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Decomposing the Grey Economy in Bulgaria: A General-Equilibrium Analysis

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Abstract

This paper attempts to assess the size of the grey economy, and provide a decomposition by evasion type. The modelling approach utilizes a standard micro-founded general-equilibrium setup, which is augmented with a revenue-extraction mechanism and a government sector. The model is calibrated to Bulgaria after the introduction of the currency board (1999-2018). A computational experiment performed within this setup estimates that on average, the size of total evasion is a bit more than one-fourth of output, an estimate which is in line with the figures provided in both Philip (2014) and the European Commission (2014). Two-thirds of the model-predicted evasion is a combined result of income- and social security evasion, while the rest is due to VAT evasion.

Keywords: tax evasion, general equilibrium, Bulgaria
JEL Classification Codes: D58, E26, H26, K42

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1 Introduction and Motivation

After the fall of the Communism in 1989, Bulgaria, a small economy in South-East Europe, and an EU member state as of 2007, had to make an important decision on how to adapt its pre-existing tax system to better fit both the new market reality, and harmonize its fiscal system with that of the EU. Due to both its communist heritage, and the European social contract, which was deeply rooted in the spirit of solidarity, the public finance model in Bulgaria was organized around indirect, or consumption-based taxes.[1] Indeed, consumption tax-, or VAT revenue, is the dominant source of tax revenue in Bulgaria, and most of Central and Eastern Europe as well.[2] VAT increased in importance after its introduction and implementation in 1994 from 25% to 35% of total tax revenue in the years following the currency board implementation (in 1997), as shown in Vasilev (2017a). Over the period 1999-2018, which was a period of macroeconomic stability, the role of indirect (consumption) taxes increased from 43 % to 60% in 2009, and then slowly decreased to 50% of total tax revenue.

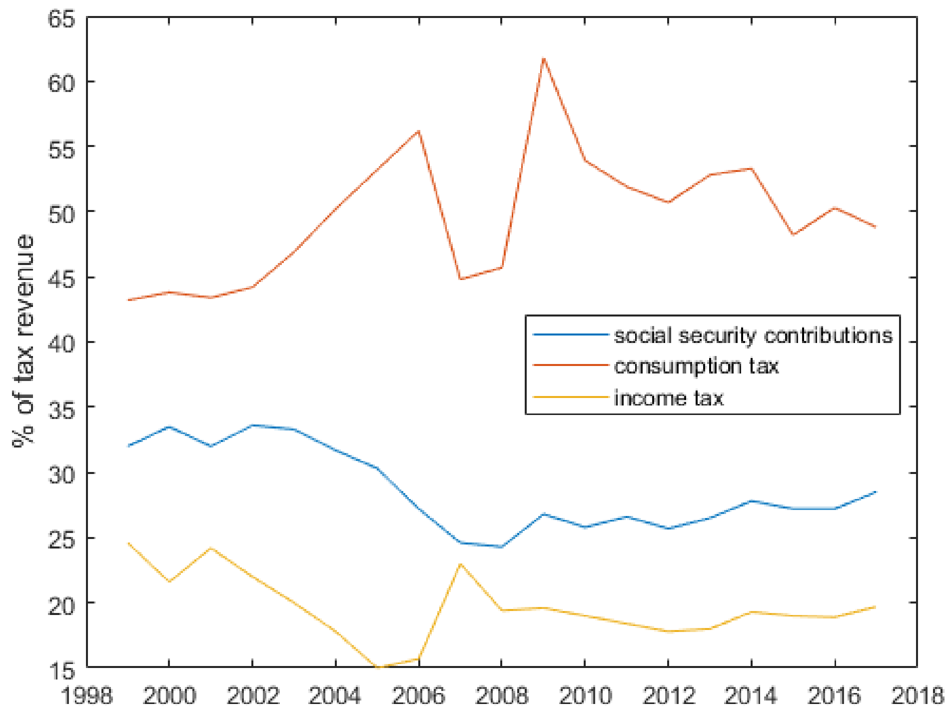
In contrast, income taxation in Bulgaria was of much smaller importance for the budget: Income taxes are responsible for 20% of total tax revenues, with the share stabilizing after the decrease of the corporate tax rate to 10 % as of 2007, and the introduction of flat (proportional) income tax rate of 10%.[3] Last, but not least, social security contributions (made by both employers and employees), despite not being taxes in the legal sense, are de facto part of the overall burden on labor.[4] In total, employees' and employers' contributions make some $25 - 33\%$ of overall tax revenue, which makes them the second most important source of revenue for the government. The dynamics of the share of the three major sources of revenue for the government, namely the VAT revenue in total tax revenue in Bulgaria, the share of income taxation in total tax revenue, and the role of social security contributions are all presented in Fig. 1 on the next page.

