Tax Evasion, Fiscal Policy and Public Debt: Evidence from Spain*

Moisés Meroño Herranz[a], Francesco Turino[a]

[a]Fundamentos del Análisis Económico (FAE), Universidad de Alicante

June 16, 2022

Abstract

We reconsider the macroeconomic effects of fiscal policy in an estimated dynamic stochastic general equilibrium model with limited tax enforcement. The results of the Bayesian estimation provide evidence in favor of a sizeable underground sector in Spain, with the associated tax evasion that has contributed, on average, to a 23% of public debt accumulation over the 1985-2015 period. From the stand point of fiscal policy, the estimated results show that the presence of tax evasion triggers a resource-reallocation mechanism that dampens the effects upon economic activity caused by an increase in government spending, while amplifies those due to changes in tax rates. Because of this mechanism, we show that tax-based consolidation plans may become completely ineffective in reducing the debt-to-GDP ratio if tax enforceability is imperfect. Moreover, by characterizing the long-run Laffer curve, we show that the actual taxation in Spain is inefficiently too high, in the sense that the government might increase tax revenues by cutting the actual tax rates on both corporate and personal income.

Keywords: Undeground economy, Tax evasion, Fiscal policy, DSGE, Bayesian estiamation, Spain.
JEL Classification: E26, E32, E62, H26, C11

*Corresponding author: Francesco Turino, Universidad de Alicante, Dpto. Fundamentos del Análisis Económico, Campus de San Vicente, 03690 Alicante, Spain. Email: fturino@ua.es. We would like to thank Luis Franjo Garcia, Francesco Serti, Iván Payá, Marco Lorusso, Francesco Ravazzolo, Federico Boffa and seminar participants at the Department of Economics of the University of Alicante, at the "First joint workshop in Applied-Macro and Microeconomics" in the Free University of Bozen/Bolzano, and at the "QED Jamboree 2019" in the NOVA School of Business & Economics for comments and suggestions. Francesco Turino thanks the Spanish Ministerio de Economía y Competitividad – grant PID2019-111208GB-I00/AEI/10.13039/501100011033 – for financial support.

1 Introduction

Recent economic events, such as the global 2008 recession, the resulting fiscal stimulus interventions in many countries and the subsequent sovereign debt crises, have spurred a renewed interest in the academic research about the macroeconomic effects of fiscal policy interventions (Leeper, Traum and Walker (2017), Sims and Wolff (2018) Alesina, Favero and Giavazzi (2019), Favero and Mei (2019), Ramey (2019), Rannenberg (2021)). However, with few exceptions (Pappa, Sajedi and Vella (2015), Basile, Chiarini, Luca and Marzano (2016)), this literature has largely ignored the role of underground transactions and tax evasion in shaping the responses of macro aggregates to changes in fiscal instruments. This is surprising given that the empirical evidence available (Medina and Schneider (2018)) has documented that the underground economy is a widespread phenomenon, with the associated tax evasion representing an issue for both developing and developed countries.

On the light of these considerations, in this paper we reconsider the macroeconomic effects of fiscal policy in an estimated dynamic stochastic general equilibrium model (DSGE) with limited tax enforcement. Our goal is twofold. First, we want to assess the extent to which the dynamics of public debt at the aggregate level is shaped by the incentives of firms and households to evade taxation at the individual level. Second, we are interested in understanding how the presence of underground transactions in the economy affects the effectiveness of fiscal policy in (i) stimulating the economic activity; and (ii) in reducing the burden of public debt (fiscal consolidation policy). In our opinion, there are two main reasons that make our approach particularly useful in addressing that research questions. On the one hand, dealing with tax evasion and underground transitions is complicated because these aggregates are not observable. The inferential procedure we implement − which is based upon Bayesian estimation and Kalman filtering technique − allows us to treat both the underground economy and tax evasion as latent variables, and to estimate their dynamics over the sample period together with the structural parameters of the model. On the other hand, a DSGE model allows to assess in a unified framework the macroeconomic effects of fiscal policy from both a short- and a long-run perspective. This property makes our approach particularly suitable for fiscal policy analysis.

Throughout the paper, we will refer to underground economy as the production of *legal goods and services that are deliberately concealed from fiscal authorities in order to avoid the payment of taxes and social security contributions*. Our model introduces economic transactions of this kind into an otherwise standard stochastic Neoclassical growth model augmented by real rigidities and a detailed government sector. To this end, we have followed Busato and Chiarini (2004) by assuming that to produce the same commodity a firm may adopt two different technologies: the regular and the underground production functions. The main difference between the two technologies is that underground production activities are detectable by the government only after a monitoring process. This property implies that tax enforcement is limited in our framework because firms may successfully conceal a fraction of their production from the government in order to escape taxation.

The model is estimated by using Spanish data at mixed-frequencies (quarterly and annual) over the 1985-2015 period. Spain makes for an interesting case study because it represents an advanced economy characterized by both a high public debt burden and − according to the estimates available (e.g. Pickhardt and Sardà (2015), Medina and Schneider (2018))

– a quantitatively important underground economy. The results of our Bayesian estimation confirm that underground sector in Spain is sizeable, with an associated tax evasion that, over the sample period, has accounted, on average, for a 27% of total tax due, an amount of resources equivalent to a 17% of the Spanish official GDP. Historically, we show that tax evasion has represented a quantitatively important determinant of debt accumulation in Spain, contributing, on average, to a 23% of public debt growth over the 1985-2015 period. Interestingly, our results also provide evidence in favor of a *double business cycle* in Spain, with the peaks of the regular economy that are in general associated with the troughs of the underground economy and vice versa.

In terms of fiscal policy, the estimated fiscal multipliers show the presence of tax evasion dampens the effects upon the official economic activity of an increase in government spending, while amplifies the consequences triggered by changes in tax rates. These findings are driven by a resource-reallocation mechanism that, in addition to the conventional channels, implies that the fraction of production that firms find convenient to conceal from tax authorities also adjusts in response to changes in fiscal instruments. We show that the same mechanism substantially worsens the recessionary effects induced by tax-based austerity plans. In this respect, our results complement and extend the findings of the recent empirical literature on the effects of austerity measures (e.g. Alesina et al. (2019), Favero and Mei (2019)) by showing that, because of tax evasion, tax hikes may even become completely ineffective in reducing the debt-to-GDP ratio. Our results also confirm the findings of Pappa et al. (2015), according to which accompanying deficit-reduction plans by reforms aimed at fighting against tax evasion would be welfare enhancing and, therefore, socially desirable. Finally, we characterize the long-run Laffer curve and show that at the actual tax rates Spain is on the slippery slope. In other words, our model predicts that taxation is inefficiently too high in Spain in the sense that the government may increase the long-run tax revenues by reducing tax rates. Because of this property, we show that a self-financed increase in government spending is welfare enhancing in the long-run, and, at the same time, leads to a lower debt-to-GDP ratio. All of these effects are amplified if the policy is carried out hand-in-hand with a reform that credibly increases the perceived cost of tax evasion.

Our paper contributes to two different strands of literature. First, it contributes to the huge literature that relies on estimated DSGE model for fiscal policy analysis (e.g. Forni, Monteforte and Sessa (2009), Cogan, Cwik, Taylor and Wieland (2010), Leeper, Plante and Traum (2010a), Leeper, Walker and Yang (2010b)), Mertens and Ravn (2012), Zubairy (2014)), Leeper et al. (2017), Sims and Wolff (2018)). We add to this literature a study of the implications for fiscal policy of imperfect tax enforcement. Our results also contribute to the relatively more recent literature on DSGE models with underground transactions and tax evasion. In this respect, our model extends the seminal framework of Busato and Chiarini (2004) by introducing several additional stochastic disturbances, non-wasteful government spending, public debt, fiscal rules and real rigidities in the form of consumption habits, convex adjustment cost of investment and variable capital utilization rate. The Bayesian-DSGE approach is borrowed from Orsi, Raggi and Turino (2014), who were the first in adopting the theory-for-measurement approach as a way to estimate the non-observable underground economy of a country. In terms of fiscal policy, our results complement and extend the findings of Pappa et al. (2015), Annicchiarico and Cesaroni (2018) and Costa Junior, Garcia-Cintado and Usabiaga (2021). With respect to these papers, our findings provide a more comprehensive picture of the implications of tax evasion for fiscal policy design.

The rest of the paper is organized as follows. Section 2 presents a description of the model. Section 3 describes the Bayesian estimation of the DSGE model and the data used. In Section 4, we use the estimated model to address the main research question of the paper. This section is organized into two subsections: one focusing on the in-sample model predictions about the non-observable size of the underground economy and tax evasion; and another one which focuses on the implications for fiscal policy design. Section 5 presents counterfactual fiscal policy experiments, while Section 6 contains concluding remarks. Further details on the model and the characterization of the first order conditions for households and firms are relegated in Appendix.

2 The model

We consider a two sectors neoclassical growth model with incomplete tax enforcement à la Allingham and Sandmo (1972), non-wasteful government consumption, and real rigidities in the form of variable capital utilization, investment adjustment costs and internal consumption habits. The economy consists of households and firms interacting in the markets of goods and factors of production (i.e. labor and capital), and government that finances public spending by collecting taxes and issuing bonds. Households and firms may under-report their taxable incomes by carrying out underground transactions, which are detectable by the government only after a monitoring process. All of the interactions among agents occur in a stochastic environment where the short-run dynamics of the economy is driven by several transitory shocks, including fiscal, demand and supply disturbances.

2.1 Firms

There is a continuum of homogeneous goods indexed by $i \in [0, 1]$, each produced by a perfectly competitive producer. Firms have access to two different Cobb-Douglass production functions − the regular and the underground one − which differ in the type and the number of inputs used to manufacture goods. We assume that with the regular production function a firm i combines regular labor, $h^m_{i,t}$, and capital, $k_{i,t}$, to produce regular output, $y^m_{i,t}$, according to the following technology

$$y^m_{i,t} = A_t \left(\Gamma_t h^m_{i,t}\right)^\alpha k^{1-\alpha}_{i,t} \tag{1}$$

where $\alpha \in (0, 1)$, Γ_t is the deterministic labor-augmenting technological progress that evolves according to $\Gamma_t = \tau\Gamma_{t-1}$ with $\tau > 1$, and A_t is a stochastic productivity component that follows a univariate autoregressive process of the form $log(A_t) = \rho_a log(A_{t-1}) + \epsilon^a_t$ in which $\epsilon^a_t \sim N(0, \sigma^2_a)$.

Regular production activities are perfectly observable by the government and any unit of corporate income − defined as revenues net of labor cost − is taxed at the corporate tax rate $\tau^c_t < 1$. Firms, however, may evade taxation by hiding part of the production to the government. To do so, a firm i may produce underground output via the following labor-intensive technology

$$y^u_{i,t} = A^u_t \left(\Gamma_t h^u_{i,t}\right)^{\alpha_u} \tag{2}$$

where $\alpha_u \in (0, 1]$, $y^u_{i,t}$ and $h^{i,u}_t$ respectively stand for underground output and underground labor, while A^u_t denotes a stochastic technological components that evolves according to $log(A^u_t) = \rho_{a^u} log(A^u_{t-1}) + \epsilon^{a^u}_t + \rho_{au}\epsilon^a_t$, in which $\epsilon^{a^u}_t \sim N(0, \sigma^2_{a^u})$ and $\rho_{au} \geq 0$.[1] The dependence of the underground-technology specific shock A^u_t on innovations, ϵ^a_t, is intended to capture the movements in underground output that are driven by changes in the overall productivity of the economy. We therefore refer to A_t as an *economy-wide* productivity shock.

Following Busato and Chiarini (2004), we assume that goods produced underground are identical to those produced with the regular technology and therefore the total final output produced by a firm i at date t, namely $y_{i,t}$, can be simply defined as

$$y_{i,t} = y^m_{i,t} + y^u_{i,t}$$

Homogeneity also implies that the price of the two goods (regular and underground) in equilibrium must be the same, which hereafter is normalized to be 1 in each period t.

Labor and capital markets are perfectly competitive. We denote by r_t the rate at which any unit of rented capital is paid by a firm. Regular labor cost is given by the wage rate w^m_t augmented by statutory social security contributions (with rate $\tau^s_t < 1$) that firms pay to the government on the behalf of their regular employees. By contrast, firms do not pay social security contributions for underground workers and therefore the cost of a unit of underground labor is simply given by the sector-specific wage rate w^u_t.

To discourage tax evasion, the government carries out random inspections to firms and forces the fraudulent ones to pay taxes on the undeclared corporate income augmented by a penalty surcharge factor $s > 1$. Denoting by $p \in (0, 1)$ the probability that a firm is inspected by the fiscal authorities, it follows that a firm's profit $-$ namely $\Pi_{i,t}$ $-$ is a random variable whose expected value can be written as[2]

$$E_t\{\Pi_{i,t}\} = (1 - \tau^c_t)y^m_{i,t} + (1 - ps\tau^c_t)y^u_{i,t} + \tau^c_t w^m_t h^m_{i,t} - TC_{i,t}$$

where $E_t\{\cdot\}$ denotes the mathematical expectation operator conditional on information available at date t, while

$$TC_{i,t} = (1 + \tau^s_t)w^m_t h^m_{i,t} + r_t k_{i,t} + w^u_t h^u_{i,t}$$

stands for total cost. A firm's decision problem can then be stated as consisting in choosing productive factors $h^u_{i,t}$, $h^m_{i,t}$, and $k_{i,t}$ so as to maximize the expected profit $E_t\{\Pi_{i,t}\}$ under the constraints given by technologies (1) and (2).

[1] La Porta and Shleifer (2014) document that informal firms are much more labor intensive than the formal ones. For this reason, we follow the literature (e.g. Busato and Chiarini (2004) and Pappa et al. (2015)) in assuming that the informal production is carried out by using labor inputs only.

[2] See Orsi et al. (2014) for further details.

