Austerity and tax compliance☆

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ABSTRACT

Relying on a novel measure of VAT compliance in a panel of 35 countries, we document a robust negative response of tax compliance to changes in tax rates. In order to rationalize this finding, we develop a theoretical framework where heterogeneous firms adjust the share of declared activity. We calibrate the model using firm-level data in Greece, and find large leakages following the recent austerity plans. We then show how differences in financial development and the size of economic activity at the margin of informality are able to explain the heterogeneous response of tax compliance to tax rates across countries.

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1. Introduction

Recent episodes of austerity in peripheral European countries have shown that the increase in tax revenues after a tax hike may be undermined by the strong response of tax compliance. While fluctuations in output due to tax hikes have been studied in the literature,[1] the aggregate implications of the response of tax compliance to such reforms have been overlooked. A decrease in tax compliance may not only reduce the impact of a fiscal adjustment, but also have collateral effect on firm decisions, e.g., through their access to external finance and investment.

In this paper, we provide evidence of a large and negative tax compliance response to fiscal consolidation episodes. We compile a catalogue of indirect tax reforms in 35 countries between 1990 and 2012, and construct a measure of Value-Added-Taxes (VAT) compliance based on the comparison between two distinct sources: reported household consumption

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collected through household surveys and tax revenues reflecting taxpayers' declarations.[2] We find a robust and sizeable negative association between changes in VAT compliance and changes in VAT rates. A VAT increase of 10% is associated with a decrease in VAT compliance of about 4%. Importantly, the elasticity of tax revenues to tax reforms is much smaller within the sample of countries with high legal enforcement.

In order to explain the quantitative response of tax compliance to tax reforms as well as its heterogeneity across institutional environments, we build a theoretical model with heterogeneous credit-constrained firms operating in a modern or a traditional sector. In the model, there is imperfect tax enforcement. *Transparency*, that is the share of declared activity, simultaneously determines access to external finance and tax pressure. A tax increase has two distinct effects on transparency. First, firms at the margin of informality do not find profitable anymore to be transparent and get access to external finance. As a consequence, they switch their activity from the modern (and transparent) sector to the traditional (and informal) sector. Second, medium-size firms still operate mainly in the modern sector but they declare less than before. At both ends of the firm size distribution, however, the response to tax increase does not pass through a transparency adjustment: very large firms remain fully transparent while very small firms remain fully informal.

We explore the quantitative implications of our model that can be measured against the initial stylized facts. We reproduce the fiscal adjustment program imposed on the Greek government by the "Troika" (EU-ECB-IMF) in 2010. We calibrate the model to match firm-level balance sheets data on 30,000 Greek firms provided by Hellastat. We find that the elasticity of tax revenues to tax hikes is about 0.5 as both transparency and output respond to the tax hikes. Three quarters come from the transparency component, against one quarter explained by the contraction in output. These estimates are consistent with the drop in VAT compliance and tax revenues observed after the fiscal consolidation in Greece.[3]

We then analyze how (i) fundamentals of the economy – tax enforcement, financial development and firm size distribution – and (ii) characteristics of tax policies affect the magnitude of the transparency response. In a first step, we run a series of counterfactual experiments and show that the aggregate transparency response to the baseline tax policy strongly depends on financial development and firm size distribution. Indeed, the differential response to the tax policy depends on the share of economic activity generated by firms at the margin of informality, which is a function of both fundamentals. For instance, Southern European countries are economies where the aggregate response of tax compliance to tax hikes is large, because tax enforcement is weak and firms at the margin of informality constitute a large share of the economy. In a second step, we modify the characteristics of the baseline tax reform to account for policy features observed in other peripheral European economies. We find that size-dependent tax reforms may be more effective than uniform tax hikes. The rationale for size-dependent tax policies in the model is that the elasticity of tax revenues to tax rates markedly depends on firm size, and is close to zero or even negative for very small firms.

The results highlighting the role of fundamentals for the response of tax compliance should be interpreted cautiously. The quantitative analysis relies on a static model in a closed economy with a mass of heterogeneous entrepreneurs, one production factor, one final good and an exogenous government. The supply of entrepreneurs and their endowments is fixed, and the main adjustment variable is transparency which governs both access to credit and tax pressure. As the firm size distribution is constant, the model does not provide insights about the long-term effects of taxation on the structure of production.[4] In addition, a proper welfare analysis would need to balance the immediate consumption costs of fiscal consolidation with possible gains in future consumption, and our model does not account for such gains.

Our contribution to the economic literature is twofold. First, we build a measure of tax compliance and study its dynamics, in particular its response to tax reforms. Second, we study the aggregate implications of the elasticity of tax compliance to tax reforms in a model with heterogeneous firms and credit frictions.

The empirical analysis of fluctuations in tax compliance relates to a public economics literature which analyzes tax evasion using micro-level data.[5] Our empirical approach exploits discrepancies between two reporting sources of income, as in Fisman and Wei (2004), Cai and Liu (2009) and Kleven et al. (2011) for instance. In contrast with this literature, we provide model-based estimates and study the implications of fluctuating tax compliance on aggregate variables.

The existence of a tax compliance response beyond the traditional behavioral response to tax rates is often ignored in the macroeconomic literature. A recent and notable exception is Pappa et al. (2015), which study the contribution of tax evasion and corruption to the size of the fiscal multiplier during the recent consolidation plans in Greece, Italy, Portugal and Spain. In line with our main findings, they show that tax hikes increase the incentives to conceal part of the activity and produce in the less productive informal sector, thus increasing output losses.

The paper speaks to a large and mostly theoretical literature examining the relationship between informal activity and financial development. Specifically, we relate to Gordon and Li (2009) in that the interaction of financial development and

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[2] This measure of VAT compliance is constructed to be orthogonal to fluctuations in each 2-digit category of goods. In an economy where taxpayers declare entirely their transactions, the ratio of *actual* annual tax revenues to the *expected* VAT revenues would be equal to 1 independently of fluctuations in sectoral output.

[3] Following the 2010 tax reforms in Greece, VAT compliance decreased by about 7% while the VAT rate increased by about 20%, that amounts to an elasticity of VAT compliance to VAT rates of −0.35. An implication is that only half of the expected additional tax revenues was collected – 1.5 instead of 3.1 points of GDP – leading to further adjustments in 2011, 2012 and 2013.

[4] See Fortin et al. (1997) for a theoretical analysis of the effect of taxation on firm distribution, and Kumar et al. (1999) and Garicano et al. (2016) for an empirical investigation of the determinants of firm size.

[5] See Andreoni et al. (1998) and Slemrod and Yitzhaki (2002) for a review, and Pomeranz (2015) for an empirical investigation of VAT evasion and third-party reporting.

imperfect tax enforcement shapes the efficiency of tax reforms. Gordon and Li (2009) study the implications of such interaction for optimal tax policy, and rationalize the differences in tax structure between developing and developed countries. A crucial assumption in this literature is that firm transparency affects access to credit, a feature that is also present in Straub (2005) and Desai et al. (2007) for instance. Two recent contributions provide empirical support for this hypothesis and document a robust and positive correlation between credit and firm transparency. Capasso and Jappelli (2013) exploit local variations in the size of the underground economy while Ellul et al. (2015) provide a micro-based analysis relating reliance on external finance to accounting transparency and tax pressure.

Finally, our modeling with a dual technology borrows from the literature on shadow economies.[6] We slightly depart from this literature (Rauch, 1991; Straub, 2005) because we allow firms to adjust their degree of informality rather than being fully informal or fully transparent.

The paper is organized as follows. In Section 2, we introduce a measure of tax compliance and show its response to fiscal consolidation episodes. Motivated by this empirical analysis, we describe our quantitative framework in Section 3. In Section 4, we calibrate our model using quasi-exhaustive firm-level balance sheet data in Greece. We match important moments of the distribution of firms, and study the evolution of the calibrated economy under the 2010 austerity program. In Section 5, we then generalize our analysis and show the role of fundamentals of our economy, i.e. legal enforcement and the number of firms at the margin of informality, and the characteristics of tax reforms for the aggregate response of tax compliance to tax rates. Finally, Section 6 concludes.

2. The elasticity of tax compliance to fiscal consolidation

In this section, we show that fluctuations in tax compliance should not be overlooked when evaluating the aggregate response of an economy to fiscal consolidation. In this regard, we compile a catalogue of tax reforms, associate indirect tax rates and reported consumption for 2-digit categories of goods, and construct an annual measure of VAT compliance for about 35 countries between 1990 and 2012.[7]

We then study the dynamics of tax compliance and show that there exists a strong and robust negative association between changes in tax compliance and tax rates in our sample of 35 countries, even when controlling for fluctuations in output. Tax compliance is not only a factor that affects tax revenues in the long run but it also fluctuates markedly. Importantly, the elasticity of tax compliance to tax rates is larger among countries of our sample with lower legal enforcement.

2.1. Data sources

To construct a measure of VAT compliance, we use three different data sources.[8] First, we collect a decomposition of tax revenues by tax instruments, as declared by each national tax authority. Second, we collect household consumption measures as reported by national statistical offices and use these 2-digit good category consumption measures as a proxy for the potential tax base. Third, we create a dataset of VAT reforms in which we document changes in tax rates, but also and more crucially changes in the tax base.

Tax revenues

For European Union countries, data on tax revenues are collected centrally by Eurostat under the European system of national and regional accounts (ESA 2010) transmission programme. European Union member states are legally obliged to transmit this information.[9] VAT revenues are generally recorded on an accrual basis, which may introduce some noise in reports. For instance, revenues are calculated based on the transaction time but there could be a time difference between transaction and cash receipt. Along the same lines, a transaction can be declared but may not be collected. For non-EU/OECD members, we take advantage of the OECD Model Tax Convention to collect revenues from the category *Value added type taxes (VAT)*. Finally, we complete our data on tax revenues by directly collecting detailed national accounts from national statistical offices.

