

As this model assumes identical marginal costs between the two intermediate goods sectors, the key to the dynamics of the relative price of investment goods will be the relative price stickiness between the two intermediate sectors: if the investment goods sector is more (less) sticky than the consumption goods sector, the relative price of investment goods falls (rises) after an exogenous increase in ITC. In a similar vein, Edge and Rudd (2011) calibrate their model and assume an extreme case where consumption goods are sticky and investment goods are completely flexible. Our contribution here is to quantify the impact of the investment price channel on the fiscal multiplier by estimating, rather than calibrating, the relative stickiness of prices.

We find that the estimated price stickiness parameters for the consumption and investment sector are equal to 0.76 and 0.80, respectively. The two sectors are characterized by very similar and high degrees of price stickiness, which leads to an almost unresponsive relative price of investment to any shock in our model. This can be easily seen in figure 5, which presents the responses to an ITC shock for this version of the model. The responses of output, investment and consumption are very similar to those of our benchmark analysis (figure 1). Finally, table 6 shows the output multipliers in this model, which look very similar to the benchmark multipliers (panel A). We therefore conclude that the relative price of investment does not drive the response of the economy following an ITC shock, and our baseline conclusions remain robust to this modification.

7 Conclusions

Existing studies on how incentives to private investment in the form of ITC affect private investment find negligible impacts. In this paper, we show that the output effects of these incentives hinge critically on their assessment in a general equilibrium context. Introducing these incentives to private investment in the form of ITC in a standard DSGE model with nominal frictions can generate an overwhelmingly significant and persistent effect on output. Our multiplier estimates suggest that the data are fairly informative about the size of ITC multipliers: the present-value long-run output multiplier is substantially larger than 1 and exceeds, over longer horizons, in magnitude and duration the government spending multiplier and the labor and capital tax multipliers.

This effect is due to a surge in private investment, which increases the marginal product of labor and raises labor demand, employment, and output, which we refer to as *labor demand effect*. Moreover, the induced rise in the real wage rate causes a substitution effect towards consumption, which dampens the initial negative wealth effect. However, these effects have a substantial time-to-build lag, which implies that ITC policies likely have a small, or even muted, impact in the short run compared to the rise in disposable income and the associated demand stimulus triggered by an increase in public spending or tax cuts. Our results remain robust to a battery of alternative scenarios. When prices are flexible, the long-run multiplier remains close to the benchmark model. The *labor demand effect* produces even stronger effects on output when the labor market is flexible, allowing for wages to readjust.

Our policy message is that compelling arguments about the efficacy of ITC policies need to take into account their side effects in the labor market. Further progress on estimating the output effects of ITC policies (e.g., in studies with plant-level data), may require the estimation of their side effects, including the rise in labor demand and the degree of investment inertia, to properly assess their long-term macroeconomic impacts.

References

[1] Abel A., 1982. Accelerated depreciation of the efficacy of temporary fiscal policy: implications for an inflationary economy. *Journal of Public Economics* 19(1): 23–47.

[2] Altug S., Demers F., Demers M., 2009. The investment tax credit and irreversible investment. *Journal of Macroeconomics* 31(4): 509–522.

[3] Auerbach A., Summers L., 1979. The investment tax credit: an evaluation. NBER Working Paper 404.

[4] Bronzini R., de Blasio G., Pellegrini G., Scognamiglio A., 2008. The effect of investment tax credit: evidence from an atypical program in Italy. Bank of Italy Working Papers 661.

[5] Caiumi A., 2011. The evaluation of the effectiveness of tax expenditures - a novel approach: an application to the regional tax incentives for business investments in Italy. OECD Taxation working papers 5.

[6] Chen Y., He Z., Zhang L., 2018. The effect of investment tax incentives: Evidence from China's value-added tax reform. *International Tax and Public Finance* 25(4): 913–945.

[7] Chirinko R., Wilson D., 2008. State investment tax incentives: a zero-sum game. *Journal of Public Economics* 92(12): 2362–2384.

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

[9] Edge R., Rudd J., 2011. General-equilibrium effects of investment tax incentives. *Journal of Monetary Economics* 58(6): 564–577.

[10] European Commission, 2014. A Study on R&D Tax Incentives. Taxation Papers, Working Paper N. 52.

[11] Galí J., López-Salido J.D., Vallés J., 2007. Understanding the effects of government spending on consumption. *Journal of the European Economic Association* 5(1): 227–270.

[12] Goolsbee A., 1998. Investment tax incentive, prices and the supply of capital goods. *The Quarterly Journal of Economics* 113(1): 121–148.

[13] Holland D., Vann R., 1998. Income Tax Incentives for Investment. In: V. Thuronyi (ed.), *Tax Law Design and Drafting, Volume 2*, chapter 23, International Monetary Fund.

[14] House C.L., Mocanu A, Shapiro M.D., 2019. Stimulus effects of investment tax incentives: production versus purchases. Working Paper.

[15] Huffman G.W., 2008. An analysis of fiscal policy with endogenous investment-specific technological change. *Journal of Economic Dynamics and Control* 32(11): 3441–3458.

