Department of Economics - FEA/USP

Endogenous Tax Compliance and Macroeconomic Performance Driven by Satisficing Evolutionary Dynamics

LEONARDO BARROS TORRES

GILBERTO TADEU LIMA

JAYLSON JAIR DA SILVEIRA

WORKING PAPER SERIES Nº 2024-10

DEPARTMENT OF ECONOMICS, FEA-USP
WORKING PAPER Nº 2024-10

Endogenous Tax Compliance and Macroeconomic Performance Driven by Satisficing Evolutionary Dynamics

Leonardo Barros Torres (l.barrostorres@surrey.ac.uk)

Gilberto Tadeu Lima (giltadeu@usp.br)

Jaylson Jair da Silveira (jaylson.silveira@ufsc.br)

Abstract:

We incorporate tax evasion to a demand-led macrodynamic model of capacity utilization and output growth rate. The frequency of tax evaders is endogenously time-varying, driven by imitation-augmented satisficing evolutionary dynamics involving pecuniary and non-pecuniary factors reflecting the distribution of tax morale across taxpayers. Consequently, the microdiversity of tax compliance behavior and the macrodynamics of economic activity are co-evolutionarily coupled. Matching empirical evidence, long-run heterogeneity in tax compliance is a stable evolutionary equilibrium, and the higher the median tax morale, the lower the frequency of tax evaders. Other comparative statics matching empirical evidence are obtained analytically and through numerical simulations.

Keywords: Tax compliance behavior; tax morale; satisficing evolutionary dynamics; capacity utilization; output growth rate.

JEL Codes: B52; C52; D33; E12; E70; H26.

Endogenous tax compliance and macroeconomic performance driven by satisficing evolutionary dynamics

Leonardo Barros Torres
(Corresponding author)[1]

PhD Candidate at University of Surrey, School of Economics
Guildford, Surrey – UK

Gilberto Tadeu Lima

Professor at University of São Paulo, Department of Economics
São Paulo, SP – Brazil

Jaylson Jair da Silveira

Associate Professor at Federal University of Santa Catarina, Department of Economics and International Relations
Florianópolis, SC – Brazil

Abstract

We incorporate tax evasion to a demand-led macrodynamic model of capacity utilization and output growth rate. The frequency of tax evaders is endogenously time-varying, driven by imitation-augmented satisficing evolutionary dynamics involving pecuniary and non-pecuniary factors reflecting the distribution of tax morale across taxpayers. Consequently, the microdiversity of tax compliance behavior and the macrodynamics of economic activity are co-evolutionarily coupled. Matching empirical evidence, long-run heterogeneity in tax compliance is a stable evolutionary equilibrium, and the higher the median tax morale, the lower the frequency of tax evaders. Other comparative statics matching empirical evidence are obtained analytically and through numerical simulations.

Keywords: Tax compliance behavior; tax morale; satisficing evolutionary dynamics; capacity utilization; output growth rate.

JEL: B52; C62; D33; E12; E70; H26.

[1]Please address any correspondence to **l.barrostorres@surrey.ac.uk**

A preliminary version of this paper was presented at the 49th Eastern Economic Association Annual Meetings, New York City, February 2023. We are grateful to conference participants and to Gustavo Pereira Serra, Vinicius Curti Cícero and Rodrigo Toneto for useful comments. Any remaining errors are our own. This study was supported by CNPq (the Brazilian National Council of Scientific and Technological Development) [grant numbers 311811/2018-3 (GTL) and 313628/2021-1 (JJS)]. This study was also financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001.

1. Introduction

Government expenditures constitute an important component of aggregate demand formation and hence play a significant role in the determination of the level of macroeconomic activity. Yet the volume of tax revenues from different sources very often becomes a binding constraint to the expansion of government expenditures. Meanwhile, tax compliance by individuals and corporations is in and of itself a complex decision that has been shown to be conditioned by a host of objective, subjective and social factors (see, e.g., Torgler, 2007; Alm et al., 2010; Daude et al., 2013). The estimated level of tax evasion varies across countries, but it is typically non-negligible and sometimes relatively high. In the US, for example, the estimated levels and percentages of gross and net tax evasion represent a considerable loss of revenues for the federal government, as shown in Table 1 below.[1]

Table 1 around here.

This paper contributes to the literature on tax compliance and macroeconomic performance by setting forth a two-class aggregate demand-led model with the possibility of tax evasion by firm-owner capitalists. Output is produced by a large number of imperfectly competitive firms deliberately holding excess capacity in capital. Labor is in permanent excess supply, so that it is not a constraint on output expansion in face of an increase in aggregate demand up to full capacity utilization of the available capital stock. The model features firm-owner capitalists, wage-earner workers, and a balanced-budget government that relies on taxation on gross profit and wage income to finance its expenditures. Taxation on gross profit income, however, is subject to evasion, and the actual amount of government revenues (taxes paid by complying capitalists and fines paid by tax evading ones detected in the auditing process) is endogenously time-varying driven by imitation-augmented satisfic-

[1] In Table 1, the level of overall tax noncompliance is measured by the tax gap, with the word 'tax' including both taxes and refundable and nonrefundable tax credits. The amount of true tax liability that is not paid voluntarily and timely defines the gross tax gap. The voluntary compliance rate is the percentage of total true tax liabilities paid voluntarily and timely. The gross tax gap includes nonfiling (tax not paid on time by those who do not file required returns on time), underreporting (tax understated on timely filed returns), and underpayment (tax that was reported on time, but not paid on time). The net tax gap is the gross tax gap less tax that subsequently was paid, either voluntarily but late or collected through IRS administrative and enforcement activities. Thus, the net compliance rate is the percentage of total true tax liabilities paid voluntarily or not.

ing evolutionary dynamics in the spirit of the evolutionary contributions of Herbert Simon (1955; 1956) on bounded rationality. As a result, the macrodynamics of the level of economic activity, which is measured by the rates of capacity utilization and output growth, is coevolutionarily coupled to the microdynamics of tax compliance across firm-owner capitalists.

Firm-owner capitalists and wage-earner workers are taxed on their respective gross income, but at different tax rates. The tax rate on profit income is higher than the tax rate on wage income. Workers cannot evade taxation because there is employer source-withholding of taxes on wage income, and firm-owner capitalists comply in remitting withheld taxes on wage income to the government on the workers' behalf. The functional distribution of gross income between profits and wages is an exogenously given constant. Through taxation, however, the government becomes a further claimant on the gross income generated in the production process with the use of capital and labor. Therefore, the after-tax (or disposable) wage share in gross income is also an exogenously given constant. Nonetheless, due to the possibility of evasion of taxation on profit income, the after-tax (or disposable) profit share in gross income and hence the share of the actual (or disposable) government revenues in the form of taxes and fines in gross income are endogenously determined. In fact, as in a given short run each firm-owner capitalist can be in one of three positions (tax compliant, tax evader who is not caught, or tax evader who is caught and fined), the distribution of the gross profit share net of paid taxes and fines (or net profit share) across firm-owner capitalists is also endogenously determined.

Tax evasion, thus, can be seen as a weapon to which an individual firm-owner capitalist may be willing to resort to in the inherent distributional conflict over income in a capitalist economy. Yet there is no assurance that she will be successful in an attempt to increase her net profit income by evading taxation, as she may get caught and fined. As both the pre- and the after-tax wage share in income are exogenously given constant, the model features a distributional conflict between capitalists and the government over the gross profit share in income. Tax evading capitalists who are not caught raise their after-tax profit share relatively to both the tax complying and the tax evading capitalists who are caught at the expense of the actual government revenues. The dynamics of such distributional conflict between capitalists and the government and in some sense among capitalists themselves, as well as the resulting distributions of the pre- and the after-tax profit income that will ultimately persist over time (in other words, such distributions in the long-run equilibrium) are determined by the operation of a satisficing evolutionary protocol. Although the net profit income (and hence the resulting net profit share in income) associated with each tax compliance strategy an individual firm-owner capitalist can follow (complying, detected evading and non-detected evading) is an exogenously given constant, the frequency distribution of such strategies and hence the average net profit income across capitalists and the actual government revenues are endogenously time-varying.

In addition to incorporating pecuniary factors such as the tax rate on profit income and the expected punishment of tax evaders who are caught and fined, our novel analytical framework based on satisficing evolutionary dynamics is also well suited to incorporate a non-pecuniary factor affecting tax compliance for which empirical evidence has been found in the literature. This important factor is dubbed tax morale. In fact, the threat of detection and hence pecuniary punishment is a factor inhibiting tax evasion, and there is evidence showing that increased enforcement based on pecuniary punishment usually results in increased tax compliance levels (see, e.g., Chatzimichael et al., 2019). Yet empirically observed tax compliance levels measured in different ways and using different methodologies are very often higher than warranted by the level of such enforcement based on pecuniary costs and benefits. A possible reason for such a discrepancy is that although the threat of detection and punishment and hence the net benefit associated with tax compliance have pecuniary dimensions to them, tax compliance behavior is also subject to idiosyncratic non-pecuniary motivations and proclivities of individual taxpayers.

More broadly, an individual taxpayer may overestimate (or underestimate for that matter) the extent to which the existing structure of enforcement based on pecuniary costs and benefits to which she is subject poses a threat of detection and pecuniary punishment to her specifically. Ultimately, it is the threat of detection and pecuniary punishment in the eyes of the beholder who is contemplating the possibility of not complying with her legally due tax obligations that will influence her decision. Yet idiosyncratic non-pecuniary motivations and proclivities can also play a significant separate role in driving tax compliance, independently from the influence that subjective factors may have on the estimation or perception of the expected threat of detection and hence pecuniary punishment made by a taxpayer. In effect, there is considerable evidence that non-pecuniary motivations and proclivities that form a tax morale offer a plausible explanation for what has been dubbed a puzzle. The latter is not why there is so much tax evasion (or few tax compliance), but instead why there is less tax evasion (or more tax compliance) than could be expected solely on the basis of pecuniary factors (see, eg., Lubian and Zarri, 2011; Luttmer and Singhal, 2014). In light of this puzzle of tax compliance, our novel analytical framework based on satisficing evolutionary dynamics is well suited to also incorporate a non-pecuniary factor such as tax morale affecting tax compliance.

Unlike the standard analytical procedure used in the literature, we plausibly conceive of tax morale as being either compliance-leaning or noncompliance-leaning (or even compliance neutral). This novel understanding is predicted on the idea that an individual taxpayer may have mixed moral feelings with respect to complying or not complying with her due tax obligations. As a result, it is on balance that she will ultimately have either a compliance-leaning tax morale or a noncompliance-leaning one. Even though an individual taxpayer cannot question the lawfulness of a tax obligation levied on her by the government except when it violates the legal tax system, she may nevertheless consider her non-pecuniary motivations and proclivities towards noncompliance as morally warranted. Therefore, the tax morale held by an individual, in the sense proposed in this paper, has the potential of either reinforcing or weakening (and possibly more than offsetting) the set of pecuniary factors that also participate in the determination of her tax compliance decision. Besides, our satisficing evolutionary approach to tax compliance behavior interestingly allows differentiating a deepening (intensive margin) from a widening (extensive margin) of either type of overall tax morale (compliance-leaning or noncompliance-leaning) across taxpayers.

Our novel analytical framework based on an imitation-augmented satisficing behavior allows treating the microdynamics of the frequency distribution of tax compliance strategies in the population of firms and the macrodynamics of the level of economic activity as co-evolutionary phenomena. In keeping with considerable empirical evidence, heterogeneity in tax compliance behavior emerges as a persistent longer-run outcome owing to pecuniary and non-pecuniary factors, an example of the latter being tax morale.

Additionally to the relevant issue of what are potential driving factors behind tax compliance (or the lack thereof), the existing literature (which is almost completely dominated by orthodox approaches) has also been addressing theoretically and empirically the similarly relevant issue of the implications of tax evasion for the level of economic activity. In effect, it is clear the importance of tax revenues as a fundamental mechanism to sustainably finance government expenditures, which are a source of aggregate demand formation. However, the predictions that have been suggested by the existing theoretical literature and the evidence that has been provided by empirical studies are mostly mixed. To some extent due to the complex nature of the two-way dynamic interactions between tax evasion and the income-generation process, it is not surprising that opposite theoretical results have been derived and often ambiguous empirical evidence has been found for the issue of whether tax evasion impacts positively or negatively on different measures of the level of macroeconomic activity.

Theoretical modeling using a supply-led framework has found that the impact of tax evasion on the growth rate of output or per capita income can be either positive or negative depending on the transmission channels that are considered and the relative strength of the effects at play (see, e.g., Caballe and Panades, 1997; Lin and Yang, 2001; Chen, 2003; Célimène et al., 2016; Ivanyna et al., 2016; Varvarigos, 2017). In fact, theoretical modeling studies using a supply-led framework have also found similar mixed qualitative results for the impact of tax evasion on the level of output or per capita income (see, e.g., Célimène et al., 2016; Varvarigos, 2017; Bethencourt and Kunze, 2019, 2020). On the empirical front, Tsakumis et al. (2007), using data for 50 countries and different measures of tax evasion, found a negative relation between tax evasion and per capita income. The same negative relation between tax evasion and per capita income is found by Schneider et al. (2010) and Bethencourt and Kunze (2020). Meanwhile, Vasilopoulou and Thomakos (2017) use data from 23 OECD countries for the period 2005-2013 and found that higher incidence of tax evasion is associated to lower output growth, a result echoed by Stavjaňová and Vítek (2022), who use data from the 27 EU countries and the UK for the period 2003-2014.