Household consumption

In countries complying with the ICLS Resolution on household income and expenditure statistics (2003), household consumption is collected by statistical offices using integrated surveys (e.g., the Income, Expenditure and Wealth questionnaires). One purpose of this data collection is to estimate baskets of goods and services and compute consumer price indices. There are two differences with tax reporting that are worth mentioning. First, while tax revenues are based on taxpayers'

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[6] See Enste and Schneider (2000) and Porta and Shleifer (2008) for a review.

[7] A recent contribution constructs a similar measure for EU countries (CPB, 2013) between 2000 and 2011. In contrast with this study, our dataset includes non-EU countries and covers a larger time span.

[8] Our measure of tax compliance identifies tax evasion from discrepancies between two reporting sources of income, a strategy similar to Cai and Liu (2009) and Kleven et al. (2011) for instance. Closer to our empirical measure, Fisman and Wei (2004) look at the discrepancies between the declared exports of Hong Kong to China and the imports of China from Hong Kong to measure empirically tax evasion, and they show that these discrepancies are not due to measurement errors as they are systematically higher for those goods subject to higher taxation.

[9] The format is a list of National taxes (the National Tax List) that are subsequently aggregated in common categories. As regards VAT, we focus on category *D.211: Value added type taxes (VAT)*.

declarations, the *Households Final Consumption Expenditure* is reported by (final good) buyers who are not legally accountable for tax evasion. Second, household surveys are less standardized across countries than accounting reports and there may exist significant variation in survey design.

There is a number of measurement issues arising with these surveys, and the extent to which they affect the final consumption measure may differ across countries. We list several of them below. First, there may exist a difference between the time of acquisition and the time of use. Our ideal measure should be computed using the time of acquisition for a better comparison with VAT revenues. Second, expenditure may be computed as an accounting variable, i.e., a purchase value or a payment approach, or a consumption costs approach estimating the service flow from the good acquisition. Third, goods may be consumed gradually. The choice between a payment approach and a consumption costs approach is then particularly relevant. In most cases, statistical offices use the payment approach which fits our purposes. Apart from definitions, there are other differences across household surveys that could affect our analysis. Some statistical offices use a fixed reference period and then interview all households during a short period of time, some others define a moving reference period usually corresponding to the 12 previous months. Data collection may also vary: the process could be guided by an interviewer or the questionnaire can be completed by a household member. The scope of the survey and the sampling design are less problematic. Sample size and questions are designed such as to provide precise estimates for the baskets of goods and services, which is also our variable of interest. One difference of our measure with standard price indices is that we do not sum the different consumption categories to determine a cost of living, but we also weight them by their supposed VAT rate to determine the *VAT content* of the consumption basket.

Value-added tax rates

We retrieve VAT rates and we reference the types of goods (at the 2 digit level) that are subject to these rates for each country/year. This data collection supports our empirical approach and allows us to estimate fluctuations in VAT compliance with sufficient precision. For example, in a large number of countries, categories like medical services, international public transport, basic food products or cultural services are subject to reduced rates or exemptions and—very importantly—the set of exempt categories are frequently updated.

For European Union members after 2005, we use two administrative sources, the European Commission and Eurostat, to construct the monthly VAT rates for about 80 expenditure categories. We complete this dataset for European Union members before 2005 and other countries by using national sources. This exercise requires some harmonization across expenditure categories in different accounting systems. It also requires some cleaning that we describe in the online Appendix. Finally, we collect other taxes such as to control for simultaneous changes in income tax or corporate tax.

Among the sample of 35 countries, we can identify 65 major VAT reforms implying changes in VAT rates larger than 5%. About 45 of these reforms are associated with an increase in the effective VAT rate and can be labeled as episodes of "fiscal consolidation". In contrast, about 20 reforms imply lower effective rates. These large fiscal episodes are quite equally spread across countries.

2.2. A measure of VAT compliance

In order to construct a measure of VAT compliance, we need *declared* transactions and a counterfactual measure that would capture the *actual* transactions. We use VAT revenues as a proxy for declared transactions. The difference between declared transactions and VAT-charged transactions is minimal and comes from arrears from defaulting legal entities. We use household-based consumption measures as a proxy for actual transactions based on the fact that households are not liable for reporting consumption of undeclared transactions.[10]

Aggregate tax compliance is the ratio between tax revenues from total declared transactions and the counterfactual tax revenues from actual transactions. Letting $DT_{t,c,j}$ (resp. $AT_{t,c,j}$) denote the declared (resp. actual) transactions and $\tau_{t,c,j}$ denote the good-specific VAT rates for each good j in country c and year t, our measure $TC_{t,c,j}$ of VAT compliance is defined as:

$$TC_{t,c} = \frac{\sum_j \tau_{t,c,j} DT_{t,c,j}}{\sum_j \tau_{t,c,j} AT_{t,c,j}}.$$

Letting $T_{t,c}$ denote VAT revenues in year t for country c, and $C_{t,c,j}$ the reported consumption of good j in year t and country c, we have that:

$$TC_{t,c} = \frac{T_{t,c}}{\sum_j \tau_{t,c,j} C_{t,c,j}}.$$

Intuitively, the measure TC_t uses two different sources and capture the discrepancies between the two sources. We argue that such discrepancies capture, for a large share, tax evasion decisions. It is true, however, that they also may capture loose enforcement from tax authorities. For instance, tax authorities may tolerate informal exemptions for some sectors, regions, or newly-taxed activities.

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[10] In few countries, however, there may exist an interaction between the type of transactions and household reports. Indeed, in China, consumers have incentives to ask for VAT revenues as they serve for national lottery and households may better keep track of registered transactions than undeclared transactions. In this case, we would underestimate fluctuations in tax compliance.

Table 1
Elasticity of tax compliance to tax rates.

Panel A: Standard VAT rate VAT compliance	(1)	(2)	(3)	(4)
Elasticity β	−0.316***	−0.330***	−0.393***	−0.388***
	(0.066)	(0.079)	(0.087)	(0.087)
	[602]	[475]	[420]	[420]
Panel B: Effective VAT rate VAT compliance	(1)	(2)	(3)	(4)
Elasticity β	−0.410***	−0.382***	−0.451***	−0.449***
	(0.055)	(0.065)	(0.072)	(0.071)
	[602]	[475]	[420]	[420]
Country fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Economic cycle	Yes	Yes	Yes	Yes
Government expenditures	No	Yes	Yes	Yes
Sectoral composition	No	No	Yes	Yes
Trade	No	No	No	Yes

Significantly different than zero at * 90% confidence, ** 95% confidence, *** 99% confidence. Robust standard errors are reported between parentheses. The number of observations for each specification is reported between brackets. Each cell displays the estimate of a separate regression (see Eq. (1)).

Given the availability (time coverage and data quality) of our main data sources across countries, our final dataset covers an unbalanced panel of 35 (mostly European) countries between 1990 and 2012.[11]

There exist several adjustments that we need to implement for our empirical measure to be as close as possible from the theoretical benchmark $TC_{t,c}$. First, we are interested in the short-term fluctuations of this measure, and we need to smooth the "high-frequency" measurement error. Tax reforms are often implemented during the year, while national accounts are closed at the end of each period, i.e., year or quarter. For this reason, we need to generate the effective tax rate for a unit of consumption in a given period. When tax rates were changed during the course of the year, we construct the annual effective tax rate by weighting each tax rate by the consumption observed during its spell. When consumption could not be observed at a higher frequency than the period, we construct the annual effective tax rate by weighting each tax rate by the duration within the period during which it was enforced. Second, some tax reforms did not modify rates but also modify the category of goods that are subject to the different tax regimes. In such instances, we redefine our tax base. Third, some reforms modify the tax environment without modifying the tax rates per se. For instance, a reform may considerably simplify the registration process. We collect this information and control for any such reforms in our regression analyses. We describe some of these challenges in greater details in the online Appendix.

2.3. Tax compliance and tax reforms

To uncover the correlation between VAT compliance and VAT reforms, we estimate the following specification in first difference:

$$\Delta TC_{t,c} = \alpha a_{t,c} + \beta \Delta \tau_{t,c} + \gamma \cdot \mathbf{X}_{t,c} + \mu_c + \nu_t + \varepsilon_{t,c}, \tag{1}$$

where t stands for years and c stands for the country. Δ is the log-difference operator, i.e., $\Delta x_t = \ln(x_t) - \ln(x_{t-1})$, a_{tc} is the HP-filtered GDP per capita, and τ_{tc} is the effective VAT tax rate. The vector $\mathbf{X}$ includes time-varying controls, such as the existence of concomitant tax reforms, growth in trade balance, sectoral output and government expenditures. μ_c captures the country-specific trends in tax compliance, and ν_t captures year-Fixed Effects. $\varepsilon_{t,c}$ is the error term. The coefficient of interest β can be interpreted as the elasticity of tax compliance to tax rates conditional on output fluctuations.

We report in Table 1 the results of specification (1) estimated on our sample of countries. We find an elasticity of VAT compliance to standard VAT rate of about −0.40 (see panel A) and −0.45 with respect to effective VAT rates (see panel B), i.e., when weighting standard, reduced and super-reduced rates by their incidence.