[16] Joint Committee on Taxation, 2011. Present law and historical overview of the Federal Tax System. JCT Publications, JCX-1-11.

[17] Jones J. B., 2002. Has fiscal policy helped stabilize the postwar U.S. economy? *Journal of Monetary Economics* 49(4): 709–746.

[18] Justiniano A., Primiceri G.E., Tambalotti A., 2010. Investment shocks and business cycles. *Journal of Monetary Economics* 57(2): 132–145.

[19] Karier T., 1998. The investment tax credit. *New Directions for Evaluation*, 95–115.

[20] Kato A., La Croix S., Mak J., 2009. Small state, giant tax credits: Hawaii's leap into high technology development. Working Papers 200914, University of Hawaii at Manoa, Department of Economics.

[21] Klemm A., Van Parys S., 2012. Empirical evidence on the effects of tax incentives. *International Tax and Public Finance* 19(3): 393–423.

[22] Leeper E.M., Plante M., Traum N., 2010. Dynamics of fiscal financing in the United States. *Journal of Econometrics* 156(2): 304–321.

[23] Lyon A., 1989. The effect of the investment tax credit on the value of the firm. *Journal of Public Economics* 38(2): 227–247.

[24] Miao J., Wang P., 2014. Lumpy investment and corporate tax policy. *Journal of Money Credit and Banking* 46(6): 1171–1203.

[25] Office of Tax Policy Analysis, 1996. The effectiveness of the ITC: an evaluation of New York's investment tax credit. *New York State Department of Taxation and Finance.*

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

[27] Ramey V.A., 2011. Can government purchases stimulate the economy?. *Journal of Economic Literature* 49(3): 673–685.

[28] Smets F., Wouters R., 2003. An estimated dynamic stochastic general equilibrium model of the euro area. *Journal of the European Economic Association* 1(5): 1123–1175.

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

[30] Uhlig H., 2010. Some Fiscal Calculus. *American Economic Review* 100(2): 30–34.

[31] Worldwide Corporate Tax Guide, 2018. available at https://www.ey.com/gl/en/services/tax/worldwide-corporate-tax-guide—country-list.

[32] Zubairy S., 2014. On fiscal multipliers: estimates from a medium scale DSGE model. *International Economic Review* 55(1): 169–195.

[33] Zwick E., Mahon J., 2017. Tax policy and heterogeneous investment behavior. *American Economic Review* 107(1): 217–248.

Table 1. Estimated parameters

	Prior distribution			Posterior distribution	
Parameter	Density	Mean	Std.Dev.	Mean	$[5^{th}, 95^{th}]$
Intertemp. elasticity (inverse) σ	$\mathcal{G}$	1.50	0.50	2.91	[2.25, 3.65]
Frisch elasticity (inverse) θ	$\mathcal{G}$	2.00	0.50	1.67	[1.05, 2.39]
Consumption habits ν	$\mathcal{B}$	0.50	0.20	0.51	[0.40, 0.62]
Investment adjustment costs γ	$\mathcal{G}$	5.00	0.50	4.72	[4.02, 5.49]
Capital utilization cost ψ	$\mathcal{G}$	5.00	0.50	4.72	[3.93, 5.57]
Prices' stickiness parameter χ_p	$\mathcal{B}$	0.66	0.10	0.81	[0.77, 0.85]
Wages' stickiness parameter χ_w	$\mathcal{B}$	0.66	0.10	0.70	[0.63, 0.76]
Taylor rule, inflation ζ_π	$\mathcal{N}$	1.60	0.20	1.99	[1.77, 2.22]
Taylor rule, output ζ_y	$\mathcal{N}$	0.10	0.05	0.06	[0.03, 0.09]
Taylor rule, output growth ζ_{yd}	$\mathcal{N}$	0.10	0.05	0.21	[0.17, 0.25]
SS price markup η_p^{ss}	$\mathcal{N}$	0.15	0.05	0.16	[0.10, 0.21]
Labor taxes, B coefficient $\rho_{\tau^l,b}$	$\mathcal{G}$	0.30	0.25	0.10	[0.02, 0.19]
Capital taxes, B coefficient $\rho_{\tau^k,b}$	$\mathcal{G}$	0.30	0.25	0.07	[0.02, 0.14]
ITC, B coefficient $\rho_{itc,b}$	$\mathcal{G}$	0.30	0.25	0.23	[0.03, 0.59]
Gov. spending, B coefficient $\rho_{g,b}$	$\mathcal{G}$	0.30	0.25	0.02	[0.00, 0.05]
Transfers, B coefficient $\rho_{T,b}$	$\mathcal{G}$	0.30	0.25	0.82	[0.29, 1.46]
Labor taxes, Y coefficient $\rho_{\tau^l,y}$	$\mathcal{G}$	0.15	0.10	0.14	[0.03, 0.31]
Capital taxes, Y coefficient $\rho_{\tau^k,y}$	$\mathcal{G}$	0.15	0.10	0.28	[0.09, 0.53]
ITC, Y coefficient $\rho_{itc,y}$	$\mathcal{G}$	0.15	0.10	0.15	[0.03, 0.36]
Gov. spending, Y coefficient $\rho_{g,y}$	$\mathcal{N}$	-0.05	0.05	0.01	[-0.07, 0.09]
Transfers, Y coefficient $\rho_{T,y}$	$\mathcal{N}$	-0.05	0.05	-0.05	[-0.13, 0.03]
Production technology autocorr. ρ_A	$\mathcal{B}$	0.70	0.20	0.99	[0.97, 1.00]
Investment technology autocorr. ρ_z	$\mathcal{B}$	0.70	0.20	0.68	[0.57, 0.77]
Preferences autocorr. ρ_μ	$\mathcal{B}$	0.70	0.20	0.83	[0.75, 0.89]
Price markup autocorr. ρ_p	$\mathcal{B}$	0.70	0.20	0.94	[0.88, 0.98]
Wage markup autocorr. ρ_w	$\mathcal{B}$	0.70	0.20	0.96	[0.93, 0.98]
Taylor rule autocorr. ρ_R	$\mathcal{B}$	0.70	0.20	0.84	[0.81, 0.86]
Labor taxes autocorr. ρ_{τ^l}	$\mathcal{B}$	0.70	0.20	0.96	[0.93, 0.99]
Capital taxes autocorr. ρ_{τ^k}	$\mathcal{B}$	0.70	0.20	0.95	[0.91, 0.98]
ITC autocorr. ρ_{itc}	$\mathcal{B}$	0.70	0.20	0.96	[0.92, 0.99]
Gov. spending autocorr. ρ_g	$\mathcal{B}$	0.70	0.20	0.97	[0.96, 0.99]
Transfers autocorr. ρ_T	$\mathcal{B}$	0.70	0.20	0.72	[0.63, 0.81]
MA term of price markups θ_p	$\mathcal{B}$	0.50	0.20	0.51	[0.31, 0.69]
MA term of wage markups θ_w	$\mathcal{B}$	0.50	0.20	0.89	[0.83, 0.93]

