UCD CENTRE FOR ECONOMIC RESEARCH

WORKING PAPER SERIES

2022

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

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

WP22/12

April 2022

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 Kalyvitis§

April 10, 2022

Abstract

This paper studies how investment tax incentives stimulate output in an estimated medium-scale dynamic stochastic general equilibrium model. We find that the horizon following a positive shock to 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. Anticipation does matter with output being adversely affected before the materialization of the shock yielding a fiscal multiplier above 1 in the long run.

JEL classification: E32, E62, H29

Keywords: investment tax credit, fiscal policy, 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 for 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., accelerated depreciations) 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]

Despite the appealing nature of such policies in terms of boosting investment and output, the evidence of the impact of these policies in the literature is mixed. These findings are mainly based on partial equilibrium theoretical and empirical specifications, which do not address interactions with other markets, thus neglecting important feedback through the adjustment of factor and goods prices. Further, the literature does not quantify the efficacy of such policies relative to the budget costs they engender.

This paper structurally estimates 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 for the U.S. economy, along the lines of Smets and Wouters (2007) and Justiniano et al. (2010). Our main analysis is based on the impact of a temporary shock to ITC. The model features a rich fiscal policy sector in which ITC and other spending and tax policies interact endogenously, while 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 multiplier of ITC is above unity over the long run, 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

[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] Detailed description of all types of investment tax incentives used globally can be found in EY, Worldwide Capital and Fixed Assets Guide 2021; EY, Worldwide Corporate Tax Guide 2021; PwC, Worldwide Tax Summaries. The European Commission (2014) report describes the implementation of these incentives in EU countries.

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.

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.

We stress that the ITC multiplier exceeds the multiplier of capital income taxes. First, this is because ITC has a strong impact on the after-tax price of investment, while capital taxes have a limited impact on the after-tax stream of capital income. This makes ITC more effective in stimulating investment and output compared to capital tax cuts. Second, the tax base of capital taxes is larger than that of ITC, which implies greater tax revenue losses for capital tax cuts compared to ITC hikes, rendering the former policy a more expensive tool. These results highlight the importance of assessing investment tax incentives in a fiscal multiplier context.

A standard feature of investment tax incentives is that they are largely anticipated due to considerable lags between their announcement and their implementation. We find that anticipation of investment incentive policies does matter for their effectiveness as firms postpone investment until implementation, in line with previous findings for other tax policies (Yang, 2005; Mertens and Ravn, 2011). Our results show a strong initial decrease of output but subsequently a substantial expansion, with the long run multiplier of the anticipated ITC remaining consistently above 1.

Our paper contributes to two strands of the literature: that which studies the impact of investment tax incentives and that which assesses the size of the fiscal multiplier. The former typically examines the effects of investment tax incentives in partial equilibrium models.[3] In a general equilibrium context, Pereira (1994) examines the efficiency of ITC

[3] According to this literature, the overall picture for the effectiveness of investment tax incentives is mixed. See, e.g., in Hall and Jorgenson (1967), Summers (1981), Abel (1982), Auerbach and Hasset (1992), Cummins et al. (1994), Chirinko et al. (1999), House and Shapiro (2008) and Bond and Xing

based on a finite-horizon model and finds that ITC are distortionary and not always increase investment and output. Edge and Rudd (2011) compare the effects of temporary investment allowances between partial equilibrium and general equilibrium models, and analyze the stabilization properties of such policies within a calibrated model. We contribute to this literature by estimating a medium-scale DSGE model, using a Bayesian approach, and quantifying the effects of investment tax incentives on investment, consumption, and output in the U.S. over the short and long run. Our empirical framework takes into account the interaction of the capital market with other markets and the anticipated nature of tax policies. This permits us to pinpoint the mechanisms of investment tax incentives and gauge their impact on the macroeconomy.

In its analysis on the size of the fiscal multiplier, our paper builds on Forni et al. (2009), Uhlig (2010), Leeper et al. (2010), and Zubairy (2014), who address the aggregate effects of fiscal policy. The assessment is based on the net present-value fiscal multiplier, which stresses the importance of the long-run consequences of fiscal stimuli. Based on a neoclassical model, Uhlig (2010) finds that the multiplier for government spending turns negative in the long run due to distortionary taxation that finances government debt. Leeper et al. (2010) use a more detailed 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 endogenous responses of fiscal instruments to government debt, 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 government spending and income tax multipliers based on a medium-scale New Keynesian model with nominal rigidities and deep habits in consumption. Our fiscal policy environment builds on the aforementioned literature using a rich fiscal policy block with endogenous policy rules. This enables us to make a direct comparison of tax incentives with other fiscal policies (government spending, labor and capital taxation) over the short and long run. Our analysis 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 briefly discusses the theoretical model. Section 3 introduces the data, the estimation methodology, and the results from

(2015).

the Bayesian estimation. Section 4 presents the main results on impulse responses and fiscal multipliers. Sections 5 inspects the role and impact of various mechanisms. Section 6 discusses the importance of policy anticipation. Section 7 addresses the role of changes in the relative price of investment. Section 8 introduces investment tax incentives in the form of investment allowances. Section 9 concludes.

2 A DSGE model with investment tax incentives

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).

2.1 The main model

The model follows Christiano et al. (2005), Smets and Wouters (2003; 2007), and Justiniano et al. (2010). It is a dynamic stochastic general equilibrium model that features nominal rigidities, frictions in the consumption and investment decisions, a public sector that conducts fiscal policy, and a monetary policy authority.

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

Households are characterized by consumption habits and face investment adjustment costs. Wages are sticky in the short run, with wage rigidities arising at the household level. Price rigidities arise at the intermediate goods firm level. We consider a rich fiscal policy structure where the fiscal instruments endogenously adjust for output and government debt deviations from their steady state, as in Leeper et al. (2010) and Zubairy (2014).

Investment tax incentives enter the household sector either as ITC, namely a subsidy on the purchase of investment goods (price subsidy), or as investment allowances (tax base deductions). In the benchmark model that follows, we consider investment tax incentives in the form of ITC, while in section 8 we consider investment allowances.

The model is driven by several exogenous shocks in order to fit U.S. business cycles as much as possible. In particular, we consider a price and wage markup shock, a total factor productivity shock, a preference shock in the consumers' utility, an investment-specific shock, and shocks to fiscal and monetary policy rules.

2.2 Equations affected by the ITC

The economy is populated by a continuum of households indexed by $j \in [0,1]$. Households, in period t, derive utility from consumption, c_t, and supply differentiated labor (hours), $l_{j,t}$. They hold their financial wealth in government bonds, B_{t-1}, and state-contingent securities with net cash inflow $D_{j,t}$. They also own capital stock, $\bar{k}_{t-1}$, determine its utilization rate, u_t, and spend on new investment, i_t. Households receive income from renting capital to the intermediate goods firms at a real rate, r_t, from working at a real wage rate, $w_{j.t}$, and from firms' profits, Π_t. They choose sequences $\{c_t, B_t, \overline{k}_t, i_t, u_{t,} w_{j,t}\}$ so as to maximize their expected lifetime utility subject to the intertemporal budget constraint:

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

and the demand for labor services. 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. Investment tax credits (ITC) are expressed as a subsidy rate, itc_t, to investment.[4]

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, ITC with a subsidy rate itc_t, lump-sum transfers, T_t, and debt

[4] We also estimate models where firms own the capital of the economy and tax incentives enter the firm's problem. They produce very similar results. The equivalence of the two versions of the model is presented in the online appendix.

repayment. The government budget constraint reads:

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

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 government debt. The former endogenous component accounts for countercyclical policy and "automatic stabilizers" (e.g., progressive taxation, and unemployment benefits), while the latter accounts for debt financing dynamics that are necessary to ensure fiscal solvency. In particular, the ITC rate, itc_t, 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:

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

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

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

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 parameters ρ later in the estimation part.

3 Estimation methodology

3.1 Data

The estimation uses a standard Bayesian approach (Smets and Wouters, 2003; 2007) 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 with the GDP deflator and the U.S. population. Hours worked are expressed in per capita terms and the wage rate is transformed into real terms. Price inflation is the quarterly growth rate of the GDP deflator. In line with the literature, we calculate average, effective labor income and capital income tax rates based on national accounts and revenue statistics. These rates are consistent with the tax distortions faced by the representative agent in the model. 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):

[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 give 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).