In the benchmark regression (column 1), we control for country-specific trends, year-Fixed effects and the country economic cycle. The estimates are extremely robust to the addition of controls for government expenditures (column 2), sectoral composition (column 3) and trade (column 4).[12]

This estimated elasticity is an average measure across potentially very different countries – with strong or weak institutions. To uncover the differences across countries, we use a simple dichotomy exercise and separate our sample between

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[11] The list of countries in the sample is: Australia, Austria, Belgium, Bulgaria, Canada, Chile, Colombia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France Germany, Greece, Hungary, Ireland, Israel, Italy, Japan, Korea, Luxemburg, Malta, Netherlands, New Zealand, Norway, Poland, Portugal, Roumania, Russia, Serbia, Slovak Republic, Slovenia, South Africa, Spain, Sweden, Switzerland and the United Kingdom.

[12] The estimates are also robust when we control for simultaneous income or corporate tax reforms.

Table 2

Elasticity of tax compliance to tax rates – high versus low legal enforcement.

Panel A: Standard VAT rate VAT compliance	(1)	(2)	(3)	(4)
Elasticity β_l	−0.376***	−0.455***	−0.637***	−0.637***
	(0.084)	(0.107)	(0.116)	(0.115)
Difference $\beta_h - \beta_l$	0.159	0.265*	0.523***	0.535***
	(0.133)	(0.153)	(0.168)	(0.167)
	[602]	[475]	[420]	[420]
Panel B: Effective VAT rate VAT compliance	(1)	(2)	(3)	(4)
Elasticity β_l	−0.445***	−0.434***	−0.571***	−0.572***
	(0.066)	(0.080)	(0.088)	(0.088)
Difference $\beta_h - \beta_l$	0.110	0.148	0.335**	0.344**
	(0.115)	(0.133)	(0.145)	(0.144)
	[602]	[475]	[420]	[420]
Country fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Economic cycle	Yes	Yes	Yes	Yes
Government expenditures	No	Yes	Yes	Yes
Sectoral composition	No	No	Yes	Yes
Trade	No	No	No	Yes

Significantly different than zero at * 90% confidence, ** 95% confidence, *** 99% confidence. Robust standard errors are reported between parentheses. The number of observations for each specification is reported between brackets. Each column in each panel displays the estimate of a separate regression (Eq. (1) augmented by the interaction with a dummy *high-enforcement country*).

above- and below-median countries along the *Time of debt enforcement proceedings*, as measured in Djankov et al. (2008).[13] We then estimate the elasticities β_h (below-median) and β_l (above-median) in a similar specification as (1) with interactions.

We report the separate estimates in Table 2. While the elasticity of tax compliance to tax rates is around $\beta_l = -0.50$ for low-enforcement countries, it falls around $\beta_l = -0.20$ for high-enforcement countries (see columns 3 and 4).

In the remainder of the paper, we develop an analytical framework which helps to understand (i) the magnitude of the empirical elasticity, and (ii) the possible sources of differences across countries.

3. A model of firm transparency and investment

This section presents a static model of firm transparency and investment which allows to derive macro-elasticities of tax revenues, transparency and output to taxes, accounting for firm size heterogeneity.

There are two crucial ingredients in our framework, and two main margins of adjustments. We assume that entrepreneurs face financial frictions under the form of a collateral constraint, and there is imperfect tax enforcement. We further assume that one margin of adjustment, *transparency*, governs both access to credit and tax pressure.[14] This assumption relies on the hypothesis that concealed activity is less pledgeable than declared activity. A lower tax compliance would reduce the capacity to levy funds. We also introduce two technologies, a traditional technology, and a more productive modern technology which requires an innovation. The fixed cost to operate in the modern sector implies that very small firms, which are not able to levy sufficient funds for investment in the modern technology to be profitable, mostly operate in the informal sector with the traditional technology and without external financing.

For the sake of exposure, the model specification is minimal. We ignore demand effects, and, as there is a unique final good, there is no substitutability between differentiated goods as a response to differential taxation. There is a unique production factor whose supply is infinitely elastic, subject to a collateral constraint. The supply of entrepreneurs and their endowments is considered as given in our closed economy, and we ignore the impact of taxation on the general structure of production including foreign direct investments. The government policy is taken as given and the model is static such that we do not rationalize the use of a fiscal consolidation. We assume that a tax authority exogenously sets an audit schedule.

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[13] Countries below-median are Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Japan, Luxembourg, Netherlands, New Zealand, Norway, Sweden, Switzerland, United Kingdom.

[14] The perfect correlation between transparency and access to credit seems to contradict recent findings in Artavanis et al. (2016). They find that the ratio of credit over income granted by bankers depends on the income declared by the borrower and the bankers' beliefs on undeclared activity. Bankers anticipate how reported income maps into real income based on the occupation of borrowers. Occupations characterized by high tax evasion are therefore those which are offered large loans relatively to their reported income. However, this result does not imply that borrowers can pledge their concealed activity exactly as their reported activity. Instead, the amount of credit is a function of their reported income multiplied by an occupation-specific factor, and a higher reported income for a given individual in each occupation would still be associated with looser credit constraints.

Finally, we disregard fiscal corruption, which is potentially important in countries with relatively low tax enforcement. While corruption does not modify tax receipts for the government for a given transparency, it does modify the entrepreneur's behavior ex-ante through the share that is captured by corrupt officials. Fiscal corruption could affect our conclusions if the surplus share that is captured by fiscal officials responds to taxes.

3.1. Environment

The economy lasts for one period and is populated by a continuum of risk-neutral entrepreneurs of measure one. Each entrepreneur is endowed with ω. Let $G(\cdot)$ denote the cumulative distribution of endowments.[15]

Firms produce a unique consumption good and use capital as the unique production factor. The market for the consumption good is perfectly competitive and there is an infinitely elastic demand at price $p = 1$.

There are two technologies available to entrepreneurs in order to produce the consumption good: a traditional one and a modern one. With the modern technology, capital can be used to produce the consumption good according to the following production function:

$$f(k) = Ak^\alpha.$$

By contrast, the returns on the traditional technology are linear and equal to ρ.

The access to the modern technology is conditional on producing an "innovation", whose success is subject to an idiosyncratic draw depending on innovation efforts. When an entrepreneur invests c, the entrepreneur gets access to the modern technology with probability $p(c)$. Since the access to the modern technology is stochastic, there may exist relatively informal firms using the traditional technology and relatively transparent firms using the modern technology for a same initial endowment.

We turn to the firm organization. Each entrepreneur owns a unique firm that is organized in a unit mass of homogeneous plants. The plants or establishments are homogeneous in the sense that entrepreneurs cannot use a different technology or different production factors across plants. We assume however that entrepreneurs can choose the fraction of plants whose value added is concealed. Each plant is either fully declared or fully informal, and let γ denote the fraction of declared plants (thereafter transparency). By assumption, γ is the share of declared collateral and output.

There is a tax authority which mechanically raises taxes τ on the reported value added, i.e., the value added generated in the declared establishments.[16] The tax authority has access to an audit technology and monitor firms in order to retrieve the concealed value added. Let $z(\omega)$ denote the probability to be monitored for a firm with initial endowment ω, and let us assume that z is an increasing function.[17] When a concealed plant is detected by the tax authority, firms pay the tax $\theta\tau$ on the concealed value added that is retrieved. $\theta \geq 1$ is the exogenous punishment for being detected.

We turn to financial markets. We assume that the economy is small and that the international financial market is willing and able to supply an unlimited amount of risk-less bonds that yield the international interest rate $r > 0$. Among entrepreneurs, those with small endowments might want to borrow in order to expand their investment in the modern technology. They can do so by issuing bonds, which are subject to a financial friction. Entrepreneurs can only pledge a share λ of declared endowment to their creditors.[18] As a result, entrepreneurs face the following credit constraint, which crucially depends on transparency[19]:

$$(1+r)(k-\omega) \leq \lambda\gamma\omega. \tag{2}$$

The timing of actions is as follows. Entrepreneurs invest in innovation, receive the innovation draw and decide whether to adopt the modern technology or not upon innovation success. Further, entrepreneurs decide on their level of transparency, which is going to jointly determine how many plants can be pledged to lenders and taxes to be paid to the government. They borrow capital $(k - \omega)$ at the international interest rate subject to the pledgeability constraint. Finally, they produce

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[15] We use heterogeneity in endowments in order to generate differential response to tax hikes across firms. However, one can think that such heterogeneity can also be indirectly generated by differences in fundamentals, e.g., heterogeneity in productivity, or in industry (and their reliance on external financing).

[16] We assume that there is only one unique tax rate on a unique final good. Accordingly, our model will not be able to generate the dynamic compositional effects justifying our careful empirical construction of tax compliance (see Section 2). In our quantitative results, we consider as fixed the share of firms subject to reduced and super-reduced tax rates (see Section 4).

[17] This assumption can be rationalized with a tax authority optimizing its auditing behavior, and subject to fixed or linear auditing costs as a function of endowment. An increasing auditing schedule would then arise as the equilibrium schedule, as smaller firms have otherwise higher incentives to be transparent (due to the collateral constraint).

[18] We assume here that only endowment can be pledged and not future earnings. The reason is essentially that, when entrepreneurs can freely adjust the extent to which they declare activity, they may not have any commitment to report future earnings once they have received funds from the investors. By contrast, endowment can be pledged when debt is contracted.

[19] Note that creditors can only seize a fraction of entrepreneur's endowment in transparent plants, and taxes are junior to this recovery process. This assumption rules away a potential gambling-for-resurrection behavior from entrepreneurs where they would evade taxes and leave creditors with the tax arrears in case of monitoring. We assume that creditors observe firm's endowment and technology but the recovery technology is fully inefficient at recovering funds from concealed plants. Alternatively, we can relax this assumption and assume that there exists two technologies $\lambda_t > \lambda_c$ to recover funds from transparent and concealed firms.

and reimburse their creditors. In parallel, once a technology has been adopted, the tax authority monitors with an audit effort z and firms pay taxes or fines following the audit outcome.