Notes: N: Normal distribution, B: Beta distribution, G: Gamma distribution, and IG: Inverse Gamma distribution.

Table 1. Continued					
	Prior distribution			Posterior distribution	
Parameter	Density	Mean	Std.Dev.	Mean	[5^{th}, 95^{th}]
TFP σ_A	$\mathcal{IG}$	0.01	0.10	0.01	[0.00, 0.01]
IS σ_z	$\mathcal{IG}$	0.01	0.10	0.08	[0.07, 0.10]
Preference σ_μ	$\mathcal{IG}$	0.01	0.10	0.03	[0.02, 0.04]
Price markup σ_p	$\mathcal{IG}$	0.01	0.10	0.03	[0.02, 0.05]
Wage markup σ_w	$\mathcal{IG}$	0.01	0.10	0.48	[0.27, 0.76]
Monetary policy σ_R	$\mathcal{IG}$	0.01	0.10	0.01	[0.00, 0.02]
Labor tax σ_{τ^l}	$\mathcal{IG}$	0.01	0.10	0.03	[0.02, 0.03]
Capital tax σ_{τ^k}	$\mathcal{IG}$	0.01	0.10	0.02	[0.01, 0.02]
ITC σ_{itc}	$\mathcal{IG}$	0.01	0.10	0.42	[0.38, 0.45]
Gov. expenditure σ_g	$\mathcal{IG}$	0.01	0.10	0.01	[0.01, 0.01]
Transfers σ_T	$\mathcal{IG}$	0.01	0.10	0.39	[0.27, 0.55]

Notes: N: Normal distribution, B: Beta distribution, G: Gamma distribution, and IG: Inverse Gamma distribution.

Table 2. Fiscal multipliers for output				
Benchmark model				
Shock	g	τ^l	τ^k	itc
t=0	0.75	0.07	0.24	0.15
	[0.69 0.81]	[0.04 0.10]	[0.20 0.28]	[0.05 0.28]
t=1	0.55	0.11	0.39	0.52
	[0.48 0.62]	[0.06 0.16]	[0.33 0.46]	[0.32 0.75]
t=2	0.46	0.12	0.52	0.82
	[0.38 0.54]	[0.05 0.19]	[0.43 0.61]	[0.57 1.12]
t=3	0.40	0.12	0.62	1.06
	[0.31 0.49]	[0.04 0.21]	[0.50 0.74]	[0.76 1.44]
t=4	0.35	0.12	0.70	1.27
	[0.25 0.46]	[0.01 0.22]	[0.56 0.84]	[0.91 1.68]
t=5	0.31	0.10	0.76	1.42
	[0.19 0.44]	[-0.02 0.23]	[0.58 0.93]	[1.02 1.87]

Notes: g: government spending, τ^l: labor tax rate, τ^k: capital tax rate, itc: investment tax credit