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

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

3.2 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 parameters related to consumption habits, the intertemporal elasticity of substitution, the elasticity of labor supply and investment adjustment costs are broadly in line with microeconometric estimates and the Bayesian literature (Smets and Wouters, 2007; Leeper et al., 2010). Similarly, the parameters related to monetary policy (Taylor rule) are consistent with previous empirical evidence for the Volcker-Greenspan period (Clarida et al., 2000). The Calvo probabilities are centered around an average length of price and wage contracts of three quarters, in line with the estimates of Nakamura and Steinsson (2008). Parameters related to the fiscal policy rules are set according to Zubairy (2014). The persistence of the AR(1) processes follows a

[7] A valid critique of our approach is that we use legislated ITC data to capture the effect of unanticipated ITC shocks. In section 6 we control for the anticipatory nature of ITC.

beta distribution centered around 0.7 and covers a reasonable range of values. Finally, the standard deviations of the shocks follow an inverse-gamma distribution (Smets and Wouters, 2007; Justiniano et al., 2010).

3.3 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 to 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 estimates of adjustments costs in the empirical literature. In our sensitivity analysis, we experiment with other values for this parameter to explore the robustness of our findings regarding the multiplier of ITC. The intertemporal elasticity of substitution parameter, σ is significantly higher than unity, indicating a relatively low intertemporal elasticity of substitution for consumption. Similarly, the estimated habits in consumption, ν, are moderate, very close to the estimates of Leeper et al. (2010), and somewhat lower than those reported by Smets and Wouters (2007) and Zubairy (2014). The estimates also suggest high price and wage stickiness and a relatively aggressive monetary policy when correcting for inflation and output deviations from their steady state. 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 corrected via all fiscal instruments except for government spending.

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 $\zeta_{y,d}$	$\mathcal{N}$	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]

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.

4 Results

4.1 Impulse responses

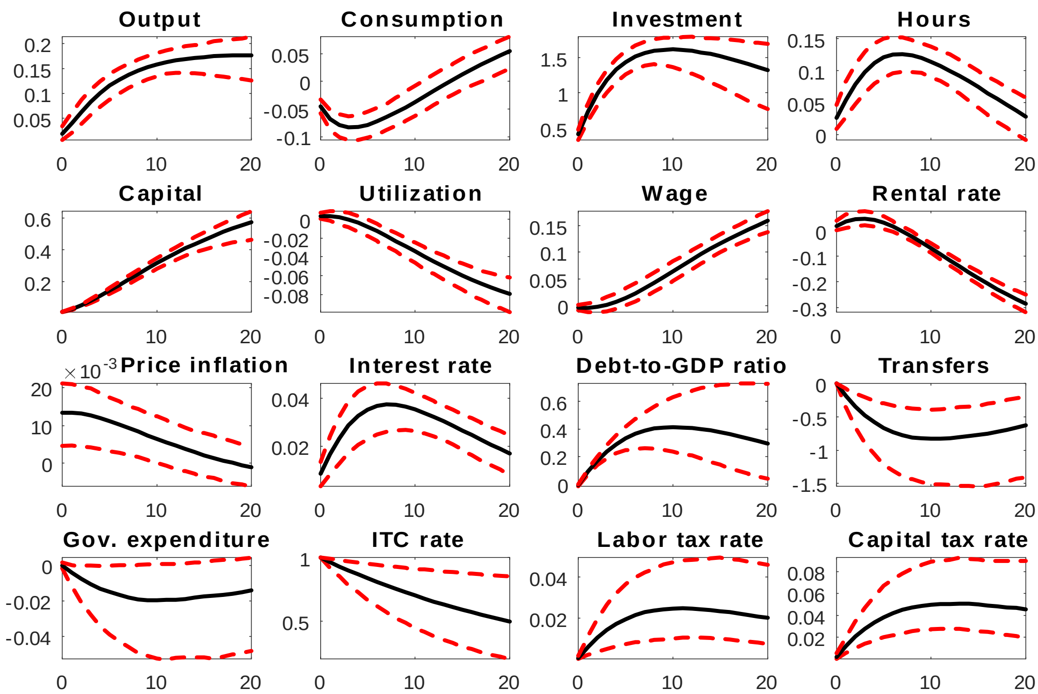
Figure 1 presents the model variables' responses to an ITC shock.[8] The shock is normalized to a one percentage point increase in the ITC rate. The x-axis shows quarters after the shock, and the y-axis shows percentage deviations from the steady state (with the exception of the y-axis for tax rates, 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 the after-tax price of investment falls and, in the presence of investment adjustment costs, induces a hump-shaped and gradual rise in investment and output (*aggregate demand effect*). The increasing demand for investment and the relatively scarse supply lead to the crowding out of consumption in the first periods after the shock. In turn, as capital accumulates at a higher pace, *aggregate supply* starts rising in a persistent way. Since the increase in investment is gradually met by expanded supply, the crowding out of consumption becomes less necessary, and consumption starts rising in the medium run. Overall, the aforementioned mechanisms induce a significant and persistent rise in output, with its qualitative pattern closely

[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.

following that of investment. In particular, following a one percentage point rise in the ITC rate, output rises by 2.87% cumulatively over the five-year horizon, with an estimated 95% confidence interval of [2.24%, 3.40%]. The corresponding estimated cumulative rise in investment amounts to 28.88% with a confidence interval of [22.58%, 33.16%], whereas consumption falls by -0.56% with a confidence interval of [-1.08%, -0.02%] over the five-year horizon.

Figure 1. Responses to an ITC shock, benchmark model



Notes: The graph shows the median (black solid lines) and the 5th and 95th 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.

Furthermore, a temporary increase in ITC has implications for the labor market. The increase in aggregate demand lowers price markups and shifts labor demand upwards (*labor demand effect*). This leads to a protracted increase in hours worked and the real wage. At the same time, the increasing accumulation and supply of capital leads to a significant decline in its rental rate and triggers a substitution of hours with capital. Nevertheless, the *labor demand effect* dominates over the horizon thus inducing a persistent rise in equilibrium hours.

Regarding the financing 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 hours. This ensures that the effects of the ITC shock on output, consumption, and investment are long-lived.[9]

4.2 Fiscal multipliers

To highlight the quantitative differences in how various fiscal policies affect output, we present the output multipliers of the 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.

Following Uhlig (2010) 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 rate, R.[10]

[9] The responses to the rest of the fiscal shocks are in the online appendix. As a general note, we find that those shocks are largely financed through distortionary taxation and the responses are in line with the literature (see, e.g., Leeper et al., 2010; Zubairy, 2014).

[10] 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.

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 the multipliers of Leeper et al. (2010) but somewhat smaller than those in Zubairy (2014). 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.

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

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.

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 investment. This is a sluggish and persistent process due to investment adjustment costs.

We note that the capital tax multiplier is higher than the ITC multiplier on impact, but it follows behind thereafter. This can be explained by the combined optimality conditions for capital and consumption, according to which the marginal cost of capital given by the after-tax price of investment, $u_{c,t}(1 - itc_t)$, is equal to the marginal benefit of capital given by the infinite discounted sum of future after-tax rental incomes, as shown by equation (8). This condition determines the optimal allocation of households' resources between consumption and investment.[11]

$$u_{c,t}(1 - itc_t) = E_t \sum_{j=1}^{\infty} \beta^j (1-\delta)^{j-1} u_{c,t+j} \left[\left(1 - \tau^k_{t+j}\right) r_{t+j} u_{t+j} - \kappa \left(u_{t+j}\right) \right] \tag{8}$$

A well-known property of durable goods, such as capital, is that for sufficiently low depreciation rate, δ, and high discount rate, β, the infinite stream of rental incomes is mainly driven by the distant future, which is affected very little by temporary shocks. As a result, a temporary cut in the capital tax rate, τ^k_t, will have only a small positive impact on the income stream thus triggering a modest increase in investment and a limited substitution away from consumption. On the contrary, a temporary increase in the ITC rate, itc_t, induces a direct, strong decline in the after-tax price of investment, which triggers a relatively large increase in investment and decline in consumption. The latter renders the ITC multiplier lower than the capital tax multiplier on impact. However, as ITC hikes encourage investment to a greater extent than capital tax cuts, the ITC multiplier becomes larger than the capital tax multiplier after the first quarter. A second reason for the relative pattern of the two multipliers is that ITC apply only to new capital, whereas capital income taxes apply to both old and new capital. Because the tax base of capital taxes is larger than that of ITC, the tax revenue losses induced by capital

[11] To facilitate the exposition, this is a simplified version where adjustment costs are set to zero. Importantly, this assumption does not alter the validity of our argument. The variable $u_{c,t}$ stands for the marginal utility of consumption.

tax cuts are greater than those induced by ITC increases. Accordingly, the capital tax multiplier will be lower (in absolute value) than the ITC multiplier. This result highlights the importance of assessing investment tax incentives in a fiscal multiplier context.