This paper is also related to the literature that incorporates taxation and public expenditures in an aggregate demand-led modeling framework broadly defined, nice examples of which are Laramie and Mair (1996, 2000, 2003), Dutt (2010, 2013), Commendatore and Pinto (2011), Commendatore et al. (2011), and Tavani and Zamparelli (2016). Yet to the best of our knowledge, such modeling literature on aggregate demand-led capacity utilization and/or output growth has yet to explore the possibility and implications of tax evasion – and not simply as an occurrence exogenously determined. In effect, in accordance with the empirical evidence, heterogeneity in tax compliance behavior should be treated as endogenously time-varying and coupled to the macrodynamics of the level of economic activity.

The remainder of this paper is structured as follows. Section 2 introduces the model structure. Section 3 solves for the short-run equilibrium configuration, supposing that the frequency distribution of tax compliance strategies across firm-owner capitalists and a few other variables are given or predetermined. Section 4 explores the behavior of the economy towards the long run with a focus on the evolutionarily satisficing dynamics of the frequency distribution of tax compliance strategies across firm-owner capitalists. Section 5 offers closing remarks.

2. The macroeconomic setting

The model features a two-class closed market economy that produces a single good that can be used for consumption and investment purposes. The government holds a balanced budget by using all actual public revenues (which include taxes on wage and profit income, besides fines on tax evaders who are caught) to place a demand on the single good. Two homogeneous factors of production, capital and labor, are combined by a large number of imperfectly competitive firms in the production of the single good. These production inputs are combined through a fixed-coefficient technology common to all firms:

$$X = min\{K\nu, La\}, \tag{1}$$

where X is the output level, K is the stock of capital, ν is the full-capacity output to capital ratio, which is an exogenously fixed technological parameter, L is the employment level, and a is the output to labor ratio (or labor productivity), which remains constant over time. The technical coefficient ν is a parametric constant normalized to one, and we measure the rate of capital capacity utilization, u, by the output to capital ratio, X/K.

We only consider the situation in which aggregate demand is insufficient to yield full utilization of the existing capital capacity at the current price level on the part of the population of firms. Firms produce output (and therefore hire labor) according to aggregate demand. As we consider only the situation in which firms operate with excess productive capacity (in labor and capital), labor employment is determined by production:

$$L = \frac{X}{a}. \tag{2}$$

The model economy is composed of two social classes, firm-owner capitalists and wage-earner workers, who earn profits and wages, respectively. Each firm is owned by a single capitalist, and each capitalist owns a single firm. There is no capital mobility across firms, and the large number of existing firms, F, is an exogenously given constant with no entry and exit of firms. The functional division of *pre-tax* aggregate income (or gross income) is given by:

$$X = wL + R, \tag{3}$$

where w is the pre-tax wage rate (which remains constant over time) and wL is the pre-tax aggregate wage bill (or gross wage income), while R is the volume of pre-tax aggregate profit (or gross profit income). From (1)-(3), the pre-tax profit share in income or pre-tax unit profit (or gross profit share) is given by:

$$\pi = 1 - \frac{w}{a}, \tag{4}$$

which is an exogenously determined constant with $\pi \in (0, 1) \subset \mathbb{R}$, since $0 < w < a$ by assumption.

Although there may be inter-class gross income inequality, within each class there is perfect equality with respect to the distribution of the respective gross income. Through taxation, however, the government is a further claimant on the gross income generated in the production process with the use of capital and labor. The gross wage income of any worker is taxed at an exogenous and constant rate given by $\tau_w \in (0, 1) \subset \mathbb{R}$, while the profit income of any capitalist is taxed at an exogenous and constant rate given by $\tau_p \in (0, 1) \subset \mathbb{R}$. On average, a capitalist receives more gross income than a worker, so that the tax system is progressive, i.e., $\tau_p > \tau_w$. Therefore, while the after-tax profit income is given by $(1 - \tau_p)R$, the after-tax wage income is given by $(1 - \tau_w)wL$. Accordingly, while the after-tax or net profit share is given by $\pi^n = (1 - \tau_p)\pi$, the after-tax or net wage share is given by

$\sigma^n = (1 - \tau_w)\sigma$, where $\sigma = \frac{wL}{X}$ is the pre-tax or gross wage share.

Following Kalecki (1971), Kaldor (1955), Robinson (1956, 1962) and Pasinetti (1962), we assume that workers and capitalists behave differently with respect to consumption. Workers homogeneously consume all their net wage income, while capitalists homogeneously save an exogenously constant fraction, $s_p \in (0, 1) \subset \mathbb{R}$, of their net profit income. Thus, the sum of consumption expenditures and tax payments does not exceed gross income for both classes, as there is no borrowing (in the case of tax evading capitalists who are caught and penalized, the resulting fine does not exhaust their gross profit income, as described later).

The model is cast in real terms, as the general price level of the single good remains constant over time and therefore the rate of price inflation is equal to zero. Firms sell their demand-determined output production in an imperfectly competitive market for the single good. The price of the single good is set by all firms as a constant and homogeneous markup factor (one plus the markup) over their common nominal unit labor cost, which remains constant. There is no tax shifting by firms, that is, the tax burden does not have any impact on price formation. As all the components of the price of the single good are constant, the general price level and the (real) wage rate remain constant as well. Moreover, as the markups applied by firms are constant, the gross and net wage shares, σ and σ^n, as well as the gross and net profit shares, π and π^n, are also constant.

Meanwhile, the rate of employment is given by $\eta = L/N$, where N is the labor supply, which is given at a point in time that we define as the short run. The employment rate is linked to the state of the product market in the following way:

$$\eta = uk, \tag{5}$$

where k is the ratio of capital to labor force in productivity units, $k \equiv K/(Na)$. The stock of capital and the labor supply, and hence the ratio of capital to labor force in productivity units, are given at a point in time that we define as the short run. Therefore, the fixed-coefficient nature of the technology implies that an increase in output in the short run is necessarily accompanied by an increase in employment.

An individual firm-owner capitalist periodically chooses (and possibly switches) between two available and mutually exclusive strategies with respect to her legally due tax obligations on her profit income: she either complies (*tax complying strategy*) or does not comply (*tax evading strategy*). In a given period there is a proportion $\lambda \in [0, 1] \subset \mathbb{R}$ of tax evading (or type e) firms, while the remaining proportion, $1 - \lambda$, is composed by tax complying (or type c) firms. The frequency distribution of tax compliance strategies across firms, $(\lambda, 1 - \lambda)$, is given in the short run as resulting from previous dynamics, but it varies endogenously over time towards the long run according to an evolutionary dynamic to be specified down the road.

Thus, although the after-tax profit share given by $(1 - \tau_p)\pi$ remains constant, its composition is endogenously time-varying. Workers are unable to evade taxation because there is employer source-withholding of taxes on wage income, and firm-owner capitalists comply in remitting withheld taxes on wage income to the government on the workers' behalf.[2] Therefore, the wage payments that workers receive from firms is net of the respective taxation, and the wage taxes so withheld are not pocketed by evading firms and added to their net profit shares. On the other hand, firm-owner capitalists periodically decide whether or not to comply with their legally due tax obligations on profit income, given (among other reasons) that it is common knowledge that not all taxpayers are audited. Nonetheless, all noncompliant firms which are audited are certainly detected (including with respect to the amount of taxes evaded) and are unable to avoid (through corruption, for example) either being fined or, once fined, paying in full the ensuing fine for having evaded taxation on their profit income.[3]

Despite the risk of being audited and hence detected and fined, a strictly positive proportion of capitalists may decide to evade taxation on their profit income. The considered tax compliance choice is specified as an all-or-nothing choice: due taxes on profit income are either fully paid or fully evaded.[4] The probability with which a tax evading firm is detected

[2] In actual tax systems, the share of wage income periodically (e.g., monthly or in every paycheck) withheld from workers is typically a credit against the workers' (usually) annual income tax bill (which considers tax credits or deductions etc.) If too much wage income is withheld, workers receive a tax refund or may have to pay the government some further income later on if not enough is withheld. We assume that no such refund or further tax payment applies with respect to taxation on either wage or profit income.

[3] The model also excludes the possibility of tax amnesty, which is the opportunity granted to taxpayers of exceptionally writing off an existing tax liability (including interests and fines) by paying a smaller fraction of the total amount due. An informative overview of the several issues involved in tax amnesties is offered in Marchese (2020).

[4] See Alm et al. (2009), Bazart and Bonein (2014) and Bazart et al. (2016) for evidence from laboratory experiments on tax compliance that the frequency of measures of tax evasion at the individual level such as

and hence fined is given by $\varepsilon \in (0,1) \subset \mathbb{R}$, which is exogenously given. The detection of tax evading firms occurs in the course of costly tax audits periodically conducted by the government. The auditing of firms for tax purposes has a fixed cost that is a component of the flow of expenditures by the balanced-budget government and hence represents a further source of aggregate demand formation. Given that the amount of government expenditures depends on the actual public revenues (actual tax collection plus fines applied on tax evading firms that are detected and fined), however, we adopt the simplifying assumption that the considered fixed audit cost is sufficiently low to be always covered by the actual government revenues. When a tax evading capitalist is detected, she has to pay a fine given by an exogenously constant penalty rate, $\gamma \in (\tau_p, 1) \subset \mathbb{R}$, over her gross profit income, which is the profit income she ended up with after having evaded her legally due tax obligations. Note that we have assumed that $\gamma > \tau_p$, which ensures that a tax evading capitalist who is detected forfeits a larger portion of her gross profit income than she would have forfeited if she had complied with her due tax obligations. Moreover, we assume that $\gamma < 1$, which in turn ensures that the fine imposed on a tax evading capitalist who is detected does not exhaust her gross profit income. It follows that the expected (average) net profit share of tax evading capitalists and the average net profit share of tax complying capitalists are, respectively, given by:

$$\pi_e^n = \varepsilon(1-\gamma)\pi + (1-\varepsilon)\pi = (1-\varepsilon\gamma)\pi \qquad \text{and} \qquad \pi_c^n = (1-\tau_p)\pi, \tag{6}$$

so that the average net profit share across firm-owner capitalists, $\bar{\pi}^n \in (0,1) \subset \mathbb{R}$, is given by:

$$\bar{\pi}^n = \lambda\pi_e^n + (1-\lambda)\pi_c^n = \pi_c^n + (\pi_e^n - \pi_c^n)\,\lambda = (1-\tau_p)\pi + (\tau_p - \varepsilon\gamma)\pi\lambda \equiv \bar{\pi}^n(\lambda), \tag{7}$$

where $\frac{\partial \bar{\pi}^n(\lambda)}{\partial \lambda} = (\tau_p - \varepsilon\gamma)\pi$. Thus, the average net profit share is a strictly increasing, constant or strictly decreasing function with respect to the proportion of tax evading capitalists depending on whether the expected net pecuniary benefit (in units of gross profit share)

the ratio of tax paid to owed not infrequently peaks at zero and one.

associated with the tax evading strategy, given by $(\tau_p - \varepsilon\gamma)\pi$, is strictly positive, null, or strictly negative, respectively.

Tax evasion can then be seen as a weapon to which an individual firm-owner capitalist may be willing to resort to in the inherent distributional conflict over income in a capitalist economy. Yet there is no assurance that she will be successful in an attempt to increase her net profit income by evading taxation, as she may get caught and fined. In fact, the net profit share of a tax evader who is not caught is greater than the net profit share of a tax compliant capitalist, but the net profit share of a tax evader who is caught and fined is lower than the net profit share of a tax compliant capitalist (recall our assumption above that $\gamma > \tau_p$). Tax evaders who are not caught succeed in raising their actual net profit income (which then becomes equal to their gross profit income) at the expense of the actual government revenues. However, tax evaders who are caught and hence fined face a reduction in their actual net profit income (which then becomes lower than the net profit income of tax compliant capitalists) in benefit of the actual government revenues.[5] Of course, it follows that the very same decomposition applies to the gross profit share, $\pi = R/X$. Hence, it is not only the distribution of gross profit income between firm-owner capitalists and the government that is endogenous to the dynamics of the frequency distribution of tax compliance strategies across firm-owner capitalists, but also the distribution of net profit income among firm-owner capitalists themselves.