Table 3. Fiscal multipliers for key variables				
A. Private consumption				
Shock	g	τ^l	τ^k	itc
t=0	-0.22	0.07	-0.03	-0.25
	[-0.29 -0.16]	[0.04 0.11]	[-0.08 -0.01]	[-0.32 -0.18]
t=1	-0.33	0.14	-0.04	-0.41
	[-0.42 -0.26]	[0.10 0.20]	[-0.11 0.01]	[-0.51 -0.31]
t=2	-0.36	0.18	-0.03	-0.42
	[-0.45 -0.29]	[0.13 0.25]	[-0.11 0.03]	[-0.52 -0.32]
t=3	-0.38	0.21	-0.01	-0.37
	[-0.47 -0.30]	[0.15 0.28]	[-0.09 0.06]	[-0.47 -0.27]
t=4	-0.39	0.23	0.02	-0.29
	[-0.49 -0.31]	[0.16 0.30]	[-0.06 0.10]	[-0.39 -0.18]
t=5	-0.41	0.24	0.06	-0.20
	[-0.50 -0.33]	[0.17 0.32]	[-0.02 0.14]	[-0.30 -0.06]
B. Private investment				
t=0	-0.05	-0.01	0.10	0.40
	[-0.07 -0.04]	[-0.02 0.01]	[0.07 0.13]	[0.32 0.47]
t=1	-0.13	-0.01	0.27	0.95
	[-0.17 -0.09]	[-0.06 0.02]	[0.20 0.36]	[0.76 1.11]
t=2	-0.18	-0.02	0.40	1.29
	[-0.25 -0.12]	[-0.09 0.04]	[0.30 0.53]	[1.03 1.52]
t=3	-0.22	-0.03	0.49	1.50
	[-0.30 -0.14]	[-0.12 0.05]	[0.35 0.65]	[1.19 1.79]
t=4	-0.25	-0.03	0.54	1.64
	[-0.35 -0.15]	[-0.15 0.06]	[0.39 0.72]	[1.30 1.96]
t=5	-0.28	-0.04	0.57	1.73
	[-0.39 -0.16]	[-0.18 0.06]	[0.40 0.78]	[1.37 2.06]
C. Hours				
t=0	0.49	0.05	-0.08	0.10
	[0.45 0.52]	[0.03 0.07]	[-0.11 -0.06]	[0.03 0.18]
t=1	0.37	0.08	-0.01	0.29
	[0.33 0.41]	[0.06 0.11]	[-0.04 0.02]	[0.18 0.43]
t=2	0.34	0.10	0.03	0.40
	[0.29 0.38]	[0.07 0.14]	[-0.01 0.07]	[0.26 0.56]
t=3	0.32	0.11	0.05	0.44
	[0.27 0.37]	[0.07 0.15]	[0.00 0.10	[0.30 0.61]
t=4	0.31	0.11	0.04	0.44
	[0.26 0.36]	[0.08 0.16]	[-0.01 0.10]	[0.31 0.61]
t=5	0.31	0.12	0.03	0.42
	[0.26 0.36]	[0.07 0.17]	[-0.03 0.09]	[0.29 0.57]

Notes: g: government spending, τ^l: labor tax rate,
τ^k: capital tax rate, itc: investment tax credit

Table 4. Fiscal multipliers for output				
Model with investment allowances				
Shock	g	τ^l	τ^k	s
t=0	0.77	0.06	0.24	0.25
	[0.69 0.86]	[0.03 0.10]	[0.20 0.28]	[0.12 0.38]
t=1	0.56	0.11	0.38	0.71
	[0.48 0.65]	[0.05 0.18]	[0.32 0.45]	[0.48 0.94]
t=2	0.46	0.14	0.50	1.08
	[0.38 0.55]	[0.05 0.23]	[0.41 0.60]	[0.79 1.39]
t=3	0.41	0.15	0.59	1.39
	[0.30 0.50]	[0.04 0.26]	[0.47 0.72]	[1.04 1.74]
t=4	0.36	0.16	0.66	1.64
	[0.23 0.48]	[0.02 0.30]	[0.51 0.83]	[1.23 2.02]
t=5	0.33	0.16	0.72	1.85
	[0.18 0.45]	[0.00 0.32]	[0.55 0.91	[1.39 2.27]

Notes: g: government spending, τ^l: labor tax rate, τ^k: capital tax rate, s: investment allowance rate