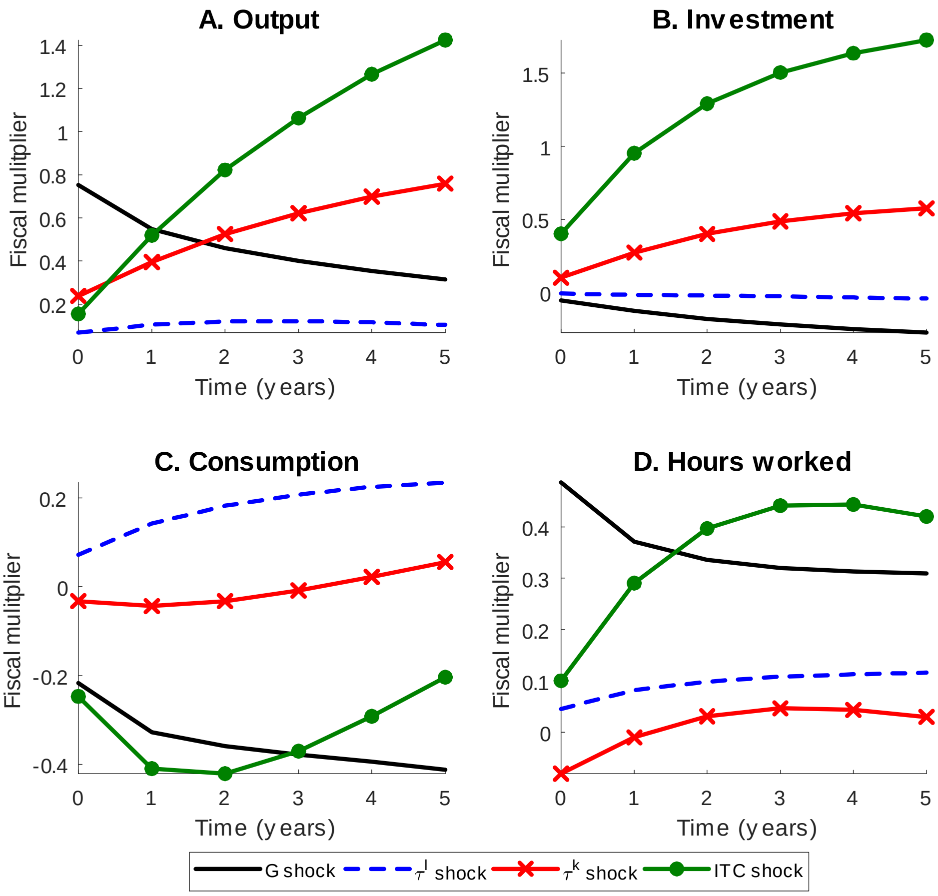
From a policy perspective, it is important to quantify the effects of fiscal policy on key variables, namely the components of output (investment and consumption) and hours worked, as the response of these variables can shed light on the transmission of ITC shocks. To this end, in panels A, B, and C of table 3 and in panels B, C and D of figure 2 we report the present-value cumulative multipliers for private investment, private consumption, and hours worked, respectively, for the four types of shocks. The government spending multipliers for investment and consumption 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 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., Forni et al., 2009; 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 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 investment by $1.73. This effect is almost three times higher than the respective effect of capital taxes on investment and explains why the ITC multiplier of output is higher than the capital tax multiplier of output (after the first quarter).

Table 3. Fiscal multipliers for key variables				
A. Investment				
Shock	g	τ^l	τ^k	itc
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]
B. Consumption				
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]
C. Hours worked				
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

Figure 2. Fiscal multipliers, benchmark model



Notes: Each graph shows the medians of the posterior distribution of the fiscal multipliers for the four fiscal shocks.

The ITC multiplier for 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 expansion of aggregate supply, which attenuates the initial crowding out of consumption. Moreover, as shown before, increases in ITC crowd out consumption to a larger extent than capital tax cuts, which explains why the ITC multiplier of output is lower than the respective capital tax multiplier on impact.

Following an ITC shock, the increase in aggregate demand and labor demand result 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 exceeds the multipliers for the other fiscal instruments in any horizon after the first year.

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

5 Inspecting the mechanism

In this part we inspect how our model specification and the assumed frictions affect the size and time profile of the ITC multiplier. Although the estimated posterior distribution of the fiscal multiplier accounts for parameter uncertainty, it does not convey information on how the multiplier responds to changes in the parameter values or specific model assumptions. To this end, we calculate the output multipliers for alternative scenarios with respect to key parameters of our benchmark model. Letting θ_0 be any tested parameter and Θ_1 the vector of the rest of the parameters, we compute the *conditional posterior distribution* of the ITC multiplier of output, $f(\Theta_1|\theta_0, Y)$.[12] We generate the conditional posterior distribution of the multiplier for alternative values of θ_0 and subsequently plot and compare the median multipliers of those distributions. The heterogeneity among these distributions reveals how sensitive is the ITC multiplier with respect to the conditioning parameter θ_0.[13]

5.1 Investment adjustment costs

Our baseline results indicate that the delayed response of investment drives the slow increase in output following an ITC shock and the time-to-build pattern of the ITC multiplier. In this section we examine how important is the magnitude of our estimated investment adjustment costs for our findings.

The size of the estimated investment adjustment cost parameter varies greatly in the empirical literature depending on the econometric specification used.[14] DSGE-based estimates of the adjustment cost parameter, γ, are quite disperse and usually lie between

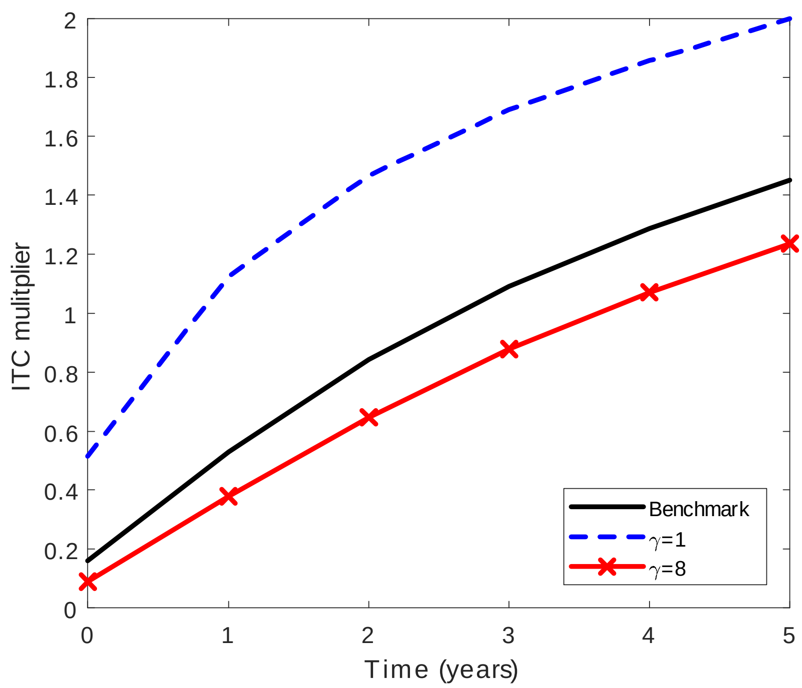
[12]In particular, for a given value of the parameter of interest, θ_0, we randomly draw a set of values for the rest of the parameters Θ_1 from their posterior distributions (MCMC chains), we solve the model and compute the ITC multiplier for output. We repeat the process 1,000 times keeping fixed the value of θ_0 and we obtain the conditional posterior distribution of ITC multipliers, $f(\Theta_1|\theta_0, Y)$.