2.2 Representative household

The representative household has preference in period 0 given by

$$E_0 \left\{ \sum_{t=0}^{\infty} \beta^t \xi_t^c \left[log\left(cc_t/\Gamma_t\right) - B_0 \frac{(h_t^m + h_t^u)^{1+\xi}}{1+\xi} - B_1 \frac{(h_t^u)^{1+\phi}}{1+\phi} \right] \right\} \tag{3}$$

where cc_t is the *effective* consumption index, $\beta \in (0,1)$ stands for the subjective discount factor, B_0, B_1, ξ, $\phi \geq 0$ are preference parameters, and ξ_t^c is an inter-temporal preference shock, which evolves according to $log(\xi_t^c) = \rho_{\xi^c} log(\xi_{t-1}^c) + \epsilon_t^{\xi^c}$ where $\epsilon_t^{\xi^c} \sim N(0, \sigma_{\xi^c}^2)$. To ensure that the economy evolves along a balanced growth path equilibrium, we assume that the household derives utility from the object cc_t relative to the deterministic level of labour-augmenting technological progress, Γ_t.

As in Sims and Wolff (2018), the *effective* consumption index, cc_t, is defined as a CES aggregator of private (c_t) and government (G_t) consumption:

$$cc_t = \left[\alpha_1 (c_t - \gamma_c c_{t-1})^{\alpha_2} + (1-\alpha_1) G_t^{\alpha_2}\right]^{\frac{1}{\alpha_2}} \tag{4}$$

where $\alpha_1 \in (0,1)$ is the share of private consumption in the effective one, $\alpha_2 \in (-\infty, 1]$ is a parameter controlling for the elasticity of substitution between private and government consumption in the utility, and $\gamma_c \in [0,1]$ is the degree of internal habit formation. When $\alpha_2 < 0$, private and government consumption are complements. They are instead substitutes when $\alpha_2 \in (0,1]$. As $\alpha_2 \to 0$, the composite consumption index (4) takes the Cobb-Douglas specification and therefore the instantaneous utility function becomes additively separable in private and government consumption.

Households supply labor to firms and may evade taxation by reallocating labor services from the regular to the underground market, avoiding in this way the payment of personal income taxes on the unreported labor earnings $w_t^u h_t^u$. Preferences specification in turns implies that $-$ in addition to the disutility of total hours worked $-$ households face an idiosyncratic cost of working in the underground sector as captured by the last term in (3). As in Busato and Chiarini (2004), we interpret this extra disutility component as capturing the cost associated with the lack of social or health insurance in the underground sector.

In addition to labor earnings, the other sources of household's income are (i) lump-sum transfers from the government T_t; (ii) returns from one-period government bonds B_t, each paying the gross interest rate R_t; (iii) dividends from the ownership of firms; and (iv) capital income. The latter is taxed at the personal income tax rate $\tau_t^h < 1$ and is given by the return of capital rented to firms $r_t z_t \bar{k}_t$, in which z_t denotes the utilization rate that transforms physical capital, $\bar{k}_t$, into the effective one k_t according to the rule $k_t = z_t \bar{k}_t$. In turn, the stock of physical capital held by the household evolves over time according to the following law of motion

$$\bar{k}_{t+1} = x_t \, \xi_t^x \, \Psi(x_t/x_{t-1}) + (1-\delta) \, \bar{k}_t \tag{5}$$

where x_t stands for investment, $\delta \in (0,1)$ is the capital depreciation rate, ξ_t^x is an investment-specific shock that evolves according to $log(\xi_t^x) = \rho_{\xi^x} log(\xi_{t-1}^x) + \epsilon_t^{\xi^x}$ in which $\epsilon_t^{\xi^x} \sim N(0, \sigma_{\xi^x}^2)$, and $\Psi(\cdot)$ is a standard quadratic investment adjustment cost satisfying $\Psi(\tau) = \Psi'(\tau) = 1$ and $\Psi''(\tau) = \psi > 0$ as in Smets and Wouters (2007) and Justiniano, Primiceri and Tambalotti (2010).

Households' total income may finance expenditures for consumption and investment purposes and purchases of government bonds, and therefore the household budget constraint takes the form

$$x_t + c_t + B_{t+1}/R_t = \left(1 - \tau_t^h\right)\left(w_t^m h_t^m + r_t z_t \bar{k}_t\right) + w_t^u h_t^u + B_t + T_t + \Pi_t - \Omega(z_t)\bar{k}_t \qquad (6)$$

where $\Pi_t = \int_0^1 \Pi_{i,t} di$ are aggregate profits, while $\Omega(z_t) = r_{ss}\left(\omega z_t^2/2 + (1-\omega)z_t + \omega/2 - 1\right)$ is a standard convex specification for the capital utilization cost (see e.g. Iacoviello and Neri (2010)), in which r_{ss} denotes the rental rate of capital evaluated in the steady state and $\omega > 0$.

Accordingly, the representative household at time 0 chooses sequences of consumption, investment, hours of work in the regular and underground sector, government bonds, physical capital and capital utilization rate so as to maximize the inter-temporal utility function (3) subject to, the *effective* consumption index (4), the capital law of motion (5) and the budget constraint (6).

2.3 Government

The government raises taxes and issues one-period bonds to finance purchases of goods, G_t, and transfers to the households so as to satisfy the period-by-period budget constraint

$$\frac{B_{t+1}}{R_t} = G_t + T_t + B_t - FR_t$$

where $FR_t = G_t^c + G_t^h + G_t^s$ denotes total fiscal revenues collected through (i) taxation on corporate income, i.e. $G_t^c = \tau_t^c \int_0^1 \left(y_{i,t}^m - h_{i,t}^m w_t^m + psy_{i,t}^u\right) di$; (ii) taxation on personal income; i.e. $G_t^h = \tau_t^h (h_t^m w_t^m + r_t k_t)$; and (iii) social security contributions, i.e. $G_t^s = \tau_t^s w_t^m \int_0^1 h_{i,t}^m di$. Given that tax enforcement is imperfect, fiscal revenues will be lower than the amount of taxes due to the government as long as agents carry out underground transactions, with tax evasion by firms and households that in each period amounts to

$$TE_t = (1-p)\tau_t^c \int_0^1 y_{i,t}^u di + \tau_t^h w_t^u h_t^u + \tau_t^s w_t^u \int_0^1 h_{i,t}^u di$$

Following Leeper et al. (2010a), we introduce several fiscal rules that allow for movements in the instruments that the government uses for fiscal policy purposes with the final goal of ensuring budget solvency. These instruments are divided into two different groups: taxes and public expenditure. The first group includes corporate tax rate, τ_t^c, household income tax rate, τ_t^h, and social security contributions, τ_t^s, while the second covers both, government consumption, G_t, and transfers to the households, T_t.

We assume that each tax rate − in log-linear form − evolves according to a first-order auto-regressive process, augmented by two endogenous factors controlling for (i) movements in the economic activity observed by the government (i.e. total regular production) and (ii) public debt. The first endogenous factor allows for *automatic stabilizer* components to movements in fiscal instruments, while the second one controls for adjustments that ensure budget solvency. We also assume that exogenous innovations affecting tax rates may correlate.[3] Accordingly, rules governing taxes dynamics are specified as follows

$$ln(\tau_t^c) = ln(\tau^c) + \rho_{c1}\left(ln(y_t^m) - ln(y^m)\right) + \rho_{c2}\left(ln(B_t) - ln(B)\right) + \phi_{cs}u_t^s + \phi_{ch}u_t^h + u_t^c$$

$$ln(\tau_t^s) = ln(\tau^s) + \rho_{s1}\left(ln(y_t^m) - ln(y^m)\right) + \rho_{s2}\left(ln(B_t) - ln(B)\right) + \phi_{cs}u_t^c + \phi_{sh}u_t^h + u_t^s$$

$$ln(\tau_t^h) = ln(\tau^h) + \rho_{h1}\left(ln(y_t^m) - ln(y^m)\right) + \rho_{h2}\left(ln(B_t) - ln(B)\right) + \phi_{ch}u_t^c + \phi_{sh}u_t^s + u_t^h$$

where a variable without time index t denotes a steady state value whereas $y_t^m = \int y_{i,t}^m di$ stands for the aggregate production in the regular sector. For $i = c,h,s$, the ρ_{i1}'s and ρ_{i2}'s are fiscal policy parameters, which control for cyclical movements in the fiscal instruments (automatic stabilizers) and debt financing respectively, while

$$u_t^i = \rho_i u_{t-1}^i + \epsilon_t^i$$

denotes a stationary fiscal policy shock with i.i.d. innovations ϵ_t^i that are normally distributed with mean 0 and standard deviation σ_i. Parameters ϕ_{ch}, ϕ_{cs} and ϕ_{sh} control for the intensity thought which a fiscal shock in one tax rate results into unpredictable movements in the other tax rates.

Fiscal rules for public expenditures instruments are specified in a way that is similar to tax rates, except for the fact that we assume that innovations in government consumption and transfers are uncorrelated. Specifically, G_t and T_t obey to the following laws of motion

$$ln(G_t) = ln(G) - \rho_{g1}\left(ln(y_t^m) - ln(y^m)\right) - \rho_{g2}\left(ln(B_t) - ln(B)\right) + u_t^g$$

$$ln(T_t) = ln(T) - \rho_{T1}\left(ln(y_t^m) - ln(y^m)\right) - \rho_{T2}\left(ln(B_t) - ln(B)\right) + u_t^T$$

where, for $i = g, T$, $u_t^i = \rho_i u_{t-1}^i + \epsilon_t^i$ are fiscal policy shocks with $\epsilon_t^i \sim N(0, \sigma_i^2)$.

2.4 Symmetric equilibrium

We restrict the analysis to symmetric equilibria where firms produce the same amount of goods and use the same amount of inputs, both in the regular and the underground markets.

[3]As in Leeper et al. (2010a), we made this assumption to capture that unexpected fiscal policy interventions often imply simultaneous changes in tax rates.

The symmetric equilibrium is formally derived by imposing the following market clearing conditions

$$c_t + x_t + G_t + \Omega(z_t)\bar{k}_t = \int_0^1 y_{i,t} di$$

$$h_t^u = \int_0^1 h_{i,t}^u di \qquad h_t^m = \int_0^1 h_{i,t}^m di \qquad k_t = \int_0^1 k_{i,t} di$$

As underground transactions are not recorded by the government, GDP in the economy does not necessarily coincide with total production. To close the model, we need therefore to introduce a proper definition of official − or measured − GDP. This paper assumes that the latter is simply given by total regular production, i.e.,

$$GDP_t = \int_0^1 y_{i,t}^m di$$

3 Parameter estimates

Market clearing and optimality conditions are first detrended and log-linearized around the deterministic steady-state, and then solved by using the method proposed by Sims (2002). The resulting VAR(1) process is augmented by a measurement equation to obtain a state-space system, which is estimated by means of Bayesian techniques using mixed frequency data over the 1985-2015 period.[4] We use 9 time series as observable variables, that is (i) quarterly figures on consumption, investment, regular wages, fiscal revenues from corporate taxation, social security contributions, fiscal revenues from personal income taxation, government consumption, public debt and (ii) annual observations for social security tax rate (i.e. τ_t^s). The corresponding measurement equation is the following

$$\begin{bmatrix} dlCons_t \\ dlInv_t \\ dlWages_t \\ dlG_t^c \\ dlG_t^s \\ dlG_t^h \\ dlG_t \\ dlB_t \\ l\tau_t^s \end{bmatrix} = \begin{bmatrix} \gamma \\ \gamma \\ \gamma \\ \gamma \\ \gamma \\ \gamma \\ \gamma \\ \gamma \\ l\tau^s \end{bmatrix} + \begin{bmatrix} \hat{c}_t - \hat{c}_{t-1} \\ \hat{x}_t - \hat{x}_{t-1} \\ \hat{w}_t - \hat{w}_{t-1} \\ \hat{G}_t^c - \hat{G}_{t-1}^c \\ \hat{G}_t^s - \hat{G}_{t-1}^s \\ \hat{G}_t^h - \hat{G}_{t-1}^h \\ \hat{G}_t - \hat{G}_{t-1} \\ \hat{B}_t - \hat{B}_{t-1} \\ \hat{\tau}_t^s \end{bmatrix}$$

[4]Parameter estimates are obtained using a Monte Carlo Markov chain approach, which is characterized by three main steps (see e.g. An and Schorfheide (2007)). First, we specify prior distributions for the structural parameters. Second, we compute the mode of the posterior kernel by using the numerical optimization procedure implemented by Sims (1999). Third, using the posterior mode as a starting point, we implement a Metropolis-Hastings algorithm to sample from the posterior distributions of each estimated parameter.

where l and dl stand for log and log difference, respectively, τ^s is the steady state value of the social security tax rate, while a hat on a variable denotes log-deviation from the steady state. Quarterly data − extracted from the *Quarterly Database of the Spanish Economy* (BDREMS) − have been deflated with the implicit GDP deflator (2010 base year) and transformed to per capita terms by using working age population. Annual data on social security tax rate have been taken from the Social Security Budget report published by the Spanish *Ministerio de Empleo y Seguridad Social*.