Table 5. Fiscal multipliers for output								
	Flexible prices				**Flexible wages**			
Shock	g	τ^l	τ^k	itc	g	τ^l	τ^k	itc
t=0	0.68	0.10	0.32	0.13	0.80	0.25	0.29	0.29
	[0.62 0.73]	[0.07 0.18]	[0.27 0.38]	[0.05 0.22]	[0.75 0.83]	[0.21 0.31]	[0.25 0.34]	[0.20 0.35]
t=1	0.50	0.17	0.46	0.48	0.70	0.42	0.49	0.87
	[0.43 0.58]	[0.10 0.30]	[0.40 0.55]	[0.32 0.65]	[0.63 0.76]	[0.32 0.53]	[0.40 0.61]	[0.67 0.99]
t=2	0.42	0.19	0.55	0.76	0.64	0.46	0.62	1.28
	[0.33 0.53]	[0.10 0.35]	[0.46 0.68]	[0.55 0.98]	[0.55 0.74]	[0.32 0.61]	[0.47 0.80]	[0.97 1.44]
t=3	0.37	0.19	0.62	0.97	0.59	0.47	0.69	1.57
	[0.26 0.50]	[0.07 0.36]	[0.51 0.78]	[0.73 1.22]	[0.48 0.72]	[0.29 0.65]	[0.50 0.93]	[1.18 1.76]
t=4	0.32	0.19	0.68	1.14	0.55	0.46	0.74	1.78
	[0.19 0.47]	[0.04 0.37]	[0.52 0.86]	[0.87 1.41]	[0.40 0.69]	[0.24 0.66]	[0.50 1.02]	[1.33 2.00]
t=5	0.28	0.18	0.72	1.29	0.51	0.45	0.77	1.95
	[0.13 0.45]	[0.01 0.38]	[0.54 0.93]	[0.99 1.58]	[0.34 0.67]	[0.20 0.67]	[0.49 1.10]	[1.44 2.18]

Notes: g: government spending, τ^l: labor tax rate, τ^k: capital tax rate, itc: investment tax credit

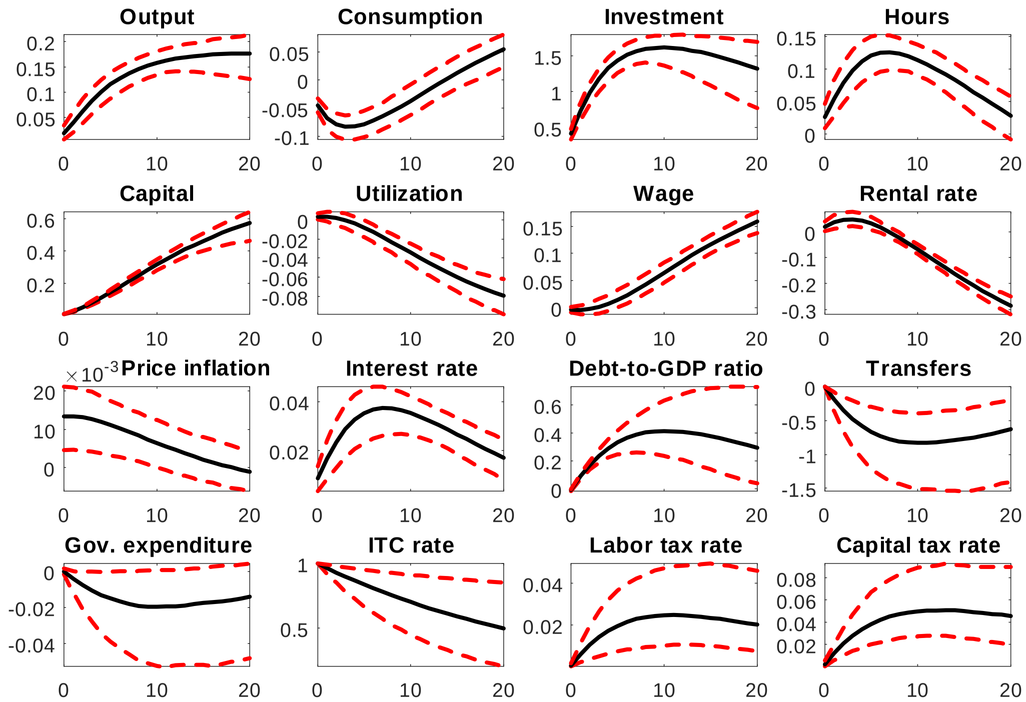
Table 6. Fiscal multipliers for output

Two-sector model

Shock	g	τ^l	τ^k	itc
t=0	0.77	0.06	0.24	0.18
	[0.71 0.83]	[0.04 0.10]	[0.20 0.28]	[0.08 0.29]
t=1	0.57	0.11	0.39	0.55
	[0.50 0.63]	[0.06 0.17]	[0.33 0.46]	[0.37 0.74]
t=2	0.48	0.13	0.51	0.85
	[0.40 0.55]	[0.06 0.21]	[0.42 0.62]	[0.61 1.09]
t=3	0.43	0.15	0.61	1.09
	[0.33 0.52]	[0.05 0.24]	[0.49 0.74]	[0.80 1.39]
t=4	0.38	0.15	0.68	1.28
	[0.28 0.50]	[0.03 0.26]	[0.54 0.84]	[0.95 1.63]
t=5	0.35	0.16	0.74	1.45
	[0.22 0.48]	[0.01 0.28]	[0.57 0.92]	[1.08 1.82]