As properly explained shortly, all firms accumulate capital at the same rate, which implies that the aggregate capital stock, K, remains uniformly distributed across firms. It follows that:[6]

$$\frac{K_e}{\lambda} = \frac{K_c}{1-\lambda} = K, \tag{8}$$

where K_j is the total capital stock of firms of type $j = e, c$. It then follows from (8) that

[5]In effect, if we add together the net profit income of the subpopulation of tax evaders who are not caught, $\lambda(1-\varepsilon)R$, the net profit income of the same subpopulation who is caught and fined, $\lambda\varepsilon(1-\gamma)R$, the net profit income of the subpopulation of tax compliant capitalists, $(1-\lambda)(1-\tau_p)R$, and the actual taxes and fines on profit income accruing to the government, $[(1-\lambda)\tau_p + \lambda\varepsilon\gamma]R$, the total sum is equal to the gross profit income, R. In fact, we have that $[\lambda(1-\varepsilon) + \lambda\varepsilon(1-\gamma) + (1-\lambda)(1-\tau_p) + \lambda\varepsilon\gamma + (1-\lambda)\tau_p]R = R$

[6]The meaning of the implied assumption in (8) can be explained as follows. Recall that F is the (constant) total measure of firms in the economy and let F_e be the measure of tax evading firms. As the aggregate capital stock is uniformly distributed across firms, it follows that $\frac{K_e}{F_e} = \frac{K_c}{F-F_c} = \frac{K}{F}$. We obtain (8) by multiplying both sides of these equalities by F and using the definition $\lambda = \frac{F_e}{F}$.

the proportion of the aggregate capital stock that is uniformly available to the firms of each type is proportional to the share of each type in the population of firms, that is, $K_e/K = \lambda$ and $K_c/K = 1 - \lambda$.

As we assumed earlier that prices are equalized across firms, it is warranted to further assume that aggregate demand is uniformly distributed not only across firms following the same tax compliance strategy, but also across tax compliance strategies. Therefore, capacity utilization is also equalized across tax compliance strategies:

$$u_e = u_c = u = \frac{X}{K}, \tag{9}$$

where $u_j \equiv X_j/K_j$ is the measure of the rate of capital utilization of type $j = e, c$ firms.[7] Given that output production and labor productivity are equalized across firms, labor employment is equalized across firms as well.[8]

Based on the homogeneity in (9) and using the profit shares defined in (6), we can express the expected profit rates of tax evading and tax complying firms, respectively, as follows:

$$r_e^n = \pi_e^n u = (1 - \varepsilon\gamma)\pi u \qquad \text{and} \qquad r_c^n = \pi_c^n u = (1 - \tau_p)\pi u, \tag{10}$$

so that the average net profit rate across firm-owner capitalists, $\bar{r}^n$, is simply:

$$\bar{r}^n = \lambda r_e^n + (1 - \lambda) r_c^n = [\lambda \pi_e^n + (1 - \lambda)\pi_c^n]u = \bar{\pi}^n(\lambda)u \equiv \bar{r}^n(\lambda). \tag{11}$$

Note that the response of the average net profit rate to a change in the proportion of tax evading capitalists, given the rate of capacity utilization, is qualitatively the same as the respective response of the average net profit share in (7), that is, $\frac{\partial \bar{r}^n(\lambda)}{\partial \lambda} = \frac{\partial \bar{\pi}^n(\lambda)}{\partial \lambda} u = (\tau_p - \varepsilon\gamma)\pi u$.

Firms make decisions to accumulate capital independently from available savings. The

[7] Therefore, we are assuming that firms are also homogeneous as regards the exogenously constant ratio of capital to full capacity output.

[8] Thus, the same equalization applies to the ratio of capital to labor force in productivity units, $k = K/(Na)$ in (5).

desired rate of growth of the capital stock of firm i is described by:

$$g^d(i) = \frac{I(i)}{K(i)} = \alpha_1 u^{\mathrm{E}}(i) + \alpha_2 \pi^{n^E}(i), \tag{12}$$

where $g^d(i)$ is the desired investment $I(i)$ as a proportion of the capital stock $K(i)$ of the ith firm, $u^{\mathrm{E}}(i)$ is its expected capital capacity utilization, and $\pi^{n^E}(i)$ is its expected net profit share. Meanwhile, $\alpha_1 \in \mathbb{R}_{++}$ and $\alpha_2 \in \mathbb{R}_{++}$ are parametric constants. The specification in (12) is an expectations-augmented version of the capital accumulation function suggested by Bhaduri and Marglin (1990), from which it is known that the resulting output growth can vary positively or negatively with the (average) profit share depending on the relative strength of the several effects at play. We could assume that firms (even when following the same tax compliance strategy) have heterogeneous expectations with respect to their net profit share and rate of capital capacity utilization in the relevant future. Yet we postulate that, by virtue of facing an inescapably uncertain future, firms conventionally and uniformly proxy such expected levels by the respective current average levels. In this model, an individual firm may evade taxation in some period(s) of the relevant future and will or will not be detected and hence penalized. Therefore, as firms do not know in advance how they will behave in the relevant uncertain future as regards tax compliance, it is reasonable to assume that firms proxy their expected net profit share by the current average net profit share.

Facing an uncertain future, thus, the ith firm behaves adaptatively by proxying its expected capital capacity utilization by the current average capital capacity utilization, which is u in (9), and its expected net profit share by the current average net profit share, which is $\bar{\pi}^n$ in (7). Therefore, we can rewrite (12) and aggregate over all firms to get:

$$g^d = \alpha_1 u + \alpha_2 \bar{\pi}^n(\lambda) = \alpha_1 u + \alpha_2[1 - \tau_p + (\tau_p - \varepsilon\gamma)\lambda]\pi. \tag{13}$$

3. Short-run equilibrium

The short run is defined as the time period in which the stock of capital, K, the labor supply, N, and the frequency distribution of tax compliance strategies across firm-owner capitalists, $(\lambda, 1 - \lambda)$, can all be taken as given or predetermined. The supply-demand equilibrium in the market for the single good can be expressed as:

$$X = C + I + G, \tag{14}$$

where C stands for private consumption, I for private investment, and G for government expenditures. Therefore, the flow of government expenditures is a source of aggregate demand alongside private consumption and private investment on capital formation. As described in the preceding section, the detection of tax evading capitalists occurs in the course of costly tax audits periodically conducted by the government. Such an auditing activity has a fixed cost that is a component of the flow of expenditures of the government. However, as the government continuously runs a balanced budget, we further assume that the considered fixed audit cost is low enough to be always covered by the actual government revenues (note that the expected amount of such revenues is strictly positive even in the event that all capitalists follow the tax evading strategy, as the probability with which a tax evading capitalist is detected and fined is, by assumption, strictly positive).

As a balanced-budget government satisfies the condition represented by $T = G$, where T denotes the actual tax revenues (collected taxes plus fines paid by caught and penalized tax evaders), we have:

$$S = I, \tag{15}$$

where $S = X - T - C$ stands for private saving.

Normalizing (15) by the capital stock, we have:

$$\bar{g}^s = g^d, \tag{16}$$

where average private saving as a proportion of the capital stock is given by:

$$\bar{g}^s = \frac{s_p \bar{R}^n(\lambda)}{K} = s_p \bar{r}^n(\lambda) = \frac{s_p \bar{R}^n(\lambda)}{X} \frac{X}{K} = s_p \bar{\pi}^n(\lambda) u, \tag{17}$$

where $\bar{R}^n(\lambda) = \lambda(1 - \varepsilon\gamma)R + (1 - \lambda)(1 - \tau_p)R$ is the average net profit income, whereas the average net profit share, $\bar{\pi}^n$, is given by (7), and the average net profit rate, $\bar{r}^n$, is given by (11) (recall that firm-owner capitalists homogeneously save an exogenously constant fraction,

$s_p \in (0,1) \subset \mathbb{R}$, of their net profit income, whereas workers do not save). Considering that the government runs a balanced budget, the demand-led nature of the model implies that private saving is determined by private investment in capital accumulation.

Given that aggregate output is determined by aggregate demand, and labor is always in excess supply, the rate of capacity utilization adjusts to ensure that the product market short-run equilibrium in (14) is achieved. Substituting (12) and (17) into (16), we find that the short-run equilibrium capacity utilization at period t is thus given by:

$$u^* = \frac{\alpha_2 \bar{\pi}^n(\lambda)}{s_p \bar{\pi}^n(\lambda) - \alpha_1} \equiv u^*(\lambda; \vec{\mu}), \tag{18}$$

which is parameterized by the vector $\vec{\mu} = (\pi, \tau_p, \varepsilon, \gamma, s_p, \alpha_1, \alpha_2)$ containing exogenous and parametric determinants of the short-run equilibrium value of the rate of capacity utilization in (18), and where $\bar{\pi}^n$ is given by (7). In order to guarantee that such short-run equilibrium rate of capacity utilization is stable, we further assume that $(\partial \bar{g}^s / \partial u) > (\partial g^d / \partial u)$, which is equivalent to a strictly positive denominator in (18). The substance of this demand-led output-adjustment stability condition known as the Keynesian stability condition is that, all else constant, saving should be more responsive to changes in capacity utilization than investment. This guarantees that any excess demand or supply in the market for the single good is eliminated rather than exacerbated by changes in capacity utilization.

As usual in demand-led models, the paradox of thrift holds: a rise in the propensity to save of capitalists, s_p, by representing an aggregate demand leakage, lowers the level of economic activity as measured by the rate of capacity utilization in the short run. A change in any of the parameters of the investment function, α_1 and α_2, by changing investment in the same direction, changes capacity utilization in the same direction in the short run as well. Meanwhile, the short-run equilibrium value of capacity utilization in (18) varies negatively with the gross profit share, π.

As the government spends all the actual public revenues on placing a demand on the single good, a rise in the tax rate on profit income, τ_p, by lowering the average net profit share and hence raising the actual public revenues, raises the rate of capacity utilization in the short run. In fact, as the permanent running of a balanced budget by the government is equivalent to the government's propensity to spend out of the actual public revenues being equal to one, a rise in the tax rate on profit income represents a net aggregate demand injection in the short run. In this balanced-budget context, therefore, an increase in the tax rate on profit income is a mechanism of "forced dissaving" or "forced spending" at the level of the overall economy, given that the propensity to save of the government, which is zero, is lower than the propensity to save of capitalists, which is strictly positive. Therefore, the reason why the tax rate on wage income, τ_w, does not feature in the expression for the short-run equilibrium capacity utilization in (18) is that, as in the case of the government, the propensity to save of workers is equal to zero. Meanwhile, an increase in the probability of detection of a tax evading firm, ε, or in the penalty rate, γ, by raising the expected pecuniary punishment for evading taxation and hence lowering the average net profit share and augmenting the actual public revenues, raises capacity utilization in the short run.

As regards the impact of a change in the proportion of tax evading capitalists on the short-run equilibrium value of capacity utilization, it follows from (18) that:

$$\frac{\partial u^*(\lambda;\vec{\mu})}{\partial \lambda} = \frac{\partial u^*(\lambda;\vec{\mu})}{\partial \bar{\pi}^n} \frac{\partial \bar{\pi}^n(\lambda)}{\partial \lambda}, \tag{19}$$

the sign of which depends on the sign of $\partial\bar{\pi}^n/\partial\lambda = \tau_p - \varepsilon\gamma$, which is ambiguous (recall that we assumed earlier that $\gamma > \tau_p$ and $\varepsilon \in (0,1) \subset \mathbb{R}$). Considering that $\partial u^*/\partial\bar{\pi}^n = \frac{-\alpha_1\alpha_2}{[s_p\bar{\pi}^n(\lambda)-\alpha_1]^2} < 0$, it follows that $\partial u^*/\partial\lambda$ is also strictly negative (positive) if τ_p is strictly greater (lower) than $\varepsilon\gamma$, that is, if the pecuniary cost associated with complying with taxation is strictly greater (lower) than the expected pecuniary cost of tax evasion, which is represented by the expected pecuniary punishment for evading taxation. Per (5), all these qualitative comparative statics results for the rate of capacity utilization in the short-run equilibrium also apply to the employment rate.

It should be recalled, however, that the frequency distribution of tax compliance strategies is given in the short run but varying over time according to the satisficing evolutionary dynamic to be specified and explored in the next section, hence there may exist a polymorphic equilibrium represented by $\lambda^* \in (0,1) \subset \mathbb{R}$ that depends on parameters featuring in the expression for the short-run equilibrium capacity utilization in (18). In a long-run equilibrium configuration with $\lambda^* \in (0,1) \subset \mathbb{R}$, changes in a given parameter may impact on the rate of capacity utilization also mediated by changes in the value of such a polymorphic equilibrium.

We can compute the output growth rate in the short-run equilibrium by substituting u^* in (18) into $\bar{g}^s$ in (17), with which we get:

$$g^* = s_p\bar{\pi}^n(\lambda)u^*(\lambda;\vec{\mu}) = \frac{s_p\alpha_2[\bar{\pi}^n(\lambda)]^2}{s_p\bar{\pi}^n(\lambda) - \alpha_1} \equiv g^*(\lambda;\vec{\mu}). \tag{20}$$

Therefore, except for the components of the average net profit share, using the expression above we get for $g^*(\lambda;\vec{\mu})$ the same qualitative comparative statics results that we got for u^*: an increase in the propensity to save of capitalists or a decrease in any of the parameters of the investment function, α_1 and α_2, reduce the level of economic activity as measured by the output growth rate in the short run. Meanwhile, since $\partial u^*/\partial\bar{\pi}^n < 0$, the impact of a change in the average net profit share on the short-run equilibrium value of the output growth rate is ambiguous:

$$\frac{\partial g^*(\lambda;\vec{\mu})}{\partial\bar{\pi}^n} = s_p\left[u^*(\lambda;\vec{\mu}) + \bar{\pi}^n(\lambda)\frac{\partial u^*(\lambda;\vec{\mu})}{\partial\bar{\pi}^n}\right] = \frac{s_p\alpha_2\bar{\pi}^n(\lambda)[s_p\bar{\pi}^n(\lambda) - 2\alpha_1]}{[s_p\bar{\pi}^n(\lambda) - \alpha_1]^2}. \tag{21}$$

4. Long-run equilibrium

In the transition to the long run our earlier assumptions with respect to stability ensure that the short-run equilibrium values of the rates of capital capacity utilization, employment and output growth are always attained. The economy then moves towards the long run driven by changes in the stock of capital, K, the labor supply, N, and the frequency distribution of tax compliance strategies in the population of firm-owner capitalists, $(\lambda,\, 1-\lambda)$. In order to sharpen our focus on the evolutionarily coupled dynamics of the frequency distribution of tax compliance strategies in the population of firm-owner capitalists and the level of macroeconomic activity, we assume that the supply of labor grows endogenously at the same rate as the capital stock.[9]

In addition to incorporating pecuniary factors such as the tax rate on profit income and the expected punishment of tax evaders who are caught and fined, our novel analytical framework based on satisficing evolutionary dynamics is also well suited to incorporate a

[9]In the long-run equilibrium, therefore, the constancy of the frequency distribution of tax compliance strategies guarantees the constancy of the average net profit share and thereby of the rates of capital capacity utilization, employment and output growth.

non-pecuniary factor affecting tax compliance for which there is considerable empirical evidence: tax morale. This analytical framework also allows treating the microdynamics of the frequency distribution of tax compliance strategies in the population of firms and the macrodynamics of the level of macroeconomic activity as co-evolutionary phenomena affected by tax morale.