[1]Yet another reason was the absence of sufficiently qualified tax administration in the early 1990s.

[2]In this paper, "consumption tax" an "VAT" will be used interchangeably.

[3]The income tax revenue is approximately equally divided between labor an capital income.

[4]This is because the proceeds go into several common pools - the State Pension Fund (NOI), the State Health care Fund (NZOK), the Unemployment Fund, the Disability Fund, etc.



Source: NSI (2019), author's calculations.

Figure 1: Fiscal importance of different tax revenues in Bulgaria (1999-2017)

Still, problems with tax evasion are pervasive in Bulgaria. In particular, the ability of the government to collect all its taxes might be an issue, due to inefficient institutions. Having said that, informal economic activity is a phenomenon observed not only in developing countries but also in emerging and developed economies. In particular, informality is well-spread in Eastern and Southern Europe and reaches its highest in Bulgaria where the informal production amounts to a third of officially reported GDP in the late 2000s, as shown in Schneider and Medina (2018).

Given that consumption taxation, income taxation, and social security contributions makes almost all of the tax revenue in Bulgaria, in this paper we focus on these types of taxes, and there will be a certain degree of evasion associated with each of these three categories. Indeed, as pointed out in Di Nola *et al.* (2019), a major form of tax evasion in Europe is through hiding wages, social contributions and profits in formally registered firms is.[5] Our study is in line with the mechanism at work in that paper, and in addition encompasses Vasilev (2017), who only considers VAT evasion. Finally, relative to Angelopoulos *et al.* (2009), the model in this paper allows for social security contributions. In addition, the model allows us not only to estimate the size of the loss from tax evasion, but also to decompose the grey economy into evaded VAT, evaded income taxes, and evaded social security contributions.[6] This is yet another contribution where the paper tries to add value, and extend earlier studies.[7]

The setup in this paper is a relatively standard micro-founded general-equilibrium framework with a detailed government sector, populated by a unit mass of homogeneous households and augmented with a tax revenue extraction mechanism as in Vasilev (2017a,b). Similarly to Angelopoulos *et al.* (2009, 2011), each one-member household can decide to spend working time on rent-seeking activities and try to hide (or equivalently, extract) part of the tax revenue from the government.[8] To the best of our knowledge, no such setup, exists for transition and/or development countries.[9] Furthermore, models that are disciplined by both theory and data are useful tools to inform policy makers on issues, whose effects are otherwise hard to

[5] Williams (2008), among others, emphasizes the practice of firms to report lower official wages and compensate their employees with informal cash payments, often in an envelope, and thus commonly referred to as "envelope wages."

[6] In reality, the different types of evasion would require different types of government policies to address them. In the model we assume a constant degree of evasion across tax revenue sources, mostly to keep the setup parsimonious and for better tractability.

[7] Our study also adds value to an older literature, namely the Computable General Equilibrium (CGE) literature - see De Melo *et al.* (1992) for a recent study. However, in contrast to the CGE literature, our model utilizes the Dynamic Stochastic General Equilibrium (DSGE) class of models, which are micro-founded and grounded in optimizing behavior, while CGE models are static and *ad hoc*.

[8] The model is a closed economy in order to emphasize the mechanism of rent-seeking at work. In addition, the rent-seeking process in our setup will not interaction with the trade sector (or foreign economies for that matter), as most of the trade that Bulgaria exercises is with the rest of the EU, so there are no tariffs to be evaded.

[9] An alternative approach to modeling tax evasion, widespread in the literature, relies on random government audits and the enforcement of penalties; This approach was started by Allingham and Sandmo (1972), and recently utilized in macroeconomics by Di Nola et al. (2021). We leave this alternative approach for future work.

measure. After all, model-based estimates of the losses associated with tax fraud (and more importantly, allowing for decomposition of the grey economy into different sub-components) for transition and developing countries, based on optimal behavior, are still missing from the public finance literature.[10] Lastly, the study in this paper could be also relevant for Eastern European countries considering EU accession, such as Albania, Serbia, Montenegro, North Macedonia, who are following a similar public finance model to that of Bulgaria.