We have not specified yet whether entrepreneurs could have incentives in lending their endowment. We assume (i) that the return to the traditional technology is equal to the international interest rate $\rho = r$ and (ii) that credit is fully transparent and taxed at the same rate τ. This implies that (i) entrepreneurs prefer to invest in the traditional technology rather than lending, except if they are fully transparent, and (ii) never borrow to produce in the traditional technology.

In the following lines, we describe the equilibrium allocation characterizing our economy. In order to clarify the entrepreneurs' trade-off between low tax compliance and access to credit, we start with the entrepreneur's program once innovations have been made.

3.2. The entrepreneur

The traditional entrepreneur. We first consider an entrepreneur endowed with ω and the traditional technology, subject to an audit effort $p(\omega)$ from tax authorities. This traditional entrepreneur solves the following program:

$$\pi_\omega^{tr} = \max_\gamma \{[1 - \tau\gamma - (1-\gamma)\theta z(\omega)\tau]r\omega\}$$

The entrepreneur never borrows nor lends, and invests exactly her endowment. Her transparency choice, however, depends on how $\theta z(\omega)$ compares to 1. Strictly above 1, she becomes fully transparent ($\gamma = 1$). Strictly below 1, she remains fully informal ($\gamma = 0$). Otherwise, she is indifferent and any γ solves the optimization program.

The modern entrepreneur. We now consider an entrepreneur endowed with ω and the modern technology, and subject to an audit effort $z(\omega)$ from tax authorities. This modern entrepreneur maximizes her profits net of taxes subject to the credit constraint of Eq. (2):

$$\pi_\omega^{md} = \max_{\gamma,k} \{[1 - \tau\gamma - (1-\gamma)\theta z(\omega)\tau]Ak^\alpha - r(k-\omega)\},$$

subject to

$$(1+r)(k-\omega) \le \lambda\gamma\omega.$$

As long as $\theta p(\omega) \le 1$ and $\omega \le (A(1-\tau)\alpha/r)^{\frac{1}{1-\alpha}}$, the credit constraint is binding.[20] In this case, the solution $\hat{k}$ verifies:

$$A\alpha k^{\alpha-1}\left[1 - \theta z(\omega)\tau - \frac{(1+r)[1-\theta z(\omega)]\tau}{\lambda}\left(\frac{1+\alpha}{\alpha}\frac{k}{\omega} - 1\right)\right] = r, \tag{3}$$

and the transparency choice $\hat{\gamma}$ is obtained by substituting the solution $\hat{k}$ into the credit constraint. Eq. (3) is very intuitive.[21] There is a trade-off between borrowing, and reaping the high returns in the modern technology and the cost that it represents in terms of transparency. In order to borrow an additional unit from lenders, the firm needs to declare part of its activity and pay taxes (second term in the square brackets below). At the optimum, the difference between the gain and the cost should be equal to the price r of borrowing.

When the credit constraint is not binding, the solution to the program is close to the solution for the traditional technology case. The entrepreneur invests up to her optimal level $(A(1 - \tau\gamma - (1-\gamma)\theta z(\omega)\tau)\alpha/r)^{\frac{1}{1-\alpha}}$ and lends the rest of her endowment. The transparency choice depends on how $\theta z(\omega)$ compares to 1. Strictly above 1, she becomes fully transparent. Strictly below 1, she remains fully informal. Otherwise, she is indifferent and any γ solves the optimization program.

We now need to determine what is the initial choice, i.e., the investment in innovation c. We describe this choice and define the equilibrium of our economy next.

3.3. Equilibrium

Given the audit schedule $z(\omega)$, the entrepreneur solves:

$$\max_c \left\{ p(c)\pi_\omega^{md}(z(\omega)) + [1 - p(c)]\pi_\omega^{tr}(z(\omega)) - c \right\},$$

which brings:

$$p'(c)\left[\pi_\omega^{md}(z(\omega)) - \pi_\omega^{tr}(z(\omega))\right] = 1. \tag{4}$$

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[20] $(A(1-\tau)\alpha/r)^{\frac{1}{1-\alpha}}$ is the frictionless optimal level of capital, so that firms with an endowment higher than this level are not financially constrained.

[21] It could be that the solution to this equation implies that transparency is greater than 1. In this case,

$$k = \min\left\{\frac{(\lambda+1+r)\omega}{1+r}, \hat{k}\right\}, \gamma = \min\{1, \hat{\gamma}\}$$

As firm size increases, the innovation cost gets relatively smaller compared to the gains, i.e., the differences between operating with the traditional or modern technologies increase, and firms invest more in innovation. As a result, the share of firms that innovate and use the modern technology increases with firm size.

Naturally, since the incentives to innovate are crucially related to the differential gains between the two technologies, any downward shift in the returns to the modern technology, for instance through more stringent credit constraint or higher taxes, will reduce the investment in innovation for all firms.

Eq. (4) completes our set of equations characterizing the equilibrium:

Definition 1. Equilibrium.

Each entrepreneur of each type ω chooses the investment in innovation c (Eq. (4)), observes the realization of the investment and produces with the modern or traditional technology, maximizes profits subject to the credit constraint (Eq. (2)), and determines the level of capital and transparency (Eq. (3)).

The equilibrium allocation may be described by looking at two distinct endowment regions. When endowment is small, entrepreneurs need access to credit, and transparency and leverage depend on firm endowment through two channels. First, the probability to operate with the modern technology increases with endowment. Second, firms borrow such as to bridge the gap between their wealth and the optimal investment (which should imply that transparency decreases with endowment), but the difference between paying and evading taxes depends on the response of tax authorities. When firms are large enough, they do not borrow anymore and transparency increases with endowment such as to leave the absolute value of concealed production constant.

3.4. The behavioral response of the economy to a tax increase

We now illustrate important implications of the model. Consider the comparative statics exercise in which an adverse tax shock affects our economy, i.e., an increase in τ.

In our framework, we can distinguish two effects related to such tax increase. In the modern sector, transparency choices, leverage and production depend on the level of taxes. After an increase in taxes, declaring more plants in order to relax the credit constraints is costlieer and entrepreneurs conceal more. This effect can be interpreted as the *intensive margin* effect, i.e. modern firms adjusting their transparency. In parallel, taxes also depress investment in innovation such that higher taxes induce a lower share of firms operating in the modern sector. This effect can be interpreted as the *extensive margin* effect. In general, both the intensive and extensive margins work in the same direction and their intensity is mostly concentrated in small and medium size firms relying on external finance.

We turn now to the aggregate response. Let $\varepsilon^{\omega}_{\tau\gamma\nu}$, $\varepsilon^{\omega}_{\gamma}$, $\varepsilon^{\omega}_{\nu}$ denote, respectively, the elasticity of tax revenues, transparency and output with respect to taxes for any given endowment ω.

$$\varepsilon^{\omega}_{x} = \frac{dx}{d\tau}\frac{\tau}{x}$$

We can define equivalent aggregate elasticities as follows:

$$\underbrace{\int \varepsilon^{\omega}_{\tau\gamma\nu} dG(\omega)}_{\varepsilon_{\tau\gamma\nu}} = 1 + \underbrace{\int \varepsilon^{\omega}_{\gamma} dG(\omega)}_{\varepsilon_{\gamma}<0} + \underbrace{\int \varepsilon^{\omega}_{\nu} dG(\omega)}_{\varepsilon_{\nu}<0}$$

Notice that our elasticities are not the elasticities of aggregate quantities with respect to taxes, but rather the individual elasticities with respect to taxes weighted by their prevalence over the population of firms. In practice, our weighted elasticities will be very close to the elasticities of aggregate quantities.

This is a small open economy: prices (including bond prices) are fixed such that there are no general equilibrium effects. The aggregate elasticities are thus easy to derive from each entrepreneur's decisions.

Before turning to the quantitative analysis, we also need to define what is the role of transparency in the output drop captured by ε_{ν}. We decompose the response of output to taxes as follows:

$$\varepsilon_{\nu} = \nu_{\nu} + \nu_{\gamma}.$$

The response of output to taxes measured by the elasticity ε_{ν} has two components: the direct component ν_{ν} and the the indirect component ν_{γ}. The direct component is defined as $\nu_{\nu} = \varepsilon_{\nu,\gamma=\bar{\gamma}}$, and is the response of output to taxes maintaining transparency fixed. The elasticity ν_{ν} therefore measures the standard output drop in response to a tax hike, which is due to the lower expected returns in investment. The second component ν_{γ} measures the indirect impact of transparency on the output drop. As transparency falls in response to the tax hikes, the firm leverage decreases, which leads to a drop in output.

In the following section, we illustrate the quantitative importance of each elasticity, as we calibrate our model to the Greek economy to reproduce the recent austerity plans.
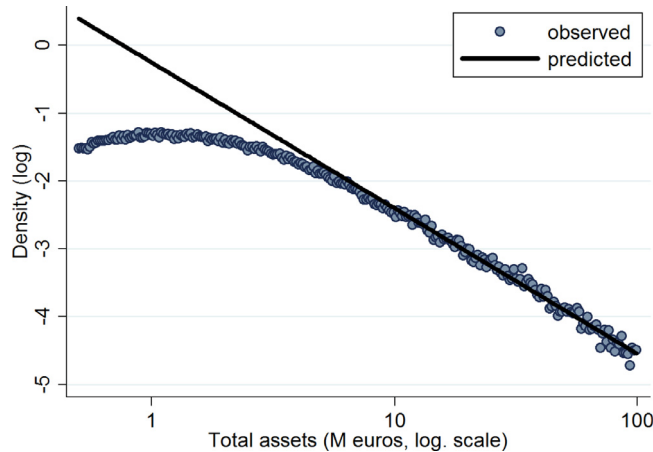
Fig. 1. Firm size distribution Greece. Note: This figure represents the observed firm size distribution in Hellastat (2009) and the predicted density computed using only firms with endowment above 10M euros. The x-axis is on a logarithmic scale.