In effect, the presence and importance of tax morale as another determining factor of tax compliance behavior has been largely documented in a variety of studies (see, e.g., Cummings et al., 2009; Lubian and Zarri, 2011; Luttmer and Singhal, 2014; Pickhardt and Prinz, 2014; Alm, 2019; Kemme et al., 2020). More broadly, there is considerable evidence that the decision by an individual regarding to comply or not to comply with her legally due tax obligations goes well beyond a simple amoral cost-benefit calculation predicated exclusively on narrowly defined pecuniary motives and considerations. Tax morale is in some sense a portmanteau term covering a wide array of motivations and proclivities affecting tax compliance which are unrelated to a strict cost-benefit pecuniary reasoning and are rather typically idiosyncratically subjective and/or socially determined.

In the satisficing evolutionary dynamics specified in what follows, tax morale broadly denotes idiosyncratic intrinsic motivations or proclivities either to comply or not to comply with legally due tax obligations. As such motivations and proclivities with respect to tax compliance are idiosyncratic, and therefore heterogeneous across capitalists, it is plausible to assume that they are randomly and independently determined across capitalists and over time. In principle, an individual capitalist may ambivalently hold both compliance-leaning motivations and proclivities as well as noncompliance-leaning ones. We plausibly and more inclusively consider that an individual capitalist may have mixed moral feelings with respect to complying or not complying with her legally due tax obligations. Therefore, it is on balance that she will ultimately have either a compliance-leaning tax morale or a noncompliance-leaning one. Although an individual capitalist cannot question the lawfulness of a tax obligation levied on her by the government except when it violates the legal tax system, she may nevertheless consider her non-pecuniary motivations and proclivities towards noncompliance as morally warranted. Our approach to tax compliance behavior allows treating capitalist taxpayers as heterogeneous along two dimensions regarding tax morale, which are whether an individual taxpayer has a compliance-leaning tax morale or a noncompliance-leaning one on balance, and how much compliance-leaning or noncompliance-leaning such net tax morale of an individual capitalist taxpayer is. There may exist firm-owner capitalists for whom the compliance-leaning motivations and proclivities and the noncompliance-leaning ones offset each other, so that they have what we dub a compliance neutral tax morale. For these capitalists, as a result, what matters for the decision whether or not to comply is solely the expected net pecuniary benefit associated with the tax evading strategy.

In fact, our approach interestingly allows differentiating a deepening (intensive margin) from a widening (extensive margin) of either type of overall tax morale (compliance-leaning or noncompliance-leaning) across capitalists. Suppose that the overall tax morale across capitalists is compliance-leaning. Given the proportion of each type of tax morale (compliance-leaning or noncompliance-leaning) in the population of capitalist taxpayers, an increase in the average degree of compliance-leaningness in this population thus raises the overall compliance-leaning tax morale along the intensive margin. Now consider that the overall tax morale in the same population is noncompliance-leaning. Given the net tax morale of each capitalist taxpayer, a rise in the frequency of capitalist taxpayers for whom the net tax morale is noncompliance-leaning raises the overall noncompliance-leaning tax morale along the extensive margin.

Thus, a key implication of the satisficing evolutionary approach to tax compliance specified shortly is that two capitalist taxpayers facing the same pecuniary benefits and costs associated with each tax compliance strategy may well choose to adopt different strategies. A capitalist whose net tax morale leans towards compliance may behave in a noncompliant manner if the expected net pecuniary benefit associated with the tax evading strategy is strictly positive and sufficiently high. Conversely, a capitalist whose net tax morale leans towards noncompliance (due, for example, to her conceiving of the tax system as unfair) may behave compliantly if the expected net pecuniary benefit associated with the tax evading strategy is strictly negative and high enough in absolute value.

Let us now describe the evolutionary dynamics that yields the law of motion of the frequency distribution of tax compliance strategies across firm-owner capitalists. Drawing on Vega-Redondo (1996, p. 91), we suppose that satisficing choice behavior in the spirit of

Simon (1955, 1956) is a trigger that transforms a given firm into a potential strategy reviser.[10] In a given point in time, a capitalist i takes the expected net pecuniary benefit associated with the tax evading strategy, as measured by the net profit rate differential represented by $r_e^n - r_c^n$, which can be strictly positive, strictly negative or equal to zero, and compares it to the satisficing minimum value $\rho_i \in \mathbb{R}$ above which she would consider as tempting on pecuniary grounds the possibility of not complying with the due tax obligations on her gross profit income. If the expected net pecuniary benefit associated with the tax evading strategy is smaller than or equal to the considered satisficing minimum value, capitalist i disconsiders the possibility of not complying with her tax obligations. Otherwise, capitalist i becomes a potential tax evader. Such temptation-triggering satisficing minimum value of the expected net pecuniary benefit associated with the tax evading strategy reflects the tax morale of the capitalist who holds it. Such tax morale depends, inter alia, on idiosyncratic characteristics of the considered capitalist. We assume that these satisficing minimum values are randomly and independently determined across capitalists and over time. We further assume that these satisficing minimum values are randomly distributed across the population of capitalists according to a cumulative distribution function $F : \mathbb{R} \to [0, 1] \subset \mathbb{R}$ which is continuously differentiable and strictly increasing.

Consequently, the probability of randomly finding a capitalist i that considers the expected net pecuniary benefit associated with the tax evading strategy as temptation-triggering is given by $Pr(r_e^n - r_c^n > \rho_i) = F(r_e^n - r_c^n)$. As a result, the mass of tax complying capitalists who become strategy reviser (in this case, potential tax evaders) is then given by $(1 - \lambda)F(r_e^n - r_c^n)$. Let us assume that each reviser actually switches to the other tax compliance strategy with probability given by the fraction of capitalists who have previously adopted the alternative strategy. This is an imitation effect, which can be associated with the idea of conventional behavior in the present context of decision making under uncertainty.

[10]For Simon, reality is complicated relative to the information collecting and processing and decision-making capacities of the individual. Deprived of the ability to optimize based on perfect knowledge, individuals must instead "muddle through" employing boundedly rational heuristics, rules-of-thumb, conventions, routines and other satisficing criteria and procedures as the bases for their decision making. Thus, choice is a process of meeting an acceptability or suitability threshold instead of choosing the best of all existing alternatives. See Caplin et al. (2011) and Hey et al. (2017) for experimental evidence on satisficing choice behavior as defined by Simon (1955), and Artinger et al. (2022) for a recent survey of advances in satisficing behavior in economics, psychology, and management following the pioneering contributions in Simon (1955).

Under this premise, the inflow to the population of tax evaders is given by:

$$(1-\lambda)F(r_e^n - r_c^n)\lambda. \tag{22}$$

Analogously, the probability of randomly finding a capitalist i for whom the expected net pecuniary benefit associated with the tax evading strategy does not trigger the temptation to evade taxation on her profit income is represented by $1 - F(r_e^n - r_c^n)$. Therefore, the mass of tax evaders who become strategy reviser (in this case, potential tax compliant capitalists) is then given by $\lambda[1 - F(r_e^n - r_c^n)]$. Considering again the imitation effect described above, now according to which potentially tax complying capitalists actually switch to the tax compliance strategy with probability given by the fraction of capitalists who have previously adopted the compliant strategy, the outflow from the population of tax evaders is given by:

$$\lambda[1 - F(r_e^n - r_c^n)](1-\lambda). \tag{23}$$

Combining the migration flows specified in (22) and (23), we get the following imitation-augmented satisficing evolutionary dynamic:

$$\dot{\lambda} = (1-\lambda)F(r_e^n - r_c^n)\lambda - \lambda[1 - F(r_e^n - r_c^n)](1-\lambda), \tag{24}$$

the space state of which is the unit interval $[0,1] \subset \mathbb{R}$. This dynamic can be simplified using the expressions for the profit rates corresponding to the each tax compliance strategy in (10) as follows:

$$\dot{\lambda} = \lambda(1-\lambda)\big[2F\big((\tau_p - \varepsilon\gamma)\pi u^*(\lambda;\vec{\mu})\big) - 1\big]. \tag{24a}$$

Two properties of the imitation-augmented satisficing evolutionary dynamic in (24a) are worth highlighting. The first concerns the monotonicity of the rate of change of the proportion of tax evaders, $\dot{\lambda}$, with respect to the expected net pecuniary benefit per unit of gross profit rate associated with the tax evading strategy, $\tau_p - \varepsilon\gamma$, when there is heterogeneity in tax compliance strategy, i.e., $\lambda \in (0,1) \subset \mathbb{R}$. Intuitively, any increase in such expected net pecuniary benefit provokes an increase in the rate of change of the proportion of tax evaders for any level of coexistence of the two available tax compliance strategies, given that

$\partial\dot{\lambda}/\partial(\tau_p - \varepsilon\gamma) = 2\lambda(1-\lambda)F'\big((\tau_p - \varepsilon\gamma)\pi u^*(\lambda;\vec{\mu})\big)\pi u^*(\lambda;\vec{\mu}) > 0$ for all $\lambda \in (0,1) \subset \mathbb{R}$.

The second property of the imitation-augmented satisficing evolutionary dynamic in (24a) that is worth stressing regards the tax morale of the population of firm-owner capitalists, as measured by the median of the distribution F. Let m be the median of the distribution F, so that, by definition, $F(m) = 1/2$. When $m < 0$, more than half of the population of firm-owner capitalists would consider evading taxation (that is, would become potential tax evaders) even if the expected net pecuniary benefit of the tax evading strategy, given by the net profit rate differential, $r_e^n - r_c^n = (\tau_p - \varepsilon\gamma)\pi u^*$, were strictly negative, provided it were not too negative, that is, $m < (\tau_p - \varepsilon\gamma)\pi u^* < 0$. Therefore, an economy whose tax morale in the population of firm-owner capitalists is described by a unimodal distribution F with $m < 0$ is an economy in which the capitalist class has a *noncompliance-leaning tax morale*. This means that there is a predominance of capitalists who become potential tax evaders not only when the expected net pecuniary benefit represented by $\tau_p - \varepsilon\gamma$ (which can be alternatively expressed per unit of either gross profit or gross profit share or gross profit rate) is strictly positive, but also when such expected benefit is moderately negative. Meanwhile, when $m > 0$, more than half of the population of firm-owner capitalists would not consider evading taxation (that is, would not become potential tax evaders) even if the expected net pecuniary benefit of the tax evading strategy, given by the net profit rate differential $r_e^n - r_c^n = (\tau_p - \varepsilon\gamma)\pi u^*$, were strictly positive, provided it were not too positive, that is, $0 < (\tau_p - \varepsilon\gamma)\pi u^* < m$. Thus, an economy whose tax morale in the population of firm-owner capitalists is characterized by a unimodal distribution F with $m > 0$ is an economy in which the capitalist class has a *compliance-leaning tax morale*. This means that there is a predominance of capitalists who do not become potential tax evaders not only when the expected net pecuniary benefit represented by $\tau_p - \varepsilon\gamma$ is strictly negative, but also when such expected benefit is moderately positive.

The imitation-augmented satisficing evolutionary dynamic in (24a) has two monomorphic equilibria featuring survival of a single tax compliance strategy in each, and, under certain plausible conditions, one polymorphic equilibrium featuring the two tax compliance strategies as survivors. These results regarding the existence of evolutionary equilibria can be formally established as follows.