[13]The corresponding sets of impulse responses, for each experiment, are presented in the online appendix which also contains sensitivty tests with respect to parameters that are not considered below and have minor relevance for the ITC transmission.

[14]For a detailed discussion, see House and Shapiro (2008).

2 and 8 (Christiano et al., 2005; Smets and Wouters, 2007; Justiniano et al., 2010). Given the heterogeneity in the estimated magnitude of investment adjustment costs, we calculate the ITC multiplier for alternative values of the adjustment cost parameter, $\gamma = 1$ and $\gamma = 8$. Figure 3 compares the ITC multiplier for these cases with the benchmark multiplier. As can be readily seen, the five-year multiplier remains above 1 regardless of the degree of adjustment costs.

Figure 3. The ITC multiplier and investment adjustment costs



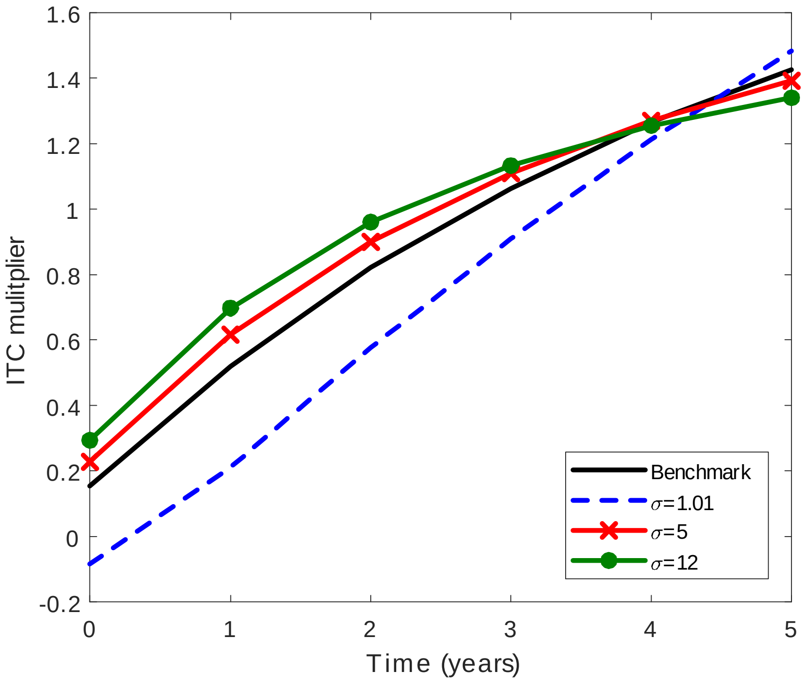
Notes: The graph shows the medians of the posterior distribution of the ITC multiplier for different degrees of investment adjustment costs.

5.2 Intertemporal elasticity of substitution

According to our benchmark analysis, as the interest rate rises following the ITC shock, households give up a higher amount of current consumption and increase savings for future consumption. This behavior is largely determined by the inverse of the intertemporal elasticity of substitution, σ. In particular, higher values of σ make households less willing to transfer consumption over time and, as a result, the interest rate has a smaller impact, through the Euler equation, on current consumption. By contrast, for low values of σ the interest rate significantly affects the intertemporal consumption profile of households.

To assess the importance of the intertemporal channel for the ITC multiplier we allow σ (which is found to be 2.91 in our estimated model) to take the values $\sigma = 1.01$, 5 and 12. In figure 4 we see that for higher values of σ the ITC multiplier is larger on impact, reflecting the fact that households are less willing to give up current consumption for a given increase in the interest rate following the ITC shock and, consequently, aggregate demand is crowded out less. Notably, very low values of σ (very high elasticities of substitution) yield a negative ITC multiplier on impact because consumption is crowded out to a large extent. However, the multiplier increases at a faster rate over the following periods as consumption recovers and investment rises. Overall, the value of the ITC multiplier converges over the five-year horizon.

Figure 4. The ITC multiplier and the intertemporal elasticity of substitution



Notes: The graph shows the medians of the posterior distribution of the ITC multiplier for different values of the intertemporal elasticity of substitution.

5.3 Monetary policy

Another possible mechanism that affects the magnitude and time profile of the ITC multiplier is monetary policy and its impact on investment. In our model, households carry their wealth to the future in the form of physical capital and government bonds. The stance of monetary policy affects the response of interest rates and the price of government bonds to ITC shocks, and eventually determines households' optimal allocation between bonds and investment in capital.

To address the impact of monetary policy on the ITC multiplier we conduct a set of experiments on the parameters and rules that drive monetary policy. Our framework assumes that there exists an independent monetary policy authority that satisfies the Taylor principle and sets the nominal interest rate, R_t, in response to deviations of inflation, π_t, output, y_t, and output growth from their steady states according to

$$\widehat{R}_t = \rho_R \widehat{R}_{t-1} + (1 - \rho_R) \left[\zeta_\pi \widehat{\pi}_t + \zeta_y \widehat{y}_t \right] + \zeta_{y,d} \widehat{\left(\frac{y_t}{y_{t-1}} \right)} + \epsilon_t^R, \tag{9}$$

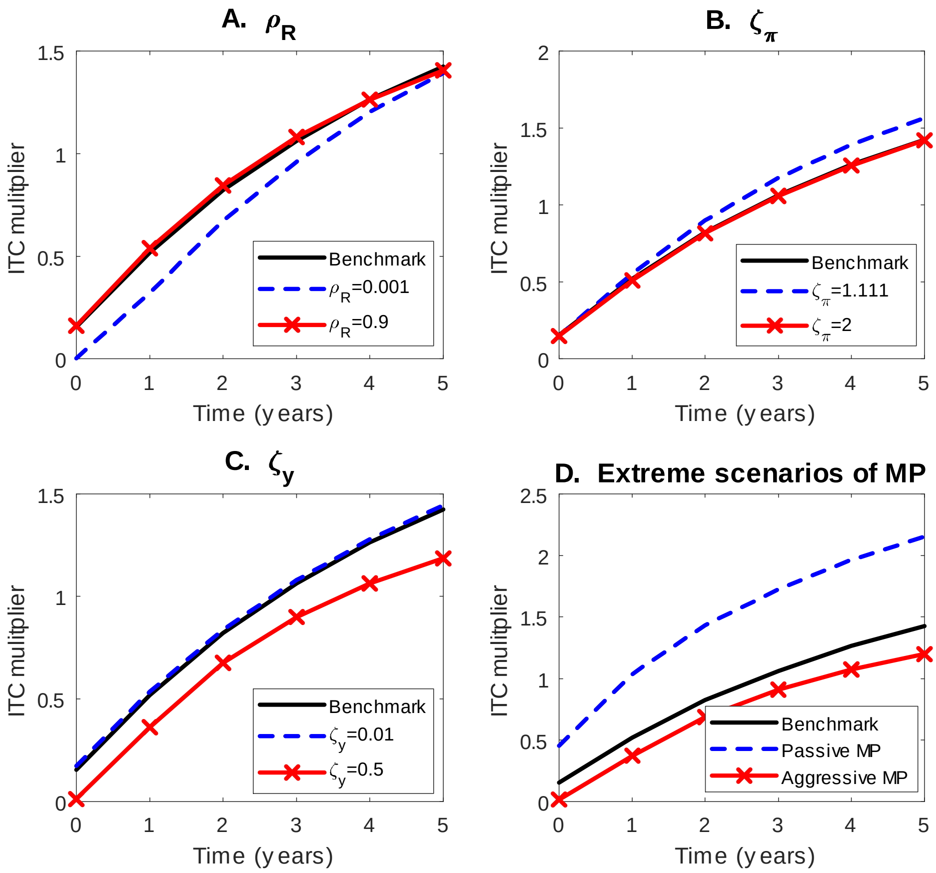
where ϵ_t^R is a monetary shock and is *i.i.d.* $N(0, \sigma_R^2)$. The estimated monetary policy parameters (reported in Table 1) indicate a high degree of interest rate smoothing and a significant response to inflation. We examine how the stance of monetary policy affects the ITC multiplier by considering different values of the interest rate smoothing parameter, ρ_R, the inflation coefficient, ζ_π, and the output coefficient, ζ_y. We also examine two extreme-case scenarios of monetary policy.