Bulgaria was chosen as a suitable testing case for the tax evasion mechanism in this paper, as the country with the largest grey economy sector in the EU (Schneider and Medina 2018, Schneider and Enste 2013). Bulgaria is also unique in the sense that the consumption tax rate in Bulgaria is non-differentiated, and income tax rate is proportional (flat) as of 2008, and not progressive like in many countries in Western Europe and the US.[11] A computational experiment performed within this setup estimates that on average, the size of total evasion is a bit more than one-fourth of output, an estimate which is in line with the figures provided in both Philip (2014) and the European Commission (2014). Two-thirds of the model-predicted evasion is a combined result of income- and social security evasion, while the rest is due to VAT evasion.

The rest of the paper is organized as follows: Section 2 describes the model setup, Section 3 describes the model calibration, Section 4 characterizes the symmetric steady-state, Sections 5 proceeds with the out-of-steady-state dynamics of model variables, and compares the simulated second moments of theoretical variables against their empirical counterparts, and Section 6 discusses some of the model assumptions and limitations. Section 7 concludes.

[10] This structural modeling approach differs greatly from the (ad hoc) MIMIC econometric approach utilized in Schneider and Medina (2018), Schneider and Enste (2013), among others.

[11] This greatly simplifies the analysis in this paper, and allows for better tractability of the model, and clearer findings. Having said that, the model can be easily adapted and extended to more general fiscal environments.

2 Model Description

There is a unit mass of households who derive utility out of consumption, leisure and public services. The time available to households can be spent in productive or in activities leading to overall tax evasion. The benefit from opportunistic behavior is measured in terms of the share of extracted tax payments. Thus, the government is not able to collect all the tax revenue, and will spend less on utility-enhancing public purchases and government transfers. On the production side, there is a representative firm, which produces a homogeneous final good, which could be used for consumption, investment, or government purchases.

2.1 Households

There is a unit mass of one-member households, indexed by i. Each household i maximizes its expected utility function:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \ln c_{it} + \gamma \ln[1 - h_{it}] + \ln g_t^c \right\}, \tag{1}$$

where E_0 is the expectations operator as of period $t = 0$, c_{it} denotes household's i private consumption in period t, h_{it} are non-leisure hours in period t, g_t^c is per-household consumption of public services, $0 < \beta < 1$ is the discount factor, and $\gamma > 0$ is the relative weight that each household attaches to leisure.

Each household i starts with an initial stock of physical capital k_{i0}, and has to decide how much to add to it in the form of new investment. Every period physical capital depreciates at a rate δ, where $0 < \delta < 1$. The law of motion for physical capital is then

$$k_{i,t+1} = i_{it} + (1 - \delta) k_{it}, \tag{2}$$

and the real interest rate is r_t, hence the before-tax capital income of household i in period t equals $r_t k_{it}$.

In addition to capital income, each household can generate labor income. However, not all hours are spent in productive activities: only η_{it} share, $0 < \eta_{it} < 1$, is dedicated to working in the representative firm, where the hourly wage rate is w_t, so labor income equals

$w_t\eta_{it}h_{it}$. The remaining hours, $(1-\eta_{it})h_{it}$, are used to engage in activities, whose aim is to evade paying taxes. The reward from engaging in tax evasion is that each household can capture a share of the lost government tax revenue, and thus add to its income. The rent-extraction technology, R_t, is represented by the following technology, which is akin to the one used in Angelopoulos *et al.* (2009), and Vasilev (2017a,b):

$$R_t = \tau^c C_t + (\tau^y + \tau_t^{e,ss})\left[r_t K_t + w_t H_t + \Pi_t\right], \tag{3}$$

where τ^c is the VAT/consumption tax rate, C_t denotes aggregate consumption, τ^y is the common income tax rate,, $\tau_t^{e,ss}$ are the social security contributions born by the employer, K_t is aggregate capital, H_t is aggregate productive labor, and Π_t are aggregate profits. Since the individual household is assumed to be small relative to the aggregate, aggregate variables and the total amount of the rent are taken as given. Parameter θ, $0<\theta<1$, is chosen to denote the share of total tax revenue evaded, while $\frac{(1-\eta_{it})h_{it}}{\int_i (1-\eta_{it})h_{it}}$ would represent the endogenous probability of winning the "prize" (or getting a larger per-household "slice" of the rent pie). Every household takes the time spent rent-seeking by the other households as given, and optimally chooses time directed to increasing the probability of winning.[12]

Next, household i's problem can be now simplified to

$$E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \ln c_{it} + \gamma \ln[1-(1-\eta_{it})h_{it} - \eta_{it}h_{it}] + \ln g_t^c \right\} \tag{4}$$

s.t.