3.1 Prior distributions and calibrated parameters

Prior distributions are summarized in Table 1. For the parameters that are commonly used in the DSGE literature, we consider prior densities that are consistent with previous studies (Smets and Wouters (2007), Burriel, Fernández-Villaverde and Rubio-Ramírez (2010), Iacoviello and Neri (2010), Havranek, Rusnak and Sokolova (2017) among others). In particular, we assume that the labor elasticity of regular production, α, is beta distributed with a mean of 0.65 and standard deviation of 0.01. The capital discount factor, δ, follows a quite disperse beta distribution with a mean fixed at the standard quarterly value of 0.025. The parameter controlling for the degree of internal habit formation, γ^c, is assumed to be beta distributed with mean 0.5 and standard deviation 0.2, while the inverse of the Frish elasticity of total labor supply, ξ, is distributed according to a gamma random variable with mean 1 and a standard deviation of 0.15. The elasticity of investment adjustment cost, ψ, is gamma with a mean of 4 and a standard deviation of 0.4, while for the curvature parameter in the capital utilization cost, ω, we use the normalization adopted in Smets and Wouters (2007) by choosing a beta distribution (centered at 0.5) for the auxiliary parameter $\phi_u = \omega/(1+\omega)$. For the weight of private consumption in the object cc_t, α_1, we assume a beta distribution centered at 0.8. The same value has been used by Bouakez and Rebei (2007), Sims and Wolff (2018) and Pappa et al. (2015). The parameter controlling for the elasticity of substitution between private and government consumption in the utility function, α_2 is assumed to follow a truncated Normal distribution over the interval $(-\infty, 1)$, centered at -0.2. This value corresponds to the calibration adopted in Pappa et al. (2015) for Spain. Finally, we assume that the deterministic growth rate of technology, τ, follows a normal distribution with mean 1.004 and standard deviation 0.002, while the long-run social security tax rate τ^s is beta distributed with a mean of 0.285 and a standard deviation of 0.01. The prior means of τ and τ^s respectively match the quarterly average growth rate of per capita GDP in Spain and the average social security tax rate, both computed over the 1985-2015 period.

As for the underground-related parameters, we assume that the inverse of the elasticity of irregular labor supply, ϕ, is gamma distributed with mean equal to 1 and standard deviation equal to 0.15 as in Orsi et al. (2014). The labor elasticity of the underground output α_u is beta with a mean of 0.665 and a standard deviation of 0.10, while the preference parameter B_1 follows a disperse gamma distribution centered at 68.09. Conditional to all of the other prior parameter values, the prior means of α_u and B_1 imply a steady state equilibrium where (i) the underground production (y^u) accounts for 25.6% of total output ($y^u + y^m$); and (ii)

Table 1: Prior and posterior distributions

	Prior			Posteriors			
	Prior Mean	Prior std.	Density	Mean	90% Interval		Posterior std.
Structural							
α	0.650	0.015	Beta	0.654	0.631	0.677	0.014
α_u	0.665	0.015	Beta	0.669	0.645	0.693	0.015
ϕ_u	0.500	0.100	Beta	0.552	0.426	0.675	0.076
δ	0.025	0.001	Beta	0.026	0.024	0.027	0.001
τ^s	0.285	0.010	Beta	0.285	0.276	0.293	0.005
B_1	51.75	10.00	Gamma	53.52	37.69	69.47	9.791
ξ	1.000	0.050	Gamma	0.930	0.854	1.004	0.046
ϕ	1.000	0.150	Gamma	0.869	0.676	1.060	0.117
ψ	4.000	0.400	Gamma	6.632	6.183	7.092	0.320
τ	1.004	0.002	Normal	1.004	1.003	1.004	0.000
γ_c	0.500	0.200	Beta	0.822	0.800	0.846	0.014
α_1	0.800	0.100	Beta	0.894	0.803	0.985	0.063
α_2	-0.200	0.050	Normal	-0.174	-0.260	-0.088	0.052
Fiscal rules							
ρ_{c1}	1.000	0.300	Gamma	0.822	0.590	1.055	0.142
ρ_{s1}	0.000	0.050	Normal	0.047	-0.014	0.106	0.037
ρ_{h1}	0.700	0.300	Gamma	1.211	0.892	1.528	0.193
ρ_{g1}	0.440	0.200	Gamma	0.106	0.035	0.175	0.044
ρ_{T1}	0.440	0.200	Gamma	0.416	0.130	0.691	0.181
ρ_{c2}	0.400	0.200	Gamma	0.184	0.104	0.263	0.048
ρ_{s2}	0.400	0.200	Gamma	0.039	0.013	0.064	0.016
ρ_{h2}	0.400	0.200	Gamma	0.217	0.121	0.315	0.059
ρ_{g2}	0.400	0.200	Gamma	0.040	0.012	0.068	0.018
ρ_{T2}	0.400	0.200	Gamma	0.622	0.296	0.934	0.196
ϕ_{cs}	0.100	0.050	Normal	0.007	-0.039	0.055	0.028
ϕ_{ch}	0.100	0.050	Normal	0.147	0.091	0.203	0.034
ϕ_{sh}	0.100	0.050	Normal	0.025	-0.017	0.065	0.025
Shocks							
ρ_a	0.600	0.200	Beta	0.983	0.969	0.998	0.010
ρ_{a^u}	0.600	0.200	Beta	0.986	0.974	0.999	0.009
ρ_{au}	0.500	0.100	Beta	0.405	0.257	0.547	0.088
ρ_{ξ^x}	0.600	0.200	Beta	0.921	0.880	0.964	0.02
ρ_{ξ^c}	0.600	0.200	Beta	0.653	0.601	0.703	0.031
ρ_c	0.600	0.200	Beta	0.966	0.941	0.992	0.016
ρ_s	0.600	0.200	Beta	0.958	0.922	0.995	0.025
ρ_h	0.600	0.200	Beta	0.950	0.916	0.986	0.022
ρ_g	0.600	0.200	Beta	0.980	0.963	0.998	0.011
ρ_T	0.600	0.200	Beta	0.944	0.889	0.997	0.041
σ_a	0.005	Inf	Inv. Gamma	0.009	0.008	0.010	0.001
σ_{a^u}	0.005	Inf	Inv. Gamma	0.021	0.014	0.028	0.004
σ_{ξ^x}	0.005	Inf	Inv. Gamma	0.081	0.067	0.095	0.009
σ_{ξ^c}	0.005	Inf	Inv. Gamma	0.107	0.095	0.118	0.007
σ_c	0.005	Inf	Inv. Gamma	0.017	0.015	0.019	0.001
σ_s	0.005	Inf	Inv. Gamma	0.005	0.003	0.006	0.001
σ_h	0.005	Inf	Inv. Gamma	0.023	0.020	0.025	0.002
σ_g	0.005	Inf	Inv. Gamma	0.011	0.010	0.012	0.001
σ_T	0.005	Inf	Inv. Gamma	0.066	0.057	0.074	0.005

the share of irregular labor in total hours worked (h^u/h) is equal to 0.18. These numbers are consistent with the estimates reported in Hazans (2011) and Medina and Schneider (2018).

Turning to the coefficients in the fiscal rules, the debt-financing parameters (i.e. ρ_{c2}, ρ_{h2}, ρ_{s2}, ρ_{g2} and ρ_{T2}) are assumed to be gamma distributed, with prior means of 0.40 and standard deviations of 0.2 as in Leeper et al. (2010a). Apart from the social security taxes to GDP elasticity, ρ_{s1}, the automatic stabilizer coefficients (i.e. ρ_{c1}, ρ_{h1}, ρ_{g1} and ρ_{T1}) are also assumed to follow fairly diffuse gamma distributions. The results provided by Price, Dang and Botev (2015) are useful to elicit prior means for these parameters. They estimate that revenues from corporate and personal income taxation in Spain have elasticity with respect to the output gap of 2.11 and 1.76, respectively.[5,6] These numbers imply that a 1% increase in the output gap leads to roughly a 1% increase in the average corporate tax rate, and to a 0.76% increase in the personal income average tax rate. We thus set the elasticities ρ_{c1} and ρ_{h1} to have prior means of 1 and 0.7, respectively. Koester and Priesmeier (2017) also report that the elasticity of government spending (including transfers) with respect to output is equal to -0.44, and we use this number − in absolute value − as prior mean for both parameters ρ_{T1} and ρ_{g1}. The results provided by the authors also imply that the average social security tax rate declines after a boost in the output gap, although the effect is quantitatively much milder than what implied for the other fiscal instruments. We thus assume that parameter ρ_{s1} follows a normal distribution centered at 0 so that counter-cyclical and pro-cyclical movements in the tax rate are a priori both allowed. Finally, parameters controlling for co-movements in fiscal shocks − i.e. the ϕ's − are assumed to be normally distributed with means of 0.1 and standard deviation of 0.05. These numbers are taken from Leeper et al. (2010a).

Regarding the stochastic processes, we choose beta distributions for the persistence parameters centered at 0.6 and with a standard deviation of 0.2 as in Smets and Wouters (2007). Standard errors of innovations (i.e. the σ's) follow diffuse inverse gamma distributions, and the parameter controlling for the co-movements between the two technological shocks, ρ_{ba}, is beta distributed with a mean of 0.5 and a standard deviation of 0.05.

The rest of the parameters are kept fixed in the estimation procedure, either because they are difficult to identify with our dataset or because they reflect certain characteristics that are regulated *ex-ante* by the Spanish law. Table 2 summarizes our calibration. We set the long-run corporate tax rate, τ^c, and the personal income tax rate, τ^h, respectively at 19% and 33.76%, which correspond to the average tax rates in Spain over the 1985-2015 period.[7] Furthermore, the penalty surcharge factor is fixed at $s = 1.875$ as established by the Spanish tax law, while the probability of being inspected by the government, p, is fixed at 0.02, a value that corresponds to the average percentage of firms that have been inspected in Spain over the 1996-2015 period.[8] The subjective discount factor, β, has been

[5]The elasticities are computed by using regression methods with several OECD databases over the 1990-2013 period.

[6]Similar results are found by Koester and Priesmeier (2017) who use an error correction model to disentangle short- and long-run elasticities. They find that Spain is among the countries where fiscal revenues in the short-run overshoots its long-run equilibrium level after a shock that increases output. According to they results, a 1% increase in aggregate income leads to an increase in fiscal revenues of 1.80%.

[7]These numbers are computed by using the OECD tax database.

[8]Data on firms inspections are taken from *Agencia Tributaria* (AETA).

Table 2: Calibrated parameters

Parameters	Description	Source/ Targeted Moment	Value
τ^h	Long-run income tax rate	OECD data	0.190
τ^c	Long-run corporate tax rate	OECD data	0.338
s	Surcharge factor	Spanish law	1.875
p	Audit probability	AETA	0.020
β	Subjective discount factor	Capital-Output ratio	0.967
s_g	Government consumption to GDP	BDREMS	0.170
b	Debt to GDP ratio	BDREMS	0.500
h	hours worked at the steady state	Standard	0.250

fixed at 0.9673, to match a capital to GDP ratio of 2.83, whereas the steady state ratios of government consumption and public debt to output are set to 0.17 and 0.5, respectively. These targets correspond to the actual mean values of the three ratios, computed by using the BDREMS data set over the 1985-2015 period. Finally, the preference parameter B_0, is set to a value ensuring that, conditional to the other prior parameter values, at the steady state individuals devote 1/4 of their time to working activities.

3.2 Posterior distributions

Jointly with their corresponding priors, Table 1 reports mean, 90% credible set, and standard deviation of each posterior distribution. According to the reported results, data seems to be informative in identifying parameters as the posterior standard deviations in general shrink with respect to their prior counterparts. We find in particular that structural parameters affecting households decisions are estimated quite accurately. The posterior mean values of the preference parameters ξ and ϕ decrease significantly with respect to what we assumed *a priori*, while the posterior distribution of the parameter controlling for the disutility of underground labor, B_1, is *a posteriori* less disperse around the mean. For the habit formation parameter γ^c, we find a posterior mean equals to 0.82, which is in line with other estimations of DSGE models (see e.g. Smets and Wouters (2007), Iacoviello and Neri (2010), Molinari and Turino (2018)). Moreover, the parameter controlling for the elasticity of the capital adjustment cost, ψ, appears to also be well identified. Interesting, the posterior mean values of parameters α_1 and α_2 indicate that data support a specification of our model in which private and government consumption are complements in utility, with the weight for the former that is higher than what assumed a *priori*.

As for the fiscal rules parameters, we find that the posterior means of the coefficients ρ_{T2}, ρ_{c2} and ρ_{h2} are all positive and quantitatively important, meaning that transfers and taxes on corporate and personal income have moved over the 1985-2015 period to finance debt innovations. These fiscal instruments also appear to be particularly sensitive to movements in the measured GDP, with tax rate on personal income that features the largest elasticity (at the posterior mean $\rho_{h1} = 1.2$). By contrast, we find that the social security tax rate is virtually inelastic to the endogenous components in the fiscal rule, whereas government consumption has responded counter-cyclically to movements in regular output and appears to be virtually unaffected by movements in public debt. We find in addition that innovations in corporate and personal income tax rates result into unpredictable movements in the two tax rates simultaneously (i.e. $\phi_{ch} \in [0.1, 0.2]$), whereas exogenous changes in social security contributions do not affect the other tax rates.

Concerning the remaining parameters, the steady-state rate of social security contribution, τ^s, and the parameter controlling for the labor augmenting technological progress, τ are both strongly identified with posterior distributions that are highly concentrated around a mean of 0.285 and 1.004, respectively. The estimates of α and α_u instead raise some identification concerns as prior and posterior distributions of these parameters are virtually identical. As for the exogenous shocks, estimated results provide evidence in favour of highly persistent stochastic process, with the investment-specific and the inter-temporal preference shocks that also appear strongly volatile.

4 Properties of the estimated model

In this section, we use the estimated model to asses the aggregate effects of imperfect tax enforcement with the aim of addressing the main research questions of the paper. We first characterize in-sample model's predictions about the (unobservables) size of the underground economy and tax evasion in Spain, with a specific focus on the impact of these variables on the actual pattern of public debt observed in the data. We then analyze the main implications of tax evasion for fiscal policy design, both in the short- and long-run.

