Hanging off a cliff: fiscal consolidations and default risk*

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Abstract

In countries with imperfect tax enforcement, tax compliance is volatile and markedly responds to fiscal policy. To explore the consequences of this fact, we build a model of sovereign debt with limited commitment and distortionary taxes, in which fiscal consolidations generate long-run distortions which affect default risk. The interaction of imperfect tax enforcement and limited commitment allows to reproduce the following empirical regularities. First, the sensitivity of debt price to fiscal policy differs across environments. Some highly indebted economies are hanging off a cliff, and cannot lower the cost of servicing debt with fiscal consolidations. Second, distortions give rise to pro-cyclical fiscal traps, and periods of high tax rates, low output, high tax evasion and high default risk may be long-lasting. Third, the model replicates dynamics of fiscal policies in high- and low-tax enforcement environments, and rationalizes the rise of pro-cyclical fiscal policies.

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1 Introduction

In May 2016, seven years after the start of the European sovereign debt crisis, Greece implemented its thirteenth austerity package, featuring an increase in VAT and increased excise taxes on fuel and tobacco. These successive fiscal consolidations, also observed in other peripheral European economies plagued by tax evasion, did not reduce debt service and exacerbated the economic downturn. Economies may thus experience long periods of high taxes, depressed demand and high default risk—a phenomenon referred to as *austerity trap* in the media.

In this paper, we study the dynamics of fiscal policy and default risk when tax enforcement is imperfect. First, we document new stylized facts about the dynamics of tax evasion, most notably its volatility and sensitivity to tax rates. Second, we provide a model of sovereign debt with limited commitment in order to explore how these fluctuations (i) affect the impact of fiscal consolidations on default risk and debt prices, (ii) contribute to the existence of an austerity trap, and (iii) rationalize the differences in dynamics of (optimal) fiscal policies across countries.

We construct a measure of tax compliance based on Value-Added-Taxes (VAT), and we uncover important stylized facts.[1] First, tax compliance is volatile, and there is a large heterogeneity in such volatility across countries. Second, the volatility of tax compliance is driven by its pro-cyclicality and its sensitivity to tax rates. In some economies with imperfect tax enforcement, a larger share of taxpayers hide their activity in downturns and in periods of austerity. In contrast with the standard behavioral response, the magnitude of the tax compliance response implies sharply decreasing marginal returns to taxes, and some economies display an extreme form of fiscal fatigue (Ghosh et al., 2013).

We then analyze the implications of fluctuations in tax compliance on the dynamics of optimal fiscal policy in a model where a benevolent government uses fiscal policy as a consumption-smoothing instrument. The key ingredients of our model are imperfect tax enforcement and limited commitment. The government smoothes consumption on behalf of the household, and does so with a distortionary instrument (i.e., an indirect tax). Entrepreneurs can adopt two technologies in order to produce the final good: an unobserved technology—which constitutes the informal sector of the economy—and a verifiable technology—the formal sector—with production

[1] Our proxy for general tax compliance is a measure of VAT compliance, and there may be differential responses to different tax instruments that we ignore. The rationale for analyzing VAT is manyfold: it constitutes a large share of tax revenues, even more so in developing economies; it is an important instrument of adjustment for governments; reconstructing counter-factual tax revenues under perfect tax compliance requires very few assumptions.

complementarities.[2] We assume that this choice is staggered, as in Calvo (1983), and an entrepreneur may be able to reset technology with a certain probability in each period. An increase in tax rates distorts the choice of entrepreneurs, and diverts them away from the formal sector thereby affecting the future cost of raising tax revenues. Importantly, the government has limited commitment such that debt prices reflect future incentives to default, and thus the degree to which the economy is expected to be distorted. Finally, there are two sources of punishment which give (limited) commitment to the government following a default: market exclusion and a direct output cost possibly reflecting a failure of the domestic banking sector (Mendoza and Yue, 2012).

The novelty of the model is to introduce dynamic distortions through tax evasion. In standard models of sovereign debt with limited commitment (Eaton and Gersovitz, 1981; Arellano, 2008), the price of debt depends on the (endogenous) debt level and an exogenous state variable, e.g., current productivity. In this benchmark, a fiscal consolidation reduces future debt levels and unambiguously lowers default risk. By contrast, our model adds another endogenous state variable which affects default risk, i.e., the expected distortions as captured by tax compliance. A fiscal consolidation affects the contemporary technological choice of entrepreneurs, which increases the future expected cost of raising tax revenues and tilts the future trade-off between repayment and default. This indirect effect mitigates the gains in debt service through the "debt level" effect.[3]

The model displays interesting dynamics for high debt levels: the dynamic system is characterized by an attractor close to the default zone which behaves as an austerity trap. Investors have low expectations on potential reimbursement thereby preventing the government to accumulate further deficits. The government cannot implement reflation policies either and is forced to increase taxes. The economy either escapes the austerity trap after a small negative *exogenous* shock and the government defaults. Or the economy needs a very large *exogenous* push to re-

[2] In practice, the level of tax compliance in the economy is the outcome of the evasion by taxpayers and the degree of tax enforcement by the government. In the paper, we focus on the fluctuations in tax compliance that stem from the choice of taxpayers to declare their activity. We therefore consider the effort by the government in uncovering undeclared activity as constant, both with respect to the cycle and to changes in tax rates. This is consistent with the idea that changes in tax enforcement represent structural reforms implemented at lower frequency.

[3] Letting $q(b, \gamma)$ denote the debt price as a function of contracted debt b and the size of the formal sector γ, we have that:

$$\frac{dq}{d\tau} = \frac{\partial q}{\partial b}\frac{db}{d\tau} + \frac{\partial q}{\partial \gamma}\frac{d\gamma}{d\tau},$$

and any increase in tax rate τ would affect default risk through a fiscal surplus effect (i.e., the decrease in debt b) and a tax evasion effect (i.e., the decrease in the size of the formal sector γ).

create some fiscal space and weaken the indirect tax compliance effect. In austerity traps, the economy hangs off a cliff.

We calibrate and simulate our model with aggregate productivity shocks and public expenditure shocks. We use the moments uncovered in the empirical section to calibrate the three important unobserved fundamentals characterizing the choice of entrepreneurs. The level of tax compliance and its elasticity of tax rates mostly pin down two quantities which affect the contemporaneous trade-off faced by entrepreneurs, i.e., the distribution of returns in the informal sector and the level of complementarities in the formal sector. The theoretical persistence of tax compliance is mostly driven by the staggered technological choice, and the empirical persistence of tax compliance pins down the period probability to reset technology. The remaining parameters of the model are calibrated in the same fashion as standard models of sovereign defaults (Aguiar and Gopinath, 2006; Arellano, 2008).

We assess the model performance and its ability to reproduce (i) the sensitivity of debt prices to policy shocks, (ii) the dynamics of fiscal policies for high-debt levels, and the occurrences of periods of high tax rates, low output and high default risk, and (iii) the cyclicality of fiscal policies, across the different economic environments. First, we find, as in the data, that the sensitivity of debt prices to policy shocks is markedly lower in economies with low tax enforcement and high debt levels because the tax compliance channel sharply affects the cost of raising future tax revenues.[4] Second, the model rationalizes periods of austerity for economies with low tax enforcement. However, these episodes are rather short-lived and often lead to a default. Third, the cyclicality of fiscal policies strongly depends on the state of the economy. Economies with high tax enforcement implement counter-cyclical fiscal policy. This counter-cyclical fiscal policy—e.g., reducing tax rates in recessions and vice-versa in booms—helps credit-constrained households smooth the fluctuations in income along the business cycle. By contrast, economies with low tax enforcement display markedly different dynamics depending on debt levels. For low initial debt levels, the government adopts a counter-cyclical fiscal policy which maintain reasonably low debt levels in most future states of the World. However, in catastrophic states, the economy may fall in an austerity trap. In such occurrences, economies implement very costly pro-cyclical fiscal policies, a paradox that has been highlighted and discussed in the recent literature.[5]

[4]The degree of tax enforcement in the model is jointly characterized by the distribution of returns in the informal sector and the level of complementarities in the formal sector. Consequently, it relates to the production technology rather than a tax collection technology. In practice, economies may also differ along the latter dimension, a possibility that we ignore.

[5]See von Hagen and Harden (1995); Aaron Tornell (1999); Kaminsky et al. (2004); Ilzetski and Vegh (2008) on government expenditures and tax revenues, and more recently Vegh and Vuletin

The impact of dynamic distortions through tax evasion are not qualitatively different from that of more standard fiscal multipliers. There are, however, two quantitative implications of the tax compliance channel which cannot be reproduced through more standard behavioral responses to fiscal policy. In countries with low tax enforcement, leakages through output are one order of magnitude lower than those implied by tax evasion, and we show that they are insufficient to explain the occurrences of austerity traps. Moreover, standard distortions are quite comparable across economic environments, and we find that they are unable to generate the observed differences in fiscal dynamics across countries.[6]

This paper contributes to different strands of the literature.

We contribute to the literature on sovereign default and limited commitment, which hinges on the original contribution of Eaton and Gersovitz (1981). As in Arellano (2008), we assume market exclusion upon default, and default mostly occurs in bad times.[7] In contrast with the two previous contributions, however, we explicitly model fiscal policy as a distortionary instrument which affects the future cost of raising tax revenues. One novelty of our approach, compared to a number of contributions (see for instance Aguiar et al., 2005; Cuadra et al., 2010; Bi, 2012; D'Erasmo and Mendoza, 2013; Arellano and Bai, 2016), is that distortions induced by fiscal policy do not only affect the contemporaneous choice of fiscal policies, but they crucially impact future repayments and thus the debt pricing schedule.[8] Some economies are thus at risk of creating a tax evasion overhang.[9] This mechanism is what generates austerity traps.

Our framework rationalizes the use of pro-cyclical fiscal policies in developing economies (Kaminsky et al., 2004; Ilzetski and Vegh, 2008; Vegh and Vuletin, 2015). Many theoretical mechanisms have been discussed to explain how pro-cyclical policies arise, most of them based on imperfect commitment or weak states (with weak

(2015) on tax rates.

[6]The elasticity of tax receipts t to tax rates τ, which determines the slope of the Laffer curve and indirectly the magnitude of distortions, can be written as a function of the elasticities of output y and tax compliance γ, i.e., $\partial \ln(t)/\partial \ln(\tau) = 1 + \partial \ln(y)/\partial \ln(\tau) + \partial \ln(\gamma)/\partial \ln(\tau)$. We find that differences in the latter is what drives variation in the dynamics of fiscal policies across environments.