4. Austerity in Greece

We provide in this section a quantitative analysis of the aggregate transparency response to tax hikes. We build on the previous theoretical framework and calibrate the model on a benchmark economy, i.e., Greece just before the 2010 adjustment program.

The organization of this section is as follows. We first study the crisis episode through the lens of our model: we provide some numerical estimates for the elasticities of transparency and output. We then provide additional insights on the distributional implications of tax hikes in our framework and discuss their empirical support.

4.1. The benchmark calibration

Our model allows us to match precise moments of firm heterogeneity. Naturally, these degrees of freedom are obtained at the expense of some others: we consider the size distribution of firms as exogenous based on the fact that firm endowment is not as responsive as investment or transparency. Similarly, we shut down the possibility for technology and other fundamentals of the economy to evolve.

We calibrate the model using firm-level balance sheet data from Hellastat.[22] This dataset consists in comprehensive balance sheet information of Greek firms over the period 2001–2013. Firms have to publish their balance sheets whenever two of the following three criteria are fulfilled: (i) turnover: 3M, (ii) total assets: 1.5M, (iii) average staff: 50 people. We therefore observe the universe of registered firms above these thresholds and smaller firms that publish their accounts on a voluntary basis. After cleaning the data for missing observations, we are left with more than 25,000 firms per year. The dataset is an unbalanced panel.[23]

Our sample of firms represents a very high share of Greek economic activity (more than 80%). Firms with assets above 9 million euros are observed with certainty and very small firms (with assets below 100,000 euros) are mostly unobserved. Between those two thresholds, we only observe a sub-sample of firms, which, in practice, may be biased. Fig. 1 shows that the firm size distribution is Pareto above the threshold of 9 million euros, as the logarithm of density is a straight line when firm size is Pareto distributed. The distance between the Pareto benchmark and our data can be interpreted as the "missing firms" in the sample.

In order to account for these missing firms, we assume that the real distribution of firms $g(\omega)$ is the Pareto distribution estimated in Fig. 1, and suppose that unobserved firms are fully informal in 2009 and remain fully informal after the tax increase. This assumption is a compromise between two extreme assumptions: 1. that we observe all firms, and 2. that the missing firms are similar (in terms of transparency and leverage) to the observed ones. As a robustness check, we compute our main quantities of interest in both cases, and use the results as reasonable bounds for the true elasticities.

Another question that arises is whether we observe the actual endowment of firms or whether this variable already suffers from under-reporting. In the model, taxes are not directly based on firm endowment but on value added, and we suppose that firm endowment is fully observed by tax authorities. In order to be consistent with the model, we consider that the assets reported in Hellastat reflect total firm size including assets that could be related to undeclared activity. By

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[22] We thank the research director of the Foundation for Economic and Industrial Research (IOBE), Aggelos Tsakanikas, and Evaggelia Valavanioti for giving us access to Hellastat data.

[23] There is non-negligible exit in the recession, mainly driven by small firms with a higher-than-average leverage. We can perform the same exercise on the balanced panel without significant differences in the results.
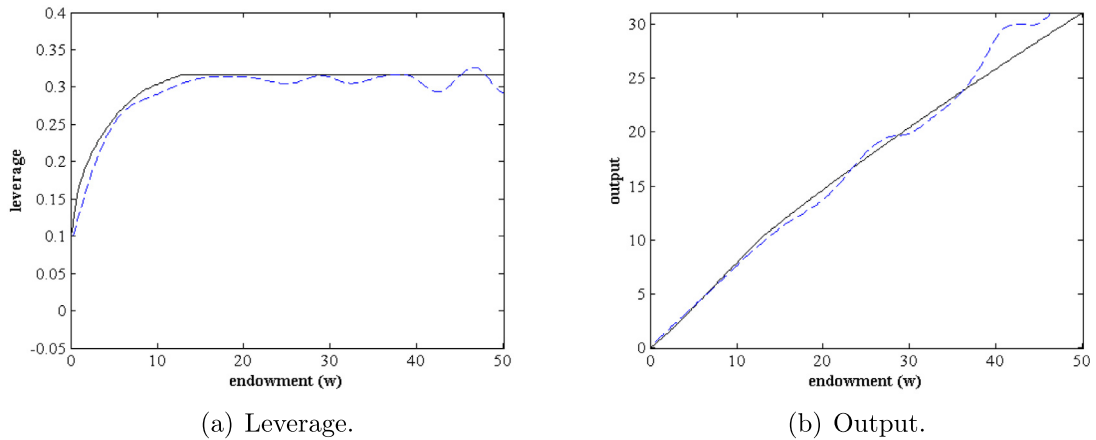
(a) Leverage.　　　　　　　　　　　　　　　　(b) Output.

Fig. 2. Empirical and theoretical leverage and output. Note: Benchmark calibration. The solid lines are the calibrated leverage and output, the dashed lines are the empirical leverage and output for firms with assets between 0.5 and 50M euro (smoothed using a HP filter).

Table 3
Austerity in Greece – benchmark calibration.

	Interpretation	Value	Rationale
α	Returns to scale	0.82	Sales – Hellastat (2009)
r	Interest rate	0.08	Bank of Greece (2009)
A	Productivity factor	0.92	Distribution output – Hellastat (2009)
λ	Collateral pledgeability	0.50	Distribution leverage – Hellastat (2009)
β_p	Innovation (scale)	0.30	Distribution leverage – Hellastat (2009)
c_0	Innovation (factor)	2.10	Distribution leverage – Hellastat (2009)
ψ	Shape (size dist.)	1.9	Distribution size – Hellastat (2009)
θ	Punishment	1.5	Tax Procedure Code (2010)
τ	VAT – low rate	0.045 (18%)	VAT – Greece (2009)
	VAT – medium rate	0.09 (12%)	VAT – Greece (2009)
	VAT – high rate	0.019 (70%)	VAT – Greece (2009)

Note: see Section 4 and the Appendix Section B.3 for a detailed description of the calibration.

contrast, one can think that reported assets are assets in declared plants in which case we would need to consider that the observed firm size distribution is an endogenous object that is (slightly) different from reported firm size distribution because of misreporting.

We describe in the online Appendix how we calibrate the model, and match the most important empirical moment—the distribution of leverage across firms (Fig. 2). Table 3 reports the benchmark calibration. We later show the sensitivity of our results to these parameters.

At the initial equilibrium, the level of aggregate transparency in the economy, defined as the ratio between the aggregate tax base and aggregate output, is equal to 0.82. This is slightly higher than what is typically estimated in the literature,[24] and we may underestimate the influence of small firms in our analysis. However, those informal firms typically do not respond to changes in tax conditions—they form an inelastic informal sector. Accounting for these firms boils down to adding a fixed informal sector, which would mechanically reduce our estimates for aggregate transparency.

4.2. Quantitative results

Using our benchmark calibration, we analyze the effect of changes in the VAT rate on our economy. The objective of our numerical simulations is to replicate the 2010 Greek fiscal consolidation and analyze how the transparency response could explain the observed misalignment between predicted tax revenues and actual tax revenues. To this purpose, we set the same tax rates as the government and estimate our predicted tax revenues, and the elasticities (ε_γ, ε_v).

We update the VAT rates according to the austerity measures implemented in 2010. The minimum VAT rate increased from 4.5% to 5.5%, the reduced VAT rate from 9% to 11% and the standard VAT rate from 19% to 23%. The repartition along VAT categories is invariant with firm size. In practice, we run three experiments for firms subject to the low, medium and

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[24] The shadow economy in Greece is typically estimated around 25%. See Schneider et al. (2010).

Table 4
Austerity in Greece – results.

	Baseline experiment	Fixed transparency
	Percentage changes	
Tax rate	21.410	21.410
Tax base	−9.218	−1.390
Output	−2.073	−1.065
Transparency	−7.341	−0.332
	Elasticities	
Tax revenue $\varepsilon_{\tau\gamma\nu}$	0.557	0.951
Transparency ε_γ	−0.343	0.000
Output ε_ν	−0.099	−0.049

Note: see Section 4 for description of the experiments.

high tax rates and we aggregate our results – using as weights the shares of firms producing goods subject to each VAT regime – in order to deduce the aggregate response of the economy.

The results are reported in the second column of Table 4. Following the increase in the tax rates, the model predicts a drop in the tax base of 9% explained by a decrease of transparency (−7%) and output (−2%). Given the amplitude of both responses (essentially the transparency adjustment), almost half of the increase in taxes is diluted and does not translate in higher tax revenues.

We can interpret these results in terms of elasticities to taxes. We find that the elasticity of tax revenues to the change in VAT rate introduced by the austerity plans is $\varepsilon_{\tau\gamma\nu} = 0.56$. The model-based behavioral response is composed of two elements, the standard behavioral response with a decrease in the real activity, and the decrease in the extent to which the activity is declared. We estimate the second element to be the largest: the transparency response ε_γ accounts for a bit more than three quarters of the fall in the tax base (−0.34 out of −0.44), whereas the output response ε_ν accounts for the remaining quarter (−0.10 out of −0.44). The elasticity of transparency to tax rates ε_γ is consistent with (i) the systematic empirical analysis conducted in Section 2 which gave a range between −0.2 (high legal enforcement) and −0.5 (low legal enforcement), and (ii) the empirical evidence on the elasticity of tax compliance to the Greek tax reform in 2010 (see online Appendix).[25] We interpret this finding as an external validation of our calibration strategy, since we did not use this moment (the observed fall in VAT compliance) to calibrate the model.