First, panel A in figure 5 shows the fiscal multiplier when the interest rate smoothing parameter, ρ_R, is perturbed, taking the values 0.001 and 0.9. A lower ρ_R implies that monetary policy raises the interest rate more rapidly following a positive ITC shock, which increases the incentive to save in bonds and attenuates the expansionary impact of ITC on aggregate demand. Importantly, the long-run ITC multiplier remains robustly large.

Next, we allow for the inflation coefficient, ζ_π, to take the values 1.111 and 2.[15] For a lower inflation coefficient ($\zeta_\pi = 1.111$) monetary policy becomes less responsive to deviations of inflation from its steady state. In this case, following an ITC shock and the subsequent increase in inflation, the interest rate rises less. This induces a weaker incentive to save in bonds and a stronger desire to consume and invest in capital, thus yielding an ITC multiplier larger than the benchmark, though their difference is small (panel B in figure 5).

[15] The value 1.111 is the smallest accepted inflation coefficient that is consistent with a determinate equilibrium in the model.

Figure 5. The ITC multiplier and monetary policy



Notes: The graph shows the medians of the posterior distribution of the ITC multiplier for different monetary policy parameters.

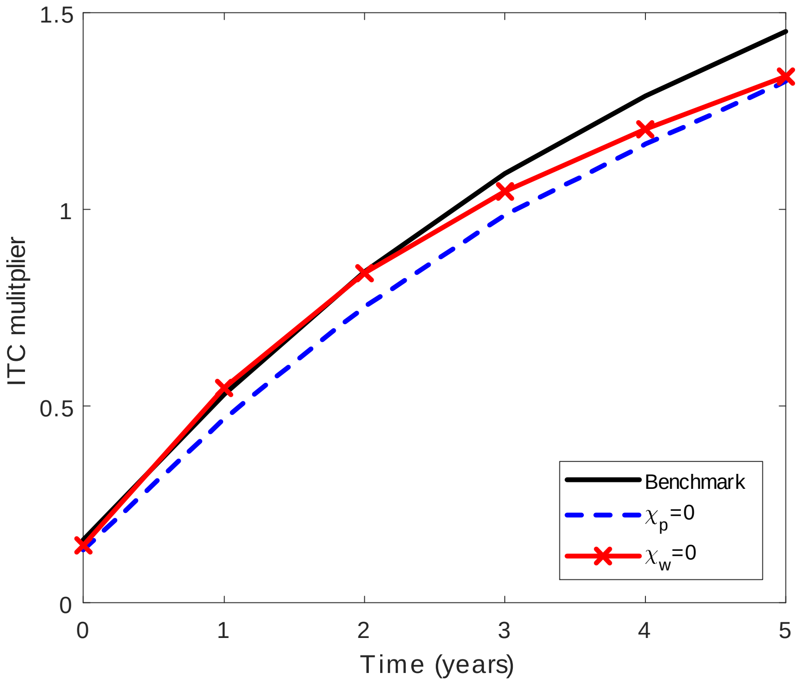
A similar picture emerges when the parameter on output, ζ_y, takes the values 0.01 and 0.5. For a higher ζ_y the ITC multiplier is smaller on impact and in the long run, because the nominal interest rate rises more sharply following an ITC shock. However, the difference in terms of the ITC multiplier is small and the multiplier remains above 1 over the five-year horizon (panel C in figure 5).

Finally, in panel D of figure 5 we examine two extreme cases of monetary policy stance, one where monetary policy is very aggressive to stabilize both inflation and output ($\zeta_\pi = 2$ and $\zeta_y = 0.5$), and a second one where monetary policy does not react significantly to changes in inflation and output ($\zeta_\pi = 1.111$ and $\zeta_y = 0.01$). In the case of the aggressive monetary policy, the interest rate rises sharply, which leads to a strong crowding out of consumption and investment. This effect constrains the ITC multiplier close to zero on impact, but its value exceeds 1 over the five-year horizon. On the other hand, an extremely accommodative (passive) monetary policy induces a weak crowding out of aggregate demand and enhances the stimulative effect of ITC, yielding an ITC multiplier that exceeds 2 over the five-year horizon.

5.4 Nominal rigidities

In their analysis on the effects of investment allowances, Edge and Rudd (2011) point out the role of price and wage rigidities. In our model nominal rigidities affect the responsiveness of prices and interest rates following an ITC shock. In turn, this determines the magnitude of the intertemporal effect on households and the crowding out effect on aggregate demand.

Figure 6. The ITC multiplier and nominal rigidities



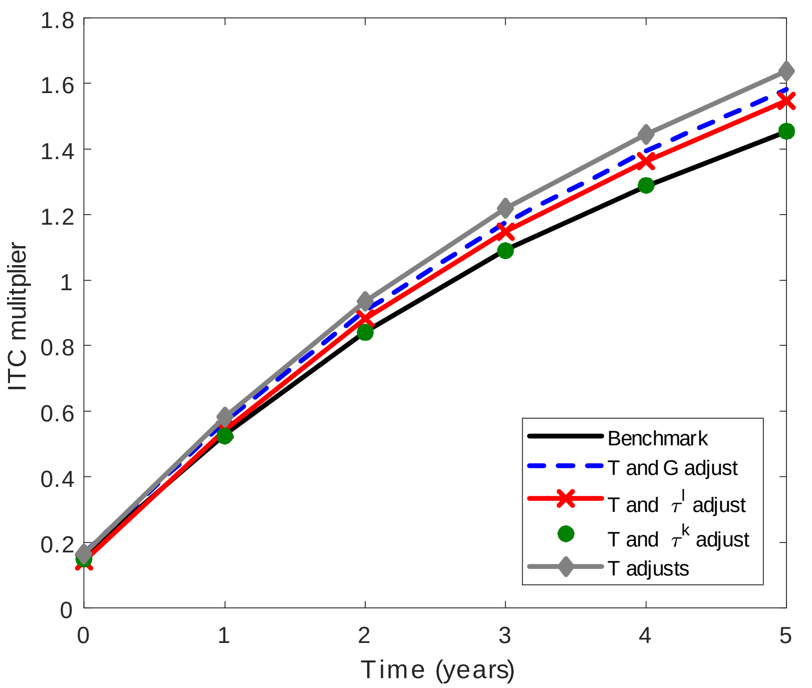
Notes: The graph shows the medians of the posterior distribution of the ITC multiplier for the benchmark model versus a model with flexible prices ($\chi_p = 0$) and a model with flexible wages ($\chi_w = 0$).

In figure 6 we consider more closely how price and wage rigidities contribute to the size of the ITC multiplier. In particular, we compare the ITC multiplier of the benchmark model with the ITC multiplier of a version of the model with flexible prices ($\chi_p = 0$) and another version with flexible wages ($\chi_w = 0$). Price stickiness increases the size of the multiplier through the whole horizon, in line with the theoretical predictions, whereas wage stickiness appears to be less relevant. Both experiments yield ITC multipliers that are very close to the benchmark.

5.5 Endogenous fiscal policy

Investment tax incentives imply foregone revenue that eventually will be financed through more taxes or spending cuts. Previous studies suggest that the debt financing scheme matters for the way that agents respond to fiscal shocks (see, e.g., Leeper and Yang, 2008). What is more, "automatic stabilizers," operating through the endogenous response of spending and tax instruments to variations in output growth, could also alter the transmission pattern of fiscal policy and the size of the relevant fiscal multiplier. In our benchmark model we consider a rich fiscal policy setting where *all* fiscal instruments are assumed to feature "automatic stabilizers" and a debt-correcting component, letting the data speak for the magnitude of adjustments to those endogenous components.

Figure 7. The ITC multiplier and endogenous fiscal policy



Notes: The graph shows the medians of the posterior distribution of the ITC multiplier for different schemes of the systematic response of fiscal policy.