Proposition 1 (Existence of evolutionary equilibria). *For a given vector of parameters* $\vec{\mu} = (\pi, \tau_p, \varepsilon, \gamma, s_p, \alpha_1, \alpha_2)$*, the imitation-augmented satisficing evolutionary dynamics in* (24a) *has:*

(i) Two monomorphic equilibria, given by $\lambda = 0$ *and* $\lambda = 1$*;*

(ii) A unique polymorphic equilibrium $\lambda^* = \frac{\bar{\pi}^{n^*} - \pi_c^n}{\pi_e^n - \pi_c^n} \in (0,1) \subset \mathbb{R}$*, where* $\bar{\pi}^{n^*} = \frac{\alpha_1 m}{s_p m - \alpha_2(\tau_p - \varepsilon\gamma)\pi}$*, if* $\pi_e^n - \pi_c^n = (\tau_p - \varepsilon\gamma)\pi \neq 0$ *and, additionally, the following condition holds:*

$$\min\{\pi_e^n, \pi_c^n\} < \bar{\pi}^{n^*} < \max\{\pi_e^n, \pi_c^n\}, \tag{25}$$

which can be written in terms of the median of the distribution of tax morale in the population of firm-owner capitalists as:

$$\begin{cases} \frac{\alpha_2 \pi_c^n(\pi_e^n - \pi_c^n)}{s_p \pi_c^n - \alpha_1} \equiv m_c < m < m_e \equiv \frac{\alpha_2 \pi_e^n(\pi_e^n - \pi_c^n)}{s_p \pi_e^n - \alpha_1} < 0, & \textit{for } \pi_e^n - \pi_c^n = (\tau_p - \varepsilon\gamma)\pi < 0, \\ 0 < m_e < m < m_c, & \textit{for } \pi_e^n - \pi_c^n = (\tau_p - \varepsilon\gamma)\pi > 0; \textit{ and} \end{cases} \tag{26}$$

(iii) A continuum of polymorphic equilibria, given by the set $(0,1) \subset \mathbb{R}$*, if* $\pi_e^n - \pi_c^n = (\tau_p - \varepsilon\gamma)\pi = 0$ *and* $m = 0$*.*

Proof: See Appendix A. □

Based on the properties of the average net profit share function in (7), we have three possible situations in which a polymorphic equilibrium given by $\lambda^* \in (0,1) \subset \mathbb{R}$ can arise, as established formally in (25)-(26) and illustratively depicted in Figure 1 below. The first situation arises when the population of firm-owner capitalists has a *noncompliance-leaning tax morale* ($m < 0$) and the expected net pecuniary benefit per unit of gross profit share associated with tax evasion is moderately negative. In this situation, firm-owner capitalists whose subjective motivations and proclivities are noncompliance-leaning on balance, and actually strong enough to more than offset the expected net pecuniary loss associated with adopting the tax evading strategy, will ultimately follow such a tax compliance strategy. The second situation occurs when the population of firm-owner capitalists has a *compliance-leaning tax morale* ($m > 0$) and the expected net pecuniary benefit per unit of gross profit share associated with tax evasion is moderately positive. In this situation, firm-owner capitalists whose subjective motivations and proclivities are either noncompliance-leaning on balance or even compliance-leaning on balance, but in the latter case not strong enough to more than offset the expected net pecuniary gain of adopting the tax evading strategy, will ultimately follow such a tax compliance strategy. Finally, there is a continuum of polymorphic equilibria given by the set $(0, 1) \subset \mathbb{R}$ when the population of firm-owner capitalists has a *compliance neutral* tax morale ($m = 0$) and the expected net pecuniary benefit per unit of gross profit share accruing to tax evasion is null.

Figure 1 here.

A natural question that arises regards whether the dynamic described in (24a) can take the economy to the long-run equilibrium configuration featuring the coexistence of both tax compliance strategies, that is, whether heterogeneity in tax compliance (and hence partial tax evasion) emerges as a persistent outcome.

In order to illustrate the convergence to the polymorphic long-run equilibrium, consider the situation with the population of firm-owner capitalists having a *compliance-leaning tax morale* ($m > 0$) and the expected net pecuniary benefit represented by $\tau_p - \varepsilon\gamma$ being moderately positive. Assume that only firm-owner capitalists whose tax morale is noncompliance-leaning on balance adopt the tax evading strategy, that is, $\lambda \in (0, \lambda^*)$. Considering that F is continuously differentiable and strictly increasing, there is at least one firm-owner capitalist whose tax morale is compliance-leaning on balance, but for whom the current expected net pecuniary benefit accruing to the tax evading strategy is above her minimum satisficing value. Such firm-owner capitalist thus becomes a potential tax evader who will adopt the tax evading strategy with probability equal to the current strictly positive frequency of tax evaders. Assume now that not only firm-owner capitalists whose tax morale is noncompliance-leaning on balance, but also those whose tax morale is strongly compliance-leaning on balance adopt the tax evading strategy, that is, $\lambda \in (\lambda^*, 1)$. There is then at least one firm-owner capitalist whose tax morale is compliance-leaning on balance and strong enough to more than offset the expected net pecuniary gain of adopting such strategy. Such firm-owner capitalist thus becomes a potential tax compliant who will adopt the tax complying strategy with probability equal to the current strictly positive (albeit low) frequency of tax compliant firm-owner capitalists. It follows that the imitation-augmented satisficing protocol in (24a) ensures that the polymorphic long-run equilibrium given by $\lambda^* \in (0, 1) \subset \mathbb{R}$ is asymptotically stable. It should be noted that in a polymorphic evolutionary equilibrium there might be firm-owner capitalists who switch strategies, although the outflow from the subpopulation of tax evaders and that from the subpopulation of tax compliant capitalists offset each other. Therefore, the absence of macrodynamics might mask a ceaseless microdynamics of tax compliance strategy switching.

The stability properties of the evolutionary equilibria formally identified in Proposition 1 are established in the following proposition.

Proposition 2 (Stability properties of evolutionary equilibria). *For a given vector of parameters $\vec{\mu} = (\pi, \tau_p, \varepsilon, \gamma, s_p, \alpha_1, \alpha_2)$, the equilibria of the imitation-augmented satisficing evolutionary dynamic in (24a) exhibits the following dynamic properties:*

(i) Case $\pi_e^n - \pi_c^n = (\tau_p - \varepsilon\gamma)\pi < 0$: in this case $m_c < m_e < 0$.

- *(a) Subcase $m \leq m_c$: there are only monomorphic equilibria, with $\lambda = 0$ ($\lambda = 1$) being unstable (asymptotically stable) for any initial $\lambda \in (0, 1) \subset \mathbb{R}$.*
- *(b) Subcase $m_c < m < m_e$: the two monomorphic equilibria are unstable and the polymorphic equilibrium is asymptotically stable for any initial $\lambda \in (0, 1) \subset \mathbb{R}$.*
- *(c) Subcase $m \geq m_e$: there are only monomorphic equilibria, with $\lambda = 0$ ($\lambda = 1$) being asymptotically stable (unstable) for any initial $\lambda \in (0, 1) \subset \mathbb{R}$.*

(ii) Case $\pi_e^n - \pi_c^n = (\tau_p - \varepsilon\gamma)\pi > 0$: in this case $0 < m_e < m_c$.

- *(a) Subcase $m \leq m_e$: there are only monomorphic equilibria, with $\lambda = 0$ ($\lambda = 1$) being unstable (asymptotically stable) for any initial $\lambda \in (0, 1) \subset \mathbb{R}$.*
- *(b) Subcase $m_e < m < m_c$: the two monomorphic equilibria are unstable and the polymorphic equilibrium is asymptotically stable for any initial $\lambda \in (0, 1) \subset \mathbb{R}$.*
- *(c) Subcase $m \geq m_c$: there are only monomorphic equilibria, with $\lambda = 0$ ($\lambda = 1$) being asymptotically stable (unstable) for any initial $\lambda \in (0, 1) \subset \mathbb{R}$.*

(iii) Case $\pi_e^n - \pi_c^n = (\tau_p - \varepsilon\gamma)\pi = 0$: in this case $m_c = m_e = 0$.

- *(a) Subcase $m < 0$: there are only monomorphic equilibria, with $\lambda = 0$ ($\lambda = 1$) being unstable (asymptotically stable) for any initial $\lambda \in (0, 1) \subset \mathbb{R}$.*
- *(b) Subcase $m = 0$: any $\lambda \in [0, 1] \subset \mathbb{R}$ is a neutrally (Lyapunov) stable equilibrium.*
- *(c) Subcase $m > 0$: there are only monomorphic equilibria, with $\lambda = 0$ ($\lambda = 1$) being asymptotically stable (unstable) for any initial $\lambda \in (0, 1) \subset \mathbb{R}$.*

Proof: See Appendix B. □

Proposition 2 above clarifies the behavior of tax evasion in the economy when the polymorphic long-run equilibrium does not exist. When the median tax morale in the population of firm-owner capitalists is strong enough such that the monomorphic equilibrium $\lambda = 0$ is asymptotically stable, there may well exist firm-owner capitalists who are potential tax evaders, but the absence of actual tax evaders does not allow a behavior imitation process to happen: the satisficing trigger is left longing for the imitation gunshot. Conversely, when the median tax morale in the population of firm-owner capitalists is low enough such that the monomorphic equilibrium $\lambda = 1$ is asymptotically stable, there might exist firm-owner capitalists who are tempted to adopt the tax complying strategy yet the pervasiveness of tax evasion does not allow them to find a compliant role model. Figure 2 illustrates the long-run behavior of tax evasion according to the cases described in Proposition 2.

Figure 2 around here.

We can then derive several comparative statics results for the polymorphic equilibrium that are in accordance with the empirical evidence. Applying the implicit function theorem to the long-run equilibrium condition in (A.2), we obtain the following comparative statics results regarding the parameters of the tax system:

$$\frac{\partial \lambda^*}{\partial \tau_p} = \frac{-\pi \left[u^*(\lambda^*; \vec{\mu}) - (1-\lambda^*)(\tau_p - \varepsilon\gamma)\pi \frac{\partial u^*(\lambda;\vec{\mu})}{\partial \bar{\pi}^n} \right]}{\left[(\tau_p - \varepsilon\gamma)\pi\right]^2 \frac{\partial u^*(\lambda;\vec{\mu})}{\partial \bar{\pi}^n}}; \qquad \text{and} \tag{27}$$

$$\frac{\partial \lambda^*}{\partial (\varepsilon\gamma)} = \frac{\pi \left[u^*(\lambda^*; \vec{\mu}) + \lambda^*(\tau_p - \varepsilon\gamma)\pi \frac{\partial u^*(\lambda;\vec{\mu})}{\partial \bar{\pi}^n} \right]}{\left[(\tau_p - \varepsilon\gamma)\pi\right]^2 \frac{\partial u^*(\lambda;\vec{\mu})}{\partial \bar{\pi}^n}}. \tag{28}$$

The common denominator in (27) and (28) is strictly negative. Therefore, we have:

$$\frac{\partial \lambda^*}{\partial \tau_p} \gtrless 0 \iff \tau_p - \varepsilon\gamma \gtrless \frac{u^*(\lambda^*; \vec{\mu})}{(1-\lambda^*)\pi \frac{\partial u^*(\lambda;\vec{\mu})}{\partial \bar{\pi}^n}} \in \mathbb{R}_- \quad \text{and } \tau_p - \varepsilon\gamma \neq 0; \qquad \text{and} \tag{29}$$

$$\frac{\partial \lambda^*}{\partial (\varepsilon\gamma)} \gtrless 0 \iff \tau_p - \varepsilon\gamma \lessgtr \frac{u^*(\lambda^*; \vec{\mu})}{-\lambda^*\pi \frac{\partial u^*(\lambda;\vec{\mu})}{\partial \bar{\pi}^n}} \in \mathbb{R}_+ \qquad \text{and } \tau_p - \varepsilon\gamma \neq 0. \tag{30}$$

Per (29), therefore, an increase in the tax rate on profit income, by increasing the expected net pecuniary benefit of the tax evading strategy, which is given by $\tau_p - \varepsilon\gamma$, results in a higher proportion of tax evading capitalists only if such benefit is strictly positive or moderately strictly negative. Meanwhile, per (30), an increase in the expected punishment, by decreasing the expected net pecuniary benefit of the tax evading strategy, results in a lower proportion of tax evading capitalists only if such benefit is strictly negative or moderately strictly positive.

As expected, a higher median tax morale reduces the proportion of tax evading capitalists in the long run, since from (18) we have:

$$\frac{\partial \lambda^*}{\partial m} = \frac{1}{\left[(\tau_p - \varepsilon\gamma)\pi\right]^2 \frac{\partial u^*(\lambda;\vec{\mu})}{\partial \bar{\pi}^n}} < 0. \tag{31}$$

The comparative statics results presented above are supported by numerical simulations with empirically plausible parameters, as shown in Figures 3, 4 and 5 below. We proxy the tax rate on profit income with the average income tax rate in the US in 2022, $\tau_p = 0.25$, and the penalty rate for tax evasion with the statutory penalty for substantial understatement of income tax according to the US Internal Revenue Service (IRS), $\gamma = 0.2$. We consider that the probability of detection is $\varepsilon = 0.05$. Therefore, we explore a plausible situation in which the net pecuniary benefit per unit of profit share associated with the tax evading strategy is moderately strictly positive, $(\tau_p - \varepsilon\gamma)\pi > 0$. Capitalists' propensity to save is assumed to be $s_p = 0.25$ and the gross profit share in income, $\pi = 0.36$. The parameters of the investment function, α_1 and α_2, are set in order to match the monomorphic equilibrium $\lambda = 0$ with the economy operating at a rate of capacity utilization equal to $u^* = 0.83$, namely $\alpha_1 = 0.056$ and $\alpha_2 = 0.036$. Finally, calibrating the median tax morale parameter is actually a difficult task, given the scarcity of available estimates and the potentially diverse units of measurement. We cautiously set it to $m = 0.06$, a value close to its upper bound in condition (26).