$$(1+\tau^c)c_{it} + k_{i,t+1} - (1-\delta)k_{it} = (1-\tau^y)[w_t\eta_{it}h_{it} + r_t k_{it} + \pi_{it}] + g_t^t + \theta R_t \frac{(1-\eta_{it})h_{it}}{\int_i (1-\eta_{it})h_{it}}, \tag{5}$$

[12] That is, the government only collects $1-\theta$ share of all taxes, which is net of the cost of tax collection.

where g_{it}^t is household i's government transfer, and π_{it} is the profit income earned by each household. The problem generates the following optimality conditions:

$$c_{it} : \frac{1}{c_{it}} = \lambda_{it}(1+\tau^c) \tag{6}$$

$$k_{i,t+1} : \lambda_{it} = \beta E_t \lambda_{i,t+1}[1 + (1-\tau^y)r_{t+1} - \delta] \tag{7}$$

$$\eta_{it}h_{it} : \frac{\gamma}{1-h_{it}} = \lambda_t(1-\tau^y)w_t \tag{8}$$

$$(1-\eta_{it})h_{it} : \frac{\gamma}{1-h_{it}} = \lambda_t \theta R_t \frac{1}{\int_i (1-\eta_{it})h_{it}} \tag{9}$$

$$TVC_i : \lim_{t\to\infty} \beta^t \lambda_{it} k_{i,t+1} = 0, \tag{10}$$

where λ_{it} is the Lagrangian multiplier attached to household i's budget constraint in period t.

The first optimality condition states that for each household, in equilibrium the marginal utility of consumption should equal the marginal utility of wealth, corrected for the consumption tax rate. The second equation is the so-called "Euler condition," which describes how each household chooses to optimally allocate physical capital over time. Next, at the margin, each hour spent working for the firm should balance the benefit from doing so in terms of additional income generates, and the cost measured in terms of lower utility of leisure. Similarly, the disutility from an hour spent rent-seeking should equate the benefit (in terms of captured tax revenue). The last condition is the boundary, or "transversality condition" (TVC), which states that at the end of the horizon, the value of physical capital should be zero.

2.2 Firm

There is a representative firm in the economy, which produces a homogeneous product. The price of output is normalized to unity. The production technology is Cobb-Douglas and uses both physical capital, k^f, and labor hours, h^f, to maximize static profit

$$\Pi_t = A_t(k_t^f)^\alpha (h_t^f)^{1-\alpha} - (1+\tau_t^{e,ss})[r_t k_t^f - w_t h_t^f], \tag{11}$$

where A_t denotes the level of technology as of period t, and $\tau_t^{e,ss}$ denote social contributions paid by the employer on the employees' behalf. Since the firm rents the capital from households, the problem of the firm is a sequence of static profit maximizing problems. In equilibrium, there are no profits ($\Pi_t = \pi_{it} = 0$), and each input is priced according to its marginal product, *i.e.*:

$$k_t^f : \alpha \frac{y_t}{k_t^f} = (1 + \tau_t^{e,ss}) r_t, \tag{12}$$

$$h_t^f : (1-\alpha) \frac{y_t}{h_t^f} = (1 + \tau_t^{e,ss}) w_t. \tag{13}$$

2.3 Government

In the model setup, the government is levying taxes on labor and capital income, collecting social security contributions made by the employer on the workers' behalf,[13] as well as taxing consumption in order to finance spending on utility-enhancing government purchases. However, due to tax evasion (which could be due to inefficiencies in the way tax officials operate), the government is able to collect only $1-\theta$ share of the consumption tax revenue. The government budget constraint is as follows:

$$g_t^c + \int_i g_{it}^t = (1-\theta)\left\{\tau^c C_t + (\tau^y + \tau^{e,ss})\left[r_t K_t + w_t H_t + \Pi_t\right]\right\} \tag{14}$$

Government consumption-to-output ratio would be chosen to match the average share in data, and government transfers would be determined residually in each period so that the government budget is always balanced.

2.4 Exogenous stochastic processes

The exogenous processes for total factor productivity, A_t will follow AR(1) processes in natural logarithms:

$$\ln A_{t+1} = (1-\rho_a)\ln A + \rho_a \ln A_t + \epsilon_{t+1}^a \tag{15}$$

where A is the steady-state values of the TFP processes, $0 < \rho_a < 1$ is the persistence parameters, and the productivity innovations are drawn from the following distributions: $\epsilon_t^a \sim i.i.d N(0, \sigma_a^2)$.

[13] As explained in the calibration section, social security contributions paid by each worker are treated as an additional effective tax on labor.