In this section we examine the role of the systematic response of fiscal policy for the transmission of ITC. In particular, we ask how the path of the ITC multiplier would be in four counterfactual scenarios characterizing the endogenous adjustments of the fiscal policy rules: i) only transfers adjust, ii) only transfers and government consumption adjust, iii) only transfers and labor taxes adjust, and iv) only transfers and capital taxes adjust.[16] To do so, for each counterfactual scenario, we restrict the debt coefficients, $\rho_{\cdot,b}$, and the output coefficients, $\rho_{\cdot,y}$, of the fiscal instruments that do not adjust to zero. The respective ITC multipliers are presented in figure 7. It can be readily seen that the assumed systematic response of fiscal policy matters only in long horizons. Adjustments through transfers and government spending are the least costly in terms of output gains. Yet, the long-run ITC multiplier is robustly large.

6 Anticipation effects

Real-world tax policies and reforms do not hit the economy unexpectedly; they take time to be deliberated upon, to be passed and to be implemented. In practice, the direction and principles of the forthcoming tax policies are known well in advance of their implementation through cabinet directives, prolonged committee work and public debates. Moreover, the details of the legislation take time to work out and to garner majority support, whereas there is usually a lag between the passage of the law and the actual implementation of the new tax rules, which often apply retroactively to the date a law is introduced.

Although it is generally believed that anticipated future temporary increases in ITC would lead to postponing investment until the implementation of the tax reform, the answer is not clear cut. For instance, in the presence of investment adjustment costs, there may be incentive to smooth investment across time to minimize the adjustment costs, and consequently anticipated increases in ITC could stimulate investment even before the materialization of the policy (Summers, 1981). House and Shapiro (2008) provide ample evidence which show that the bonus depreciation allowances provided in the 2002 and 2003 U.S. tax bills generated positive investment responses prior to their signing, which is consistent with a credible anticipation of the enactment of the retroactive

[16] Transfers should adjust in all cases in order to ensure determinacy of equilibrium.

policy.

To examine whether our main findings are affected by the anticipation of ITC policy, we follow Mertens and Ravn (2011) and Schmitt-Grohe and Uribe (2012) and introduce policy anticipation in the model. In particular, the ITC rate, the income tax rates $x_t \in \{\tau_t^k, \tau_t^l\}$, and spending and transfers $m_t \in \{g_t, T_t\}$ now read:

$$\begin{aligned} \widehat{itc}_t &= -\rho_{itc,y}\widehat{y}_t - \rho_{itc,b}\hat{b}_{t-1} + \widehat{e}_t^{itc}, \\ \widehat{e}_t^{itc} &= \rho_{itc}\widehat{e}_{t-1}^{itc} + \varepsilon_{0,t}^{itc} + \varepsilon_{4,t-4}^{itc}, \\ \varepsilon_{j,t}^{itc} &\sim i.i.d.N(0, \sigma_{j,itc}^2), \end{aligned} \tag{10}$$

$$\begin{aligned} \widehat{x}_t &= \rho_{x,y}\widehat{y}_t + \rho_{x,b}\hat{b}_{t-1} + \widehat{e}_t^{x}, \\ \widehat{e}_t^{x} &= \rho_{x}\widehat{e}_{t-1}^{x} + \varepsilon_{0,t}^{x} + \varepsilon_{4,t-4}^{x}, \\ \varepsilon_{j,t}^{x} &\sim i.i.d.N(0, \sigma_{j,x}^2), \end{aligned} \tag{11}$$

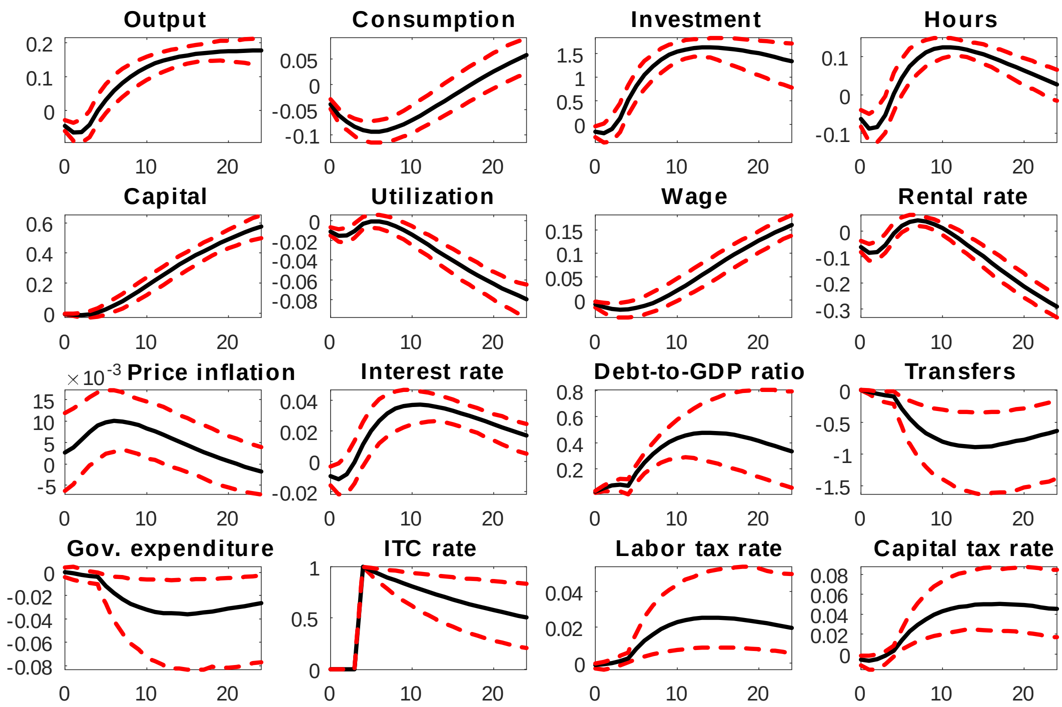
$$\begin{aligned} \widehat{m}_t &= \rho_{m,y}\widehat{y}_t - \rho_{m,b}\hat{b}_{t-1} + \widehat{e}_t^{m}, \\ \widehat{e}_t^{m} &= \rho_{m}\widehat{e}_{t-1}^{m} + \varepsilon_{0,t}^{m} + \varepsilon_{4,t-4}^{m}, \\ \varepsilon_{j,t}^{m} &\sim i.i.d.N(0, \sigma_{j,m}^2), \end{aligned} \tag{12}$$

What makes this version of the model distinct to the benchmark is the existence of two different exogenous shocks in each policy rule ($\varepsilon_{j,t}^{itc}, \varepsilon_{j,t}^{x}, \varepsilon_{j,t}^{m}$ for $j = \{0, 4\}$). The subscript j denotes the anticipation horizon of the exogenous shock. For instance, $\varepsilon_{0,t}^{itc}$ is an exogenous shock to the ITC rate with zero periods of anticipation (unanticipated shock) whereas $\varepsilon_{4,t}^{itc}$ is the exogenous shock to the ITC rate with four periods of anticipation (four-quarter anticipated shock).

Figure 8 presents the responses to a four-quarter ahead anticipated ITC shock. Policy anticipation makes households postpone their investment purchases until the implementation of the policy thus leading to an insignificant response of investment in the first quarters. As households expect a rise in future prices and interest rates following an anticipated increase in ITC, their consumption significantly falls immediately after the news arrive. The combined aforementioned effects lead to a contraction of aggregate demand, output and hours in the first four quarters. However, they all start rising shortly after the implementation of the policy, with the long-run patterns remaining qualitatively similar to those of an unanticipated shock (benchmark model, figure 1).

Table 4 presents the output multipliers of the anticipated fiscal shocks for the first five years after the implementation of the policy.[17] The ITC multiplier outperforms the multipliers of the other fiscal shocks in the medium and long run. Moreover, the multiplier of the anticipated ITC shock is smaller than the multiplier of the unanticipated ITC shock (fourth column, table 2) and even becomes negative on impact. Nevertheless, the output gains after the implementation of the policy compensate for the short-run losses and the cumulative long-run ITC multiplier remains consistently above 1.

Figure 8. Responses to an anticipated ITC shock



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.

[17] Because the fiscal instruments are almost unresponsive in the quarters *before* the materialization of the shock, the ratios of the multipliers for those quarters are not well defined.