Figures 3, 4 and 5 around here.

Under the calibration detailed above, the equilibrium frequency of tax evaders in the population of firm-owner capitalists is 12.8%, which is not too far from the estimated net tax evasion of 9.5% of corporate income tax and a close match to the estimated net tax evasion of 12.9% of total true tax liabilities in the US for the period 2014-2016, as observed in Table 1. The following results are also in accordance with the empirical evidence, at least qualitatively. Accounting for persistent heterogeneity in tax compliance strategies reduces capital capacity utilization to 70% and the output growth rate to 4.9%. As expected, Figure 3 depicts a positive relation between the tax rate on profit income and the frequency of tax evaders. Given that not all tax evaders are detected and fined, an increase in the tax rate on profit income increases the average net profit share, but decreases capital capacity utilization, as discussed in Section 3, and also the output growth rate. Meanwhile, Figures 4 and 5 describe a negative relation between the frequency of tax evaders and the probability of detection of a tax evading capitalist and the penalty rate, respectively. Owing to the combined effect of the lower frequency of tax evaders and the higher proportion of tax evaders who are detected and fined, an increase in the probability of detection lowers the average net profit share and raises the capital capacity utilization and the output growth rate. The response of such variables to an increase in the penalty rate is qualitatively similar: an increase in the penalty rate, due to the combined effect of the lower frequency of tax evaders and the higher amount of fines paid by those who are detected, lowers the average net profit share and raises the capital capacity utilization and the output growth rate.

5. Concluding remarks

This paper contributes to the literature on tax compliance and endogenous macroeconomic dynamics by developing a demand-led model featuring a balanced-budget government. Through taxation on wage and profit income the government is a further claimant on gross income, while through expenditures it contributes to aggregate demand formation. Workers cannot evade taxation owing to the existence of employer source-withholding of taxes on wage income. Firm-owner capitalists comply in remitting withheld taxes on wage income to the government on the workers' behalf, but they can try to avoid complying with their own legally due tax obligations.

Thus, tax evasion can be properly seen as a weapon to which an individual firm-owner capitalist may be willing to resort to in the inherent distributional conflict over income in a market economy. However, there is no assurance that she will be successful in an attempt to increase her net profit income by evading taxation, as she may get detected and hence inescapably fined. As both the pre- and the after-tax wage share in income are exogenously given constants, the model ultimately features a distributional conflict between capitalists and the government over the gross profit share in income.

The frequency distribution of tax evaders in the population of firm-owner capitalists is endogenously time-varying driven by imitation-augmented satisficing evolutionary dynamics. These tax compliance dynamics are driven by pecuniary factors (the tax rate and the expected punishment of tax evaders who are detected and fined, given by the probability of detection multiplied by the penalty rate) and an empirically evidenced non-pecuniary factor dubbed tax morale. As a result, the microdiversity of tax compliance behavior across firm-owner capitalists and the macrodynamics of economic activity are co-evolutionarily coupled.

In keeping with the empirical evidence, there is a long-run configuration featuring heterogeneity in tax compliance behavior as stable equilibrium, yet the higher the median tax morale of firm-owner capitalists, the lower the frequency of tax evaders across them. In such a polymorphic long-run equilibrium, a (marginal) rise in the tax rate on profit income, by raising the expected net pecuniary benefit of the tax evading strategy, results in a higher (lower) proportion of tax evading capitalists if that benefit is (is not) strictly positive or even moderately strictly negative. Meanwhile, a (marginal) rise in the expected punishment applied on tax evaders, by reducing the expected net pecuniary benefit of the tax evading strategy, results in a lower (higher) proportion of tax evading firm-owner capitalists if that benefit is (is not) strictly negative or even moderately strictly positive. Definite results for all such comparative statics which are in accordance with the empirical evidence are obtained through numerical simulations.

Appendix A. Existence of evolutionary equilibria

Considering the satisficing evolutionary dynamic in (24a), it is straightforward to see that at $\lambda = 0$ and at $\lambda = 1$ we have $\dot{\lambda} = 0$, as the cumulative distribution function $F : \mathbb{R} \to [0, 1] \subset \mathbb{R}$ is bounded.

Meanwhile, a polymorphic equilibrium for (24a) exists if there is $\lambda^* \in (0,1) \subset \mathbb{R}$ such that $\lambda^*(1-\lambda^*)\big[2F\big((\tau_p - \varepsilon\gamma)\pi u^*(\lambda^*;\vec{\mu})\big) - 1\big] = 0$. Since $\lambda^*(1-\lambda^*) > 0$, the previous equality holds if, and only if, $2F\big((\tau_p - \varepsilon\gamma)\pi u^*(\lambda^*;\vec{\mu})\big) - 1 = 0$, or, equivalently:

$$F\big((\tau_p - \varepsilon\gamma)\pi u^*(\lambda^*;\vec{\mu})\big) = \frac{1}{2}. \tag{A.1}$$

Given the median of the distribution of tax morale in the population of firm-owner capitalists, m, the polymorphic equilibrium condition in (A.1) implies the following equality:

$$(\pi_e^n - \pi_c^n)u^*(\lambda^*;\vec{\mu}) = (\tau_p - \varepsilon\gamma)\pi u^*(\lambda^*;\vec{\mu}) = m. \tag{A.2}$$

Given that $\pi u^*(\lambda^*;\vec{\mu}) > 0$, it follows from (A.2) that a polymorphic equilibrium exists only if the expected net pecuniary benefit of the tax evading strategy is exactly offset by a compliance-leaning tax morale of the population of firm-owner capitalists economy, as characterized by the median tax morale m. In other words, a necessary condition for the existence of a polymorphic equilibrium $\lambda^* \in (0,1) \subset \mathbb{R}$ is that $\tau_p - \varepsilon\gamma < 0$ ($\tau_p - \varepsilon\gamma > 0$) if, and only if, $m < 0$ ($m > 0$). Meanwhile, it is then required that $\tau_p = \varepsilon\gamma$ in the case that $m = 0$ for the condition in (A.2) to be satisfied. To put it synthetically:

$$sgn(\tau_p - \varepsilon\gamma) = sgn(m), \tag{A.3}$$

where $sgn(\cdot)$ denotes the sign function.

By substituting the short-run equilibrium value of capacity utilization in (18) into the long-run equilibrium condition in (A.2), we can solve for the long-run equilibrium average net profit share across firm-owner capitalists:

$$\bar{\pi}^{n^*} = \frac{\alpha_1 m}{s_p m - \alpha_2(\pi_e^n - \pi_c^n)} = \frac{\alpha_1 m}{s_p m - \alpha_2(\tau_p - \varepsilon\gamma)\pi}, \tag{A.4}$$

where $\pi_e^n = (1-\varepsilon\gamma)\pi$ and $\pi_c^n = (1-\tau_p)\pi$ by (6), so that $\pi_e^n - \pi_c^n = (\tau_p - \varepsilon\gamma)\pi$.

Suppose that $\pi_e^n - \pi_c^n \neq 0$. Considering the expression above and the average net profit share in (7), the long-run equilibrium condition in (A.2) holds if, and only if, $\bar{\pi}^n(\lambda^*) = \bar{\pi}^{n^*}$ or, equivalently:

$$\pi_c^n + (\pi_e^n - \pi_c^n)\lambda^* = \bar{\pi}^{n^*}, \tag{A.5}$$

from which it follows that:

$$\lambda^* = \frac{\bar{\pi}^{n^*} - \pi_c^n}{\pi_e^n - \pi_c^n}, \text{ for } \pi_e^n - \pi_c^n \neq 0. \tag{A.6}$$

Considering Figure 1 and the condition in (A.2), it is straightforward to see that the existence and uniqueness of a polymorphic long-run equilibrium $\lambda^* \in (0,1) \subset \mathbb{R}$ is guaranteed by the conditions in (25) of Proposition 1. These conditions, using the expression in (A.4), can be written in terms of the median of the distribution of tax morale in the population of firm-owner capitalists as in (26) in the same proposition.

In the particular case in which $\pi_e^n - \pi_c^n = 0$, the satisficing evolutionary dynamic in (24a) becomes $\dot{\lambda} = \lambda(1-\lambda)\big[2F(0) - 1\big]$. In this case, if $m = 0$, which is consistent with (A.3), we have $\dot{\lambda} = 0$ for all $\lambda \in (0,1) \subset \mathbb{R}$. In other words, when the median tax morale across firm-owner capitalists is compliance-neutral ($m = 0$), as discussed in Section 4, and $\pi_e^n - \pi_c^n = 0$, there will be a continuum of polymorphic equilibria, given by the set $(0,1) \subset \mathbb{R}$.

Appendix B. Stability properties of the evolutionary equilibria

First, from the imitation-augmented satisficing evolutionary dynamics in (24a) we have that:

$$sgn(\dot{\lambda}) = sgn\Big(2F\big((\tau_p - \varepsilon\gamma)\pi u^*(\lambda;\vec{\mu})\big) - 1\Big), \text{ for all } \lambda \in (0,1) \subset \mathbb{R}; \quad \text{and} \tag{B.1}$$

$$\frac{\partial}{\partial \lambda}\left[2F\big((\tau_p - \varepsilon\gamma)\pi u^*(\lambda;\vec{\mu})\big) - 1\right] = 2F'\big((\tau_p - \varepsilon\gamma)\pi u^*(\lambda;\vec{\mu})\big)(\tau_p - \varepsilon\gamma)\pi\frac{\partial u^*(\lambda;\vec{\mu})}{\partial \lambda}. \tag{B.2}$$

From the expression for the short-run equilibrium value of the rate of capacity utilization in (18) and the Keynesian stability condition, it follows that $\frac{\partial u^*(\lambda;\vec{\mu})}{\partial \bar{\pi}^n} = \frac{-\alpha_1\alpha_2}{[s_p\bar{\pi}^n(\lambda) - \alpha_1]^2} < 0$ for all $\lambda \in [0,1] \subset \mathbb{R}$. From (7), meanwhile, we have that $\frac{\partial \bar{\pi}^n(\lambda)}{\partial \lambda} = (\tau_p - \varepsilon\gamma)\pi$, so that

$\frac{\partial u^*(\lambda;\vec{\mu})}{\partial \lambda} = \frac{\partial u^*(\lambda;\vec{\mu})}{\partial \bar{\pi}^n} \frac{\partial \bar{\pi}^n(\lambda)}{\partial \lambda} = \left(\frac{\partial u^*(\lambda;\vec{\mu})}{\partial \bar{\pi}^n}\right)(\tau_p - \varepsilon\gamma)\pi$. Inserting the latter derivative into (B.2), we can infer that:

$$\frac{\partial}{\partial \lambda}\left(2F\big((\tau_p - \varepsilon\gamma)\pi u^*(\lambda;\vec{\mu})\big) - 1\right) = 2F'\big((\tau_p - \varepsilon\gamma)\pi u^*(\lambda;\vec{\mu})\big)\big[(\tau_p - \varepsilon\gamma)\pi\big]^2 \frac{\partial u^*(\lambda;\vec{\mu})}{\partial \bar{\pi}^n} < 0, \tag{B.2a}$$

for all $\lambda \in [0, 1] \subset \mathbb{R}$ and $\tau_p - \varepsilon\gamma \neq 0$.

Moreover, considering (6), (7) and (18), it is important to note that:

$$m_c \equiv \frac{\alpha_2 \pi_c^n(\pi_e^n - \pi_c^n)}{s_p \pi_c^n - \alpha_1} = (\pi_e^n - \pi_c^n)u^*(0;\vec{\mu}); \quad \text{and} \tag{B.3}$$

$$m_e \equiv \frac{\alpha_2 \pi_e^n(\pi_e^n - \pi_c^n)}{s_p \pi_e^n - \alpha_1} = (\pi_e^n - \pi_c^n)u^*(1;\vec{\mu}). \tag{B.4}$$

Given those previous results, let us analyze each possible case and corresponding subcases.

(i) Case $\pi_e^n - \pi_c^n = (\tau_p - \varepsilon\gamma)\pi < 0$: in this situation, $m_c < m_e < 0$.

(a) Subcase $m \leq m_c$: as $m \leq m_c < m_e$ and using (B.4), it follows that $(\pi_e^n - \pi_c^n)u^*(1;\vec{\mu}) > m$, which implies that $F\big((\pi_e^n - \pi_c^n)u^*(1;\vec{\mu})\big) > F(m) = \frac{1}{2}$, so that $2F\big((\pi_e^n - \pi_c^n)u^*(1;\vec{\mu})\big) - 1 > 0$. Based on this last inequality and the derivative in (B.2a), we can infer that $2F\big((\pi_e^n - \pi_c^n)u^*(\lambda;\vec{\mu})\big) - 1 > 0$ for all $\lambda \in (0, 1) \subset \mathbb{R}$ and, by (B.1), $\dot{\lambda} > 0$ for all $\lambda \in (0, 1) \subset \mathbb{R}$. As a result, the equilibrium $\lambda = 0$ ($\lambda = 1$) is unstable (asymptotically stable) for any initial $\lambda \in (0, 1) \subset \mathbb{R}$.