[7]The empirical evidence in favor of counter-cyclical defaults is quite thin. Tomz and Wright (2007), for instance, finds a weak relationship between default occurrences and the output gap. In our framework, the history of previous shocks would also impact default probability via the level of tax compliance in the economy.

[8]Recently, Mendoza and Yue (2012) and Bocola (2016) have studied how default itself may distort the domestic economy through the collapse of the banking sector, thereby providing some additional commitment for governments to repay.

[9]Dovis et al. (2015) develops a model in which a similar dynamic component affects the future cost of fiscal policies. Their framework relies on inequality across domestic citizens as the endogeneous state variable affecting default risk, thereby describing an *inequality overhang*.

domestic institutions—e.g., subject to corruption).[10] Our approach relies on the former, and the proximity to a "debt ceiling" following a string of negative shocks is what drives some economies to implement pro-cyclical fiscal policies (Aguiar et al., 2005; Cuadra et al., 2010). A novel feature of our analysis is that fluctuations in tax compliance amplify the costs of these pro-cyclical policies. There is a consumption cost coming from imperfect consumption smoothing, but also an output cost arising from the dynamic distortions induced by fluctuations in tax compliance.

One important contribution is to provide novel stylized facts on the fluctuations in tax compliance. We construct a measure of tax compliance for many developed and developing countries in the post-war period.[11] Our measure uses two different sources, i.e., taxes as received by the government and the reported consumption of goods at a highly disaggregated level, and capture any discrepancies between these two sources. We show that tax compliance is, in some countries, very volatile. In these countries, tax compliance is strongly counter-cyclical and very responsive to tax rates. These findings may relate to the (large) literature estimating the size of the fiscal multiplier across countries, the type of fiscal shock or its timing (Alesina and Ardagna, 2009; Romer and Romer, 2010; Favero et al., 2011; Auerbach and Gorodnichenko, 2012; Ilzetzki et al., 2013; Alesina et al., 2015). In particular, our findings could shed light on the observed differences in estimates of fiscal multipliers between taxes and expenditures and along the business cycle.

Fluctuations in tax compliance imply, in our model, that governments experience low returns to fiscal consolidations in terms of debt service. When debt levels are high, the government uses pro-cyclical fiscal policies, and the (high) sensitivity of tax compliance to tax rates translates into a (low) sensitivity of debt prices to fiscal policy. This observation relates to the concept of fiscal fatigue developed in Ghosh et al. (2013).

Our paper relates to the literature having investigated the implication of corruption or tax evasion in the recent crisis for peripheral Euro economies (see for instance Pappa et al., 2015; Pappadà and Zylberberg, 2017). In Pappa et al. (2015), tax hikes increase the incentives to conceal part of the activity and produce in the less productive informal sector, thus increasing output and welfare losses. This mechanism affects the size of the fiscal multiplier and explain the failure of the recent consolidation plans in Greece, Italy, Portugal and Spain. One addition of the present analysis

[10] See Kaminsky et al. (2004) for instance on international capital flows, or von Hagen and Harden (1995); Aaron Tornell (1999); Alesina et al. (2008) for explanations based on the redistribution effect of increasing taxes; the competition among taxpayers to receive the proceeds from the positive shock; or the desire to limit rents that politicians could capture.

[11] We extend the dataset and the results of Pappadà and Zylberberg (2017). In particular, we analyze the volatility of VAT compliance, and its determinants beyond the volatility in tax rates.

is to consider the impact of such mechanism on sovereign default.

The key ingredients of our model are (i) imperfect access to credit for households which forces the government to save and borrow on their behalf, (ii) limited commitment for the government, which constrains its capacity to smooth consumption through debt only, and (iii) imperfect tax compliance which induces frictions in transfers between the government and the households. The first two ingredients are standard in debt models à la Eaton and Gersovitz (1981). The last ingredient borrows from the literature on shadow economies with dual technology (Rauch, 1991; Enste and Schneider, 2000; Straub, 2005). An important aspect of our modeling of the formal sector is that there exist complementarities across producers, and taxes strongly reduce total output and not only available income. Such pattern could be generated by spillovers across production units through innovation, but could also be related to increasing returns to tax compliance. A recent contribution, Pomeranz (2015), presents evidence in favor of enforcement spillovers in VAT, a feature that would be captured by complementarities across producers of the formal sector.

The remainder of the paper is organized as follows. In Section 2, we describe our data sources and how we construct measures of state capacity. We then present some stylized facts. Motivated by these observations, we introduce in Section 3 a model of sovereign debt augmented with imperfect tax enforcement and dynamic distortions. Section 4 derives the qualitative predictions of the model, while Section 5 presents the quantitative analysis. Finally, Section 6 briefly concludes.

2 Data

In this section, we describe the construction of a tax compliance indicator based on Value-Added Taxes (VAT), and provide some descriptive statistics on the dynamics of taxes and tax compliance. We then discuss novel stylized facts. We find that tax compliance is volatile, and we divide countries into two groups, those with high volatility of tax compliance and those with low volatility. We show that such volatility is driven by the differential elasticity of tax compliance to the economic cycle and to tax rates. In countries with high volatility, tax compliance strongly responds to changes in economic conditions. Finally, changes in tax compliance are persistent such that a tax hike may affect tax collection on impact and in the medium-run.

2.1 A measure of tax compliance

To measure tax compliance, we rely on a simple flat tax, the Value-Added Tax, which—as will be shown later—is the preferred instrument to adjust fiscal policy to economic fluctuations.

A measure of tax compliance would ideally compare tax receipts to expected receipts as predicted by tax rates and actual expenditures. Letting $t_{i,t,c}$, $\tau_{i,t,c}$ and $c_{i,t,c}$ denote VAT revenues, VAT rate and consumption of good i in year t and country c, the ideal measure of VAT compliance should be defined as:

$$\gamma_{t,c} = \frac{\sum_i t_{i,t,c}}{\sum_i \tau_{i,t,c} c_{i,t,c}}.$$

The gap between tax revenues and expected tax revenues—as captured by the distance between $\gamma_{t,c}$ and 1—reflects imperfect tax enforcement from tax authorities. Such measure cannot shed light on the nature of tax leakages, whether they come from informal exemptions, corruption of tax authorities or non-cooperative tax evasion from agents. However, this measure is orthogonal to possible changes in consumption patterns $c_{i,t,c}$ as a response to differential tax rates across goods. Fluctuations in $\gamma_{t,c}$ may only come from changes in tax compliance *within* good categories.

We construct a proxy for this measure using distinct data sources for tax revenues and reported consumption for 48 disaggregated good categories between 1979 and 2013 in about 40 countries.[12] First, we observe total VAT receipts $\sum_i t_{i,t,c}$ as reported by the government in national accounts. We also track tax reforms and recreate the level of indirect taxes for a detailed set of goods (see an example in the online Appendix Table A1). We extract from the European Commission documentation and national sources the different tax rates and we reference the types of goods (at the 2-digit level) that are subject to these rates for each country/year. 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 these categories are frequently updated. Second, we use annual household expenditure surveys to create actual consumption in each sub-category of good. The information in household surveys comes from the purchaser side thereby alleviating potential under-reporting for undeclared transactions.

There exist several adjustments that we need to implement in order to get as close as possible from the theoretical benchmark.

First, we are interested in the short-term fluctuations of the measure $\gamma_{t,c}$, and

[12] We rely on OECD and Eurostat and their harmonized 48 COICOP (Classification of Individual Consumption by Purpose) sub-categories of goods.

we cannot allow for "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 are 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. A more precise description of our time and seasonal adjustments is available in the online Appendix.

Second, some tax reforms do not modify rates but also modify the category of goods that are subject to the different tax regimes. For instance, for countries entering in the European Union, art galleries would pass from category 1 to category 3. In such instances, we redefine our tax base correctly when our decomposition in the different categories allows us to observe exactly the category that has been modified. When, instead, we do not observe consumption in art galleries, but we observe consumption for a larger category ("cultural goods"), we reconstruct a synthetic tax base for art galleries and the other cultural goods by considering the average share of art galleries among cultural goods over the period. Along the same lines, VAT can be collected for all registered firms or there may exist a minimum threshold. In the case of a reform affecting this threshold, we recreate the new tax base by subtracting the average share of value added created by firms below the threshold. A more precise description of our adjustments for changes in categories and exemptions, and an estimation of the measurement error that we introduce with our corrections are available in the online Appendix.

Third, for certain goods, the 2-digit consumption category is not precise enough and may include 3-digit goods that are differentially taxed (one such example is the category CP061, or "medical products"). In this case, we construct the synthetic consumption of each of these 3-digit goods by using the consumption shares observed in the United States.

Fourth, some reforms modify the tax environment without modifying the tax rates per se. For instance, online registration considerably simplifies the registration process. We collect this information and later control for any such reforms in our empirical specifications.

2.2 Descriptive statistics

In this section, we briefly discuss the main object of interest, i.e., the fluctuations in the measure of tax compliance. We then provide descriptive statistics for (i) the composition of tax revenues and its variation across years, (ii) the cyclicality of the different tax instruments, and (iii) the measure of VAT compliance.

First, we calculate the within-country standard deviation of tax compliance between 1995 and 2013, as a proxy for the overall volatility of tax compliance.[13] Figure 1 plots these volatilities, and compare them to another measure of imperfect tax enforcement, i.e., the size of the informal sector (2005–2012) as computed in Schneider and Enste (2013). We find wide disparity in the volatility of tax compliance across countries, and, interestingly, this disparity is only partly reflecting differences in the size of the informal sector. While there is a positive correlation between the two measures, some countries with a small informal sector markedly differ along the fluctuations in tax compliance. In what follows, we define two groups of countries: those with above-median standard deviation of tax compliance (red in Figure 1) and those with below-median standard deviation (blue in Figure 1).[14]

Second, we report descriptive statistics for tax revenues, tax rates and tax compliance in Table 1. For each variable, we display its sample average, its average in each of the two groups of countries, and we generate two indicators of within-country fluctuations: the coefficient of variation to capture overall volatility, and the correlation with the cycle to estimate its cyclical component.

As apparent in Table 1, VAT, income taxes and corporate taxes account respectively for 32%, 28% and 15% of total tax revenues, and these shares that are similar in both groups of countries. The volatilities of VAT and income taxes are similar in magnitude, and they both appear to be orthogonal on average to economic conditions. However, looking at tax revenues may provide a biased image of fiscal policy over the cycle, and we also analyze the sensitivity of tax rates to economic conditions. Indeed, we can see that, while tax revenues are mostly acyclical or mildly pro-cyclical, the average rates for VAT, income taxes, and corporate taxes are counter-cyclical and quite strongly so for VAT (correlation of -.20). Even though VAT contribute less to global variations in tax revenues than the income tax, its influence on fiscal policy along the economic cycle is large.