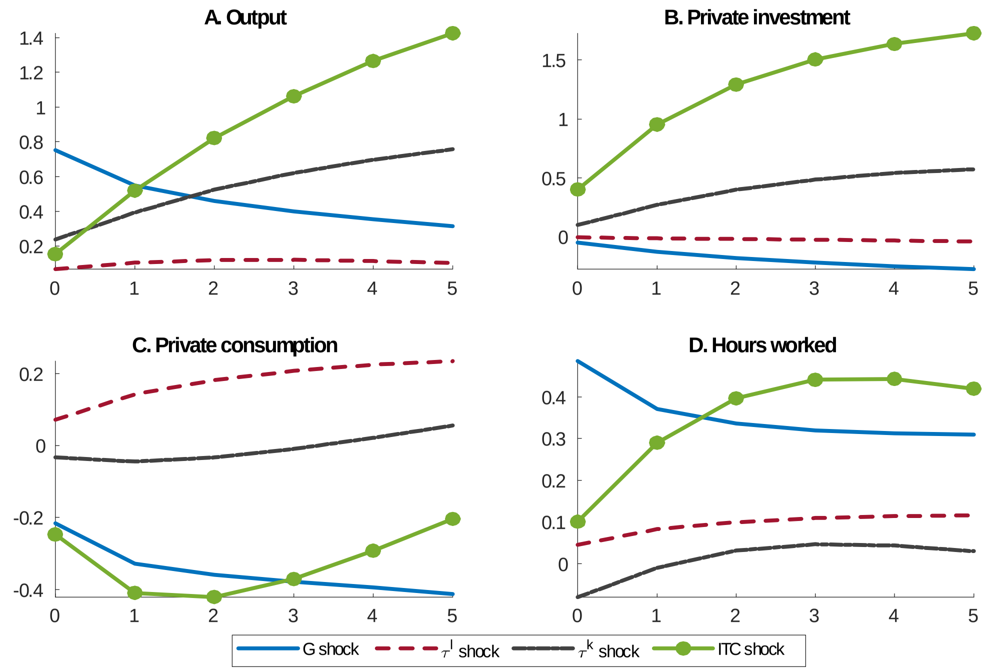
Notes: g: government spending, τ^l: labor tax rate, τ^k: capital tax rate, itc: investment tax credit

Figure 1. Responses to an ITC shock, benchmark model



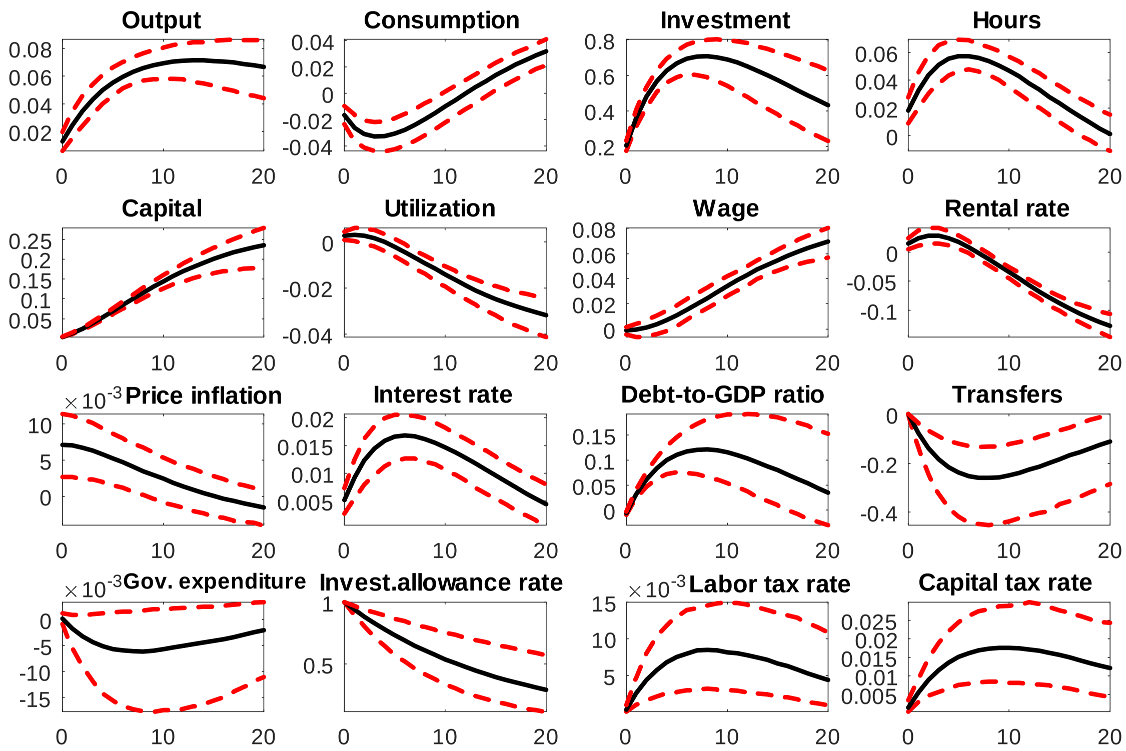
Notes: The graph shows the median (black solid lines) and the 5^{th} and 95^{th}percentiles (red dashed lines) of the posterior distribution of the impulse responses. The shock is equal to one percentagepoint increase in the investment tax credit rate. The y-axis measures the percentage deviation from steady state and the x-axis the time horizon in quarters.