2.5 Market Clearing

In addition to the optimality conditions from the household's and firm's problem, as presented in the previous subsections, and the government budget constraint above, we need to impose consistency among the different decisions. More specifically, this would require that in equilibrium (i) aggregate quantities equal the sum of individual allocations, and (ii) output, capital and labor markets all clear, or for all t:

$$\int_i \left[c_{it} + k_{i,t+1} - (1-\delta)k_{it} \right] + g_t^c = y_t \tag{16}$$

$$\int_i c_{it} = C_t \tag{17}$$

$$\int_i g_{it}^t = g_t^t \tag{18}$$

$$\int_i k_{it} = k_t^f = K_t \tag{19}$$

$$\int_i \eta_{it} h_{it} = h_t^f = H_t. \tag{20}$$

2.6 Dynamic Competitive Equilibrium (DCE)

Given the process followed by technology $\{A\}_{t=0}^{\infty}$, the average tax rates $\{\tau^c, \tau^y\}$, initial individual capital endowments stock $k_{i0}, \forall i$, and aggregate allocations $\{C_t, H_t, K_t\}_{t=0}^{\infty}$, the decentralized dynamic competitive equilibrium is a list of sequences $\{c_{it}, i_{it}, k_{it}, \eta_{it}, h_{it}\}_{t=0}^{\infty}$ for each household i, input levels $\{k_t^f, h_t^f\}$ chosen by the firm in each time period t, a sequence of government purchases and transfers $\{g_t^c, g_t^t\}_{t=0}^{\infty}$, and input prices $\{w_t, r_t\}_{t=0}^{\infty}$ such that (i) each household i maximizes its utility function subject to its budget constraint; (ii) the representative firm maximizes profit; (iii) government budget is balanced in each period; (iv) all markets clear.

2.6.1 Symmetric DCE

In the general, non-symmetric, case it is very difficult to solve the system defined in the subsection above. More specifically, the model in its general formulation can generate a multitude of distributions of capital stock holdings across households, and in this sense, the equilibrium is indeterminate. Therefore, we will concentrate on a particular equilibrium, one in which all households are identical, or the symmetric solution. This requires setting

$k_{i0} = k_0$, and imposing symmetry in the DCE system for all i, which in turn greatly simplifies the optimality conditions derived above. Since the model features a unit mass of households, this produces $c_{it} = C_t, k_{it} = K_t, h_{it} = h_t, \eta_{it} = \eta_t$, etc. In addition, in the symmetric equilibrium every household will receive an equal share of the pie.[14]

3 Data and Model Calibration

To compute the size of overall tax evasion in Bulgaria, we will focus on the period after the introduction of the currency board (1999-2018). Data on output, consumption and investment was collected from National Statistical Institute (2020), while the real interest rate is taken from Bulgarian National Bank Statistical Database (2020). The calibration strategy described in this section follows a long-established tradition in modern macroeconomics: first, the discount factor, $\beta = 0.973$, is set to match the steady-state capital-to-output ratio in Bulgaria, $k/y = 3.491$, in the steady-state Euler equation. The labor share parameter, $\alpha = 0.429$, was obtained as the average value of labor income in aggregate output over the period 1999-2018.[15] The relative weight attached to the utility out of leisure in the household's utility function, γ, is calibrated to match that in steady-state consumers would supply one-third of their time endowment to working. This is in line with the estimates for Bulgaria as well over the period studied. The depreciation rate of physical capital in Bulgaria, $\delta = 0.05$, was taken from Vasilev (2015b). It was estimated as the average depreciation rate over the period 1999-2014. The share of working time used in rent-extraction, $1 - \eta = 1/3$, was set as the average hidden employment share as estimated by Center for the Study of Democracy (2015). The average income tax rate was set to $\tau^y = 0.22$,[16] and the average

[14]Since the main objective is to make a prediction about the aggregate size of the extracted tax, not how the degree of evasion is distributed across the population, the focus on the symmetric DCE is not a significant limitation of the analysis.

[15]This value is slightly higher as compared to other studies on developed economies, due to the overaccumulation of physical capital, which was part of the ideology of the totalitarian regime, which was in place until 1989.

[16]This is a sum of two parts: the average effective tax rate on income between 1999-2007, when Bulgaria used progressive income taxation, and equal to the proportional income tax rate introduced as of 2008, *plus* the average amount of social security contributions made by each worker. Technically, $\tau^y = \hat{\tau}^y(1 - \tau^{w,ss}) + \tau^{w,ss}$ since social security payments are deducted from the tax base for income taxation, where $\hat{\tau}^y$ is the

social contribution rate paid by the employer on the workers' behalf is $\tau^{e,ss} = 0.234$. Finally, the tax rate on consumption is set to its value over the period, $\tau^c = 0.2$. The TFP process is estimated from the detrended series of the Solow residuals by running an AR(1) regression. Table 1 below summarizes the values of all model parameters used in the paper.