Table 4. Fiscal multipliers for output				
Four-quarter anticipation				
Shock	g	τ^l	τ^k	itc
t=0	-1.09	0.72	1.68	-1.84
	[-1.41 -0.79]	[0.49 1.07]	[1.27 2.18]	[-3.28 -0.41]
t=1	0.05	0.30	0.94	0.07
	[-0.06 0.18]	[0.20 0.42]	[0.79 1.11]	[-0.44 0.66]
t=2	0.14	0.25	0.98	0.56
	[0.03 0.27]	[0.15 0.38]	[0.83 1.14]	[0.11 1.12]
t=3	0.16	0.23	1.04	0.87
	[0.03 0.30]	[0.12 0.37]	[0.89 1.21]	[0.43 1.46]
t=4	0.15	0.22	1.10	1.10
	[0.01 0.31]	[0.09 0.37]	[0.93 1.28]	[0.65 1.74]
t=5	0.14	0.20	1.15	1.28
	[-0.03 0.31]	[0.06 0.37]	[0.95 1.34]	[0.82 1.96]

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

7 Accounting for the price of investment

An ongoing debate on the impact of investment tax incentives is whether they trigger adjustments to investment goods prices thus offsetting any beneficial effects of such policies. Because these adjustments take place along the supply curve of investment goods, their size will be primarily determined by the price elasticity (slope) of the supply of investment goods. Goolsbee (1998) estimates a significantly upward-sloping supply curve of capital equipment for the United States, which implies that a 10% investment tax credit raises equipment prices 3.5-7.0%. On the contrary, Whelan (1999) finds no evidence of a systematic relationship between tax incentives and equipment prices, once controlling for omitted variables in the estimation model of Goolsbee (1998).[18] Similarly, 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. This finding corroborates the evidence by House and Shapiro (2008) on the negligible impact of the 2002-2004 U.S. bonus depreciation policy on the price of investment. In line with the aforementioned literature, our benchmark estimates suggest that investment goods prices (price inflation, shown in figure 1) barely react to ITC shocks thus permitting relatively strong adjustments to equilibrium investment and output, and a big ITC

[18]Whelan (1999) finds that tax incentives are highly correlated with supply shocks (e.g. input costs of equipment producers) and, as a result, it is necessary to control for supply shocks in the regressions.

multiplier.[19]

Based on a two-sector production model, Edge and Rudd (2011) show that movements in the *relative* price of investment (i.e. the market price of investment goods normalized by the market price of the consumption goods) might also drive the effects of investment tax incentives. Because we assume a common price for investment and consumption goods in our benchmark model, the relative price of investment is invariant at 1. In this part, we extend our model along the lines of Edge and Rudd (2011), accounting for movements in the relative price of investment and quantifying its impact on the ITC multiplier. To this end, we assume 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. In all other aspects the model remains the same, so we present only the modified portion.[20]

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,

$$p_{it}^{j*} = (1 + \eta_{p,t}^{j}) \frac{E_t \sum\limits_{s=0}^{\infty} (\beta \chi_p^j)^s \Lambda_{t,t+s} mc_{t+s} y_{it+s}^{j}}{E_t \sum\limits_{s=0}^{\infty} (\beta \chi_p^j)^s \Lambda_{t,t+s} y_{it+s}^{j}}, \tag{13}$$

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

As marginal costs of the two intermediate sectors are identical, the key to the dynamics of the relative price of investment will be the relative price stickiness between the two sectors: if the investment goods sector is more (less) sticky than the consumption goods

[19] A one percentage point increase in ITC makes price inflation rise by only 0.012% on impact.

[20] This specification is equivalent to a model with two preliminary good sectors that produce either consumption or investment (preliminary) goods with identical technologies and perfectly mobile factors of production between sectors. We also estimate a version of the model with heterogeneous production functions and limited factor mobility. It produces very similar results.

sector, the relative price of investment goods falls (rises) after an exogenous increase in ITC. 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 price of investment and a relatively weak price channel.[21] Table 5 shows the output multipliers in this model, which are very close to the benchmark multipliers (table 2). 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.

Table 5. 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

8 Investment allowances

Tax-based investment incentives can take various forms when implemented. The investment tax credits, examined in the previous sections, 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

[21] The impulse responses of this version of the model look very similar to the benchmark and can be found in the online appendix.

in the macroeconomic implications of such policies.[22] Edge and Rudd (2011), for example, examine a model with investment allowances in the form of accelerated depreciation and simulate the effects of historical episodes of such policies (2003 and 2008 U.S. bonus depreciations). House et al. (2019) approximate tax deductions with a comprehensive investment tax subsidy, defined as the sum of investment tax credits and the present-value of future depreciation allowances.[23]

Although investment allowances and ITC seem to work in a similar fashion, they differ in that investment allowances enter the capital tax base and trigger a non-trivial interplay with capital taxes. Our aim here is to verify whether the baseline conclusions extend to the case of investment allowances. To this end, we modify the benchmark model by assuming that investment tax incentives take the form of a deduction in capital taxes that households pay. In particular, the households' budget constraint now reads:

$$c_t+i_t+B_t = r_t u_t \bar{k}_{t-1} - \tau_t^k (r_t u_t \bar{k}_{t-1} - s_t i_t) + (1-\tau_t^l) w_{j,t} l_{j,t} + T_t + \Pi_t + D_{j,t} + R_{t-1}\frac{B_{t-1}}{\pi_t} - \kappa(u_t)\bar{k}_{t-1}, \tag{14}$$

where $s_t i_t$ denotes the total amount of capital tax deductions (investment allowances), and s_t denotes the investment allowance rate.[24] The model remains the same in all other aspects. We estimate the model based on the benchmark dataset, replacing the ITC rate series with a measure of investment allowances.[25]

Table 6 presents the estimated output multipliers for this version of the model. The

[22]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%.

[23]Also, Zwick and Mahon (2017) find a positive impact of bonus depreciations on investment for smaller firms in the U.S., but an ambiguous effect on long-term capital stock. Maffini et al. (2019) exploit an exogenous change in the qualifying threshold for depreciation allowances in the U.K., and find that the firms which benefited from this change substantially increased their investment within the first 18 months. Ohrn (2019) estimates the effects of investment tax policies in the U.S. manufacturing sector based on state-level variation in the adoption of the policy, and finds that investment increased on impact, but the effect on employment and production was insignificant.

[24]The rate s can be seen as an upfront subsidy equal to the present-value of future depreciation allowances per unit of investment (Hall and Jorgenson, 1967).

[25]In particular, we use the present-value of depreciation allowances of business equipment and structures provided in Cummins et al. (1994). Since the series are at annual frequency, we proceed with a mixed frequency estimation in Dynare, with the data sample spanning the period Q1:1964-Q4:1988.The estimated impulse responses of this model are provided in the online appendix.

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 larger in any horizon. Moreover, 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 incentives remain robust regardless of the form these incentives take, namely tax credits or tax deductions.

Table 6. Fiscal multipliers for output
Model with investment allowances

Shock	g	τ^l	τ^k	s
t=0	0.86	0.04	0.24	0.38
	[0.81 0.90]	[0.01 0.07]	[0.20 0.30]	[0.24 0.49]
t=1	0.63	0.08	0.34	0.84
	[0.56 0.71]	[0.02 0.16]	[0.25 0.46]	[0.55 1.09]
t=2	0.49	0.12	0.41	1.13
	[0.41 0.59]	[0.02 0.23]	[0.27 0.59]	[0.77 1.50]
t=3	0.40	0.15	0.46	1.35
	[0.30 0.51]	[0.03 0.29]	[0.27 0.70]	[0.95 1.79]
t=4	0.34	0.17	0.49	1.56
	[0.21 0.45]	[0.02 0.34]	[0.27 0.78]	[1.10 2.04]
t=5	0.28	0.18	0.52	1.74
	[0.13 0.40]	[0.02 0.37]	[0.25 0.86]	[1.23 2.26]

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

9 Conclusions

Existing studies measuring the impact of investment tax incentives on private investment find mixed results. This paper extends previous evidence by estimating the impact of these incentives on output in a general equilibrium context. Introducing incentives for private investment in the form of ITC or investment allowances in a standard DSGE model with nominal frictions can generate an overwhelmingly significant and persistent effect of those policies on output. The estimated long-run multiplier is substantially larger than 1 and exceeds, over longer horizons, the government spending multiplier and the labor and capital tax multipliers. Increases in ITC and investment allowances have a positive impact on labor demand, suggesting a rise in hours worked and the real wage. Also, we find that anticipation of investment tax incentives does matter, causing an initial contraction of output followed by a strong expansion, leading overall to cumulative long-run gains.