Figure 2. The fiscal multipliers, benchmark model



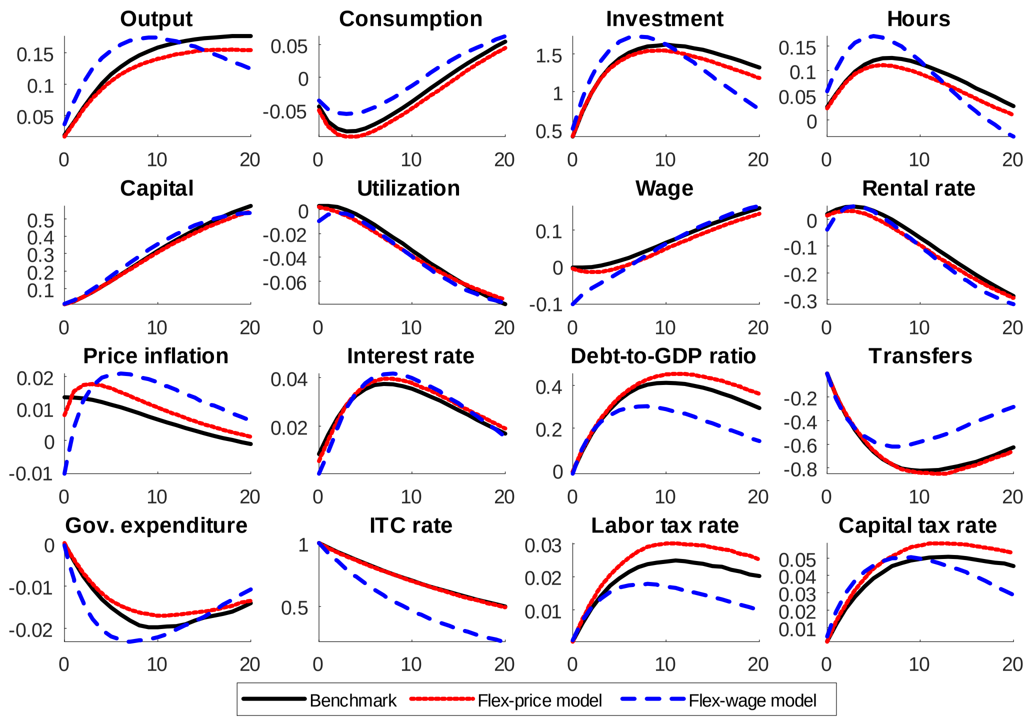
Notes: Each graph shows the medians of the posterior distribution of the fiscal multipliers for the four fiscal shocks. The y- axis measures the fiscal multiplier. and the x-axis the time horizon in years.

Figure 3. Responses to an ITC shock, model with investment allowances



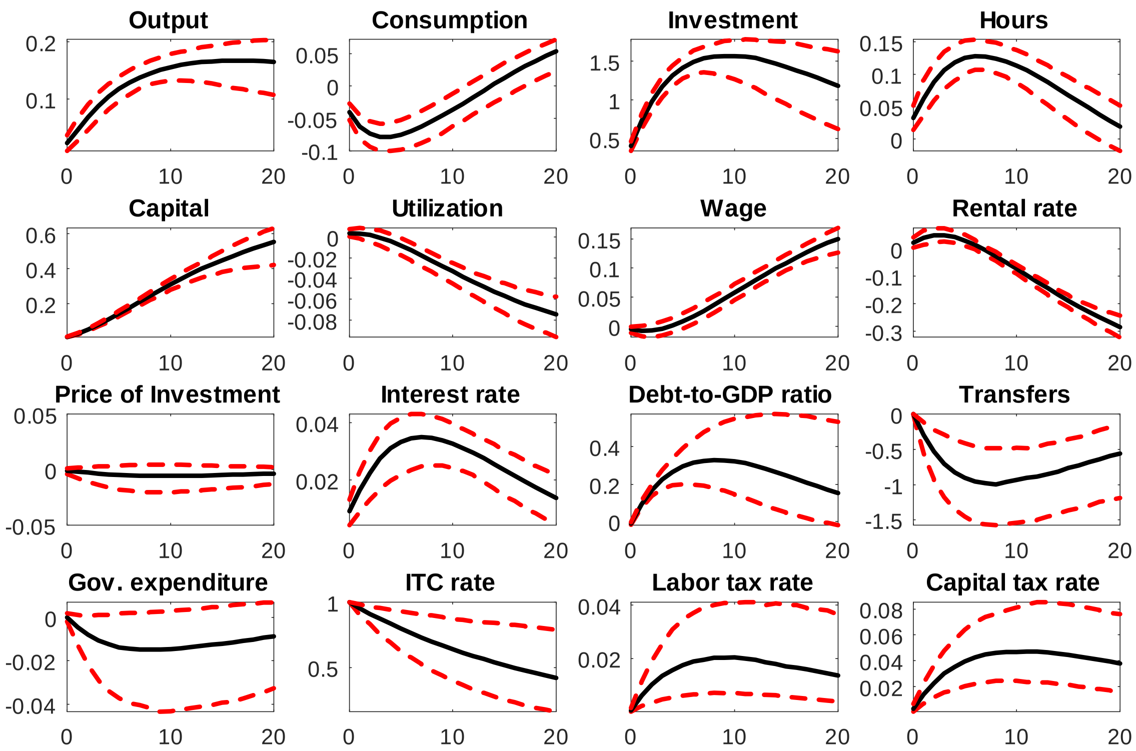
Notes: The graph shows the median (black solid lines) and the 5^{th} and 95^{th} percentiles (red dashed lines) of the posterior distribution of the impulse responses. The shock is equal to one percentage point increase in the investment allowance rate. The y-axis measures the percentage deviation from steady state and the x-axis the time horizon in quarters.