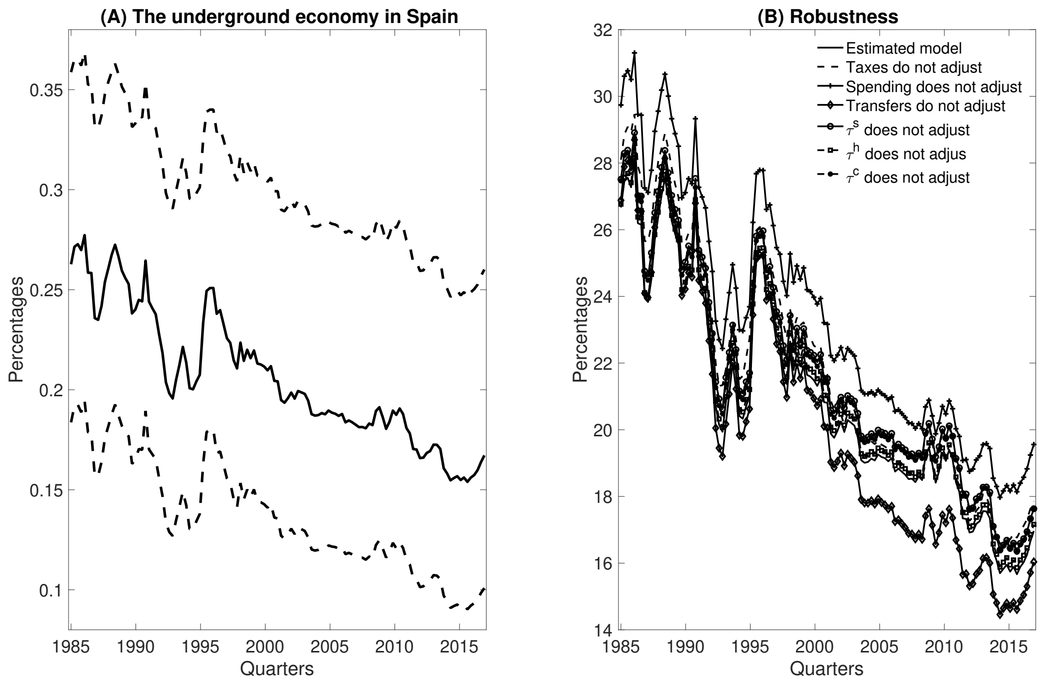
4.1 Underground economy, tax evasion and and public debt

4.1.1 The underground economy in Spain

Panel A of Figure 1 depicts the smoothed estimate of the share of underground production in total production along with the 90 percent probability bands.[9] This picture summarizes how the estimated model predicts the size and trend of the underground economy in Spain over the 1985-2015 period. As the picture illustrates, there is evidence of a smoothed downward sloping trend in the size of the underground economy, which, over the sample period, decreases from an high of around 28% in the middle eighties to a low of slightly less than 17% in the 2015. In particular, there are two major contractions in the series: one between 1985 and 1994 and the second between 1996 and 2000. In both cases, the size of the underground production declines by about 10 percentage points. By contrast, the volatility of the series decreases substantially during the 2000's, with the predicted size of the underground economy that stays virtually constant up to the begging of the 2007-2009 financial crisis where instead the figure features a sharp increase. On average, the model predicts that the underground production has accounted for a 21% of total production over the sample period. This number is in line with the available estimates in the literature (see e.g. Medina and

[9]Smoothed estimates are obtained with the Kalman smoother by setting all of the parameters to their posterior mean values.

Figure 1: The underground economy in Spain over the 1985-2015 period



Note: For each alternative version of the model, smoothed estimates of the size of the underground economy are computed with the Kalman smoother by setting all of the parameters to their posterior mean values. In Panel B estimated model refers to the benchmark case where all of the instruments adjust to movements in public debt.

Schneider (2018)), and provides further evidence in favor of a sizeable underground sector in Spain.

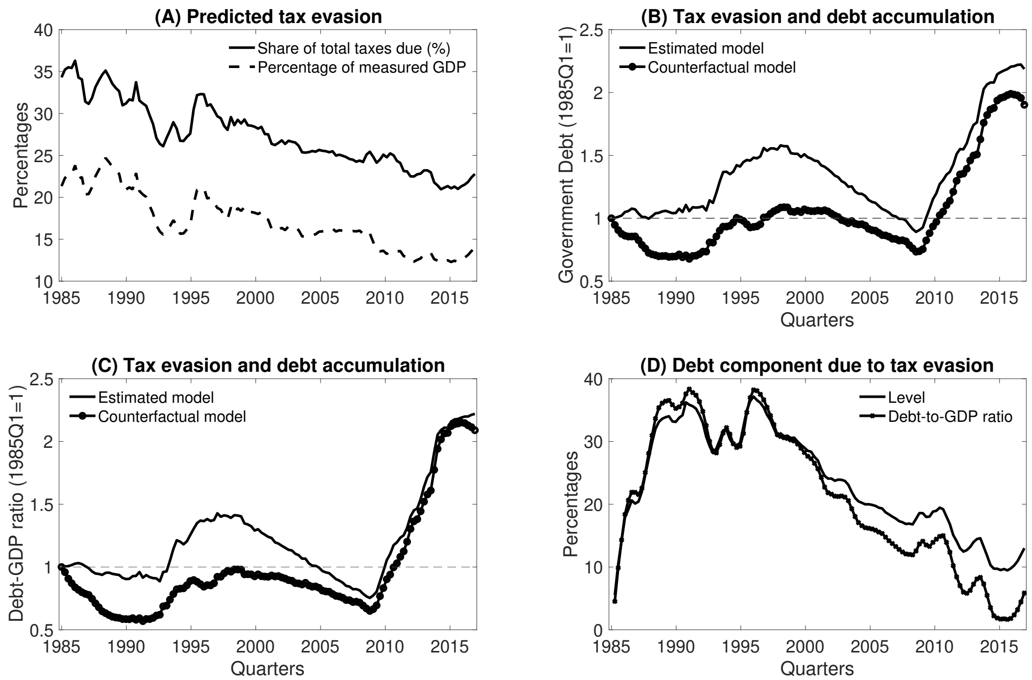
To test the robustness of the above findings, we have estimated six versions of our model that differ in which fiscal instrument adjusts to movements in debt. The goal of this experiment is to assess up to which extent the model's predictions are sensitive to the specific assumptions we made on fiscal rules. Results are summarized in panel B of Figure 1, where for each alternative model we depict the smoothed estimates of the size of the underground economy in Spain. As the picture illustrates, there are no major differences in both the estimated size and dynamics of the underground economy in Spain, thereby showing that the predictions of the baseline model are robust with respect to alternative specifications of fiscal rules.

4.1.2 Tax evasion and public debt

Panel A of Figure 2 depicts the smoothed estimates of tax evasion as a share of total tax due (continuous line) and as a percentage of measured GDP (dashed line).[10] The model predicts that losses for the Spanish government in terms of uncollected taxes has been huge over

[10]Total tax due − or alternatively potential fiscal revenues − is simply computed as the sum between tax evasion, TE_t, and total effective fiscal revenues, FR_t.

Figure 2: Tax evasion and public debt dynamics over the 1985-2015 period



the 1985-2015 period, accounting on average for 27% of total tax due, and representing an amount of resources that is equivalent to a 17% of measured GDP. In terms of dynamics, the estimated pattern of tax evasion mirrors the one predicted for the size of the underground economy, even though the former appears to be slightly less volatile.

Next, we evaluate the historical contribution of tax evasion to public debt accumulation, a feature that is of obvious interest for the purposes of our paper. One way to perform this assessment is to compare the predictions of the estimated model with those of a counterfactual model, which is identical to the estimated one apart from the fact that underground transactions are not allowed. We will refer to this last framework as *the model with perfect tax enforcement*. Results are displayed in panel B of Figure 2, where we depict the pattern of public debt predicted by the estimated model − which matches the actual data − along with the counterfactual counterpart implied by the model with perfect tax enforcement.[11] Overall, our results provide evidence in favor of an important historical contribution of tax evasion to public debt accumulation: over the whole sample period, in fact, public debt growth (relatively to the initial quarter) is substantially larger when tax evasion is taken into account. In order to substantiate this last statement, we quantify the contribution of tax evasion to public debt dynamics by subtracting the counterfactual debt path from the actual one. Panel D of Figure 2 presents our results. To provide an immediate visual repre-

[11] The reported results are obtained by setting the parameters to their posterior mean values and using the resulting smoothed estimates of the shocks to simulate both the estimated and the counterfactual model with perfect tax enforcement. To facilitate comparisons, the series reported in Figure 2 are normalized to equal 1 in the initial quarter.

Table 3: Business cycle statistics

Variables	Standard Deviation			Autocorrelation		
	Median	**5%**	**95%**	**Median**	**5%**	**95%**
Regular Production	0.02	0.01	0.02	0.84	0.75	0.90
Underground Production	0.04	0.03	0.05	0.74	0.62	0.82
Consumption	0.02	0.02	0.03	0.88	0.81	0.92
Investment	0.17	0.13	0.24	0.93	0.89	0.95
Public Debt	0.11	0.07	0.16	0.89	0.81	0.94
Tax Evasion	0.05	0.04	0.06	0.78	0.68	0.85
Fiscal Revenues	0.03	0.02	0.04	0.79	0.69	0.86
	Correlation with y^m			**Correlation with y^u**		
	Median	**5%**	**95%**	**Median**	**5%**	**95%**
Regular Production	1.00	1.00	1.00	-0.36	-0.66	0.03
Underground Production	-0.36	-0.66	0.03	1.00	1.00	1.00
Consumption	0.51	0.16	0.73	0.29	-0.09	0.59
Investment	0.22	-0.21	0.53	-0.03	-0.39	0.27
Public Debt	-0.41	-0.68	-0.03	0.31	-0.02	0.60
Tax Evasion	-0.25	-0.59	0.13	0.92	0.85	0.95
Fiscal Revenues	0.79	0.55	0.89	-0.19	-0.47	0.17

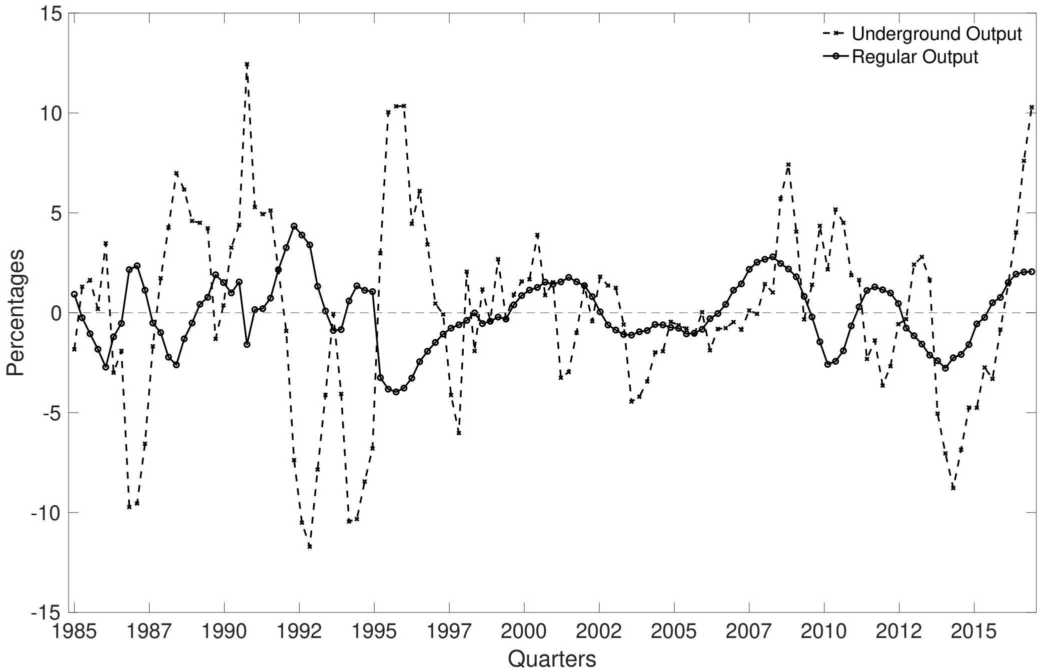
Note: Statistics reported in the table are estimated using the following procedure. First, we construct a random selection of 2,000 draws from the posterior distribution. Second, for each vector of parameters, we generate 100 artificial time series of the main variables of length equal to that of the data. Third, the resulting simulated series have been first HP(1600) filtered and then used to compute second-order moments. Finally, summary statistics for the posterior distribution of moments are computed by pooling together all simulations.

sentation of the importance of tax evasion as a determinant of public debt over time, results reported in the picture have been plotted in relative term with respect to the debt level. Accordingly, we find that the contribution of tax evasion explains on average a 23% of the quarterly debt over the 1985-2015 period. This finding clearly confirms that tax evasion has been a quantitatively important determinant of public debt accumulation in Spain. In this respect, our results show that the weight of tax evasion in public debt has grown sharply in the first half of the sample period, reaching its in-sample maximum of 37% in the year 1996. In the late period, instead, there is evidence of a slow but constant decline in the contribution of tax evasion to public debt growth. All of these findings are broadly confirmed when public debt is expressed in relative terms with respect to measured GDP (see panels C and D of Figure 2).

4.1.3 Cyclical properties

Table 3 summarizes business cycle statics for several endogenous variables, including among them underground output and tax evasion. The results reported are useful to understand

Figure 3: Double business cycle in Spain



Note: Cyclical components at the business cycle frequencies have been extracted from the smoothed estimates of regular and underground production with the HP(1600) filter. Model's predictions are computed by setting model parameters to their posterior mean values.

how the underground sector interacts with the official economic activity at the business cycle frequencies. In this respect, the estimated model predicts that the underground output (i) is around 2 times more volatile than regular output; (ii) comoves with tax evasion and public debt (i.e. the median of the correlation coefficient is equal to 0.92 and 0.31, respectively); and (iii) is strongly persistent over the business cycle (i.e. the 90% credible set for the autocorrelation coefficient is equal to $[0.62, 0.82]$). The model also predicts that the cyclical component of the underground economy is negatively correlated with that of the regular output (with a median of -0.36). This last result is particularly interesting as it provides evidence in favor of a *double business cycle* in the Spanish economy, with the peaks of the regular economy that are in general associated with the troughs of the underground economy and vice versa.[12] This last property is well apparent in Figure 3, which shows that the business cycle components of regular and underground output predicted by the estimated model move in the opposite direction for most the cycles identified in the 1985-2015 period.