Since we acknowledge that there may be "missing firms" in our sample, we assume that we do not observe informal small firms in 2009 which remain fully informal after the tax increase. We now modify this assumption and rather consider that in our sample we observe all firms. Under this assumption, the elasticity of transparency and output are very similar to our benchmark case (respectively −0.32 and −0.11). In contrast, when we assume that there exist unobserved small firms that behave exactly like the observed ones, the absolute elasticity of transparency increases significantly ($\varepsilon_\gamma = -0.48$), because there are more firms responding by adjusting their transparency. One can therefore think that the elasticity of transparency should lie between these two extremes $-0.48 < \varepsilon_\gamma < -0.32$. As regards the elasticity of output, it remains almost unchanged in both cases.

We have shown that most of the drop in expected tax revenues come from a drop in transparency. This transparency adjustment has also an impact on the extent to which output decreases. Indeed, when small and medium-size firms reduce their transparency, they tighten even further their credit constraints and reduce accordingly their credit demand. A simple experiment which highlights the quantitative impact of such channel is to replicate the fiscal consolidation maintaining constant the transparency of firms. Under the assumption of fixed transparency, the contribution of transparency to output changes is nil, i.e., $\nu_\gamma = 0$. It allows us to identify $\nu_\nu = \varepsilon_\nu$, i.e., the standard fall in output purged of the transparency effect. The last column of Table 4 reports the results of the simulation where the transparency response is shut down, that is when $\varepsilon_\gamma = 0$ and $\nu_\gamma = 0$, and the only effect that is captured is the standard fall in output $\nu_\nu = -0.05$. This result shows that the indirect impact of transparency on the output response accounts for more than half of the total output response. In other words, had the transparency been insensitive to changes in taxes, the output drop would be 1 percentage point lower. This simple exercise points to the large influence of the transparency channel both in the relatively small increase in tax revenues and in the subsequent output drop.

In addition to the aggregate estimates, it is interesting to study the distributional implications of the tax hike. Fig. 3 shows the elasticities of transparency and output to tax hike along firm size. Most of the drop in tax revenues is due to middle-size firms that either drop off the formal economy or adjust their transparency downward. In order to understand why the response of middle-size firms is important, we can represent our economy as follows. There are three types of

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[25] The comparison between the empirical elasticities and the model predictions is not straightforward. Indeed, the theoretical elasticity can be interpreted as causal as we keep fixed other characteristics of the economy (financial development, endowments, pre-tax relative returns to technology) while the empirical elasticities may partly reflect omitted variables, reverse causality or anticipations from economic agents. In addition, the empirical exercise relies on an average response across different economies with different fundamentals and different tax reforms (including changes in tax base which we do not model theoretically).
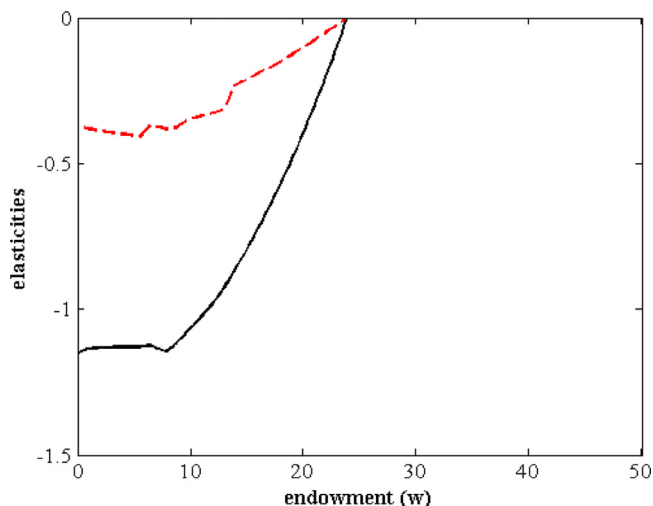
Fig. 3. Transparency and output elasticity by firm size. Note: The solid line is the elasticity of transparency ε_γ, the dashed line is the elasticity of output ε_v as a function of firm size. Both are computed using the 2010 austerity plan simulation. See Section 4 for a description of the experiment.
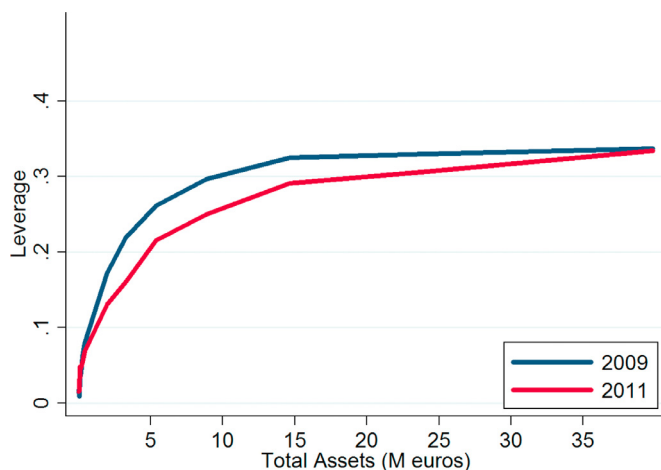

Fig. 4. Leverage as a function of firm size before and after the 2010 tax reform. Note: Source Hellastat, 2009, 2011. This graph displays the leverage by firm size (total assets) before (2009) and after (2011) the austerity plan.

firms: small informal ones, large transparent ones and middle-size firms. Following the tax hike, small firms remain informal and large firms remain transparent. If there were only such firms in the economy, there would be no transparency response to tax increase but only an output response driven by lower expected returns, and the overall elasticity of tax revenues to tax revenues would be close to 1. By contrast, middle-size firms react by changing their level of transparency, i.e., either by becoming fully informal or by reducing the extent to which they declare their activity. Tax base decreases so much for these firms that the elasticity of tax receipts to tax rates is negative. These firms are on the right-hand side of the Laffer curve: if there were only such firms in the economy, the increase in taxes would actually *reduce* tax revenues. These observations rationalize the use of size-dependent tax policies, a possibility that we further explore in Section 5.

We also find direct evidence of this size-specific credit crunch in our panel of firms (see Fig. 4): there has been a shift of credit out of small and medium-size firms during the crisis. The empirical evolution of credit along firm size is comparable to our theoretical predictions (see Fig. 5), both quantitatively and qualitatively.[26] Overall, our model does not only match well the aggregate evolution in credit and transparency, but also its distributional features.

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[26] In the online Appendix, we provide some evidence on the relationship between firm size and tax compliance elasticities. We focus on the 2010 Greek austerity plan, estimate regional tax compliance elasticities and show the importance of firm size differences across regions to predict the response of tax compliance.
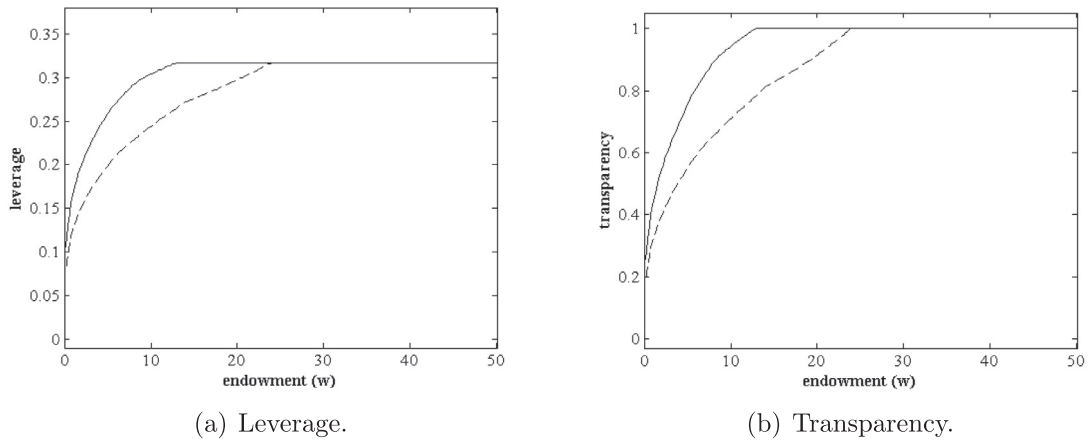
(a) Leverage.   (b) Transparency.

Fig. 5. Leverage and transparency: the impact of the 2010 tax reform. Note: Leverage and transparency along firm size for the benchmark calibration (solid line) and the 2010 austerity plan simulation (dashed line).

5. Counterfactual experiments

In this section, we perform some comparative statics and estimate how variations in the fundamentals of our economy may explain wide variations in elasticities across countries, as illustrated by our empirical analysis. We also explore the impact of other tax policies in order to further analyze the heterogeneous response along firm size.

5.1. The role of fundamentals

We now investigate which fundamentals of our economy may explain the large observed differences in the tax compliance response to tax hikes. The previous analysis shows that the elasticity of tax revenues to tax reforms depends on the number of firms at the margin between informality and formality, i.e., the number of firms relying on external finance but not fully transparent. The number of such firms is determined by (a) the range in which firms are almost indifferent between informality and access to credit, (b) the density of firms in this range, and both quantities are pinned down by fundamentals of the economy, i.e., the legal enforcement (represented here by lender protection) and firm size distribution. In the following lines, we describe our comparative statics exercise to understand the quantitative role of these two fundamentals.