[13] We choose 1995 as the starting period in order to generate the measure on a balanced panel

[14] The high-volatility group is composed of the following countries: Bulgaria, Canada, Colombia, Cyprus, Czech Republic, Greece, Hungary, Ireland, Italy, Japan, Luxemburg, Macedonia, Poland, Portugal, Romania, Russia, Slovakia, Slovenia, South Africa and Spain. The low-volatility group is composed of the following countries: Australia, Austria, Belgium, Chile, Denmark, Estonia, Finland, France, Germany, Israel, South Korea, Malta, the Netherlands, New Zealand, Norway, Serbia, Sweden, Switzerland and the United Kingdom.

To reconcile the acyclicality of VAT revenues with the sharp counter-cyclicality of effective rates, we need to analyze VAT compliance. In our sample of countries, VAT compliance is 0.87 on average, which is arguably quite high—maybe due to the over-representation of rich economies. In the sample of high-volatility economies, tax compliance is lower, around 0.84, reflecting that fluctuations in tax compliance mostly occur in economies with sizeable tax evasion. The within-country variations in tax compliance are of the same order of magnitude as variations in revenues. However, and in contrast to revenues, compliance is markedly pro-cyclical (correlation of .32) thereby counteracting the counter-cyclicality of tax rates. Overall, the cyclicality of tax revenues reflects two opposing forces: a counter-cyclical tax rate (i.e., a pro-cyclical fiscal policy), and a pro-cyclical tax compliance. Recessions are associated with high tax rates, and high tax evasion.

These descriptive statistics provide some support for the use of Value-Added Taxes to construct of a measure of tax evasion. VAT is of interest not only because, as a rather simple tax instrument, it allows for the construction of a credible measure of tax evasion across countries and over time, but also because it is the preferred tax instrument in order to adjust to economic conditions and the associated distortions seem to be counter-cyclical.

2.3 Stylized facts

In this section, we first uncover an important, yet overlooked, characteristic of tax compliance: it fluctuates markedly with economic conditions. We estimate the following baseline specification:

$$\Delta \ln \gamma_{tc} = \varepsilon_z \Delta z_{tc} + \beta \mathbf{X}_{tc} + \delta_t + \mu_c + \varepsilon_{tc}, \tag{1}$$

where t indexes the year and c stands for the country. $\Delta \ln \gamma_{tc}$, our dependent variable, is the annual percentage change in VAT compliance. z_{tc} is the the annual percentage change in (HP-filtered) GDP per capita. The vector $\mathbf{X}$ includes time-varying controls, such as the existence of concurrent tax reforms, the sectoral decomposition of economic activity, the government expenditures and trade (the ratio of exports and imports over GDP). μ_c captures country-specific trends in tax compliance and δ_t a year fixed-effect. ε_{tc} is the error term with standard errors clustered at the country level.

Panel A of Table 2 reports estimates for the elasticity ε_z: the elasticity is significantly positive and quite large (0.40). As shown in columns 2, 3 and 4, the correlation is robust to the addition of controls (sectoral composition in column 2 and trade in column 3 and government expenditures in column 4). An increase of one percent in GDP per capita is associated with an increase of 0.4 percent in tax compliance (about 0.3 percentage points).

We then estimate two differential elasticities ε_z in the two groups of countries separated by their position with respect to the median volatility. To this end, we add an interaction between Δz_{tc} and a dummy for being in the high-volatility group, and we report the results in Panel B of Table 2. The coefficient before Δz_{tc} is the average elasticity in the low-volatility group (between 0 and .08) while the sum of this coefficient and the one before the interaction term is the average elasticity in the high-volatility group (about 0.65). The sharp difference between the two groups is striking: the low-volatility group has an acyclical tax compliance on average while economic conditions explain about 10% of the overall volatility in tax compliance in the high-volatility group.[15][16]

Second, we replicate the two previous specifications but replace the explaining variable Δz_{tc} by the annual percentage change in VAT standard rates $\Delta\tau_{tc}$ such as to capture the elasticity of tax compliance to tax rates, ε_τ, in both groups of countries (controlling for the previous fluctuations in output).[17] The results, presented in Panels A and B of Table 3, show that there is a strong negative correlation between the dynamics of tax rates and tax compliance. The elasticity of tax compliance to tax rates is around -0.35 on average but there is a difference between the two groups of countries. In our preferred specifications (columns 2 and 3), the elasticity is more than four times lower for the low-volatility group -0.10 than for the high-volatility group -0.45. We show in this exercise that economies with volatile tax compliance strongly respond to economic conditions but also exhibit significantly higher behavioral response to tax hikes.

Third, we explore the *within*-country heterogeneity in the elasticity of tax compliance to tax rate. Two economies with similar fundamentals may respond differently to a tax hike, depending on economic conditions. To test for such heterogeneity, we define three dummies for periods of low output based on HP-filtered GDP growth per capita (1: negative HP-filtered growth, 2: 25%-lowest HP-filtered growth, 3. below-median HP-filtered growth), and interact them with $\Delta\tau_{tc}$ in the previous

[15] We show in Appendix Table A2 that the distinction between the two groups of economies does not overlap with a more general divide "developed"/"developing" economies as adopted in Vegh and Vuletin (2015).

[16] In the high-volatility group, the volatility in tax compliance explained by the cycle and VAT reforms is around 20% of the overall volatility. The remaining share may come from unobserved changes in economic conditions, including other reforms (e.g., credit reforms).

[17] We provide a sensitivity analysis in Appendix Table A3 with the effective VAT rates instead of the standard rate. This specification accounts for changes in exempted categories, reduced and super-reduced rates as well.

specification. We also add country-specific trends to account for possible long-term changes in tax compliance. The results, presented in Table 4, show that the elasticity of tax compliance to tax rate is around 0.29 in normal conditions, and around 0.45-0.47 in recessions. While the difference between these two coefficients is not significant, they indicate that fiscal consolidations—which are mostly implemented in downturns—are particularly distortionary when the returns to economic activity are already low.

So far, we have shown that (i) tax compliance is volatile and co-moves in the short-term with fiscal policies, and (ii) there is a large heterogeneity across countries. One interpretation of these facts, which we adopt in the theoretical framework, is that economic agents face a trade-off between declared and undeclared activity. In economies with imperfect tax enforcement (e.g., the high-volatility group), changes in distortionary tax instruments (e.g., fiscal consolidations) tilt the trade-off faced by agents and a number of these agents switch their economic activity from or to the informal sector. This response is, in nature, not that different from the more standard behavioral response in which economic agents reduce their labor supply in response to increases in taxes. It differs, however, along two important aspects: (i) the impact of the tax compliance channel on the elasticity of tax revenues to tax rate is one order of magnitude larger than the standard behavioral response, and (ii) there may exist distortions specific to production in the informal sector, e.g., arising from positive spillovers of transparency. There are enforcement spillovers in Value-Added Taxes, and the relative returns to the formal sector depend on the size of the declared activity (Pomeranz, 2015). Credit, innovation, or the structure of the production chain may also be affected by the size of the informal sector, and in turn modify the returns to the formal sector. These channels would generate positive externalities to tax compliance. These externalities would induce an inefficient decentralized allocation, with an inefficiently low tax compliance, and changes in the structure of taxes would modify the extent to which the economic activity is distorted toward the informal sector. In what follows, we will add such tax compliance channel in a simple model where a government smoothes consumption and the constraint induced by the response of the economy to distortionary tax instruments will interact with the constraint induced by the government limited commitment to repay. The objective of the model is to rationalize the dynamics of fiscal policies and their impact on default risk, and we will use the empirical estimates to discipline the modeling of the production side of the economy (and its response to taxes).

Before proceeding to the theoretical exercise, we provide a last stylized fact. In Table 5, we quantify the persistence of tax compliance over time. We regress tax compliance in period t on its lag, with year- and country-fixed effects, GDP growth and yearly changes in industrial composition as covariates, and we instrument the lagged tax compliance by lagged changes in tax rates. Our findings indicate that tax compliance is quite persistent over time—the empirical model corresponds to an AR(1) process with coefficient 0.70. This dynamic of tax compliance will be an important aspect of the model, as distortions implied by an episode of fiscal consolidation will have further repercussions on *future* tax collection.

3 A model of a small open economy

This section develops a model of a small open economy with a representative household and a government. The objective is to embed the endogenous response of tax compliance in a standard model à la Eaton and Gersovitz (1981) or Arellano (2008) where a benevolent government with limited commitment issues debt on behalf of the household.

The predictions of the model entirely derive from the interaction of two frictions. First, there is imperfect tax enforcement, i.e., the government cannot implement lump-sum payments with the household: consumption smoothing is made through a distortionary instrument that affects the cost of raising revenues in the future. Second, there is limited commitment from the government to reimburse its debt. There is a default risk which limits the government capacity to transfer consumption from the future to the present.

The intuition behind our main mechanism is straightforward. A government willing to reduce debt should increase tax rates. This increase in tax rates tilts the trade-off faced by entrepreneurs between operating in the formal sector or in the informal sector, and raises the distortions associated with future tax collection. Bondholders revise downward their expectations on future payments that could be sustained by the government. Consequently, increasing taxes would decrease debt through a direct effect but would affect the borrowing capacity of an economy through this indirect channel. With weak tax enforcement, the latter effect is strong and substantially constrains government decisions.

The theoretical predictions of the model do not rely on the exact modelling of distortions associated with imperfect tax enforcement as long as these distortions are persistent and interact with limited commitment. We rely on a simple model with staggered choice between an informal technology and a formal technology, and complementarities in the formal sector, and we calibrate the model to match—among other moments—the estimated elasticity of tax compliance to tax rates.

3.1 Preferences and technology

The economy is populated by a continuum of infinitely lived households of measure one. Letting c_t denote her consumption at time t, the representative household in this economy maximizes expected utility as given by:

$$E_t \sum_{s=t}^{\infty} \beta^{s-t} u(c_s),$$

where $\beta < 1$ denotes the discount factor and $u(\cdot)$ represents the period utility function, which satisfies $u'(\cdot) > 0$ and $u''(\cdot) < 0$. Since all households are identical, we refer to them throughout as the representative household. In what follows, we may drop time indices for the sake of exposure.

There are two types of agents who populate households. Each household is composed of a unit mass of entrepreneurs who hold one unit of an investment good in each period, and a unit mass of final good producers. There is perfect redistribution within each household such that all agents of the same household consume the same in each period.