[12]Our setup differs from the seminal model of Busato and Chiarini (2004) because − among other things − preferences specification allows for positive co-movements between underground and regular labor. Unlike the Busato and Chiarini's model, this property implies that the existence of a *double business cycle* is not granted in our theoretical framework. With respect to the seminal model, we adopt a more flexible structure because the available empirical evidence on *double business cycles* is rather mixed (see Granda-Carvajal (2012) and the references therein), so that we prefer to leave the data deciding whether regular and underground outputs are synchronized or not over the course of the Spanish business cycle.

4.2 Implications for fiscal policy

4.2.1 Fiscal multipliers

As a common practice in the literature (see e.g. Blanchard and Perotti (2002), Forni et al. (2009), Uhlig (2010), Leeper et al. (2010b), Leeper et al. (2017)), we compute fiscal multipliers to summarize the effects of transitory changes in fiscal policy instruments. In particular, we calculate fiscal multipliers in present value by using the following formula

$$\text{Present-Value Multiplier(k)} = \frac{E_t \sum_{j=0}^{k} \left(\prod_{i=0}^{j} R_{t+i}^{-1} \right) \Delta V_{t+j}}{E_t \sum_{j=0}^{k} \left(\prod_{i=0}^{j} R_{t+i}^{-1} \right) \Delta \theta_{t+j}}$$

where k denotes time horizon, ΔV_{t+j} and $\Delta\theta_{t+j}$ stand for changes in the endogenous variable V_t and the fiscal instrument θ_t, respectively, and R_{t+j} is the model-implied real interest rate. At $k = 0$ the present value multiplier equals the impact multiplier, while when $k > 0$ it reports the discounted cumulative effect over k periods of a change in the (present value of the) fiscal instrument at date t. Present value multipliers therefore embody the full dynamics of an exogenous fiscal intervention. This last property is particularity useful for the analysis of fiscal policy as it allows to provide a comprehensive picture of the effects driven by a specific fiscal instrument (see e.g. Mountford and Uhlig (2009)).

Results are displayed in Table 4, where, for each fiscal instrument, we report multipliers for measured GDP (Y^m), consumption (C), investment (X), underground production (Y^u) and tax evasion (TE) at different time horizons. For the sake of comparison, the table also provides the results from the model economy with perfect tax enforcement. For both models, the numbers reported in the table refer to fiscal policy experiments in which the 5 instruments are increased one at the time. In these experiments, parameters values are set to their posterior mean values.

Starting with measured GDP, consumption and investment, Table 4 illustrates that the fiscal multipliers for these aggregates are quantitatively modest, with estimated values that, in general, are lower than 1. In particular, we find that the 1-year (4qrts) governing spending multiplier for measured GDP is equal to 0.43, a value that is significantly lower than what found in previous studies for the Spanish economy (see e.g. de Cos and Moral-Benito (2016)). In general, our estimates show that an increase in government spending has a persistent expansionary effect on measured GDP, with a strength that is declining over time as a result of the persistent crowding out effect on both consumption and investment.[13] Tax multipliers (see panels B-D), in turn, are uniformly negative and show that the distrortionary effects of higher tax rates need time to build as multipliers become quantitatively more important as the time horizon increases.

Turning to the underground-related variables, three main findings are worth emphasizing.

[13] Government spending multipliers for consumption and investment are uniformly negative and decrease over the time horizon.

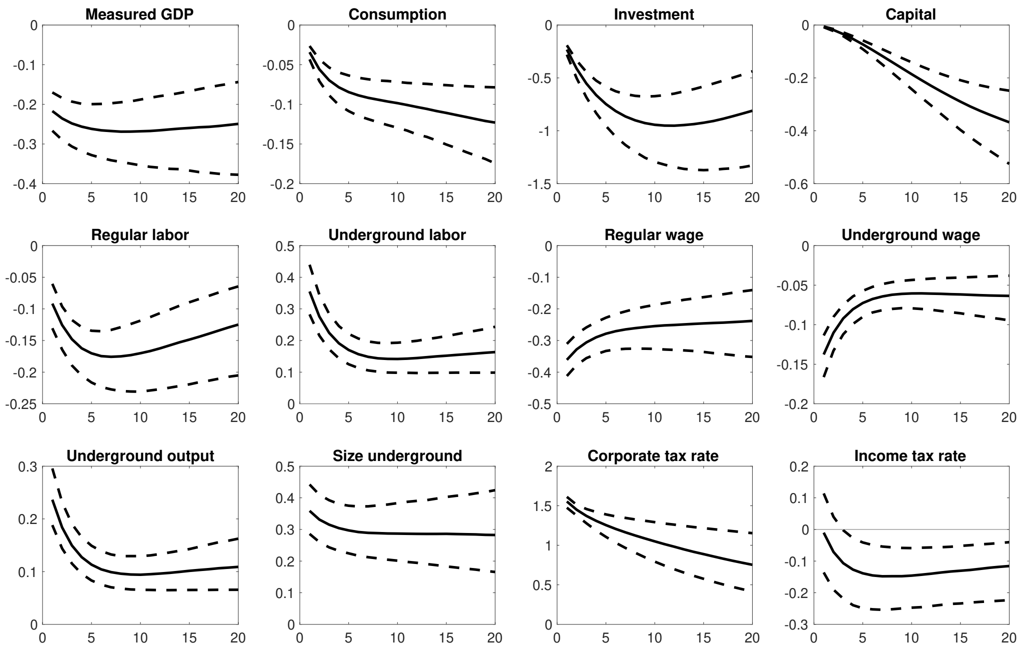
Table 4: Present value fiscal multipliers

Variable	Estimated Model Impact	4qrts	10qrts	25qrts	Perfect Tax Enforcement Impact	4qrts	10qrts	25qrts
(A) Government spending multipliers								
$PV(\Delta Y^m/\Delta G)$	0.63	0.43	0.24	0.06	0.85	0.51	0.18	-0.03
$PV(\Delta C/\Delta G)$	-0.16	-0.31	-0.47	-0.61	-0.16	-0.40	-0.64	-0.91
$PV(\Delta X/\Delta G)$	-0.04	-0.08	-0.13	-0.16	-0.04	-0.11	-0.19	-0.20
$PV(\Delta Y^u/\Delta G)$	0.21	0.19	0.17	0.17	-	-	-	-
$PV(\Delta TE/\Delta G)$	0.21	0.21	0.21	0.22	-	-	-	-
(B) Corporate tax multipliers								
$PV(\Delta Y^m/\Delta \tau^c)$	-0.17	-0.21	-0.25	-0.30	-0.15	-0.20	-0.25	-0.30
$PV(\Delta C/\Delta \tau^c)$	-0.03	-0.05	-0.08	-0.12	-0.03	-0.06	-0.09	-0.13
$PV(\Delta X/\Delta \tau^c)$	-0.02	-0.03	-0.06	-0.08	-0.02	-0.04	-0.07	-0.09
$PV(\Delta Y^u/\Delta \tau^c)$	0.05	0.04	0.04	0.04	-	-	-	-
$PV(\Delta TE/\Delta \tau^c)$	0.14	0.13	0.13	0.13	-	-	-	-
(C) Personal income tax multipliers								
$PV(\Delta Y^m/\Delta \tau^h)$	-0.18	-0.23	-0.29	-0.37	-0.10	-0.17	-0.25	-0.33
$PV(\Delta C/\Delta \tau^h)$	-0.04	-0.08	-0.12	-0.18	-0.05	-0.09	-0.13	-0.20
$PV(\Delta X/\Delta \tau^h)$	-0.02	-0.05	-0.09	-0.12	-0.03	-0.07	-0.11	-0.15
$PV(\Delta Y^u/\Delta \tau^h)$	0.09	0.08	0.07	0.07	-	-	-	-
$PV(\Delta Y^u/\Delta \tau^h)$	0.15	0.14	0.12	0.12	-	-	-	-
(D) Social security tax multipliers								
$PV(\Delta Y^m/\Delta \tau^s)$	-0.11	-0.13	-0.15	-0.18	-0.05	-0.09	-0.12	-0.14
$PV(\Delta C/\Delta \tau^s)$	-0.03	-0.06	-0.09	-0.11	-0.04	-0.07	-0.10	-0.13
$PV(\Delta X/\Delta \tau^s)$	-0.01	-0.01	-0.02	-0.02	-0.01	-0.02	-0.02	-0.03
$PV(\Delta Y^u/\Delta \tau^s)$	0.06	0.05	0.05	0.04	-	-	-	-
$PV(\Delta TE/\Delta \tau^s)$	0.10	0.09	0.09	0.08	-	-	-	-
(E) Transfers multipliers								
$PV(\Delta Y^m/\Delta T)$	-0.02	-0.20	-0.73	-2.30	-0.02	-0.16	-0.55	-1.46
$PV(\Delta C/\Delta T)$	-0.01	-0.06	-0.23	-0.90	-0.01	-0.05	-0.19	-0.64
$PV(\Delta X/\Delta T)$	-0.01	-0.05	-0.20	-0.66	-0.01	-0.05	-0.18	-0.49
$PV(\Delta Y^u/\Delta T)$	-0.01	0.03	0.09	0.29	-	-	-	-
$PV(\Delta TE/\Delta T)$	-0.01	0.08	0.28	0.76	-	-	-	-

First, consistently with the empirical evidence reported in Pappa et al. (2015), present value multipliers for underground output and tax evasion are uniformly positive, meaning that both an increase in taxes and in government consumption strengthen the incentives of agents to escape taxation. Second, the effects over time induced by a temporary increase in government spending on underground output are substantially larger than those induced by tax hikes. Third, the effects of fiscal policy interventions on tax evasion and underground output are in general persistent over time.

Most importantly for the purposes of the paper, the results from the model with perfect tax enforcement highlight that present-value multipliers may change substantially if tax

Figure 4: Responses to a corporate tax hike

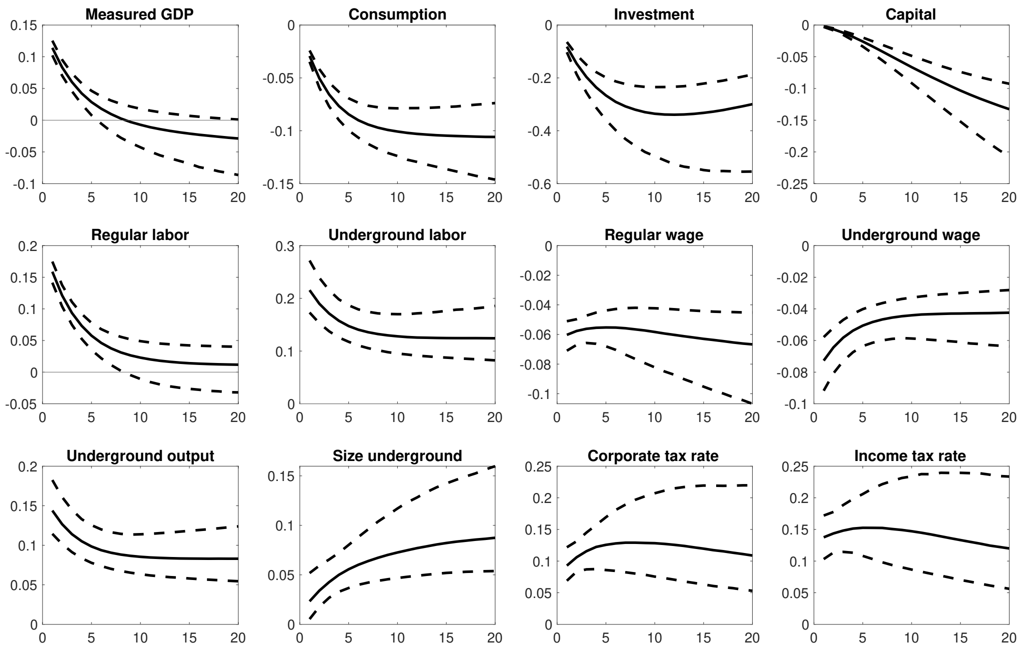


Note: Impulse-responses are measured in per cent deviations from steady state. Horizontal axes display the number of quarters after the shock.

evasion is not taken into account in the model. In particular, Table 4 shows that in comparison with the estimated framework, the counterfactual model under-predicts the effects of tax hikes on measured GDP, whereas tends to over-predict − in the short-run − the effects driven by government spending. Quantitatively, the differences across the two frameworks turn out to be important. For example, without tax evasion the model predicts a impact multiplier for measured GDP (0.85) that is around 35% larger than its estimated counterpart (0.63). In the case of taxes, multipliers in the estimated model can be even more than 50% lower than what predicted in the counterfactual framework.

To understand the economic mechanisms that underlie the estimated multipliers, in Figure 4 and Figure 5 we depict the impulse-response functions to a temporary increase in the corporate tax rate and government consumption, respectively. For each endogenous variable, the estimated mean response (solid line) is shown along with the 90 percent probability bands (dashed lines). As Figure 4 illustrates, measured GDP decreases after a corporate tax hike while underground production increases both in levels and as a share of total output. Measured GDP declines because taxation is distortionary in our model, whereas underground output increases because higher taxes strengthen the gains of firms to conceal a larger portion of their production from fiscal authorities. With respect to standard models without underground transactions, this last effect represents an additional reallocation mechanism that moves resources from the regular sector to the underground one, and amplifies the negative impacts of distortionary taxation by triggering a further fall in regular output. It is precisely the absence of this resource-reallocation mechanism that explains why the effects of tax hikes

Figure 5: Responses to an increase in government spending



Note: Impulse-responses are measured in per cent deviations from steady state. Horizontal axes display the number of quarters after the shock.