(b) Subcase $m_c < m < m_e$: we know that in the unique polymorphic equilibrium we have $2F\big((\tau_p - \varepsilon\gamma)\pi u^*(\lambda^*;\vec{\mu})\big) - 1 = 0$. Thus, considering (B.1) and (B.2a), we can conclude that $2F\big((\tau_p - \varepsilon\gamma)\pi u^*(\lambda;\vec{\mu})\big) - 1 > 0$ for any $\lambda \in [0, \lambda^*) \subset \mathbb{R}$ and $2F\big((\tau_p - \varepsilon\gamma)\pi u^*(\lambda;\vec{\mu})\big) - 1 < 0$ for any $\lambda \in (\lambda^*, 1] \subset \mathbb{R}$. Therefore, $\dot{\lambda} > 0$ for any $\lambda \in (0, \lambda^*) \subset \mathbb{R}$ and $\dot{\lambda} < 0$ for any $\lambda \in (\lambda^*, 1) \subset \mathbb{R}$. As a result, the two monomorphic equilibria are unstable, while the polymorphic one is asymptotically stable.

(c) Subcase $m \geq m_e$: as $m_c < m_e \leq m$ and using (B.3), it follows that $(\pi_e^n - \pi_c^n)u^*(0;\vec{\mu}) < m$. From this we know that $F\big((\pi_e^n - \pi_c^n)u^*(0;\vec{\mu})\big) < F(m) = \frac{1}{2}$, so that $2F\big((\pi_e^n - \pi_c^n)u^*(0;\vec{\mu})\big) - 1 < 0$. Based on this last inequality and the derivative in (B.2a), we can infer that $2F\big((\pi_e^n - \pi_c^n)u^*(\lambda;\vec{\mu})\big) - 1 < 0$ for all $\lambda \in (0,1) \subset \mathbb{R}$ and, by (B.1), $\dot{\lambda} < 0$ for all $\lambda \in (0,1) \subset \mathbb{R}$. As a result, the equilibrium $\lambda = 0$ ($\lambda = 1$) is asymptotically stable (unstable) for any initial $\lambda \in (0,1) \subset \mathbb{R}$.

(ii) Case $\pi_e^n - \pi_c^n = (\tau_p - \varepsilon\gamma)\pi > 0$: in this situation $0 < m_e < m_c$.

(a) Subcase $m \leq m_e$: given (B.4), the assumption $m \leq m_e$ implies that $(\pi_e^n - \pi_c^n)u^*(1;\vec{\mu}) \geq m$, from which we know that $F\big((\pi_e^n - \pi_c^n)u^*(1;\vec{\mu})\big) \geq F(m) = \frac{1}{2}$, so that $2F\big((\pi_e^n - \pi_c^n)u^*(1;\vec{\mu})\big) - 1 \geq 0$. Based on this last inequality and the derivative in (B.2a), we can infer that $2F\big((\pi_e^n - \pi_c^n)u^*(\lambda;\vec{\mu})\big) - 1 > 0$ for all $\lambda \in (0,1) \subset \mathbb{R}$ and, by (B.1), $\dot{\lambda} > 0$ for all $\lambda \in (0,1) \subset \mathbb{R}$. As a result, the equilibrium $\lambda = 0$ ($\lambda = 1$) is unstable (asymptotically stable) for any initial $\lambda \in (0,1) \subset \mathbb{R}$.

(b) Subcase $m_e < m < m_c$: same demonstration as in the case (i.b).

(c) Subcase $m \geq m_c$: given (B.3), the assumption $m \geq m_c$ implies that $(\pi_e^n - \pi_c^n)u^*(0;\vec{\mu}) \leq m$, from which we know that $F\big((\pi_e^n - \pi_c^n)u^*(0;\vec{\mu})\big) \leq F(m) = \frac{1}{2}$, so that $2F\big((\pi_e^n - \pi_c^n)u^*(0;\vec{\mu})\big) - 1 \leq 0$. Based on this last inequality and the derivative in (B.2a), we can infer that $2F\big((\pi_e^n - \pi_c^n)u^*(\lambda;\vec{\mu})\big) - 1 < 0$ for all $\lambda \in (0,1) \subset \mathbb{R}$ and, by (B.1), $\dot{\lambda} < 0$ for all $\lambda \in (0,1) \subset \mathbb{R}$. As a result, the equilibrium $\lambda = 0$ ($\lambda = 1$) is asymptotically stable (unstable) for any initial $\lambda \in (0,1) \subset \mathbb{R}$.

(iii) Case $\pi_e^n - \pi_c^n = (\tau_p - \varepsilon\gamma)\pi = 0$: note that in this situation the satisficing evolutionary dynamic in (24a) reduces to $\dot{\lambda} = \lambda(1-\lambda)\big[2F(0) - 1\big]$.

(a) Subcase $m < 0$: under such additional condition, we have $\dot{\lambda} = \lambda(1-\lambda)\big[2F(0) - 1\big] > 0$ for all $\lambda \in (0,1) \subset \mathbb{R}$, as $F(0) > F(m) = \frac{1}{2}$. Thus the equilibrium $\lambda = 0$ ($\lambda = 1$) is unstable (asymptotically stable) for any initial $\lambda \in (0,1) \subset \mathbb{R}$.

(b) Subcase $m = 0$: in this particular situation, we know that $F(0) = F(m) = \frac{1}{2}$, so that $\dot{\lambda} = \lambda(1-\lambda)\big[2F(0) - 1\big] = 0$ for all $\lambda \in [0,1] \subset \mathbb{R}$. Hence, any $\lambda \in [0,1] \subset \mathbb{R}$ is a neutrally (Lyapunov) stable equilibrium.

(c) Subcase $m > 0$: under this condition, it follows that $\dot{\lambda} = \lambda(1-\lambda)\big[2F(0) - 1\big] < 0$ for all $\lambda \in (0,1) \subset \mathbb{R}$, since $F(0) < F(m) = \frac{1}{2}$. Therefore, the equilibrium $\lambda = 0$ ($\lambda = 1$) is asymptotically stable (unstable) for any initial $\lambda \in (0,1) \subset \mathbb{R}$.

References

Alm, J., 2019. What motivates tax compliance? Journal of Economic Surveys 33, 353–388. doi:10.1111/joes.12272.

Alm, J., Jackson, B.R., McKee, M., 2009. Getting the word out: Enforcement information dissemination and compliance behavior. *Journal of Public Economics* 93, 392–402. doi:10.1016/j.jpubeco.2008.10.007.

Alm, J., Martinez-Vazquez, J., Torgler, B. (Eds.), 2010. *Developing Alternative Frameworks for Explaining Tax Compliance*. Routledge, London.

Artinger, F.M., Gigerenzer, G., Jacobs, P., 2022. Satisficing: Integrating two traditions. Journal of Economic Literature 60, 598–635. doi:10.1257/jel.20201396.

Bazart, C., Bonein, A., 2014. Reciprocal relationships in tax compliance decisions. *Journal of Economic Psychology* 40, 83–102. doi:10.1016/j.joep.2012.10.002.

Bazart, C., Bonein, A., Hokamp, S., Seibold, G., 2016. Behavioural economics and tax evasion: Calibrating an agent-based econophysics model with experimental tax compliance data. *Journal of Tax Administration* 2, 126–144.

Bethencourt, C., Kunze, L., 2019. Tax evasion, social norms, and economic growth. *Journal of Public Economic Theory* 21, 332–346. doi:10.1111/jpet.12346.

Bethencourt, C., Kunze, L., 2020. Social norms and economic growth in a model with labor and capital income tax evasion. *Economic Modelling* 86, 170–182. doi:10.1016/j.econmod.2019.06.009.

Bhaduri, A., Marglin, S., 1990. Unemployment and the real wage: the economic basis for contesting political ideologies. *Cambridge Journal of Economics* 14, 375–393. doi:10.1093/oxfordjournals.cje.a035141.

Caballe, J., Panades, J., 1997. Tax Evasion and Economic Growth. *Public Finance = Finances publiques* 52, 318–340.

Caplin, A., Dean, M., Martin, D., 2011. Search and satisficing. *American Economic Review* 101, 2899–2922. doi:10.1257/aer.101.7.2899.

Célimène, F., Dufrénot, G., Mophou, G., N'Guérékata, G., 2016. Tax evasion, tax corruption and stochastic growth. *Economic Modelling* 52, 251–258. doi:10.1016/j.econmod.2014.10.055.

Chatzimichael, K., Kalaitzidakis, P., Tzouvelekas, V., 2019. Tax evasion, tax monitoring expenses and economic growth: an empirical analysis in oecd countries. *Empirical Economics* 57, 285–300. doi:10.1007/s00181-018-1441-8.

Chen, B.L., 2003. Tax evasion in a model of endogenous growth. *Review of Economic Dynamics* 6, 381–403. doi:10.1016/S1094-2025(03)00002-4.

Commendatore, P., Panico, C., Pinto, A., 2011. The influence of different forms of government spending on distribution and growth. *Metroeconomica* 62, 1–23. doi:https://doi.org/10.1111/j.1467-999X.2009.04081.x.

Commendatore, P., Pinto, A., 2011. Public expenditure composition and growth: A neo-Kaleckian analysis. *Cahiers D'Economie Politique* 61, 187–222. doi:https://doi.org/10.3917/cep.061.0187.

Cummings, R.G., Martinez-Vazquez, J., McKee, M., Torgler, B., 2009. Tax morale affects tax compliance: Evidence from surveys and an artefactual field experiment. *Journal of Economic Behavior & Organization* 70, 447–457. doi:10.1016/j.jebo.2008.02.010.

Daude, C., Gutiérrez, H., Melguizo, , 2013. What drives tax morale? a focus on emerging economies. Hacienda Pública Española / Review of Public Economics 207, 9–40. doi:10.7866/HPE-rPE.13.4.1.

Dutt, A.K., 2010. Keynesian growth theory in the 21st century, in: Arestis, P., Sawyer, M. (Eds.), *Twenty-first Century Keynesian Economics*. Palgrave Macmillan York, London, pp. 39–80. doi:10.1057/9780230285415_2.

Dutt, A.K., 2013. Government spending, aggregate demand and economic growth. *Review of Keynesian Economics* 1, 105–119. doi:https://doi.org/10.4337/roke.2013.01.06.

Hey, J.D., Permana, Y., Rochanahastin, N., 2017. When and how to satisfice: An experimental investigation. *Theory and Decision* 83, 337–353. doi:10.1007/s11238-017-9600-5.

Internal Revenue Service (IRS), 2022. *Federal Tax Compliance Research: Tax Gap Estimates for Tax Years 2014-2016*. Washington, DC: IRS Office of Research, Analysis, and Statistics. URL: https://www.irs.gov/pub/irs-pdf/p1415.pdf.

Ivanyna, M., Moumouras, A., Rangazas, P., 2016. The culture of corruption, tax evasion, and economic growth. *Economic Inquiry* 54, 520–542. doi:https://doi.org/10.1111/ecin.12228.

Kaldor, N., 1955. Alternative theories of distribution. *The Review of Economic Studies* 23, 83–100. doi:10.2307/2296292.

Kalecki, M., 1971. Class struggle and the distribution of national income. *Kyklos* 24, 1–9. doi:10.1111/j.1467-6435.1971.tb00148.x.

Kemme, D.M., Parikh, B., Steigner, T., 2020. Tax morale and international tax evasion. Journal of World Business 55, 198–227. doi:10.1016/j.jwb.2019.101052.

Laramie, A., Mair, D., 2003. The effects of taxation in a Kaleckian growth model. *Metroeconomica* 54, 326–345. doi:https://doi.org/10.1111/1467-999X.00169.

Laramie, A.J., Mair, D., 1996. Taxation and Kalecki's theory of the business cycle. *Cambridge Journal of Economics* 20, 451–464.

Laramie, A.J., Mair, D., 2000. *A Dynamic Theory of Taxation*. Edward Elgar Publishing.

Lin, W.Z., Yang, C., 2001. A dynamic portfolio choice model of tax evasion: Comparative statics of tax rates and its implication for economic growth. Journal of Economic Dynamics and Control 25, 1827–1840. doi:https://doi.org/10.1016/S0165-1889(99)00081-0.

Lubian, D., Zarri, L., 2011. Happiness and tax morale: An empirical analysis. *Journal of Economic Behavior & Organization* 80, 223–243. doi:10.1016/j.jebo.2011.03.009.

Luttmer, E.F., Singhal, M., 2014. Tax morale. *Journal of Economic Perspectives* 28, 149–168. doi:10.1257/jep.28.4.149.

Marchese, C., 2020. Tax amnesty, in: Marciano, A., Ramello, G.B. (Eds.), *Encyclopedia of Law and Economics*. Springer New York, pp. 1–12. doi:10.1007/978-1-4614-7883-6_24-2.

Pasinetti, L.L., 1962. Rate of profit and income distribution in relation to the rate of economic growth. *The Review of Economic Studies* 29, 267–279. doi:10.2307/2296303.

Pickhardt, M., Prinz, A., 2014. Behavioral dynamics of tax evasion: A survey. *Journal of Economic Psychology* 40, 1–19. doi:10.1016/j.joep.2013.08.006.

Robinson, J., 1956. *The Accumulation of Capital*. Macmillan, London.

Robinson, J., 1962. *Essays in the Theory of Economic Growth*. Macmillan, London.