The consumption good can be produced with two technologies. First, the consumption good can be assembled by final good producers using investment goods. We assume that there are many varieties of such investment goods y_i and there are complementarities between the investment goods y_i when they are used as factors of production for the consumption good.[18] Final good producers assemble investment goods y_i using the following CES technology,

$$y = z \left(\int_0^1 y_i^{\phi} di \right)^{\frac{1}{\phi}},$$

where $\phi < 1$ captures production complementarities and z is a technology shock which follows a Markov process. We assume that the final good producers are fully transparent. This technology represents the formal sector of our economy.

Second, the final good can be directly produced by entrepreneurs. Entrepreneurs can transform their investment unit into the final good using a private technology with unobservable constant return R. We assume that R is known to the entrepreneur only and is distributed along a continuous probability distribution $H(.)$.

[18] These complementarities can capture spillovers across transparent firms through innovation; spillovers across transparent firms through innovation; complementarities along the production chain; (tax) enforcement spillovers along the production chain. Any mechanism, in which the relative return to the formal technology increases with the mass of producers adopting this technology, could be captured by this structure of complementarities.

This technology is not taxed and represents the informal sector of our economy.[19] We assume that markets for investment goods and the final good are perfectly competitive.

Finally, we assume rigidities in the technology choice, in the manner of Calvo (1983), and technological choice is staggered over time. In each period, there is an idiosyncratic draw determining whether an entrepreneur is allowed to change her technology. With probability $1 - \theta$, the entrepreneur can either (i) adopt the formal technology, produce an investment good and sell her unit to the final good producer, or (ii) adopt the private technology. If we assume $\theta = 0$, this choice is completely flexible across periods and the contemporary technology does not commit the entrepreneur in the future.

There is a benevolent government whose objective is twofold. First, in each period, the government needs to produce and finance a public good whose cost g_t is exogenous and subject to shocks, following a Markov process. Second, the government maximizes the welfare of the representative household by issuing debt and purchasing assets on its behalf: the household's borrowing and saving are done exclusively through the government. In order to finance the public investment and transfer from and to the household, we assume that the benevolent government can only levy indirect taxes τ on final output.[20]

3.2 Financial markets

We assume that the economy is small relative to the international financial market, and that the government can issue and trade one-period bonds on these markets. The international financial market is willing and able to purchase any asset that yields an expected return at least as high as ρ. We assume that $\rho = \beta^{-1}$ so that, with a non-distortive tax and full commitment, there would be a preference for perfectly stabilizing consumption over time.

The government smoothes the consumption of the representative household by issuing debt and purchasing assets on its behalf. The debt is financed either through taxation on the household itself or through new debt issue. The government has imperfect commitment and may default on its obligations. Let b_{t+1} and q_{t+1} respectively denote the amount and price of debt issued by the government at time t, and let $D_t \in \{0, 1\}$ denote the decision to default on previous obligations. If t_t denotes

[19] The hypothesis that one technology is fully informal while the other one is fully transparent can be relaxed. There is a need for the technology in which there exist complementarities in production to be relatively more transparent.

[20] We use an indirect tax to match the empirical estimates, but any distortionary instrument would generate the same qualitative results.

total indirect taxation levied by the government at time t, the resource constraint for the government is:

$$(1 - D_t)\, b_t - q_{t+1} b_{t+1} = t_t - g_t \tag{2}$$

We suppose that there are two sources of punishment which gives some (limited) commitment to the government. As in Arellano (2008), there is a restriction to credit following a default and reintegration to the international market is stochastic and occurs with probability ν in each period. We further assume that, during market exclusion, there is an exogenous default cost δ that is incurred by the household directly. This cost captures the fact that the domestic intermediation sector may be affected by a default through a capital flight from financial investors (Mendoza and Yue, 2012). Since transfers from the government are made through a distortionary instrument, it is not innocuous to assume that the default cost is paid by the household. A weak government, with distortionary tax instruments, would have more incentives to default, given the same debt level, because a default is a relatively efficient way to redistribute to the representative household.

In order to solve for the equilibrium of the economy, we need to understand how the government makes savings and investment decisions. We turn to these next.

3.3 Competitive Equilibrium

We now specify the timing of actions within each period.

At the beginning of each period, the aggregate shock z_t is revealed and perfectly observed by all agents. If the government is excluded from international financial markets, a reintegration draw takes place. The government then decides to repay or default on its past obligations b_t, and commits to an indirect taxation rate τ_t. Production takes place and taxes are paid by agents. International financial markets open, and sovereign bonds are traded. Finally, households consume.

In order to characterize the equilibrium of this economy, we need to explore the dynamic optimization problem of entrepreneurs, the dynamic optimization problem of the government and how investors price sovereign debt. We turn to these separate programs next.

Entrepreneurs and final good producers In order to generate fiscal fatigue—a government unable to stray from debt ceilings even with very high tax pressure—we need to derive the distortions implied by taxes.

We first describe the (static) program of final good producers. In each period, these producers take prices p_i of each intermediate good variety as given and maximize:

$$\max_{y_i} \left\{ z(1-\tau) \left(\int_0^1 y_i^{\phi} di \right)^{\frac{1}{\phi}} - \int_0^1 p_i y_i di \right\}.$$

The resulting demand is characterized by the following equation:

$$z(1-\tau) y_i^{\phi-1} \left(\int_0^1 y_i^{\phi} di \right)^{\frac{1}{\phi}-1} = p_i.$$

We now focus on the program of entrepreneurs. In each period, there is an idiosyncratic draw determining whether an entrepreneur can set her technology. With probability $1-\theta$, the entrepreneur can adopt the formal technology and sell to final good producers, or adopt the private technology. With probability θ, the entrepreneur keeps the same technology as in period $t-1$.

The aggregate transparency, γ_t, defined as the share of entrepreneurs operating in the formal sector, verifies the following dynamics:

$$\gamma_t = (1-\theta)\gamma_t^* + \theta \gamma_{t-1},$$

where γ_t^* is the share of entrepreneurs deciding to operate in the formal sector among entrepreneurs with the opportunity to modify their technology.

The decision of entrepreneurs depends on the returns to each technology in future states of nature. Formally, entrepreneurs compare the returns in the formal sector:

$$\sum_{k=0}^{\infty} E_t \delta_{t+k} r_{t+k},$$

where $r_{t+k} = (1-\tau_{t+k}) z_{t+k} \gamma_{t+k}^{\frac{1}{\phi}-1}$ is the expected price for one unit of variety i in the formal sector in period $t+k$, $\delta_{t+k} = \beta^k \theta^k \frac{u'(c_{t+k})}{u'(c_t)}$ is the (effective) discount factor between period t and period $t+k$, and θ^k is the probability for the decision in period t to be still relevant in period $t+k$, to the returns in the informal sector:

$$\sum_{k=0}^{\infty} E_t \delta_{t+k} R,$$

where R is the unobserved individual return to the private technology.

Among entrepreneurs with the opportunity to modify their technology, the share of them adopting the formal technology should be equal to the ones with sufficiently high returns in the formal sector, i.e.,

$$\gamma_t^* = H\left[\frac{\sum_{k=0}^{\infty} E_t\delta_{t+k}r_{t+k}}{\sum_{k=0}^{\infty} E_t\delta_{t+k}}\right].$$

We can then replace γ_t^* using the equation characterizing aggregate transparency, and use a first-order approximation, which brings:[21]

$$\frac{\gamma_t - \theta\gamma_{t-1}}{1-\theta} = H\left[(1-\theta\beta)r_t + \theta\beta E_t H^{-1}\left(\frac{\gamma_{t+1} - \theta\gamma_t}{1-\theta}\right)\right]. \quad (3)$$

Equation (3) describes the (sluggish) dynamics of aggregate transparency, which governs distortions on the production side of the economy, as a function of returns to the formal sector r_t (and thus taxation).

Dynamic distortions Before we turn to the consumption side of the economy, we briefly analyze the distortions implied by changes in tax rates. Letting $R_t = H^{-1}\left(\frac{\gamma_t - \theta\gamma_{t-1}}{1-\theta}\right)$ denote the level of unobserved return in the informal sector for which an individual is indifferent across technologies, we can define tax receipts t_t, output net of taxes w_t and output $y_t = w_t + t_t$, as a function of these unobserved returns,[22]

$$\begin{cases} t_t = \tau_t z_t \gamma_t^{\frac{1}{\phi}} \\ w_t = (1-\tau_t)z_t\gamma_t^{\frac{1}{\phi}} + \theta\int_{R_{t-1}}^{\infty} xdH(x) + (1-\theta)\int_{R_t}^{\infty} xdH(x) \\ y_t = z_t\gamma_t^{\frac{1}{\phi}} + \theta\int_{R_{t-1}}^{\infty} xdH(x) + (1-\theta)\int_{R_t}^{\infty} xdH(x) \end{cases} \quad (4)$$

These quantities represent the production side of the economy, and will intervene in the government problem as they govern the extent to which output is collected from households and the size of distortions. A change in tax rates induces the following

[21]We restrict our analysis to distributions H with a support such that Equation (3) implicitly defines a unique solution γ_t as a function of $(\gamma_{t-1}, \gamma_{t+1}, r_t)$. The condition is made explicit in the online Appendix.

[22]Equation (3) describes the following dynamics for unobserved returns:

$$R_t = (1-\theta\beta)r_t + \theta\beta E_t R_{t+1}.$$

distortions (through the response of transparency),

$$\begin{cases} \dfrac{\partial t_t}{\partial \tau_t} & = & z_t \gamma_t^{\frac{1}{\phi}} + \frac{z_t \tau_t}{\phi} \gamma_t^{\frac{1}{\phi}-1} \dfrac{\partial \gamma_t}{\partial \tau_t} \\ \dfrac{\partial w_t}{\partial \tau_t} & = & -z_t \gamma_t^{\frac{1}{\phi}} + \left[(1-\tau_t) \frac{z_t}{\phi} \gamma_t^{\frac{1}{\phi}-1} - R_t \right] \dfrac{\partial \gamma_t}{\partial \tau_t} \\ \dfrac{\partial y_t}{\partial \tau_t} & = & \left(\frac{z_t}{\phi} \gamma_t^{\frac{1}{\phi}-1} - R_t \right) \dfrac{\partial \gamma_t}{\partial \tau_t} \end{cases}$$

The first two terms in the first two lines represent redistribution from and to households, and they cancel out in total output. The last terms are both negative (because $\partial\gamma/\partial\tau < 0$) and they represent distortions implied by the differential tax pressure between the informal and the formal sectors.[23] As the tax rate increases, entrepreneurs switch to the less productive (but tax-free) informal sector, which, with complementarities in production, drives down the returns to the formal sector and creates a multiplier effect captured in $1/\phi$.