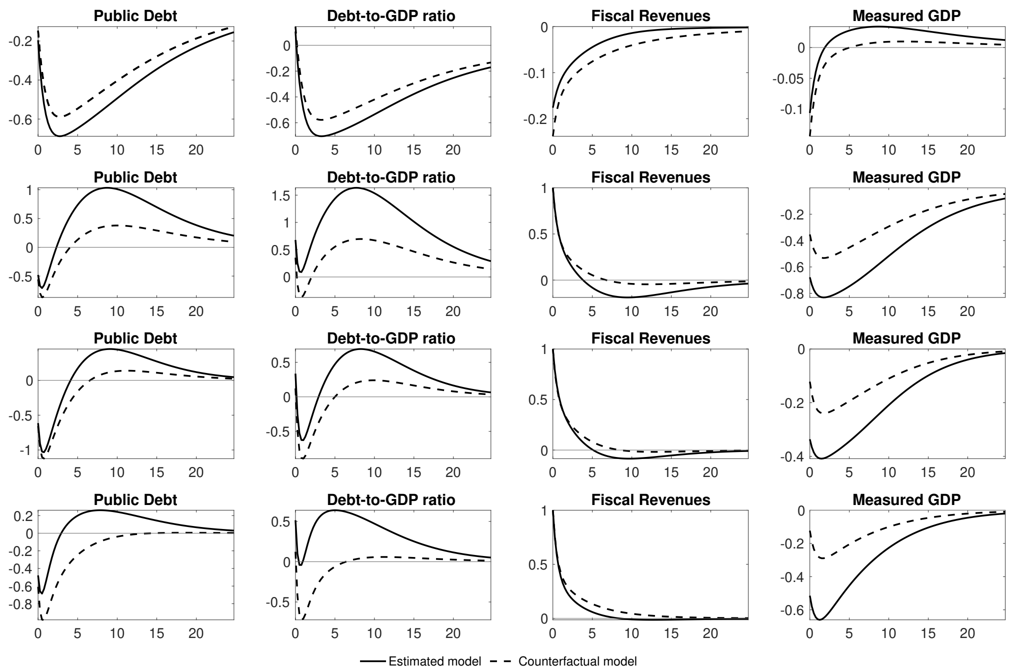
on measured GDP are under-predicted in the model with perfect tax enforcement.[14]

The resources-reallocation effect is also at work in the case of an expansion in government spending. As Figure 5 illustrates, at the impact the shock generates a negative wealth effect that induces households to (i) decrease consumption and investment; and (ii) to supply more labor in both the regular and underground markets.[15] This last effect results in an excess of supply that exerts downward pressures on the wage rates w_t^m and w_t^u, thereby pushing firms to increase both regular and underground output by demanding more regular and underground labor. However, the decline in capital stock triggered by the contraction in investment also decreases the productivity of the formal sector relative to the informal one, and therefore firms find it convenient to expand the share of their output produced underground. Moreover, given the automatic stabilizer components in the fiscal rules, the expansion in regular output also implies higher tax rates. This effect boosts the gains from tax evasion and induces firms to further expand their underground production. The resulting reallocation of resources in favor of the underground sector partially dampens the overall impact upon regular output of an increase in government consumption, thereby explaining why we find that spending multipliers for measured GDP are over-predicted in the model

[14]Impulse-response functions to personal income tax rate socially security contributions are qualitatively identical to those due to an increase in corporate tax rate. These results are available from the authors upon request.

[15]A negative wealth effect driven by a temporary increase in government spending is typical in real business cycle models. For further details see, among the others, Baxter and King (1993).

Figure 6: Expenditures-based vs tax-based deficit consolidation plans



Note: Row 1, government spending shock; row 2, corporate tax shock; row 3, personal income tax shock; row 4, social security shock. Impulse responses are measured in per cent deviations from steady state. Horizontal axes display the number of years after the shock. Parameter are set to their posterior mean values.

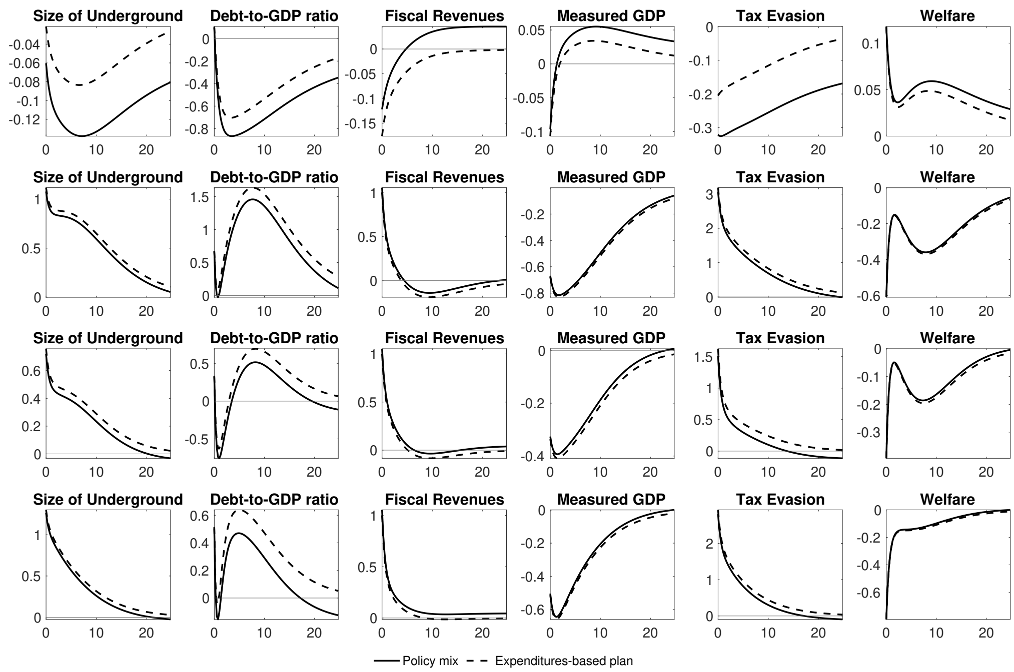
with perfect tax enforcement.

Overall, the model's predictions are consistent with the results reported in Basile et al. (2016), who, by using aggregate Italian data, provide evidence in favor of a resources-reallocation effect induces by tax evasion. On the basis of their findings, the authors conclude that it is difficult to rely upon the estimates of fiscal multipliers in countries with quantitatively important size of underground economy, unless the dynamics of the irregular and regular components of the GDP are properly disentangled. The results reported in Table 4 provides further support to this conclusion.

4.2.2 Deficit reduction plans and tax evasion

There is substantial agreement in the literature (see e.g. Alesina et al. (2019)) that deficit reduction plans (fiscal consolidation) based on government spending adjustments are more effective than tax-based plans in reducing the burden of public debt. More specifically, while both policies are in general found to be successful in reducing budget deficits, the empirical evidence provided by the literature suggests that, relative to spending cuts, tax-based consolidation plans cause larger and long-lasting recessions, thereby resulting in a more contained impact on the debt-to-GDP ratio (Favero and Mei (2019)). Imperfect tax enforcement may further reduce the effectiveness of tax-based consolidation plans because,

Figure 7: Consolidation plans vs policy mix



Note: Row 1, government spending shock; row 2, corporate tax shock; row 3, personal income tax shock; row 4, social security shock. Impulse responses of welfare are measured in deviations from steady state. Horizontal axes display the number of years after the shock. Parameter are set to their posterior mean values.

as we have highlighted in the previous section, the distorting effects of taxation are amplified when agents can engage in underground transactions.

To evaluate this last point, in Figure 6 we study the responses of public debt, debt-to-GDP ratio, fiscal revenues and measured GDP to a fiscal adjustment plan that takes the form of (i) a 1% decrease in government expenditures (first row); or (ii) tax hikes (rows 2-4), each producing a 1% increase in fiscal revenues. In order to disentangle the role of tax evasion in shaping the effectiveness of fiscal consolidation policies, the estimated impulse-response functions (continuous lines) are plotted along with their counterparts in the economy with perfect tax enforcement (dashed lines).

Focusing first on the predictions of the estimated model, we see that expenditures cuts and tax hikes are both effective in causing a fall in public debt (in levels). However, while the effect of the expenditures-based plan is persistent over time in that it induces a long-lasting decline in the level of public debt, the ones driven by tax hikes are short-lived as public debt raises above its initial steady state level after approximately four years in the case of personal income tax rate (third row), and after two years in the case of corporate taxation and social security contributions (second and fourth raw, respectively). In terms of measured GDP, the picture shows that tax hikes induce long-lasting recessions, while the expenditure-based plan has milder recessionary effects that last less than 3 years. As a consequence of these effects, in the estimated model expenditure-based plans turns out to be more effective than tax hikes in causing a decline in the debt-to-GDP ratio, a finding that is clearly consistent with the empirical evidence provided so far by the literature.

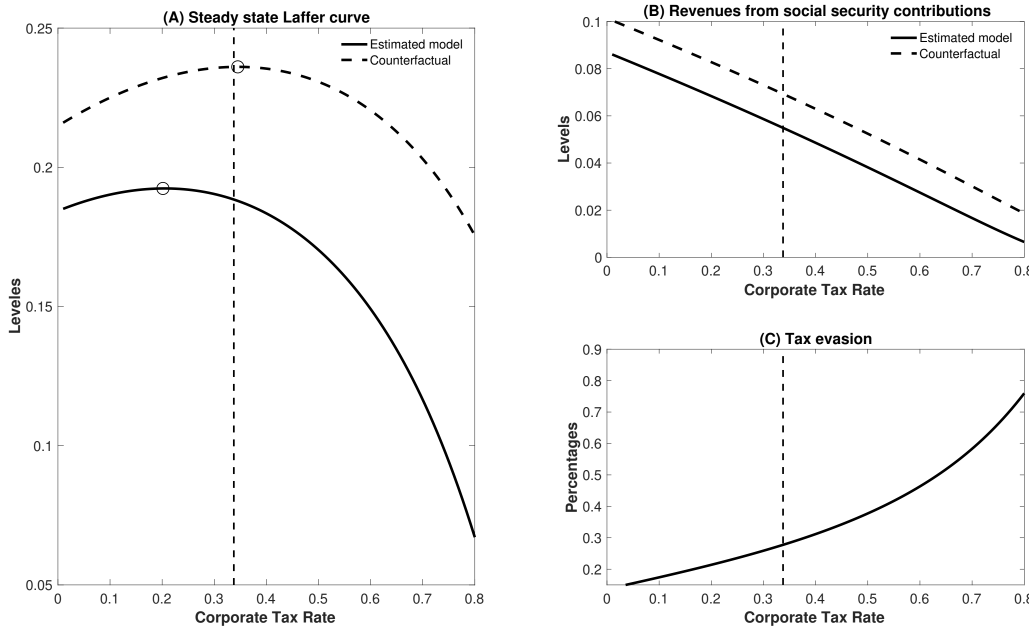
The comparison with the economy with perfect tax enforcement highlights furthermore that tax evasion plays an important role in shaping the dynamic responses of the debt-to-GDP ratio, and provides additional insights to the debate on the effectiveness of fiscal consolidation plans. In this vein, two main results of the comparison are worth emphasizing. First, the presence of tax evasion substantially dampens the effectiveness of tax-based plans. Our results show in particular that tax hikes may even become completely ineffective to reduce the debt-to-GDP ratio if tax enforceability is imperfect. This is for example the case of corporate tax hikes, where the response of debt-to-GDP ratio to an increase in the tax rate is predicted by the estimated model to be uniformly positive along the whole transition path to the steady state. As illustrated by Figure 6, these findings are triggered by the combined impact of two forces: because of tax evasion, tax-based plans cause (i) substantially larger output losses; and (ii) less persistent declines in the debt level. By contrast, we find that tax evasion mitigates the negative impact of spending cuts on measured GDP, implying both a lower fall in output and a less-lasting recession. These effects, together with a stronger decline in public debt, imply that, relative to the counterfactual economy, the presence of the underground sector makes expenditures-based consolidation plans more effective in reducing the debt-to-GDP ratio. This is our second result.

The underline mechanism behind the above findings is again the resource-reallocation effect. When government cuts expenditures, there is a reallocation of resources toward the regular sector, which reduces tax evasion and, as a result, partially compensates for the decline in fiscal revenues induced by the policy. Eventually, the resulting extra revenues allow the government to reduce further public debt. When instead fiscal policy takes the form of tax hikes, the resources-reallocation mechanism moves in the opposite direction in that higher taxes push a firm to expand the fraction of output produced underground. The resulting increase in tax evasion partially dampens the boost in fiscal revenues driven by higher tax rates, thereby lowering the total amount of resources available to reduce government budget deficit and so public debt.

An immediate corollary of the above results is that fiscal consolidation plans may be more effective if implemented in combination with policies aimed at fighting against tax evasion. This feature is well apparent in Figure 7, which shows the effects of spending cut (first row) and tax hikes (rows 2-4) accompanied by an unexpected simultaneous increase of 5% in the probability of detection.[16] The anti-fraud policy reduces the expected gains from underground transactions and therefore triggers a reallocation of resources in favor of the regular sector, which reduces tax evasion and mitigates the recessionary effects of fiscal consolidation plans. This mechanism boosts the impact of tax hikes on fiscal revenues, while dampens the negative ones caused by the spending cut. As a result, in all of the cases considered, the policy mix turns out to be more effective than the consolidation plan alone in reducing the debt-to-GDP ratio. Interestingly, Figure 7 also shows that the anti-fraud policy improves welfare by amplifying the welfare gains of expenditures-based plans and mitigating the welfare costs caused by tax hikes. This finding provides further support in favor the

[16]Simulation results are obtained by assuming that the probability of detection follows a very persistent AR(1) process. All of the remaining parameter values are set to their posterior means.

Figure 8: Corporate income taxation



Note: Vertical dashed lines refer to the average corporate tax rate of 33.8%.

implementation of consolidation plans hand-in-hand with policies aimed at discouraging tax evasion.