Schneider, F., Buehn, A., Montenegro, C., 2010. New estimates for the shadow economies all over the world. *International Economics Journal* 24, 443–461. doi:10.1080/10168737.2010.525974.

Simon, H.A., 1955. A behavioral model of rational choice. *The Quarterly Journal of Economics* 69, 99–118. doi:10.2307/1884852.

Simon, H.A., 1956. Rational choice and the structure of the environment. *Psychological review* 63, 129. doi:10.1037/h0042769.

Stavjaňová, J., Vítek, L., 2022. Tax evasion and economic growth in the eu. International Journal of Economic Policy in Emerging Economies 16, 40–57. doi:10.1504/IJEPEE.2022.124657.

Tavani, D., Zamparelli, L., 2016. Public capital, redistribution and growth in a two-class economy. *Metroeconomica* 67, 458–476. doi:https://doi.org/10.1111/meca.12105.

Torgler, B., 2007. *Tax Compliance and Tax Morale: A Theoretical and Empirical Analysis*. Edward Elgar Publishing, Cheltenham.

Tsakumis, G.T., Curatola, A.P., Porcano, T.M., 2007. The relation between national cultural dimensions and tax evasion. *Journal of International Accounting, Auditing and Taxation* 16, 131–147. doi:10.1016/j.intaccaudtax.2007.06.004.

Varvarigos, D., 2017. Cultural norms, the persistence of tax evasion, and economic growth. *Economic Theory* 63, 961–995. doi:10.1007/s00199-016-0976-1.

Vasilopoulou, Y., Thomakos, D., 2017. Tax evasion, tax administration, and the impact of growth: Tax enforcement as regulatory failure in a high tax rates, high tax evasion, and low-growth economic environment, in: Vasilopoulou, Y., Thomakos, D. (Eds.), *Taxation in Crisis. Tax Policy and the Quest for Economic Growth*. Springer, pp. 175–203.

Vega-Redondo, F., 1996. *Evolution, Games, and Economic Behaviour.* Oxford University Press UK.

	Total true tax liabilities	Tax paid voluntarily and timely	Gross tax gap	
Overall tax gap	3,307	2,811 (85 %)	496	
Individual income tax	1,740	1,383 (79.5 %)	357	
Corporate income tax	354	313 (88.4 %)	41	
Employment tax	1,131	1,038 (91.8 %)	93	
Estate tax	22	17 (77.3 %)	5	
	Enforced and late payment	Net compliance rate (%)	Net tax gap	Estimated tax evasion (%)
Overall tax gap	68	87.1	428	**12.9**
Individual income tax	51	82.4	306	**17.6**
Corporate income tax	8	90.5	34	**9.5**
Employment tax	6	92.3	87	**7.7**
Estate tax	3	90.9	2	**9.1**

Table 1: US net and gross tax gap for 2014-2016, in USD Billions. Source: Internal Revenue Service (IRS) (2022).

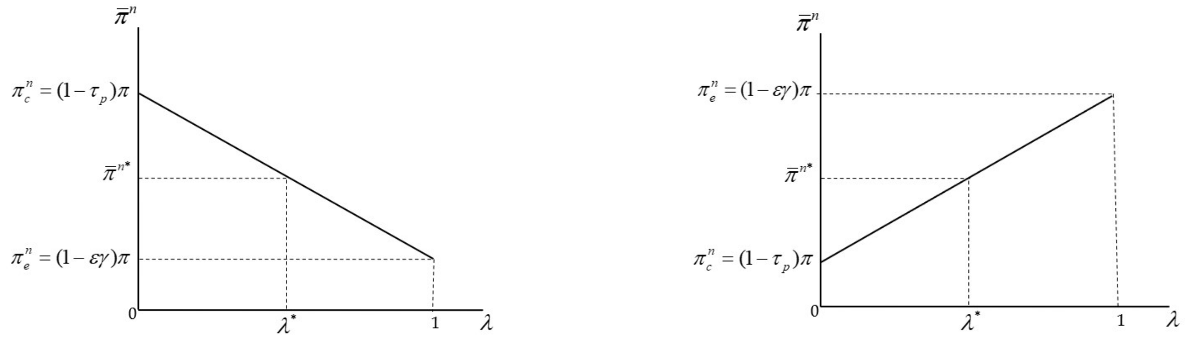
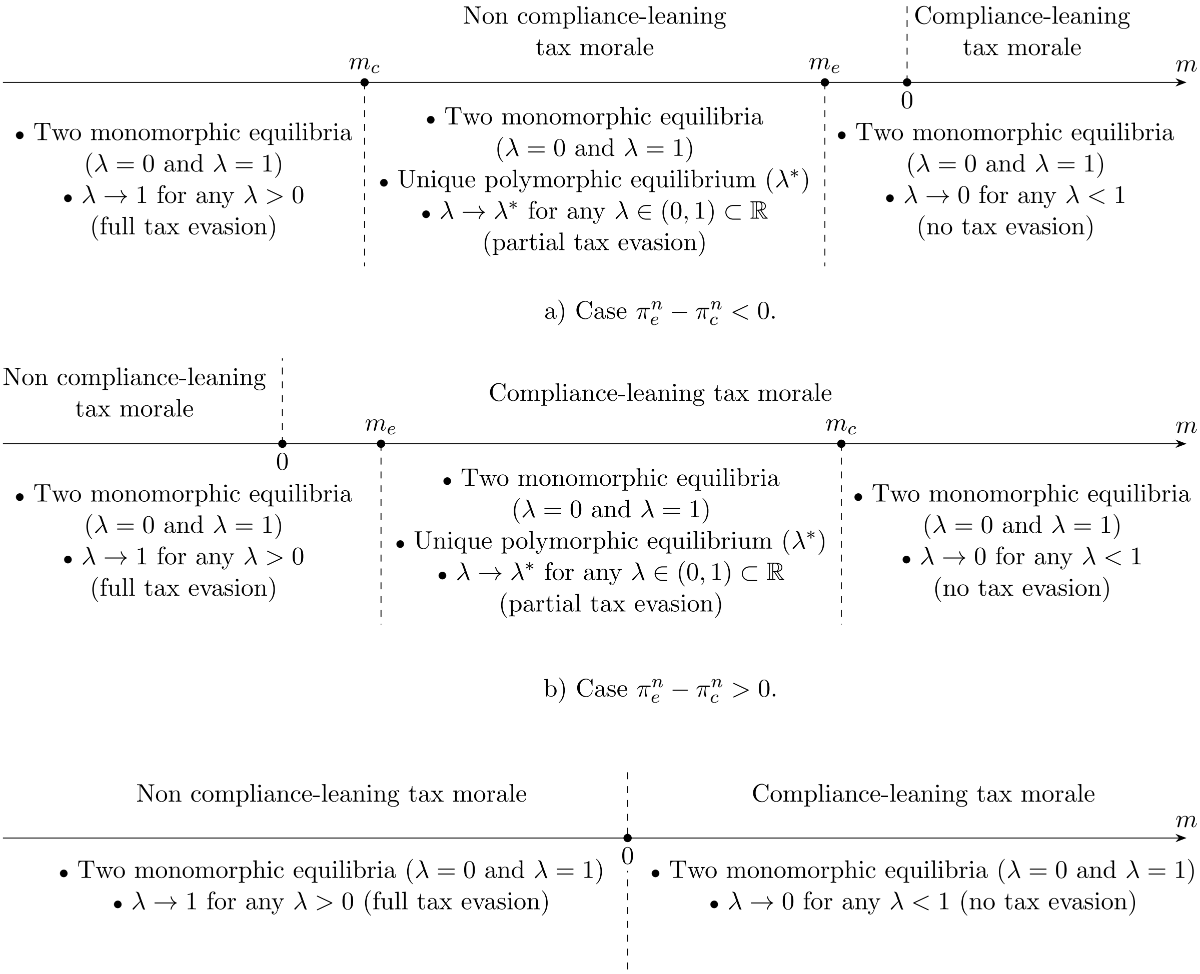


Figure 1: Left: Noncompliance-leaning tax morale ($m < 0$) and $\pi_e^n - \pi_c^n = (\tau_p - \varepsilon\gamma)\pi < 0$. Right: Compliance-leaning tax morale ($m > 0$) and $\pi_e^n - \pi_c^n = (\tau_p - \varepsilon\gamma)\pi > 0$.



a) Case $\pi_e^n - \pi_c^n < 0$.

b) Case $\pi_e^n - \pi_c^n > 0$.

c) Case $\pi_e^n - \pi_c^n = 0$.

Figure 2: Long-run behavior of tax evasion.

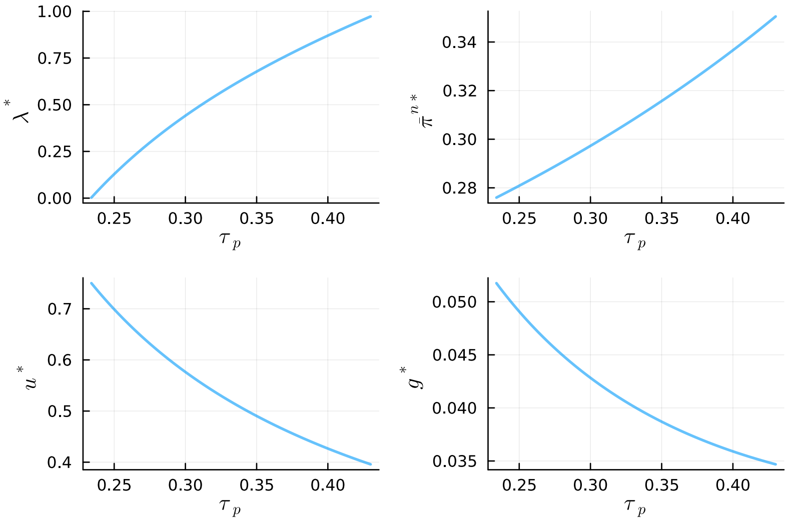


Figure 3: Effects of a change in the tax rate on profit income on the long-run equilibrium values of relevant endogenous variables. Top left: frequency of tax evaders in the population of firm-owner capitalists. Top right: average net profit share. Bottom left: capital capacity utilization. Bottom right: output growth rate.

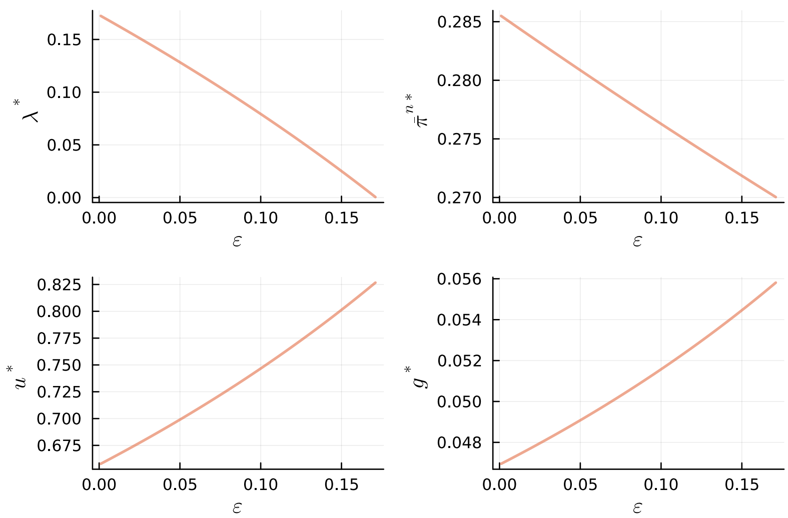


Figure 4: Effects of a change in the probability of detection on the long-run equilibrium values of relevant endogenous variables. Top left: frequency of tax evaders in the population of firm-owner capitalists. Top right: average net profit share. Bottom left: capital capacity utilization. Bottom right: output growth rate.

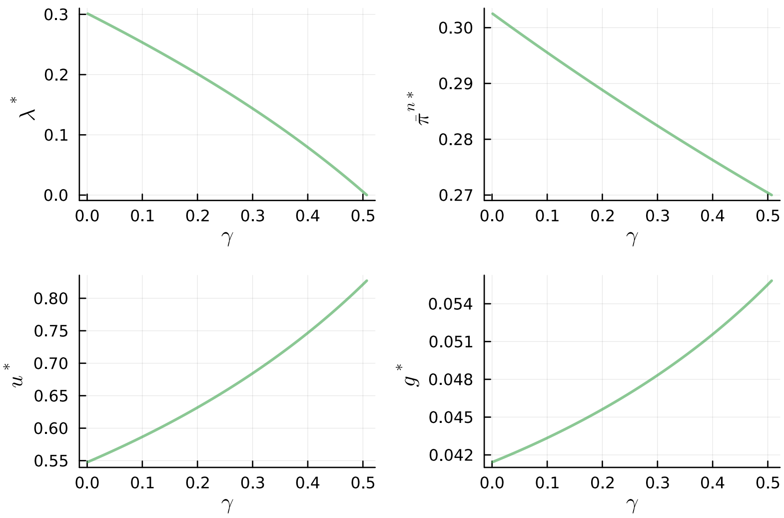


Figure 5: Effects of a change in the penalty rate on the long-run equilibrium values of relevant endogenous variables. Top left: frequency of tax evaders in the population of firm-owner capitalists. Top right: average net profit share. Bottom left: capital capacity utilization. Bottom right: output growth rate.