With lump-sum payments or non-distortive taxes, output would be independent of the degree of redistribution between households and the government. In our model, however, $\partial y/\partial\tau < 0$, and there exist leakages associated to such redistribution.

Households Households make no saving or borrowing decisions in our economy. Once they receive the output net of taxes w, their consumption is given by

$$c = w$$

In order to smooth consumption, the government needs to smooth output net of taxes through the level of these indirect taxes.

Bond prices Investors are ready to buy any bonds in period t as long as these bonds guarantee at least $\rho = \beta^{-1}$ in expectations in period $t+1$. The bond price schedule verifies

$$q_{t+1} = \beta E_t \left[1 - D_{t+1}\right] \tag{5}$$

Bond prices range between 0, when default is expected with certainty next period, and β.

Government The government is assumed to be benevolent and to maximize the welfare of consumers in each period t by choosing the levels of taxes τ_t, public savings

[23] The reader interested in the derivation of the tax compliance response $\partial\gamma/\partial\tau < 0$ may refer to the Appendix.

b_{t+1} and default decisions D_t, subject to the budget constraint (2), the endogenous response of entrepreneurs, as characterized by (3), the system of equations defining tax receipts and output (4) and the bond price schedule (5).

We are now ready to define a recursive equilibrium of our economy, and shed light on the main trade-off underlying government decisions.

4 Recursive equilibrium and dynamic properties

In this section, we define the equilibrium characterizing the economy in a recursive form, and provide some intuitions behind the main mechanisms at play in the model.

4.1 Recursive equilibrium and default sets

We first define the state of the economy in period t. Given the assumptions that (i) productivity and expenditure shocks follow a Markov process, (ii) technological choices are staggered in the manner of Calvo (1983), (iii) market reintegration is idiosyncratic, the following quantities fully characterize the economy at the beginning of period t: the state of the economy with respect to international markets, $h_t \in \{A, E\}$, where A is 'access' and E is 'exclusion'; the inherited asset position b_t; the inherited state of technological choices (γ_{t-1}, R_{t-1}); and current productivity z_t and public expenditures g_t. For convenience, let $s_t = (b_t, \gamma_{t-1}, R_{t-1}, z_t, g_t)$ denote the state of the economy, except from access to international bond markets.

A recursive equilibrium is given by a sequence of government debt $\{b_{t+1}\}$, transparency and indifference points $\{\gamma_t, R_t\}$, default decisions $\{D_t\}$ and bond price schedule $\{q_{t+1}\}$ satisfying the following conditions in all periods and histories:

Definition 1. *The government debt and default decisions maximize the representative household's welfare, given the state (h_t, s_t) of the economy, and subject to the period budget constraint (2) and the bond price schedule (5). The entrepreneurs maximize their profits, and Equations (3) and (4) define the dynamics of transparency, tax receipts and output.*

The government value function in period t is,

$$v(h_t, s_t) = \mathbb{1}_{h_t=A} v_A(s_t) + \mathbb{1}_{h_t=E} v_E(s_t),$$

where the conditional value functions v_A and v_E follow the following recursive formulations:[24]

$$v_A(s_t) = \max_{D_t, b_{t+1}, \gamma_t, R_t} \left\{ u\left(w_t - D_t\delta\right) + \beta(1 - D_t)E_t v_A(s_{t+1}) + \beta D_t E_t v_E(s_{t+1}) \right\},$$

$$v_E(s_t) = (1 - \nu)\left(u(w_t - \delta) + \beta E_t v_E(s_{t+1})\right) + \nu \max_{b_{t+1}, \gamma_t, R_t} \left\{ u\left(w_t\right) + \beta E_t v_A(s_{t+1}) \right\},$$

subject to Equations (2), (3), (4), (5) and $R_t = H^{-1}\left(\dfrac{\gamma_t - \theta\gamma_{t-1}}{1-\theta}\right)$.

As in Eaton and Gersovitz (1981) or Arellano (2008), the decision to default can be fully described by a default set $D(b, \gamma, R)$, which is a set of states of nature (z, g) under which the government prefers to default, as a function of the endogenous state variables (b, γ, R). The recursive equilibrium of this economy is then defined as a set of price functions for bonds, policy functions for the government including $D(b, \gamma, R)$ such that (i) the government policy functions solve the government problem taking as given price functions for bonds and the dynamics of transparency as defined by Equation (3), and (ii) bond prices reflect the default probabilities implied by the policy functions $D(b, \gamma, R)$.

These default sets defined above satisfy the following monotonicity property: default sets are monotonous in inherited debt. If $b_1 < b_2$, then $D(b_1, \gamma, R) \subseteq D(b_2, \gamma, R)$. The proof of this property is immediate by contradiction. Assume that there exists a state of nature (z, g) such that $(z, g) \in D(b_1, \gamma, R)$ but $(z, g) \notin D(b_2, \gamma, R)$. The maximum utility reached after a default is independent of current debt b_1 or b_2. By contrast, the maximum utility that can be reached with reimbursement depends on current debt. Let b', γ' and R' denote the chosen debt level, transparency and indifference threshold conditional on reimbursing for the state (b_2, γ, R). We have that $u\left(w(b', b_2, \gamma, R, z, g)\right) + \beta E_t v_A(b', \gamma', R', z', g')$ is greater than the value of default because $(z, g) \notin D(b_2, \gamma, R)$ by assumption. However, the utility from reimbursement associated with inherited debt b_1 and the same targets (b', γ', R') would be $u\left(w(b', b_1, \gamma, R, z, g)\right) + \beta E_t v_A(b', \gamma', R', z', g')$ and would be higher than the utility from default because

$$w(b', b_1, \gamma, R, z, g) \geq w(b', b_2, \gamma, R, z, g)$$

As a consequence, reimbursement is preferred than default, and $(z, g) \notin D(b_1)$, which contradicts the initial hypotheses.

[24]Without market access, the government makes no decisions because the period tax rate, and thus the level of transparency and the indifference thresholds, are pinned down by the budget constraint $t_t = g_t$.

4.2 Dynamic properties of the recursive equilibrium

We now study two special cases in order to better understand the dynamic properties of the recursive equilibrium. We first assume full commitment in order to highlight the impact of imperfect tax enforcement alone, and analyze optimal fiscal policies in this setting. We then discuss the dynamics in the absence of any commitment. Finally, we discuss intuitively how our mechanism modifies the conclusions of a benchmark model à la Arellano (2008), i.e., with non-distortionary redistribution between the government and households.

Full commitment When the government has perfect commitment, debt price is independent of fiscal policy and the solution to the government program verifies a slightly modified Euler equation, i.e.,

$$\lambda_t = E_t \lambda_{t+1},$$

where:

$$\lambda_t = -\frac{\partial w_t / \partial \gamma_t}{\partial t_t / \partial \gamma_t} u^{'}(w_t) - \beta \frac{1}{\partial t_t / \partial \gamma_t} E_t \frac{\partial v_A(s_{t+1})}{\partial \gamma_t}.$$

The first term is the marginal utility of consumption weighted by a factor accounting for tax leakages. The second term captures the expected future gains of a marginal increase in aggregate transparency. The leakages implied by taxes depend on the elasticity $\varepsilon_\gamma < 0$ of transparency to tax rates as follows:

$$-\frac{\partial w_t / \partial \gamma_t}{\partial t_t / \partial \gamma_t} = \frac{1 - \frac{1-\tau_t}{\tau_t} \frac{1-\phi}{\phi} \varepsilon_\gamma}{1 + \frac{1}{\phi} \varepsilon_\gamma}.$$

In addition to the desire to smooth consumption across time and states of nature—implying counter-cyclical fiscal policy—, the government takes into account (i) tax leakages and (ii) future distortions. Given that the capacity to raise tax revenues is pro-cyclical, the elasticity $|\varepsilon_\gamma|$ is larger in bad times and leakages would be higher. The optimal tax rates implemented by the government should be even more counter-cyclical than in a world without distortions, in order to equalize the weighted marginal utility of consumption over time.

No commitment When the government cannot save nor borrow, then it needs to satisfy in each period a balanced budget and

$$t_t = \tau_t z_t \gamma_t^{\frac{1}{\phi}} = g_t,$$

which implies, combined with Equation (3), that fiscal policy is pro-cyclical. In stark contrast with the perfect commitment case, the higher the distortions related to tax collection, and the higher the differences between the (high) tax rates in bad times and the (low) tax rates in good times.

Main mechanism As we have seen in the previous two cases, the government implements very different policies when fully constrained or fully unconstrained in international debt markets. We now explain the interaction of our transparency channel with limited commitment in the general case.

A fiscal consolidation would affect default risk as follows. An increase in tax rates would lead, ceteris paribus, to higher fiscal surplus and lower future debt levels. However, in our model, an increase in tax rates lowers the contemporary return r_t to the formal sector. Through Equation (3), this affects the indifference threshold between the formal and the informal sector, and thus the number of entrepreneurs operating in the informal sector. With staggered technological choices, this reponse is persistent and increases the future costs of raising tax revenues. When pricing debt, investors anticipate both the decrease in debt levels and the more indirect effect on future tax collection. The latter reduces the gains in fiscal consolidations, and is absent from any benchmark model à la Arellano (2008) with non-distortionary redistribution.

While the previous mechanism is always at work, at least qualitatively, its quantitative relevance sharply depends on fundamentals and the state of the economy. The production technology determines the elasticity of transparency to the return r_t in the formal sector. A large elasticity, related to a certain distribution of informal returns or to a low productivity shock, would make fiscal consolidations more distortionary. The probability to set technology influences how contemporary shocks affect future transparency. With fully flexible or fully rigid choices, a fiscal consolidation would have little influence on future transparency, and would not be distortionary in the long-run. Finally, the elasticity of default risk to the future costs of raising tax revenues crucially depends on the debt level. It is only above a certain debt level that the future default sets are not empty.

Our "transparency" mechanism impacts the relative return to fiscal consolidations, and the dynamics of optimal fiscal policies. Following a negative shock to productivity, the government would have the incentives to lower tax rates through three distinct channels. First, the government would be willing to smooth available income to the household. Second, low productivity induces a low indifference threshold between the formal and the informal sectors and thus larger inefficiencies and lower pre-tax income. A lower tax rate would mitigate the drop in indifference threshold. Third, low tax rates would increase the returns to tax rates in the future. Such response would be optimal, but only when debt price is not very sensitive to future debt. When, instead, debt prices markedly respond to future debt, an expansionary policy in bad times would increase debt service thereby mitigating the effect of lower distortions. In states of the economy where both the "debt" and "transparency" channels play a role, current and future tax revenues are not very sensitive to fiscal policy which has three implications: (1) default risk is not very sensitive to fiscal policy, (2) optimal fiscal policy may be (weakly) pro-cyclical; (3) the dynamics of the system is stable.