Table 1: Model Parameters

Parameter	Value	Description	Method
β	0.973	Discount factor	Calibrated
α	0.429	Capital Share	Data average
$1-\alpha$	0.571	Labor Share	Calibrated
γ	1.652	Relative weight attached to leisure	Calibrated
δ	0.050	Depreciation rate on physical capital	Data average
η	0.670	Share of working hours used productively	Data average
τ^y	0.220	Average tax rate on income	Data average
$\tau^{e,ss}$	0.234	average social contribution rate, paid by the employer	Data average
τ^c	0.200	VAT/consumption tax rate	Data average
ρ_a	0.701	AR(1) persistence coefficient, TFP process	Estimated
σ_a	0.044	st. error, TFP process	Estimated

4 Steady-State

Once the values of model parameters were obtained, the steady-state equilibrium system solved, the "big ratios" can be compared to their averages in Bulgarian data. The results are reported in Table 2 on the next page. The steady-state level of output was normalized to unity (hence the level of technology A differs from one, which is usually the normalization done in other studies), which greatly simplified the computations. Next, the model matches consumption-to-output ratio by construction; The investment and government purchases ratios are also closely approximated, despite the closed-economy assumption and the absence of foreign trade sector. The shares of income are also identical to those in data, which is an artifact of the assumptions imposed on functional form of the aggregate production function.

pure income tax, and $\tau^{w,ss}$ denote the social security contributions paid by each worker.

The after-tax return, where $\tilde{r} = (1 - \tau^y)r - \delta$ is also relatively well-captured by the model.

Table 2: Data Averages and Long-run Solution

Variable	Description	Data	Model
y	Steady-state output	N/A	1.000
c/y	Consumption-to-output ratio	0.674	0.674
i/y	Investment-to-output ratio	0.201	0.175
g^c/y	Government cons-to-output ratio	0.159	0.151
$(1+\tau^{e,ss})w\eta h/y$	Labor income-to-output ratio (inclusive of payroll tax)	0.571	0.571
$(1+\tau^{e,ss})rk/y$	Capital income-to-output ratio (inclusive of payroll tax)	0.429	0.429
h	Share of time spent working	0.333	0.333
η	Share of working time spent productively	0.670	0.670
A	Scale parameter of the production function	N/A	1.095
$\tilde{r}$	After-tax net return on capital	0.056	0.067
$\theta R/y$	Total tax evasion-to-output ratio	0.265	0.257
$\theta\tau^c c/y$	VAT evasion-to-output ratio	-	0.074
$\theta\tau^y(rk + w\eta h)/y$	Income tax evasion-to-output ratio	-	0.055
$\theta\tau^{ss}(rk + w\eta h)/y$	Social security evasion-to-output ratio	-	0.128

Next, the model predicts that the average magnitude of tax evasion relative to output is approximately 26 percent, which is very closely to the figure in both Phillip (2014) and the European Commission (2014). Next, according to the model, half of the evasion in the model is due to social security evasion, a forth is due to VAT evasion, and the rest, approximately one-fifth of total evasion, is due to income evasion.[17] Quantitatively, the combined effect of income tax evasion, and the evasion of social security contributions is responsible for three-fourths of total tax evasion, and is therefore much more important than VAT evasion, as argued also in Di Nola *et al.* (2019).

[17]Unfortunately, the sources mentioned in the body of the text do not provide a breakdown into the categories used in the model framework.

5 Out of steady-state model dynamics

Since the model does not have a closed-form (analytical) solution for the equilibrium behavior of variables outside their steady-state values, we solve the model numerically by log-linearizing the original equilibrium (non-linear) system of equations around the steady-state, which results into a first-order system of stochastic linear difference equations. First, we study the dynamic behavior of model variables to a shock to the total factor productivity process, and then we fully simulate the model to compare how the second moments of the model perform when compared against their empirical counterparts.