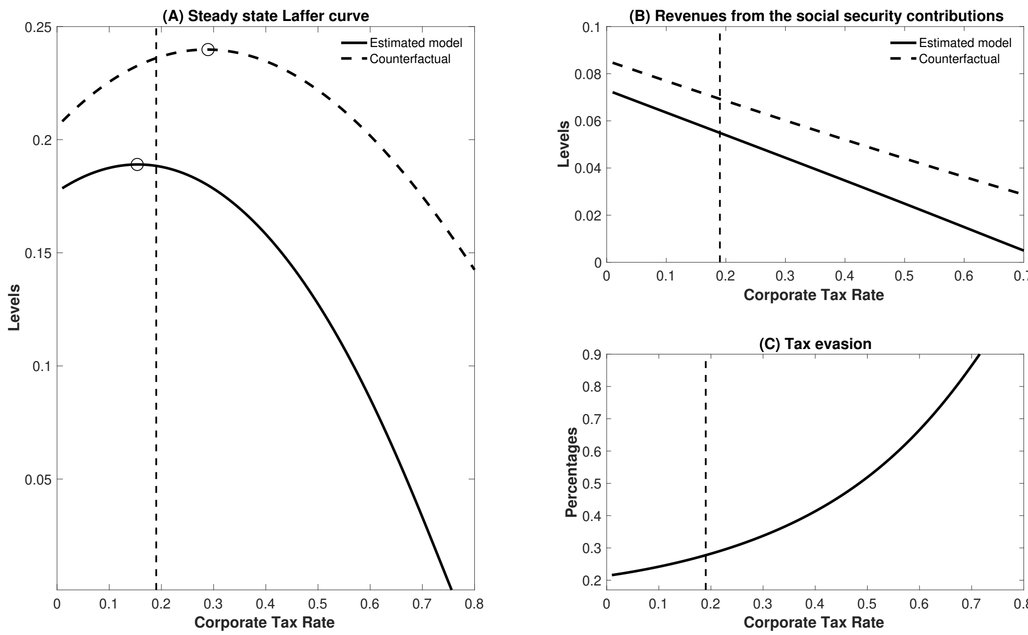
4.2.3 Steady-state Laffer curve

We further explore the aggregate implications of taxation in an economy with imperfect tax enforcement by assessing how the steady state equilibrium in the estimated model changes with the tax burden. To this end, Figure 8 depicts total fiscal revenues (Laffer curve), tax evasion as a fraction of total tax due, and revenues from social security contributions as functions of the corporate tax rate.[17] Continues lines refer to the estimated model with parameters set at the posterior mean values, while dashed lines refer to the counterfactual model with perfect tax enforcement.

As Figure 8 illustrates, the estimated Laffer curve has the typical inverted U-shape. That pattern is determined by two interacting mechanisms. On the one hand, an increase in taxation implies a fall in regular output and, as a consequence, in the tax base. On the other hand, tax evasion as a fraction of tax due is a convex function of the corporate tax rate, which increases quickly as τ^c moves from low to high values. This last mechanism reinforces the distortionary effect of taxation in that it provides a further decline in the tax base whenever the tax rate increases. In comparison with the counterfactual model,

[17] The Laffer curve is constructed by assuming that only public debt adjusts in response of changes in the tax rate. Government consumption and transfers are kept fixed to their steady state values in the model where all of parameters set at their posterior mean values.

Figure 9: Personal income taxation



Note: Vertical dashed lines refer to the average personal income tax rate of 19%.

the combined effect of the two mechanisms implies that not only total fiscal revenues are uniformly lower when tax enforcement is incomplete but also that the economy moves faster to the slippery slope of the Laffer curve as the tax rate increases. While in fact the maximum level of fiscal revenues in the counterfactual economy is reached at τ^c equal to approximately 30%, in the estimated model fiscal revenues are maximized when τ^c equal to 18%. Interesting, the pictures also illustrates that revenues from social security contributions monotonically decline with the corporate tax rate. While this is clearly a result of discretionary taxation, the comparison with the counterfactual model highlights that imperfect tax enforceability substantially amplifies the effect. At the average corporate tax rate (i.e. $\tau^c = 33.8\%$), for example, revenues from social security contributions are around 30% lower than the counterfactual counterparts. This result is particularly relevant for the Spanish economy in the light of the fact that the persistent deficit in the social security budget has raised concerns among Spanish economists about the sustainability of the public pension system (see e.g. Patxot, Solé and Souto (2017)). In this respect, the quantitatively important impact of underground transactions on social security contributions predicted by the estimated model further support that the Spanish economy might substantially benefit from fighting against tax fraud.

The above results are in general confirmed in Figure 9 where now we depict the effects driven by changes in the personal income tax rate τ^h. These findings together with those reported in Figure 8 highlight a very interesting property: at the actual (average) tax rate the estimated model and the counterfactual one yield to opposite predictions in terms of fiscal policy interventions that aim at increasing total fiscal revenues. While in fact the estimated

Table 5: Steady state effects of taxes cut

	Aggregate effects									Welfare	
	Δy^m	Δy^u	Δc	Δh^u	ΔTE	ΔFR	ΔGs	y^u/y	Bd/y^m	U_{ea}	U_{ep}
$p = 0.02$	8.4	-4.2	5.2	-6.3	-11.0	1.3	10.0	0.19	0.92	-154.6	-150.9
$p = 0.1$	10.4	-7.1	4.3	-10.4	-19.1	5.8	12.1	0.18	0.91	-154.6	-149.2
$p = 0.3$	15.5	-14.9	2.3	-21.5	-38.5	16.0	17.2	0.16	0.87	-154.6	-144.7

Note: U_{ea} refers to the households utility in the steady state *ex-ante* the fiscal policy while U_{ex} refers to the *ex-post* equilibrium. Δx refers to the percentage change of variable x with respect to its *ex-ante* steady state.

model indicates that Spain may improves its budgetary situation by lowering the personal income or the corporate tax rates, the counterfactual framework predicts that in order to increase fiscal revenues the Spanish government should instead increase these tax rates. This finding highlights once again the importance of taking into account the underground sector for fiscal policy purposes as it shows that the lack of consideration of the latter might yield to miss-leading policy recommendations.

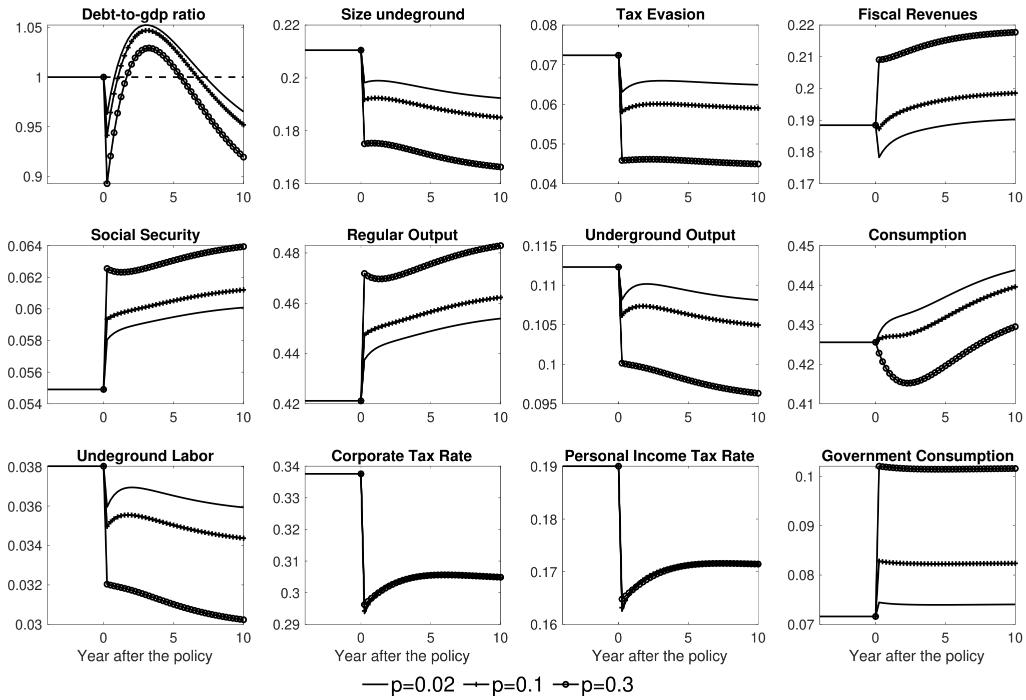
5 Fiscal policy experiments

One important implication of the results provided in section 4.2.3 is that the Spanish government may gain substantial fiscal space by permanently lowering taxes. If for example the corporate tax rate were cut up to the level that maximizes fiscal revenues in Figure 8, the steady state primary fiscal surplus would increase by around 45%. In such a circumstance, the government might further stimulate the economy − and potentially rise social welfare − by increasing expenditures together with a tax cut without worsening public indebtedness.

To assess the welfare and aggregated consequences of a self-financed fiscal stimulus, in this section we use the estimated model to perform counterfactual policy experiments. We aim at analyzing the implications of a moderate decline in the steady state values of both corporate and personal income tax rates accompanied by an increase in government expenditures, which, in the long run, is fully financed by the higher fiscal revenues. In these experiments we assume that the economy is currently at the stationary equilibrium and evaluate the implications of unanticipated − and permanent − 10% cut in the tax rates. The simultaneous increase in public expenditures takes the form of larger government consumption − which is utility-enhancing − and is determined so as to leave the steady state level of public debt unchanged. Numerical results are obtained by assuming that the debt-to-GDP ratio *ex-ante* the policy intervention is equal to 100%, a value that is in line with the actual ratio in the Spanish economy. All of the remaining parameters are instead set to their posterior mean values.

Results of the counterfactual experiments are summarized in Table 5 where we display the steady state effects of the tax policies, and in Figures 10 where we depict the transitional

Figure 10: Transitional dynamics



dynamics.[18] Starting with the long-run effects, the first row of Table 5 shows that the policy is welfare improving as the *ex-post* inter-temporal household utility, U_{ep}, is larger with respect to its counterpart in the equilibrium *ex-ante* the policy intervention, U_{ea}. This result is driven by the joint effect of two forces, which are both utility-enhancing for households. On the one hand, consumption increases by 5.2% as a result of the lower personal income taxation that pushes households to consume more. On the other hand, underground labor, h^u, decreases by 6.3% because of the lower corporate income taxation, which dampens the gains from tax evasion and pushes firms to substitute underground labor with the regular one. The resulting resources re-allocation effect drives an increase of 8.4% in regular output and a decline of 4.2% in the underground production. These two last effects jointly imply a decline in the size of the underground economy, y^u/y, which moves from an high of 21.05% in the *ex-ante* steady state to a low of 19% in the *ex-post* equilibrium.

The policy is also quite effective in discouraging tax evasion, which declines by 11%. We find in addition that the quantitatively important increase in regular output induced by the policy implies that (i) revenues from social security contributions raises by 10% in spite of the fact that total fiscal revenues only increase by 1.3%; and (ii) the debt-to-measured GDP ratio (Bd/y^m) declines by 8 percentage points. In other words, the estimated model predicts that a fiscal stimulus may be effective for fiscal consolidation purposes and, simultaneously, to improve the budgetary situation of social security system in Spain.

[18]Transitional dynamics is computed by assuming that the 10% taxes cut and the corresponding increase in government consumption are long-run targets for the government. Along the transition path, fiscal policy instruments are then adjusted to reach their long-run target levels according to the estimated fiscal rules.

In this last respect, the policy is even more effective if the fiscal stimulus is carried out hand-in-hand with interventions oriented to deter tax evasion. This property is apparent in the second and third rows of Table 5 where the effects of the policy are recomputed by raising the detection probability parameter, p, from 0.02 to 0.1 and 0.3, respectively. As explained in Section 4.2.2, a larger monitoring effort by the government has the effect of dampening the gains from tax evasion, thereby strengthening the resource-reallocation effect induced by the fiscal stimulus. The response of regular and underground outputs to the policy are then stronger the higher is the probability of detection, thereby amplifying the overall impact of a fiscal stimulus on both social security contributions and debt-to-GDP ratio.[19] On top of that, the results reported in Table 5 confirm that accompanying a fiscal stimulus by policies that increase the perceived probability of being caught evading is welfare-enhancing and therefore socially desirable.

The transitional dynamics reported in Figure 10 provides further insights of a self-financed fiscal stimulus that are worth emphasizing. First, the policy is effective in increasing social security contributions and regular output along the whole transition path, with both variables that raise substantially at the date in which the stimulus is implemented. Second, the estimated fiscal policy rules imply that both personal and corporate tax rates overshoot in the short-run. As a consequence of that pattern, tax evasion also overshoots, while underground output converges towards its *ex-post* steady state in a non-monotonic manner. Third, the debt-to-GDP ratio features an hump-shaped response to the policy. It initially decreases sharply as a consequence of the strong increase in regular output, and then it recovers completely in the sub-sequential 4 years, becoming − before declining again − even larger than its *ex-ante* steady state value. That pattern is driven by the primary fiscal surplus, which, in response of the policy, declines for several years: while in fact expenditures jumps virtually immediately to their new and higher steady state equilibrium, fiscal revenues instead declines in the aftermath of the policy. Figure 10 shows that this initial negative impact on fiscal revenues effect can nevertheless be completely overturned if the fiscal stimulus is accompanied by policy interventions that deter tax evasion. In such circumstances, the stronger response or regular output and tax evasion jointly imply an increase in the tax base that more than compensates for the lower tax rates, so that fiscal revenues immediately increase with a fiscal stimulus.

6 Concluding remarks

This paper reconsiders the macroeconomic effects of fiscal policy using an estimated DSGE model for the Spanish economy that explicitly accounts for underground transactions and tax evasion. The results of the Bayesian estimation provide evidence in favor of a sizeable underground sector in Spain, with an associated tax evasion that is predicted by the model to be a quantitatively important determinant of the actual public debt dynamics over the 1985-2015 period. In terms of fiscal policy, our results show that the presence of tax evasion amplifies the effects upon measured GDP of a changes in tax rates, while dampens the

[19]Particularly striking is the effect on the debt-to-GDP ratio, which in the economy with $p = 0.3$ declines by 13 percentage points after the fiscal stimulus.

implications driven by a boost in government spending. Because of these effects, we find that tax evasion substantially dampens the effectiveness of tax-based consolidation plans, in the sense that a tax hike may even become completely ineffective in reducing the debt-to-GDP ratio if tax enforcement is imperfect. We also characterize the long-run Laffer curve and show that, at the actual tax rates, the Spanish economy is on the slippery slope. Because of this finding, we show that a government spending increase that, in the long-run, is fully financed by lower tax rates may be substantially beneficial for Spain as it would result in a welfare enhancing boost in the economic activity accompanied by both a lower debt-to-GDP ratio and a decline in tax evasion. We show that all of these effects are amplified if the policy is carried out hand-in-hand with a reform aimed at fighting against tax evasion. These arguments provide further support to the social desirability of policies oriented at discouraging tax evasion.