In our framework, changes to fundamentals modify both the "steady state" of the economy and the elasticities of tax revenues, transparency and output to taxes. We take advantage of this observation in order to represent our elasticities, not as a function of each underlying parameter but rather as a function of steady-state quantities. For the share λ of observed investment that can be pledged, we define $\lambda \mapsto \Gamma(\lambda)$, where $\Gamma(\lambda)$ is the aggregate transparency. We compute the elasticities of tax revenues $\epsilon_{\gamma\tau\nu}(\lambda)$, transparency $\epsilon_{\gamma}(\lambda)$ and output $\epsilon_{\nu}(\lambda)$ to taxes as functions of λ. The objective is to study how the response to taxes depends on steady-state aggregate transparency when the variations in steady-state aggregate transparency are only driven by different credit market conditions. Similarly, we compute the same elasticities as functions of ψ, and define the same mapping $\psi \mapsto \Gamma(\psi)$ for the aggregate transparency as function of the shape of the firm size distribution ψ.

Figs. 6 and 7 display these elasticities. The solid blue line is the elasticity of tax receipts ($\varepsilon_{\tau\gamma\nu} = 1 + \varepsilon_{\gamma} + \varepsilon_{\nu}$), the dashed red line is the transparency component of the elasticity of tax receipts ($1 + \varepsilon_{\gamma}$). On the horizontal axis, we report aggregate transparency which moves with the underlying fundamental: it increases with the pledgeability parameter λ, whereas it decreases with the shape parameter ψ. A high level of ψ corresponds to lower tail for the firm size distribution, and the density of firms at the margin of informality is higher.

As shown in Fig. 6, as we increase the extent to which collateral can be pledged (λ), the elasticity of tax revenues to tax rate slightly increases. When financial development increases, the pressure of the credit constraint is lower for larger firm but higher for smaller firms, which are now investing more in the modern technology. Both effects together imply a higher aggregate elasticity $\epsilon_{\gamma\tau\nu}$ for more financially developed economy (medium-size firms represent a low share of the economy). The variation in transparency response across the different institutional environments is quantitatively relevant: an increase from 78% to 82% in aggregate transparency due to a change in credit constraints reduces the transparency elasticity from -0.40 to -0.25 (a variation that is of the same order of magnitude as our observed empirical estimates).

By contrast, the output response to taxes seems to be barely affected by an improvement in financial development as the gap between the blue line ($\varepsilon_{\gamma\tau\nu}$) and the dotted red line ($1 + \varepsilon_{\gamma}$) in Fig. 6 remains constant.

We then study how the relative weight of large versus small firms in the economy modifies the elasticity of tax revenues to tax reforms. An economy with a fat-tail firm size distribution (low ψ) is less responsive to taxes since most of the effect
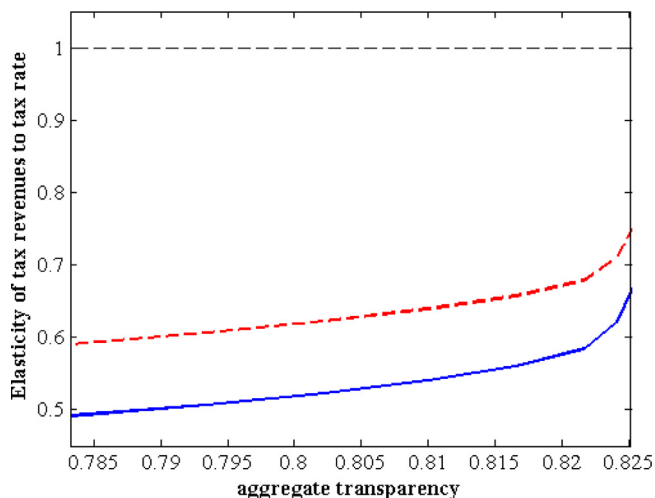
Fig. 6. Elasticity of tax revenues to tax reforms: the role of credit frictions. Note: The solid line is the elasticity of tax revenues ($\varepsilon_{\tau\gamma\nu} = 1 + \varepsilon_\gamma + \varepsilon_\nu$), the dashed line is the transparency component of the elasticity of tax revenues ($1 + \varepsilon_\gamma$). In the horizontal axis we report the aggregate transparency $\Gamma(\lambda)$ which is associated with values of $\lambda \in [0.42, 0.58]$. See Section 5 for a description of the counterfactual experiment.
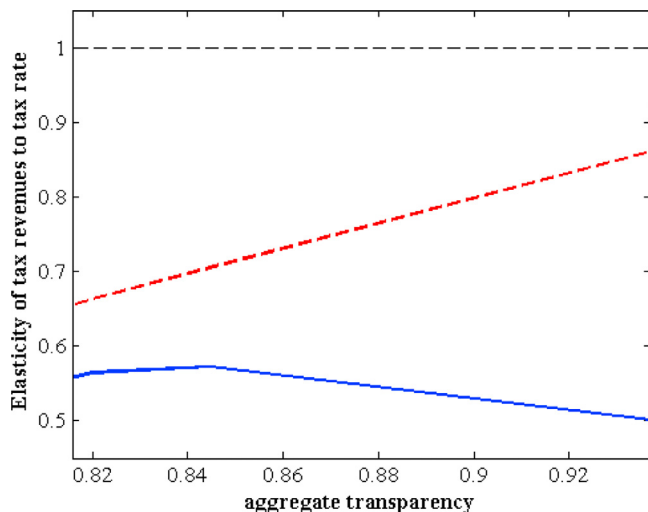

Fig. 7. Elasticity of tax revenues to tax reforms : the role of firm size distribution. Note: The solid line is the elasticity of tax revenues ($\varepsilon_{\tau\gamma\nu} = 1 + \varepsilon_\gamma + \varepsilon_\nu$), the dashed line is the transparency component of the elasticity of tax revenues ($1 + \varepsilon_\gamma$). In the horizontal axis we report the aggregate transparency $\Gamma(\psi)$ which is associated with values of $\psi \in [1.3, 2.3]$. See Section 5 for a description of the counterfactual experiment. Note that aggregate transparency is decreasing with the shape of firm size distribution ψ.

comes from the weight of medium-size firms. In parallel, the output response increases, as the number of unconstrained and large firms increases (these large firms are the ones for which the standard behavioral response to taxes is the largest). This is the reason why the gap between the dotted red line ($1 + \varepsilon_\gamma$) and the blue line ($\varepsilon_{\gamma\tau\nu}$) in Fig. 7 widens and the overall elasticity of tax revenues to taxes slightly decreases with aggregate transparency. If we only increase instead the number of medium-size firms, we would find a much lower aggregate elasticity $\varepsilon_{\gamma\tau\nu}$. To summarize, while the elasticity of tax revenues to tax reforms is not sensitive to changes in firm size distribution, the transparency response is quite responsive: an increase from 82% to 86% in aggregate transparency due to a change in firm size distribution (lower number of small firms) reduces the transparency elasticity from −0.35 to −0.28.

Finally, in Fig. 8, we plot the aggregate elasticity for different combinations of λ and ψ while keeping the sanctions at its benchmark level. The quantitative results suggest that the elasticity of tax revenues to tax reforms is in the range [0.45, 0.65]. These results are consistent with the empirical estimation of the changes in VAT compliance associated with VAT reforms shown in Table 2. The lower bound of the range of elasticity corresponds to an economy where financial development is low and the firm size distribution is shifted towards small and medium size firms. The upper bound refers instead to countries where legal enforcement is of better quality and firms on the verge of becoming informal are very
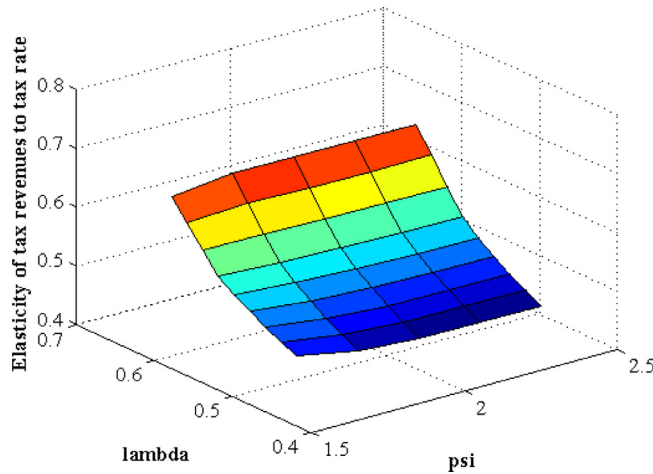
Fig. 8. Aggregate elasticity of tax revenues – credit frictions λ and firm size shape ψ. Note: This Figure represents the aggregate elasticity of tax revenues as a function of credit frictions λ and firm size shape ψ. See Section 5 for a description of the counterfactual experiment.

small.[27] This simple analysis points to the distribution of firm size as a crucial, and so far, under-explored, factor behind the success of a fiscal consolidation in raising tax revenues.

5.2. The characteristics of tax reforms

The previous section has provided comparative statics along some of the fundamentals governing the steady-state economy. The next exercise examines the sensitivity of the response to the type of tax reforms. Indeed, while most peripheral European countries in the recent crisis have increased VAT rates to a certain extent, some economies have relieved tax pressure on small and medium firms. For instance, the 2010–2011 VAT reform in Portugal (with an increase in the standard rate from 20% to 23% between 2010 and 2011) was followed by a size-dependent reduction in corporate tax rates, and a simplified corporate tax reporting system for smaller firms. In Spain, a similar phased-in reduction in corporate tax rates also featured reduced rates for small firms, and Italy raised the VAT registration threshold for smaller businesses.

One interesting feature of these fiscal reforms is their size-dependence. The rationale behind our current model should justify such policies. Indeed, as shown in Fig. 3 and briefly discussed in Section 4, the response to a VAT increase crucially depends on firm size, and size-dependent policies may be more desirable than an unconditional increase. A targeted VAT exemption for small firms, e.g., a stable rate, should neutralize both margins of the transparency response: the choice of transparency for entrepreneurs in the modern sector would not be further distorted, and the relative returns to the modern technology would be left unchanged. A reform of corporate tax rates as in Portugal or Spain or a simpler reporting system would mostly change the relative returns to the modern technology and alleviate the distortion at the extensive margin, but would not affect the choice of leverage in the modern sector.