5.1 Impulse Response Analysis: Technology Shock

This subsection documents the impulse responses of model variables to a 1% surprise innovation to technology, or total factor productivity. The impulse response functions (IRFs) are presented in Fig. 2 on the next page. First, output increases directly upon impact as a result of the improvement in technology. This expands the availability of resources in the economy, so uses of output - private consumption, investment, and government purchases also increase contemporaneously. At the same time, the increase in productivity increases the after-tax return on the two factors of production, labor and capital. The households then respond to the incentives contained in prices and start accumulating capital, and dedicates more time to productive activities, *e.g.*, a higher η. In turn, the increase in capital and labor input feeds back in output through the Cobb-Douglas production function and that further adds to the positive effect of the technology shock. In the presence of tax evasion, expressed in terms of total tax revenue, the rent also increases.[18] Over time, as capital is being accumulated, its after-tax marginal product starts to decrease, which follows from the diminishing marginal product property built in the production function. A lower interest rate then lowers the households' incentives to save in the form of capital. Next, investment starts to decrease and returns to its old steady-state value. In turn, physical capital stock also returns to its steady-state, following a hump-shaped dynamics along its transition path. The rest of the model variables (except for consumption, which inherits the hump-shaped

[18] On the one hand, this leads to more time spent on rent-seeking; on the other, the productivity also increases, so rent-seeking decreases due to more hours being relocated to work. Given that the productivity increasing is a first-order effect, which dominates the increase in the "prize", which is a second-order effect.

dynamics of wages) also return to their old steady-states in a monotone fashion as the effect of the one-time surprise innovation in technology dies out.

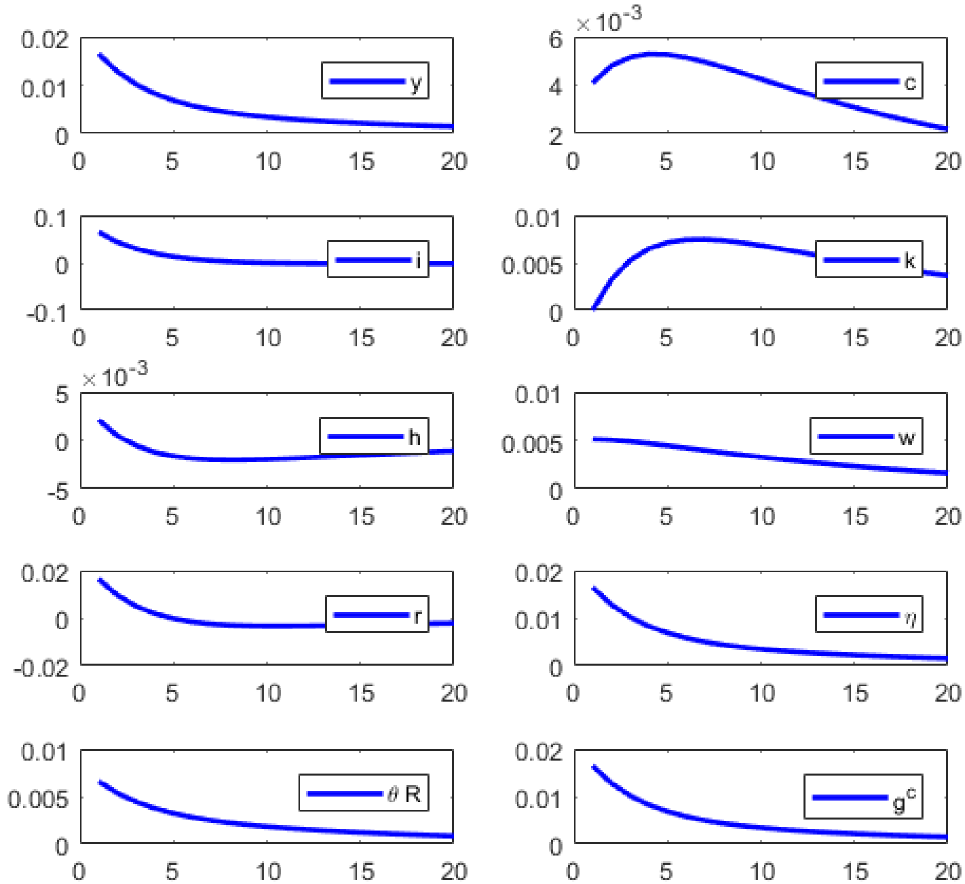


Figure 2: Impulse Responses to a 1% surprise innovation in technology

5.2 Simulation and moment-matching

As in Vasilev (2017b), we simulate 10,000 series of TFP innovations for the length of the data horizon.[19] Table 3 on the next page summarizes the second moments of data (relative volatilities to output, and contemporaneous correlations with output) versus the same moments computed from the model-simulated data at annual frequency. Similar to Vasilev

[19]Both empirical and model simulated data is detrended using the Hodrick-Prescott (1980) filter.