We illustrate this argument with a more formal analysis of the dynamics and a phase diagram in online Appendix B. We now turn to the quantitative framework.

5 Quantitative analysis

In this section, we calibrate the model to match the key facts documented in the empirical section, and we evaluate its capacity to reproduce the following empirical moments: (i) the sensitivity of default risk to fiscal policy across different economic environments, (ii) the dynamics of fiscal policies, and the occurrences and length of austerity traps, and (iii) the cyclicality of fiscal policies.

5.1 Calibration and solution method

In order to calibrate the model, we proceed as follows. We set all parameters (but the ones characterizing the production side of the economy) as is standard in models of sovereign defaults (Aguiar and Gopinath, 2006; Arellano, 2008). We then estimate the remaining parameters by matching the following moments of the steady-state economy: (a) the transparency level, (b) the elasticity of transparency to tax rate, and (c) the auto-correlation of transparency. Table 6 lists all the parameter values that we use in this quantitative exercise.

We set a yearly discount factor β corresponding to a risk-free interest rate of 6%. We use a Constant-Relative-Risk-Aversion utility function with a parameter $s = 2$. As in Arellano (2008), we assume that the output cost is 3% of the steady-state output, and the reintegration probability is set such that the average exclusion length is 5 years. These two parameters command the maximum debt that could be contracted in this economy. As in Aguiar and Gopinath (2006), we assume that the productivity and spending shocks are highly auto-correlated, and we set the standard deviations of innovation shocks to match the volatility of output and public expenditures. We normalize steady-state productivity z to be equal to 1, and public expenditures g to be 12% of output.

The model still requires parameter values for fundamentals governing the technological choice in the domestic economy. There is no direct empirical counterpart, and we use indirect moments to set these parameters. More specifically, we set a functional form for the distribution of returns H, and use a uniform distribution with parameters a_1 and a_2. We then set a_1, a_2, and θ such as to match (a) the steady-state transparency:

$$\gamma = H\left[(1-\tau)\gamma^{\frac{1}{\phi}-1}\right],$$

(b) the elasticity of transparency,

$$\frac{\partial\gamma}{\partial\tau} = -\frac{(1-\theta)(1-\theta\beta)\gamma^{\frac{1}{\phi}-1}h[H^{-1}(\gamma)]}{1+\theta^2\beta-(1-\theta)(1-\theta\beta)(1-\tau)\gamma^{\frac{1}{\phi}-2}\left(\frac{1}{\phi}-1\right)h[H^{-1}(\gamma)]},$$

and (c) the persistence of transparency,

$$\frac{\partial\gamma'}{\partial\gamma} = \frac{\theta}{1+\theta^2\beta-(1-\theta)(1-\theta\beta)(1-\tau)\gamma^{\frac{1}{\phi}-2}\left(\frac{1}{\phi}-1\right)h[H^{-1}(\gamma)]},$$

where the steady-state level of taxation verifies $\tau = g/\gamma^{1/\phi}$. In Section 2, we derive other empirical moments that we further use as over-identification tests of our calibration. Intuitively, the steady-state and volatility of transparency mostly pin down the shape of returns in the informal sector and complementarities in the formal sector, while the persistence of transparency pins down the period probability to reset technology.

In order to solve the model, we discretize the analysis and create grids for each of the state variables. In particular, the AR(1) processes for productivity and public expenditures are discretized using Tauchen (1986) method.

We solve numerically the model as a fixed point problem. As the government does not have commitment on its future policy, the problem can be solved as a fixed point problem in which we iterate over the future behavior of the government and the investor debt pricing schedule. More specifically, we first set two policy functions $s \mapsto \gamma(s)$ and $s \mapsto q(s)$, which characterizes the future transparency choice of the government, as a function of state variable s, and future expected default, as a function of contemporary transparency and debt. Given the policy functions $s \mapsto \gamma(s)$ and $s \mapsto q(s)$, we solve the dynamic problem of the government through value function iteration.[25] We then update the policy functions $s \mapsto \gamma(s)$ and $s \mapsto q(s)$, using the government choice of transparency and default obtained in the previous step, and we iterate until we converge to the fixed point.

5.2 Policy functions

We first analyze the model by plotting the government policy function (b_{t+1}, γ_t) and the debt pricing schedule q_{t+1}. For the sake of exposure, we display the two policy functions as functions of the most important state variables separately (see Figure 3) and then jointly (see Figure 4).

We first display the optimal fiscal policy as a function of inherited debt. As apparent in the top-right panel of Figure 3, the relationship between future debt b_{t+1} and inherited debt b_t is not monotonous and crucially depends on the level of inherited debt. For low levels of debt, the relationship is close to being linear as would be predicted under perfect commitment. For higher levels of debt, however, future debt flattens as a function of inherited debt, and this feature derives from two effects. First, the threat of default constrains government choices. Second, the government sometimes does default and future debt is then reset to 0. Distortions do play a role in this response: with high inherited debt, debt service increases and the government increases tax pressure thereby affecting transparency γ_t. The debt pricing schedule, displayed the in top-left panel of Figure 3, is flat and orthogonal to inherited debt levels for low levels, then it decreases steadily for higher debt levels.

Another interesting aspect of optimal fiscal policy is its relationship with inherited transparency γ_{t-1}, which captures the effect of dynamic distortions. A high inherited transparency allows the government to raise taxes with limited behavioral response, and thus magnify the returns to fiscal consolidations. By contrast, low inherited transparency significantly lowers the returns to taxes, and transfers from the household are very costly. The bottom panel of Figure 3 illustrates this mechanism. Low inherited transparency forces the government to raise tax rates with low returns to such tax hikes: future transparency remains low while debt increases, and default occurrences are then more likely.

Finally, the interaction of debt and distortions provides additional insight on the role of the external constraint in shaping optimal fiscal policy (see Figure 4 for the behavior of expected default as a bivariate function of debt and transparency). First, low levels of contracted debt flatten the dependence in transparency for default risk. Second, inherited debt sharply affects the impact of dynamic distortions. High levels

[25] In this dynamic problem, the government considers its future policy as if it was being set by another actor.

of contracted debt prevent the government from accumulating even higher levels of debt (the dependence of b_{t+1} in γ_{t-1} is low for high levels of b_t). Consequently, high inherited distortions force the government to implement very high taxes in order to limit debt accumulation. These high taxes induce high distortions, and there is high persistence in transparency. Instead, low levels of contracted debt allow the government to insure against inherited distortions, and relieve tax pressure in the economy (the dependence of b_{t+1} in γ_{t-1} is high for low levels of b_t).

5.3 Moments of the baseline economy

In this section, we evaluate the ability of the quantitative model to reproduce three key empirical facts that we describe below.

Austerity traps First, we analyze the occurrence and length of austerity traps in the model and in the data. We define an episode of austerity trap as a period of below-median output, above-median tax rate and above-median debt. We construct three indicators based on this definition: (i) the occurrence of an austerity trap, (ii) the length of austerity traps, and (iii) a variable characterizing whether the exit corresponds to a default, or a partial default. The second panel of Table 7 displays the frequency, length and outcome of austerity trap in the data, and in the 1,000 simulated economies over 30 years.

Cyclicality of fiscal policies The second panel of Table 7 displays the cyclicality of fiscal policy in the data, and in the 1,000 simulated economies over 30 years. We report the details of the empirical specification in Appendix Table A5 where we use the annual percentage change in VAT effective rates $\Delta\tau_{tc}$ as the dependent variable and the HP-filtered GDP as the explaining variable.[26] VAT rates are negatively correlated with the business cycle, which correspond to a pro-cyclical fiscal policy, in an economy where tax compliance is volatile. Fiscal policy is particularly pro-cyclical when debt levels are large. This qualitative observation is also present in the simulated economies. Fiscal policy is mostly pro-cyclical in the baseline economy when debt levels are large.

Fiscal consolidations and default risk We then quantify the ability of the model to match the relationship between episodes of fiscal consolidation and default risk, accounting for the non-exogenous timing of fiscal consolidations. In order to estimate the theoretical correlation, we simulate 1,000 economies (characterized by

[26]Our empirical approach replicates the exercise performed in Vegh and Vuletin (2015).

the same primitives as our baseline calibrated economy), hit by productivity and expenditure shocks over 100 years. We then isolate episodes of fiscal consolidations defined as the periods where tax rates increase. As can be seen in the third panel of Table 7, the correlation between the primary balance and the default risk - measured by the 10yrs yield on sovereign bond - is low because fiscal consolidations are distortive in the baseline economy. As in the data, these values are correlations, and slightly differ from the causal estimates previously described (see the description of policy functions). Indeed, the government mostly implements fiscal consolidation when the other co-variates (i.e., the shocks) make them less distortive, and the conditional effect captured in policy functions is a lower bound for the average sensitivity of default risk during fiscal consolidations.

Table 7 contrasts these estimates with the data. We collect the episodes of fiscal consolidation classified by Alesina et al. (2016) across our 30 countries and 30 years, and regress the change in 1-year bond spread on the size of these fiscal consolidations (controlling for country fixed effects). As shown in Appendix Table A4, fiscal consolidations are associated with a marked decrease in default risk, but only in the group of low-volatility countries. Instead, countries with highly-volatile tax compliance do not see large changes in default risk.

In order to make apparent the congruence between fiscal consolidation and default risk, we also provide evidence about default episodes. Table 7 presents the unconditional probability of a default and the conditional probability for economies with high debt (above the median debt over the period).

5.4 Counterfactual experiments

In this section, we depart from the baseline economy and study the dynamics of fiscal policy and default in different scenarios. We first calibrate a *high-elastic* economy (Experiment I). Second, we consider an economy with *perfect tax enforcement* where the response of tax compliance to changes in the economic environment (both business cycle and tax rates) are shut down (Experiment II). Third, we analyze a *low-default risk* economy with more commitment to reimburse (Experiment III).As in the previous section, we simulate 1,000 economies for each calibrated economy and compute the associated moments in Table 8.