References

Alesina, Alberto, Carlo Favero, and Francesco Giavazzi, "Effects of Austerity: Expenditure- and Tax-Based Approaches," *Journal of Economic Perspectives*, May 2019, *33* (2), 141–62.

Allingham, Michael G. and Agnar Sandmo, "Income tax evasion: a theoretical analysis," *Journal of Public Economics*, 1972, *1* (3), 323 – 338.

An, Sungbae and Frank Schorfheide, "Bayesian Analysis of DSGE Models," *Econometric Reviews*, 2007, *26* (2-4), 113–172.

Annicchiarico, Barbara and Claudio Cesaroni, "Tax reforms and the underground economy: a simulation-based analysis," *International Tax and Public Finance*, April 2018, *25* (2), 458–518.

Basile, Raffaella, Bruno Chiarini, Giovanni Luca, and Elisabetta Marzano, "Fiscal multipliers and unreported production: evidence for Italy," *Empirical Economics*, November 2016, *51* (3), 877–896.

Baxter, Marianne and Robert G. King, "Fiscal Policy in General Equilibrium," *The American Economic Review*, 1993, *83* (3), 315–334.

Blanchard, Olivier and Roberto Perotti, "An Empirical Characterization of the Dynamic Effects of Changes in Government Spending and Taxes on Output," *The Quarterly Journal of Economics*, 2002, *117* (4), 1329–1368.

Bouakez, Hafedh and Nooman Rebei, "Why Does Private Consumption Rise after a Government Spending Shock?," *The Canadian Journal of Economics / Revue canadienne d'Economique*, 2007, *40* (3), 954–979.

Burriel, Pablo, Jesús Fernández-Villaverde, and Juan F. Rubio-Ramírez, "MEDEA: a DSGE model for the Spanish economy," *SERIEs*, Mar 2010, *1* (1), 175–243.

Busato, Francesco and Bruno Chiarini, "Market and underground activities in a two-sector dynamic equilibrium model," *Economic Theory*, 2004, *23* (4), 831–861.

Cogan, John F., Tobias Cwik, John B. Taylor, and Volker Wieland, "New Keynesian versus old Keynesian government spending multipliers," *Journal of Economic Dynamics and Control*, March 2010, *34* (3), 281–295.

de Cos, Pablo Hernández and Enrique Moral-Benito, "Fiscal multipliers in turbulent times: the case of Spain," *Empirical Economics*, June 2016, *50* (4), 1589–1625.

Favero, Carlo A. and Pierfrancesco Mei, "Austerity and Public debt Dynamics," CEPR Discussion Papers 14072, C.E.P.R. Discussion Papers October 2019.

Forni, Lorenzo, Libero Monteforte, and Luca Sessa, "The general equilibrium effects of fiscal policy: Estimates for the Euro area," *Journal of Public Economics*, April 2009, *93* (3-4), 559–585.

Granda-Carvajal, Catalina, "Macroeconomic Implications of the Underground Sector: Challenging the Double Business Cycle Approach," *Economic Analysis and Policy*, September 2012, *42* (2), 237–256.

Havranek, Tomas, Marek Rusnak, and Anna Sokolova, "Habit formation in consumption: A meta-analysis," *European Economic Review*, 2017, *95*, 142 – 167.

Hazans, Mihails, *Informal workers across Europe: Evidence from 30 European countries*, The World Bank, 2011.

Iacoviello, Matteo and Stefano Neri, "Housing Market Spillovers: Evidence from an Estimated DSGE Model," *American Economic Journal: Macroeconomics*, April 2010, *2* (2), 125–64.

Junior, Celso J. Costa, Alejandro C. Garcia-Cintado, and Carlos Usabiaga, "Fiscal Adjustments And The Shadow Economy In An Emerging Market," *Macroeconomic Dynamics*, October 2021, *25* (7), 1666–1700.

Justiniano, Alejandro, Giorgio E. Primiceri, and Andrea Tambalotti, "Investment shocks and business cycles," *Journal of Monetary Economics*, March 2010, *57* (2), 132–145.

Koester, Gerrit and Christoph Priesmeier, "Revenue elasticities in euro area countries," Working Paper Series 1989, European Central Bank January 2017.

Leeper, Eric M., Michael Plante, and Nora Traum, "Dynamics of fiscal financing in the United States," *Journal of Econometrics*, June 2010, *156* (2), 304–321.

___, Nora Traum, and Todd B. Walker, "Clearing Up the Fiscal Multiplier Morass," *American Economic Review*, August 2017, *107* (8), 2409–2454.

___, Todd B. Walker, and Shu-Chun S. Yang, "Government investment and fiscal stimulus," *Journal of Monetary Economics*, November 2010, *57* (8), 1000–1012.

Medina, Leandro and Friedrich Schneider, "Shadow Economies Around the World: What Did We Learn Over the Last 20 Years?," *International Monetary Fund (IMF) Research Paper Series*, 2018.

Mertens, Karel and Morten O. Ravn, "Empirical Evidence on the Aggregate Effects of Anticipated and Unanticipated US Tax Policy Shocks," *American Economic Journal: Economic Policy*, May 2012, *4* (2), 145–81.

Molinari, Benedetto and Francesco Turino, "Advertising and Aggregate Consumption: A Bayesian DSGE Assessment," *Economic Journal*, August 2018, *128* (613), 2106–2130.

Mountford, Andrew and Harald Uhlig, "What are the effects of fiscal policy shocks?," *Journal of Applied Econometrics*, 2009, *24* (6), 960–992.

Orsi, Renzo, Davide Raggi, and Francesco Turino, "Size, trend, and policy implications of the underground economy," *Review of Economic Dynamics*, 2014, *17* (3), 417 – 436.

Pappa, Evi, Rana Sajedi, and Eugenia Vella, "Fiscal consolidation with tax evasion and corruption," *Journal of International Economics*, 2015, *96* (S1), 56–75.

Patxot, Concepció, Meritxell Solé, and Guadalupe Souto, "Should pensions be redistributive? The impact of Spanish reforms on the system's sustainability and adequacy," Working Papers 2017-02, FEDEA February 2017.

Pickhardt, Michael and Jordi Sardà, "Size and causes of the underground economy in Spain: a correction of the record and new evidence from the MCDR approach," *European Journal of Law and Economics*, April 2015, *39* (2), 403–429.

Porta, Rafael La and Andrei Shleifer, "Informality and Development," *Journal of Economic Perspectives*, September 2014, *28* (3), 109–26.

Price, Robert, Thai-Thanh Dang, and Jarmila Botev, "Adjusting fiscal balances for the business cycle: New tax and expenditure elasticity estimates for OECD countries," OECD Economics Department Working Papers 1275, OECD Publishing December 2015.

Ramey, Valerie A., "Ten Years after the Financial Crisis: What Have We Learned from the Renaissance in Fiscal Research?," *Journal of Economic Perspectives*, May 2019, *33* (2), 89–114.

Rannenberg, Ansgar, "State-dependent fiscal multipliers with preferences over safe assets," *Journal of Monetary Economics*, 2021, *117* (C), 1023–1040.

Sims, Christopher, "Matlab Optimization Software," QM&RBC Codes, Quantitative Macroeconomics & Real Business Cycles March 1999.

——— , "Solving Linear Rational Expectations Models," *Computational Economics*, 2002, *20* (1-2), 1–20.

Sims, Eric and Jonathan Wolff, "The Output And Welfare Effects Of Government Spending Shocks Over The Business Cycle," *International Economic Review*, August 2018, *59* (3), 1403–1435.

Smets, Frank and Rafael Wouters, "Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach," *American Economic Review*, June 2007, *97* (3), 586–606.

Uhlig, Harald, "Some Fiscal Calculus," *American Economic Review*, May 2010, *100* (2), 30–34.

Zubairy, Sarah, "On Fiscal Multipliers: Estimates From A Medium Scale Dsge Model," *International Economic Review*, February 2014, *55* (1), 169–195.

Appendix

In this section, we provide the maximization problems and first order conditions for households and firms separately.

Household problem

The decision problem of the representative household is:

$$\max_{\{c_t,\hat{k}_{t+1},u_t,h_t^m,h_t^u,Bd_{t+1}\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} \beta^t \left\{ log(cc_t)/\Gamma_t) - B_0 \xi_t^h \frac{(h_t^m + h_t^u)^{1+\xi}}{1+\xi} - B_1 \frac{(h_t^u)^{1+\phi}}{1+\phi} \right\}$$

$$s.t.$$

$$\bar{k}_{t+1} = x_t \, \xi_t^x \, \Psi(x_t/x_{t-1}) + (1-\delta) \, \bar{k}_t$$

$$x_t + c_t + Bd_{t+1}/R_t = \left(1-\tau_t^h\right)\left(w_t^m h_t^m + r_t u_t \bar{k}_t\right) + w_t^u h_t^u + Bd_t + T_t + \Pi_t - \Omega(z_t)\bar{k}_t$$

Household behavior can be derived from the following Lagrangian:

$$\begin{aligned} L_t = \sum_{t=0}^{\infty} \beta^t \Bigg\{ & log(cc_t)/\Gamma_t) - B_0 \xi_t^h \frac{(h_t^m + h_t^u)^{1+\xi}}{1+\xi} - B_1 \frac{(h_t^u)^{1+\phi}}{1+\phi} \\ & + \lambda_t \left\{ \left(1-\tau_t^h\right)\left(w_t^m h_t^m + r_t u_t \bar{k}_t\right) + w_t^u h_t^u + Bd_t + T_t + \Pi_t - \Omega(z_t)\bar{k}_t - x_t - c_t \right. \\ & \left. - Bd_{t+1}/R_t \right\} + \mu_t \left\{ x_t \, \xi_t^x \, \Psi(x_t/x_{t-1}) + (1-\delta) \, \bar{k}_t - \bar{k}_{t+1} \right\} \Bigg\} \end{aligned}$$

where λ_t and μ_t are the Lagrange multipliers for the budget constraint and the law of motion for capital, respectively.

The representative household problem must satisfy the following first order conditions with respect to consumption, capital, investment, bonds, capital utilization rate, regular labor and irregular labor, i.e.

$$\lambda_t = \xi_t^c \alpha_1 cc_t^{(-\alpha_2)} (c_t - \gamma_c c_{t-1})^{\alpha_2 - 1} - \beta \alpha_1 \gamma_c E_t \{ \xi_{t+1}^c cc_{t+1}^{(-\alpha_2)} (c_{t+1} - \gamma_c c_t)^{\alpha_2 - 1} \}$$

$$\mu_t = \beta E_t \left\{ \left(\lambda_{t+1} \left((1 - \tau_{t+1}^h)\, r_{t+1} z_{t+1} - \Omega(z_{t+1}) \right) + (1 - \delta)\ \mu_{t+1} \right) \right\}$$

$$\lambda_t = \xi_t^x\, \mu_t \left(1 - \left(\frac{x_t}{x_{t-1}} - 1 \right)^2 \frac{\psi}{2} - \frac{x_t}{x_{t-1}} \left(\frac{x_t}{x_{t-1}} - 1 \right) \psi \right) + \beta E_t \left\{ \psi\, \mu_{t+1}\, \xi_{t+1}^x \left(\frac{x_{t+1}}{x_t} - 1 \right) \left(\frac{x_{t+1}}{x_t} \right)^2 \right\}$$

$$\lambda_t = \beta E_t \left\{ \lambda_{t+1} R_t \right\}$$

$$r_t = \Omega^{'}(z_t)$$

$$\xi_t^c\, B_0\, h_t^{\xi} = w_t^m\, \left(1 - \tau_t^h \right)\, \lambda_t$$

$$\xi_t^c (B_0\, h_t^{\xi} + B_1\, h_t^{u\phi}) = w_t^u\, \lambda_t$$

Firm problem

Each firm i chooses capital, regular labor and irregular labor to maximize profits according to the following expression:

$$\max E_t \{ \Pi_{i,t} \} = (1 - \tau_t^c) y_{i,t}^m + (1 - ps\tau_t^c) y_{i,t}^u + \tau_t^c w_t^m h_{i,t}^m - TC_{i,t}$$

$$s.t.$$

$$y_{i,t}^m = A_t\, (\Gamma_t h_{i,t}^m)^{\alpha}\, k_{i,t}^{1-\alpha}$$

$$y_{i,t}^u = B_t\, (\Gamma_t h_{i,t}^u)^{\alpha_u}$$

$$TC_{i,t} = (1 + \tau_t^s) w_t^m h_{i,t}^m + r_t k_{i,t} + w_t^u h_{i,t}^u$$

The optimal decisions for $k_{i,t}$, $h_{i,t}^m$ and $h_{i,t}^u$ are given by the following first order conditions:

$$(1 - \alpha)\ \frac{y_{i,t}^m}{k_{i,t}} = \frac{r_t}{1 - \tau_t^c}$$

$$\alpha \, \frac{y^{m}_{i,t}}{h^{m}_{i,t}} = \frac{w^{m}_{t} \, (1 + \tau^{s}_{t} - \tau^{c}_{t})}{1 - \tau^{c}_{t}}$$

$$\alpha_{u} \, \frac{y^{u}_{i,t}}{h^{u}_{i,t}} = \frac{w^{u}_{t}}{1 - \tau^{c}_{t} \, p_{t} \, s}$$

Since $\tau^{c}_{t} \in (0,1)$, the condition that satisfies an interior solution with the existence of underground production in the firm's maximization problem is $(1 - \tau^{c}_{t} p_{t} s) > 0$. Otherwise, $(1 - \tau^{c}_{t} p_{t} s) \leq 0$ implies $h^{u_{t}} = 0$ and therefore, no underground production in the economy.