(2016, 2017b, 2017c), the setups overestimate the relative volatility of consumption and investment, but are still qualitative consistent with the stylized facts that consumption varies less than output, and investment varies more than output. By construction, in the model government purchases vary as much as output, which is lower than the empirical volatility.

Table 3: Business Cycle Moments

	Data	Model
σ_c/σ_y	0.55	0.79
σ_i/σ_y	1.77	2.38
σ_g/σ_y	1.21	1.00
σ_h/σ_y	0.63	0.30
σ_w/σ_y	0.83	0.65
$\sigma_{y/\eta h}/\sigma_y$	0.86	0.65
$corr(c, y)$	0.85	0.90
$corr(i, y)$	0.61	0.5
$corr(g, y)$	0.31	1.00
$corr(h, y)$	0.49	0.63
$corr(w, y)$	-0.01	0.94

With the introduction of endogenous rent-seeking time, the volatility of working hours increases and that brings variability of hours closer to that in data. In addition, wage variability is too low, but closer than that in data when compared to a model without rent-seeking, *e.g.* Vasilev (2009). We can thus safely say that the model with rent-seeking channel is a step in the right direction.

6 Discussion and model limitations

In this section we discuss the mechanics of the model, and some of the potential limitations of the study, some of which due to the simplifying modeling choices implemented in the theoretical setup, as well as some extensions. One such extension would be to distinguish the degree of evasion θ across the three different types of tax evasion, and even endogeneize each evasion parameter. Vasilev (2018) for example, motivated by empirical findings, models the degree of VAT evasion as a convex function of the consumption tax. Similarly, income tax evasion and evasion of social security contribution can be made conditional on the rates themselves. However, we do not expect any significant changes from those extensions. With the exception of VAT evasion case, which, as shown in Vasilev (2018), can produce a new result in the form of a peaking consumption-Laffer curve, the other cases produce the expected hump-shaped income-Laffer curve, and social-security-Laffer curve.[20] A direct policy implication that can also be drawn from this model is that if tax rates is lowered, that would also lower the prize.

Next, as in Angelopoulos *et al.* (2009), and Vasilev (2017a), we can endogeneize evasion and make is negatively related to spending on law and order, and tax enforcement in particular, via tax audits, etc. For example, in Angelopoulos *et al.* (2009), and Vasilev (2017a), increasing the spending on law and order by 50% is likely to produce a welfare gain of approximately 10 % higher consumption in the steady-state. This exercise is not pursued here, as it is going to provide similar results, so there is not much value-added of doing so. More importantly, the effects on all types of evasion will be proportional across the three groups, given they all share a common evasion parameter.

Lastly, the reason why in equilibrium a household would decide to engage in all the three types of tax evasion is that the flows of extracted tax revenue are seen as common property resources, and in public-finance setups individual rationality turns out to be sub-optimal from the perspective of society in general.[21] Instead of delving into the source of government inefficiency, the model took as given the authorities' inability to collect all taxes, and proceeded to quantify the aggregate cost of such evasion. However, in reality authorities could engage in information campaigns, and urge people to declare their full income, and report their employer if s/he does not do so. In other words, instead of playing the non-cooperative Nash equilibrium strategy, which results in a negative-sum repeated game, the government can inform the households that they are playing against each other, and thus they should

[20]The latter is not a surprise, as social security contributions increase cost of labor in the model.

[21]For simplicity, the analysis assumed that only households could engage in tax evasion. However, government officials could also be part of such schemes. Solving for a full-blown political economy equilibrium is left for future work.

behave cooperatively (which leads to a zero-sum game). This would eliminate the social cost in the economy by driving down evasion to zero in equilibrium, and households' total labor supply will be productively spent working in the firm.

7 Conclusions

This paper attempts to assess the size of the grey economy, and provide a decomposition by evasion type. The modeling approach utilizes a standard micro-founded general-equilibrium setup, which is augmented with a revenue-extraction mechanism and a government sector. The model is calibrated to Bulgaria after the introduction of the currency board (1999-2018). A computational experiment performed within this setup estimates that on average, the size of total evasion is a bit more than one-fourth of output, an estimate which is in line with the figures provided in both Philip (2014) and the European Commission (2014). Two-thirds of the model-predicted evasion is a combined result of income- and social security evasion, while the rest is due to VAT evasion.

Using models that are disciplined by both theory and data provides researchers with a useful tool to inform policy makers on issues, whose effects are otherwise hard to measure. Still, the measurements presented in this paper are to be taken with a grain of salt. There is need for more detailed and better modeling of the rent-seeking process, and possibly allowing for real heterogeneity across households. Nevertheless, in our opinion, quantitative theory is the approach to be followed.

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