First, we observe that austerity traps occur more often and are longer in economies with larger elasticity of tax compliance and/or higher default risk, except for the case where they last one single period because of default. These countries are therefore more often in close to a debt cliff that pushes them to increase taxes while the economy is in recession. The second panel of Table 8 shows indeed that fiscal policy is pro-cyclical in all economy - and especially so when debt is high - but in the environment with *perfect tax enforcement*. When tax compliance is not a choice variable (Experiment II), the elasticity is equal to 0 and fiscal policy turns slightly countercyclical. Finally, primary balance and spread are overall positively correlated. This implies that the fiscal efforts in producing fiscal surpluses do not tend to decrease the interest rate on sovereign debt. However, while countries with lower elasticity of tax compliance (benchmark) manage to reduce their interest payments during fiscal consolidations and high debt, countries with larger elasticity (Experiment I) do not. These countries are hanging off the cliff: they fall more often in an austerity trap and despite their fiscal surplus, they are not able to reduce their default risk. Once either the tax compliance channel or the default channel (Experiments II and III) are shut down, countries do not hang off the cliff : the correlation between primary balance and spread is negative. These results are also consistent with the empirical evidence on the yields for 10yrs sovereign bonds and the debt/gdp for low- and high-volatile countries shown in Figure 2.

6 Final remarks

While fiscal policies are known to be pro-cyclical in developing countries and acyclical in developed countries, we provide, in this paper, a rationale for this observation. In economies plagued by tax evasion, fiscal policy influences the technological choice of entrepreneurs, which affects the future trade-off between repayment and default. Following a string of negative shocks, economies subject to these internal fiscal distortions may fall in an austerity trap, i.e., an episode of high taxes, high tax evasion and high default risk. These periods are self-sustained: high tax rates generates long-run distortions which affect default risk, and such high default risk forces the government to implement fiscal consolidations. The economy can either exit the trap after a negative shock and the government defaults, or the economy needs a series of positive shocks to reduce the impact of distortions on debt service.

We first study empirically a measure of tax compliance across countries and over time, and show that (i) there are important differences across countries in the volatility of tax compliance, (ii) tax compliance responds strongly to taxes and the cycle in economies with volatile tax compliance.

We introduce this tax compliance channel in a simple model in which a government uses taxes as a consumption-smoothing instrument. We show that austerity traps and pro-cyclical fiscal policies arise from the interaction of two frictions, limited commitment which prevents the government from accumulating debt above certain levels and imperfect tax enforcement. When both frictions exist, the debt threshold is very low (the government is very likely to default because taxing households is extremely costly relatively to default costs), and the economy often ends up close to this debt ceiling. In the proximity to the debt ceiling, the inetraction of the two frictions generate lenghty austerity traps.

With perfect commitment, a government would be able to smooth consumption over time, and distortions related to imperfect tax enforcement would only affect the intertemporal program through small distortions costs: fiscal policy would be markedly counter-cyclical because high taxes are relatively less distortive in good times than in bad times.

The existence of fluctuations in tax compliance opens a new, and so far unexplored, insight on the behavior of fiscal multiplier over time and across instruments. Alesina and Ardagna (2009), Romer and Romer (2010), Favero et al. (2011), Auerbach and Gorodnichenko (2012), Ilzetzki et al. (2013), Alesina et al. (2015) have estimated fiscal multipliers, across countries, across intruments, or across the cycle. We think that, as argued in Pappa et al. (2015), (tax evasion and) corruption goes a long way into explaining the findings, particularly in countries with limited commitment both toward foreign creditors, and toward their own tax payers.

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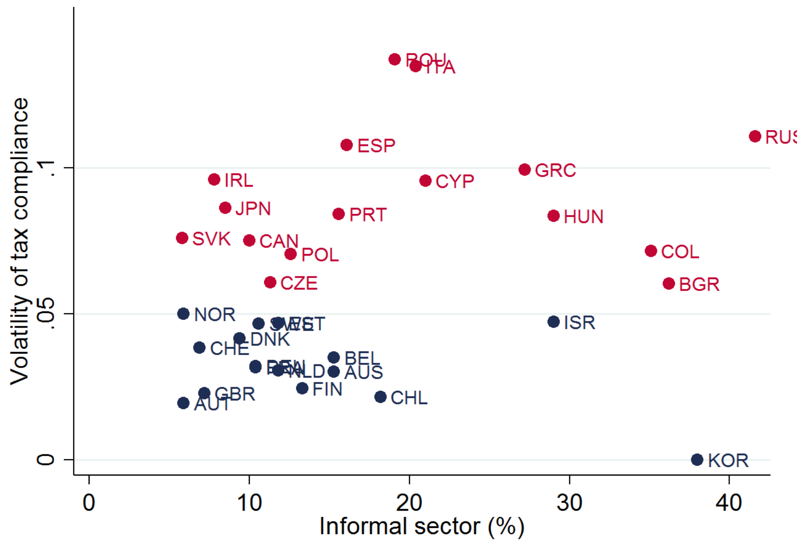
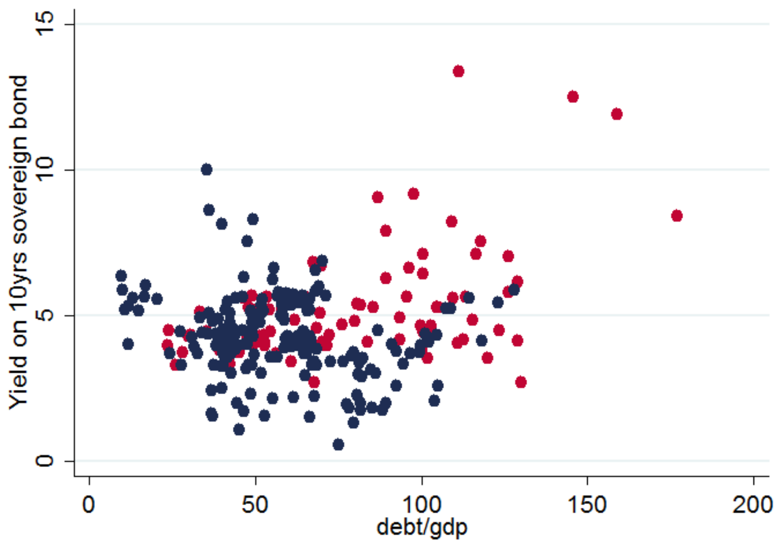
Tables and figures

Figure 1. Volatility in VAT compliance and the size of the informal sector (red: above-median volatility, blue: below-median volatility).



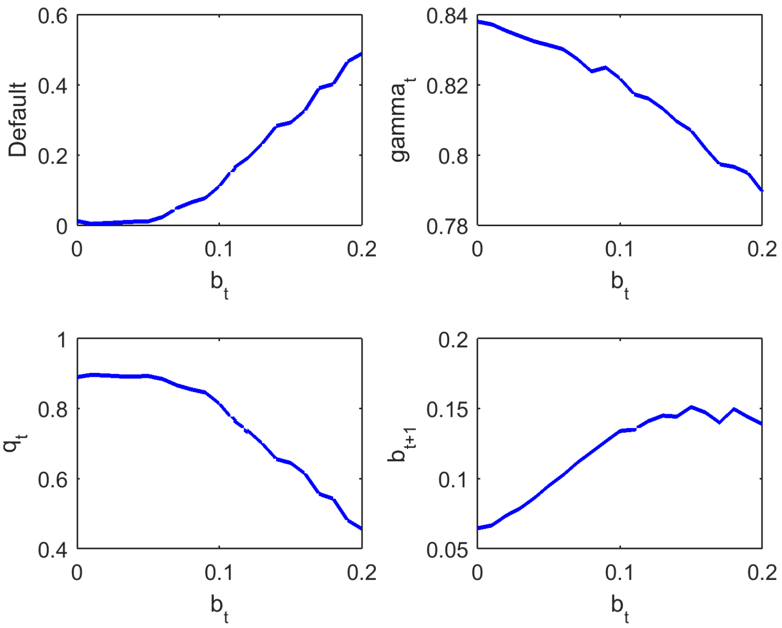
Notes: This Figure displays the within-country standard deviation of VAT compliance along the y-axis (1995–2013), and the size of the informal sector (2005–2012) as computed in Schneider and Enste (2013).

Figure 2. Volatility in VAT compliance, 10 yrs yield and sovereign debt (red: above-median volatility, blue: below-median volatility).

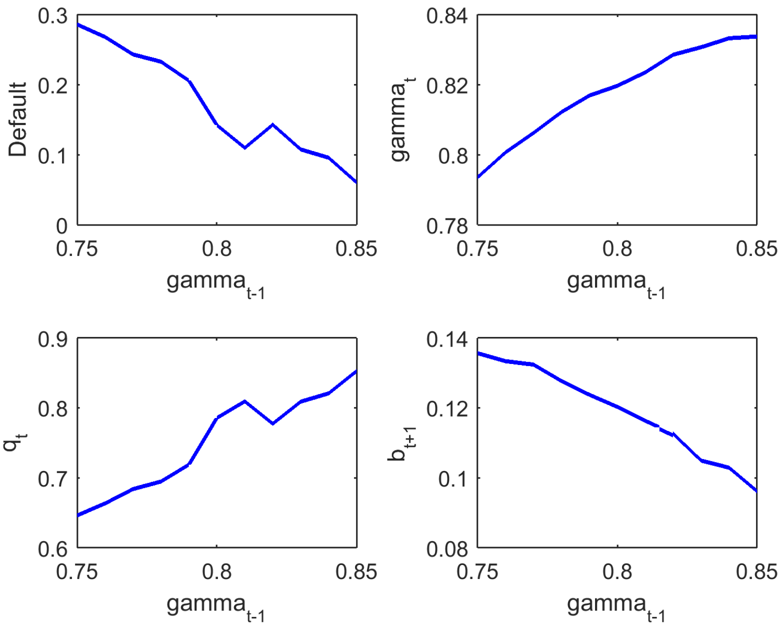


Notes: This Figure displays the 10 yrs yield on sovereign bond and the debt to gdp ratio. Each dot corresponds to a country-year pair in our sample.

Figure 3. Policy functions (policy and debt pricing schedule) as a function of inherited debt (panel a) and transparency (panel b).