Our policy message is that compelling arguments about the efficacy of investment tax incentives need to take into account the aggregate effects of such policies and their side effects on the labor market. We stress that the evaluation of investment tax incentives vis-à-vis other spending and tax policies should take place in a fiscal multiplier context, weighting the potential economic gains with the budget costs that those policies engender.

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] Auerbach A. J., Hassett K. A., 1992. Tax policy and business fixed investment in the United States. *Journal of Public Economics* 47(2): 141-170.

[3] Bond S., Xing J., 2015. Corporate taxation and capital accumulation: evidence from sectoral panel data for 14 OECD countries. *Journal of Public Economics* 130(C): 15-31.

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

[5] Chirinko R. S., Fazzari S. M., Meyer A. P., 1999. How responsive is business capital formation to its user cost?: an exploration with micro data. *Journal of Public Economics* 74(1): 53-80.

[6] 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.

[7] Clarida R., Gali J., Gertler M., 2000. Monetary policy rules and macroeconomic stability: evidence and some theory. *Quaterly Journal of Economics*, 115(1): 147.

[8] Cummins J. G., Hassett K. A., Hubbard R. G., 1994. A reconsideration of investment behavior using tax reforms and natural experiments. *Brookings Papers on Economic Activity* 35(2): 1-74.

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

[10] EY, Worldwide Capital and Fixed Assets Guide 2021, available at https://www.ey.com/en_gl/tax-guides/worldwide-capital-and-fixed-assets-guide.

[11] EY, Worldwide Corporate Tax Guide 2021, available at https://www.ey.com/en_gl/tax-guides/worldwide-corporate-tax-guide.

[12] European Commission, 2014. A study on R&D tax incentives. *Taxation Papers, Working Paper* N. 52.

[13] Forni L., Monteforte L., Sessa L., 2009. The general equilibrium effects of fiscal policy: Estimates for the Euro Area. *Journal of Public Economics* 93(3-4): 559-585.

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

[15] Hall R. E., Jorgenson D. W, 1967. Tax policy and investment behavior. *American Economic Review* 57 (3): 391-414.

[16] House C. L., Shapiro M. D., 2008. Temporary investment tax incentives: theory with evidence from bonus depreciation. *American Economic Review* 98(3): 737–68.

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

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

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

[20] Karier T., 1998. The investment tax credit. *New Directions for Evaluation* 79*:* 95–115.

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

[22] Leeper E. M., Yang S. S., 2008. Dynamic scoring: alternative financing schemes. *Journal of Public Economics* 92(1-2): 159-182.

[23] Maffini G., Xing J., Devereux M. P., 2019. The impact of investment incentives: evidence from UK corporation tax returns. *American Economic Journal: Economic Policy* 11(3): 361- 389.

[24] Mertens K., Ravn M., 2011. Understanding the aggregate effects of anticipated and unanticipated tax policy shocks. *Review of Economic Dynamics* 14(1): 27-54.

[25] Nakamura E., Steinsson J., 2008. Five facts about prices: a reevaluation of menu cost models. *Quarterly Journal of Economics* 123(4): 1415-1464.

[26] Ohrn E., 2019. The effect of tax incentives on U.S. manufacturing: evidence from state accelerated depreciation policies. *Journal of Public Economics* 180(C).

[27] Pereira A. M., 1994. On the effects of investment tax credits on economic efficiency and growth. *Journal of Public Economics* 54(3): 437-461.

[28] PwC, Worldwide Tax Summaries, available at https://taxsummaries.pwc.com.

[29] Schmitt-Grohé S., Uribe M., 2012. What's news in business cycles. *Econometrica* 80(6): 2733-2764.

[30] 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.

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

[32] Summers L., 1981. Taxation and corporate investment: a q-theory approach. *Brookings Papers on Economic Activity* 12(1): 67-140.

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

[34] Whelan K., 1999. Tax incentives, material inputs, and the supply curve for capital equipment. *Finance and Economics Discussion Serie*s 1999-21, Board of Governors of the Federal Reserve System (U.S.).

[35] Yang S.-C. S., 2005. Quantifying tax effects under policy foresight. *Journal of Monetary Economics* 52(8): 1557–1568.

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

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

UCD CENTRE FOR ECONOMIC RESEARCH – RECENT WORKING PAPERS

WP21/15 Morgan Kelly: 'Devotion or Deprivation: Did Catholicism Retard French Development?' June 2021
WP21/16 Bénédicte Apouey and David Madden: 'Health Poverty' July 2021
WP21/17 David Madden: 'The Dynamics of Multidimensional Poverty in a Cohort of Irish Children' August 2021
WP21/18 Vessela Daskalova and Nicolaas J Vriend: 'Learning Frames' August 2021
WP21/19 Sanghamitra Chattopadhyay Mukherjee: 'A Framework to Measure Regional Disparities in Battery Electric Vehicle Diffusion in Ireland' August 2021
WP21/20 Karl Whelan: 'Central Banks and Inflation: Where Do We Stand and How Did We Get Here?' August 2021
WP21/21 Tyler Anbinder, Cormac Ó Gráda and Simone Wegge: '"The Best Country in the World": The Surprising Social Mobility of New York's Irish Famine Immigrants' August 2021
WP21/22 Jane Dooley and David Madden: 'Ireland's Post Crisis Recovery, 2012-2019: Was It Pro-Poor?' September 2021
WP21/23 Matthew Shannon: 'The Impact of Victimisation on Subjective Well-Being' September 2021
WP21/24 Morgan Kelly: 'Persistence, Randomization, and Spatial Noise' October 2021 (For revised version of this paper see WP21/25)
WP21/25 Morgan Kelly: 'Persistence, Randomization, and Spatial Noise' November 2021
WP21/26 Eliane Badaoui and Frank Walsh: 'Productivity, Non-Compliance and the Minimum Wage' November 2021
WP21/27 Annette Broocks and Zuzanna Studnicka: 'Gravity and Trade in Video on Demand Services' December 2021
WP21/28 Linda Mastrandrea: 'Linking Retail Electricity Pricing and the Decarbonisation of the Energy Sector: a Microeconomic Approach' December 2021
WP22/01 Doina Caragea, Theodor Cojoianu, Mihai Dobri, Andreas Hoepner and Oana Peia 'Competition and Innovation in the Financial Sector: Evidence from the Rise of FinTech Start-ups' January 2022
WP21/02 Sandra E Black, Paul J Devereux, Fanny Landaud and Kjell G Salvanes: 'The (Un)Importance of Inheritance' January 2022
WP22/03 Claes Ek and Margaret Samahita: 'Pessimism and Overcommitment: An Online Experiment with Tempting YouTube Content' January 2022
WP22/04 Paul J Devereux: 'Fragility of the Marginal Treatment Effect' January 2022
WP22/05 Lucie Martin, Liam Delaney and Orla Doyle: 'Everyday Administrative Burdens and Inequality' February 2022
WP22/06 Karl Whelan: 'The Past, Present and Future of Euro Area Monetary-Fiscal Interactions' February 2022
WP22/07 Constantin Bürgi and Julio L Ortiz: 'Temporal Consistency of Forecasts And DataReleases' February 2022
WP22/08 Eoin T Flaherty: 'Do Former Employees of Foreign MNEs Boost Incumbent Workers' Wages in Domestic Firms?' February 2022
WP22/09 Annette Alstadsæter, Julie Brun Bjørkheim, Ronald B Davies and Johannes Scheuerer: 'Pennies from Haven: Wages and Profit Shifting' February 2022
WP22/10 Judith M. Delaney, Paul J. Devereux: 'Rank Effects in Education: What do we know so far?' March 2022
WP22/11 Lena Susanne Specht: 'International trade effects of student migration' March 2022

UCD Centre for Economic Research
Email economics@ucd.ie