Figure 4. Responses to an ITC shock, flexible prices and wages models



Notes: The graph shows the median of the posterior distribution of the impulse responses for each model (i.e. price flexibility/goods market competition and wage flexibility/labor market competion). The shock is equal to one percentage point increase in the investment tax credit rate. The y-axis measures the percentage deviation from steady state and the x-axis the time horizon in quarters.

Figure 5. Responses to an ITC shock, two-sector model



Notes: The graph shows the median (black solid lines) and the 5^{th} and 95^{th} percentiles (red dashed lines) of the posterior distribution of the impulse responses. The shock is equal to one percentage point increase in the investment tax credit rate. The y-axis measures the percentage deviation from steady state and the x-axis the time horizon in quarters.

UCD CENTRE FOR ECONOMIC RESEARCH – RECENT WORKING PAPERS

WP19/04 Sandra E Black, Paul J Devereux, Petter Lundborg and Kaveh Majlesi: 'Understanding Intergenerational Mobility: The Role of Nature versus Nurture in Wealth and Other Economic Outcomes and Behaviors' February 2019
WP19/05 Judith M Delaney and Paul J Devereux: 'It's not just for boys! Understanding Gender Differences in STEM' February 2019
WP19/06 Enoch Cheng and Clemens Struck: 'Time-Series Momentum: A Monte-Carlo Approach' March 2019
WP19/07 Matteo Gomellini and Cormac Ó Gráda: 'Brain Drain and Brain Gain in Italy and Ireland in the Age of Mass Migration' March 2019
WP19/08 Anna Aizer, Paul J Devereux and Kjell G Salvanes: 'Grandparents, Mothers, or Fathers? - Why Children of Teen Mothers do Worse in Life' March 2019
WP19/09 Clemens Struck, Adnan Velic: 'Competing Gains From Trade' March 2019
WP19/10 Kevin Devereux, Mona Balesh Abadi, Farah Omran: 'Correcting for Transitory Effects in RCTs: Application to the RAND Health Insurance Experiment' April 2019
WP19/11 Bernardo S Buarque, Ronald B Davies, Dieter F Kogler and Ryan M Hynes: 'OK Computer: The Creation and Integration of AI in Europe' May 2019
WP19/12 Clemens C Struck and Adnan Velic: 'Automation, New Technology and Non-Homothetic Preferences' May 2019
WP19/13 Morgan Kelly: 'The Standard Errors of Persistence' June 2019
WP19/14 Karl Whelan: 'The Euro at 20: Successes, Problems, Progress and Threats' June 2019
WP19/15 David Madden: 'The Base of Party Political Support in Ireland: An Update' July 2019
WP19/16 Cormac Ó Gráda: 'Fifty Years a-Growing: Economic History and Demography in the ESR' August 2019
WP19/17 David Madden: 'The ESR at 50: A Review Article on Fiscal Policy Papers' August 2019
WP19/18 Jonathan Briody, Orla Doyle and Cecily Kelleher: 'The Effect of the Great Recession on Health: A longitudinal study of Irish Mothers 2001-2011' August 2019
WP19/19 Martina Lawless and Zuzanna Studnicka: 'Old Firms and New Export Flows: Does Experience Increase Survival?' September 2019
WP19/20 Sarah Parlane and Lisa Ryan: 'Optimal Contracts for Renewable Electricity' September 2019
WP19/21 Claes Ek and Margaret Samahita: 'Pessimism and Overcommitment' September 2019
WP19/22 David Madden 'BMI Mobility and Obesity Transitions Among Children in Ireland' September 2019
WP19/23 Martina Lawless and Zuzanna Studnicka: 'Products or Markets: What Type of Experience Matters for Export Survival?' October 2019
WP19/24 Neil Cummins and Cormac Ó Gráda: 'Artisanal Skills, Watchmaking, and the Industrial Revolution: Prescot and Beyond' October 2019
WP19/25 Morgan Kelly, Cormac Ó Gráda and Peter Solar: 'Safety at Sea during the Industrial Revolution' October 2019
WP19/26 Oana Peia and Davide Romelli: 'Did Bank Lending Stifle Innovation in Europe During the Great Recession?' November 2019

UCD Centre for Economic Research Email economics@ucd.ie