In order to quantify these effects, we proceed as follows. We build upon the calibrated baseline economy and the baseline VAT reform (see Section 4), and we perform the following sensitivity experiments.

In a first step, we add to the baseline experiment the equivalent of a reduction in corporate tax rates as observed between 2013 and 2014 in Portugal, with a decrease from 25% to 23% for larger firms and a further reduction to 17% for firms with an endowment below 1M.[28] Experiment (E1) thus features the same VAT increase as in the baseline, and a reduction in corporate taxes. Column 2 of Table 5 reports the elasticities of VAT revenues, output and transparency to the VAT rate following experiment (E1). While the corporate tax reduction alleviates the transparency and output responses, its quantitative impact is negligible. The main explanation behind this pattern is that corporate taxes do affect the relative returns to the modern technology, but not the transparency choice and access to credit conditional on using the modern technology. A reduction thus pushes more firms to invest in the modern technology but the transparency choice is unaffected.

In a second step, we study two additional experiments to decompose the lower response of transparency and output observed in experiment (E1). Experiment (E2) features a uniform decrease in corporate rates from 25% to 23%, while experiment (E3) only features the reduction for small firms (from 25% to 17%). Columns 3 and 4 of Table 5 show that most of the attenuation effect observed in experiment (E1) was related to the global reduction in corporate rates (as opposed to the

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[27] Many developed countries have a firm size distribution which may be represented as a Pareto with a shape parameter close to 1, as shown by Axtell (2001) for the US or Levchenko et al. (2010) for France.

[28] The threshold for reduced corporate rates in Portugal was based on profits before taxes. In order to convert a threshold based on profits into a threshold based on endowment, we use Hellastat and choose the maximum endowment for which the median profit is below the Portuguese threshold of 12,500 euros.

Table 5
Austerity in Greece – counterfactual reforms.

	Baseline	E1	E2	E3	E4
	Elasticities				
Tax revenue $\varepsilon_{\tau\gamma v}$	0.5573	0.5653	0.5632	0.5601	0.6793
Transparency ε_γ	−0.3435	−0.3429	−0.3431	−0.3433	−0.2359
Output ε_v	−0.0992	−0.0918	−0.0937	−0.0967	−0.0848

Note: Experiment E0 represents the baseline experiment, i.e., an increase of 21.4% in the effective VAT rate. Experiments E1–E3 add to this experiment a reduction in corporate tax rates: 25–23% for large firms and 25–17% for small firms in E1, 25–23% for all firms in E2, 25–17% for small firms in E3. E4 builds on the baseline experiment (no change in corporate tax rates) and exempts small firms from the VAT increase. Small firms are firms with an endowment lower than 1 million euros.
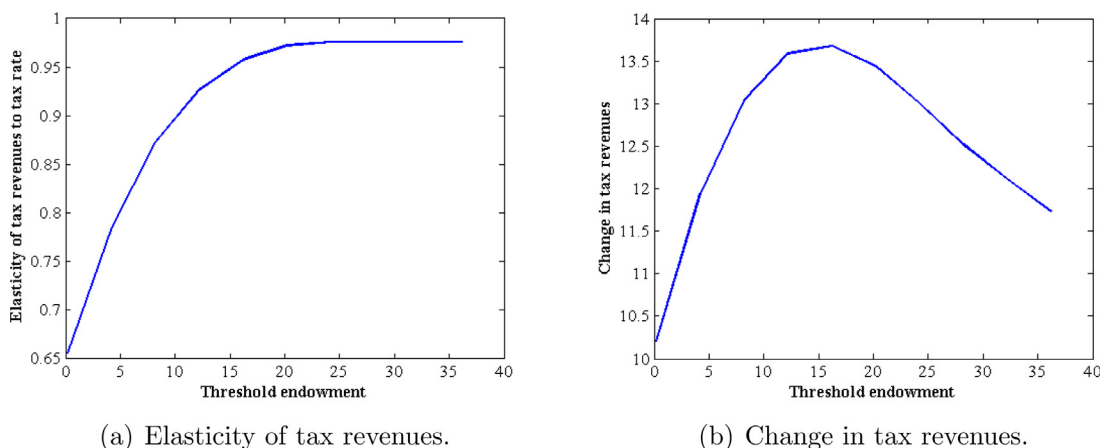

(a) Elasticity of tax revenues.   (b) Change in tax revenues.

Fig. 9. Aggregate elasticity of VAT revenues and percentage change in VAT revenues – VAT rise exemption below a threshold. Note: Response to counterfactual VAT reforms for which smaller firms are exempt from the VAT increase. For instance, for a threshold of 1 million euros, all firms below 1 million euros would be subject to the pre-reform VAT rates. See Section 5 for a description of the counterfactual VAT reforms.

additional reduction for small firms). These findings confirm, as discussed earlier, that a non-negligible source of distortion remains, even with low corporate taxes: entrepreneurs with low endowment still face high credit constraints and thus low expected returns to the modern technology.

In a third step, we allow the government to implement a size-dependent VAT reform.[29] We assume that the government increases VAT as in the baseline but only above a certain endowment threshold that we set to 1 million euros, and smaller businesses face the pre-reform VAT rates. As shown by experiment (E4) in Table 5, the transparency response to the VAT increase is then reduced by a third, and the output response is 15% smaller than in the baseline. We then vary the threshold between 0 and 40 million euros, and replicate experiment (E4) with the varying thresholds. The findings are shown in Fig. 9. The left panel reports the elasticity of tax revenues to the VAT increase as a function of the threshold, and the right panel the percentage change in tax revenues. As the elasticity of tax receipts is negative for very small firms (see Fig. 3), the aggregate elasticity of tax revenues to tax rates initially increases as the policy exempts small firms from the tax hike. It reaches its maximum when all firms for which the elasticity is negative are exempted. This finding shows that size-dependent VAT reforms are more effective than a uniform VAT hike, and there is an "efficient" threshold: a revenue-maximizing policy should exclude small and medium firms with total assets between 0 and 15 million euros.

These findings shed some light on reforms in other peripheral European economies. Size-dependent tax reforms echo the heterogeneous response of tax revenues to tax rates along firm size. The size-dependent corporate tax reforms in Portugal or Spain marginally relieved tax pressure on these very responsive firms. However, and as shown by the last counterfactual exercise, the need for a size-dependent policy is particularly pronounced through VAT because VAT distorts demand for credit in addition to tilting the trade-off between the traditional and modern sectors.

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[29] This type of tax reforms usually hinges on differential changes in standard, reduced and super-reduced rates, or a registration threshold.

6. Conclusion

When firms adjust the degree to which they declare their activity—their transparency—in response to tax changes, the standard erosion of the tax base is augmented by the erosion of transparency. We document this effect using a novel measure of VAT compliance across 35 countries. We then develop a model in which firms adjust their declared activity. We calibrate the model to the recent fiscal consolidation episode in Greece and show that there is a large behavioral response and three quarters of the overall behavioral response to the tax increase come from this transparency channel. As transparency guarantees a better access to credit market, firms switching to the informal sector are excluded from credit markets thereby depressing aggregate output.

One direct implication is that the amplitude of the transparency response depends upon the number of firms at the margin between formality and informality. The behavior of those firms is very sensitive to changes in the trade-off between credit access and tax compliance. Low tax monitoring and intermediate financial development contribute to having quite large and numerous small-medium firms for which the transparency response to taxes is important. Our quantitative analysis shows that variations in the fundamentals of the economy, i.e., the legal enforcement, the financial development and the firm size distribution, are able to explain the large differences across countries in the response of tax compliance to tax hikes shown in our empirical results. Quantitatively, we find leakages consistent with our empirical estimates. In our quantitative framework, the increase in tax revenues is almost twice lower than if tax compliance had been constant.

The policy implications of our analysis are not immediate. We show that a drastic fiscal consolidation in an economy with low tax enforcement and low financial development is very likely to be diluted. Improving these institutions would help but is a difficult task: periods of economic turbulence may not be times in which structural reforms are simple to implement. One direct implication of the model is that the efficiency of a tax increase essentially depends on the number of firms (and their size) that are almost indifferent between declaring their activity or being fully informal. Economies with low financial development and inefficient tax monitoring may be willing to implement size-dependent tax policy and exempt very responsive firms. One possible policy would consist in designing targeted tax deductions when firms rely on external finance, or simply conditioning tax payments on firm size.

Finally, there are several macroeconomic mechanisms that we ignore in our quantitative exercise. For instance, the analysis relies on a partial equilibrium model, and the supply of capital, the unique production factor, is infinitely elastic. Recent episodes of fiscal consolidation, e.g., Greece in 2010, were a response to debt overhang. As the domestic banking sector usually owns a large share of sovereign bonds, fiscal policies may indirectly affect credit supply through this default risk channel. The analysis is also in closed economy, and assumes that entrepreneurs are in fixed supply. An open economy framework could account for the sensitivity of foreign direct investment to taxation, which may not be negligible as shown in Cummins and Hubbard (1995). Last, our model ignores the motivation behind fiscal consolidations. An interesting extension would consist in endogenizing government decisions. Reducing debt levels, a positive aspect of fiscal consolidations, may come at the expense of economic viability, especially for smaller firms. A government with low financial development and loose tax enforcement would have lower incentives to implement fiscal consolidations, and higher incentives to default. We leave these extensions for further research.

Supplementary material

Supplementary material associated with this article can be found, in the online version, at 10.1016/j.euroecorev.2017.09.007.

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