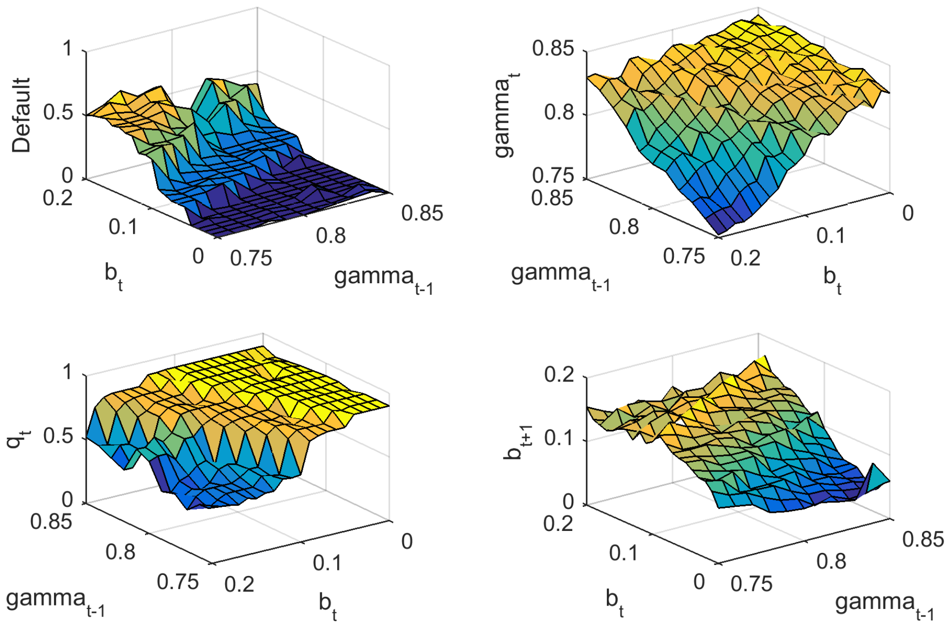
(a) Debt.



(b) Transparency.

Notes: The top panel displays the policy choice as a function of inherited debt b_t, and averaged over all possible (other) state variables. The top panel displays the policy choice as a function of inherited transparency γ_{t-1}, and averaged over all possible (other) state variables.

Figure 4. Policy functions as a function of both inherited transparency and debt).



Notes: This Figure displays the policy choice as a multivariate function of b_t and γ_{t-1}, and averaged over all possible (other) state variables.

Table 1. Descriptive statistics.

	Sample			Coefficient	
	All	High-vol	Low-vol	of variation	Cyclicality
Total tax revenues (% GDP)	21.44	20.15	22.62	.103	0.078
Corporate tax (% revenues)	15.16	16.51	14.21	.176	0.122
Income tax (% revenues)	28.85	28.03	29.43	.133	-0.027
Value-added tax (% revenues)	31.72	31.14	32.13	.096	0.028
Corporate tax rate (%)	27.97	27.40	28.41	.158	-0.041
Income tax rate (%)	42.16	37.20	46.09	.170	-0.056
Value-added tax rate (%)	14.7	13.57	14.87	.087	-0.205
VAT Compliance ratio	.874	.843	.902	.095	0.327

Notes: The *coefficient of variation* is the average coefficient of variation computed for each country (standard deviation/mean). *Correlation with the cycle* is computed by taking the annual change in the dependent variable, and estimate its correlation with the annual change in HP filtered GDP per capita. See Section 2 for the definition of High- and low-volatility countries.

Table 2. Elasticities of VAT compliance to cyclical fluctuations.

Panel A				
VAT compliance	(1)	(2)	(3)	(4)
GDP growth	.392***	.395***	.408***	.401***
	(.108)	(.124)	(.124)	(.139)
Observations	602	524	524	419
Sectoral composition	No	Yes	Yes	Yes
Trade	No	No	Yes	Yes
Government expenditures	No	No	No	Yes
Panel B				
Tax compliance	(1)	(2)	(3)	(4)
GDP growth	.018	.060	.083	.022
	(.146)	(.157)	(.159)	(.167)
GDP growth × High-volatility	.582***	.565***	.545***	.637***
	(.157)	(.167)	(.168)	(.171)
Observations	602	524	524	419
Sectoral composition	No	Yes	Yes	Yes
Trade	No	No	Yes	Yes
Government expenditures	No	No	No	Yes

Significantly different than zero at * 90% confidence, ** 95% confidence, *** 99% confidence. Robust standard errors are reported between parentheses. All specifications include year- and country-fixed effects. VAT compliance is the yearly percentage change in VAT compliance. GDP growth is the yearly difference in GDP growth, measured in percentage points. See Section 2 for the definition of the *High-volatility* dummy.

Table 3. Elasticities of VAT compliance to VAT standard rates.

Panel A				
VAT compliance	(1)	(2)	(3)	(4)
VAT rate	-.368***	-.385***	-.379***	-.371***
	(.055)	(.057)	(.057)	(.081)
Observations	539	477	477	385
Sectoral composition	No	Yes	Yes	Yes
Trade	No	No	Yes	Yes
Government expenditures	No	No	No	Yes
Panel B				
Tax compliance	(1)	(2)	(3)	(4)
VAT rate	-.110	-.115	-.104	-.053
	(.116)	(.121)	(.121)	(.136)
VAT rate × High-volatility	-.327**	-.341**	-.347**	-.477***
	(.130)	(.137)	(.137)	(.165)
Observations	539	477	477	385
Sectoral composition	No	Yes	Yes	Yes
Trade	No	No	Yes	Yes
Government expenditures	No	No	No	Yes

Significantly different than zero at * 90% confidence, ** 95% confidence, *** 99% confidence. Robust standard errors are reported between parentheses. All specifications include year- and country-fixed effects, and controls for GDP growth. VAT compliance is the yearly percentage change in VAT compliance. VAT rate is the yearly percentage change in VAT standard rate. See Section 2 for the definition of the *High-volatility* dummy.

Table 4. Elasticities of VAT compliance to VAT standard rates along the cycle.

VAT compliance	(1)	(2)	(3)
VAT rate	-.283**	-.293***	-.298***
	(.114)	(.104)	(.114)
VAT rate × Recession 1	-.172		
	(.149)		
VAT rate × Recession 2		-.185	
		(.151)	
VAT rate × Recession 3			-.149
			(.150)
Observations	419	419	419
Sectoral composition	Yes	Yes	Yes
Trade	Yes	Yes	Yes
Government expenditures	Yes	Yes	Yes

Significantly different than zero at * 90% confidence, ** 95% confidence, *** 99% confidence. Robust standard errors are reported between parentheses. All specifications include year- and country-fixed effects, and controls for GDP growth. VAT compliance is the yearly percentage change in VAT compliance. VAT rate is the yearly percentage change in VAT standard rate. *Recession 1* is equal to 1 when the HP-filtered GDP is negative; *Recession 2* is equal to 1 when the HP-filtered GDP is below the 25th percentile; *Recession 3* dummy is equal to 1 when the HP-filtered GDP is below the 50th percentile.

Table 5. Persistence of VAT compliance.

VAT compliance	OLS (1)	2SLS (taxes) (2)
VAT compliance in $t-1$	.515***	.748***
	(.042)	(.222)
Observations	448	448
F-stat (first stage)	-	13.96

Significantly different than zero at * 90% confidence, ** 95% confidence, *** 99% confidence. Robust standard errors are reported between parentheses. All specifications include year- and country-fixed effects, and controls for GDP growth and yearly changes in industrial composition.

Table 6. Calibration – Parameter values.

Parameter		Value	Rationale
Preferences			
Discount factor	β	0.90	Aguiar and Gopinath (2006)
Risk-aversion (CRRA)	s	2	Arellano (2008)
Production			
Risk-free interest rate	ρ	0.015	Arellano (2008)
Distribution (informal)	a_1	-0.12	steady-state tax compliance
Distribution (informal)	a_2	0.91	steady-state tax compliance
Complementarities	ϕ	0.5	elasticity of tax compliance
Probability to set technology	θ	0.45	persistence of tax compliance
Default			
Probability of reintegration	ν	0.04	Arellano (2008)
Output cost	δ	0.02	Arellano (2008)
Shocks			
TFP z, autocorrelation	ρ_z	0.8	GDP autocorrelation
TFP z, standard deviation	σ_z	0.03	GDP volatility
Expenditures g, autocorrelation	ρ_g	0.8	Spending autocorrelation
Expenditures g, standard deviation	σ_g	0.03	Spending volatility

Notes: See Section 5 for a detailed description of the calibration target, in particular for the technological parameters highlighted in red.

Table 7. Simulated moments: benchmark.

Description	Moment	Data	Model
Elasticity of tax compliance to tax rates	ε_{τ}	-0.20	-0.30
Average expected default	$E[D]$	–	0.027
Average expected default (high debt)	$E[D \mid b > \bar{b}]$	–	0.029
i) Austerity trap			
Occurrences	$E(AT)$	0.196	0.232
Average length AT episodes (years)	$Length(AT)$	1.860	1.215
Exit is a default	$E(D \mid AT)$	–	0.026
ii) Fiscal policy			
Corr. tax rate/output	$\rho(\tau, y)$	-0.205	-0.482
Corr. tax rate/output (high debt)	$\rho(\tau, y) \mid b > \bar{b}$	-0.458	-0.553
iii) Primary Balance and spread			
Corr. PB/spread	$\rho(PB_t, 1/q_{t+1})$	–	0.033
Corr. PB/spread in FC	$\rho(PB_t, 1/q_{t+1}) \mid \tau_{t+1}/\tau_t$	–	-0.018
Corr. PB/spread in FC and high debt	$\rho(PB_t, 1/q_{t+1}) \mid [\tau_{t+1}/\tau_t, b > \bar{b}]$	–	-0.010

This Table reports simulated moments of the baseline economy, and the corresponding empirical moments. See Section 5 for a more detailed description. Primary balance is $PB_t = t_t - g_t$. Occurrences are defined as the number of austerity trap episodes divided by the number of periods.

Table 8. Simulated moments under different scenarios.

Description	Benchmark	Exp. I	Exp. II	Exp. III
Elasticity of tax compliance to tax rates	-0.30	-0.40	0	-0.30
Average default	0.027	0.272	0.123	0.013
Average default (high debt)	0.029	0.978	0.215	0.020
i) Austerity trap				
Occurrences	0.232	0.200	0	0.207
Average length AT episodes (years)	1.215	1	–	1.174
Exit AT is a default	0.026	0.990	–	0.039
ii) Fiscal policy				
Corr. tax rate/output	-0.482	-0.139	0.075	-0.327
Corr. tax rate/output (high debt)	-0.553	-0.149	0	-0.627
iii) Primary Balance and spread				
Corr. PB/spread	0.033	0.032	-0.169	-0.048
Corr. PB/spread in FC	-0.018	0.049	-0.253	-0.123
Corr. PB/spread in FC and high debt	-0.010	0.077	-0.218	-0.185

Notes: Benchmark refers to the baseline economy while Exp. I to a low-type economy. Exp II shuts down the tax compliance channel by keeping fixed the transparency choice and Exp. III shuts down the default channel by decreasing the probability of reintegration.

Online Appendix

A Additional tables and figures

Table A1. VAT reforms in Greece (2010-2011).

Goods and services affected by VAT	Tax regime				
Reform period	Jan. 2010	Mar. 2010	Jul. 2010	Jan. 2011	Sep. 2011
Subject to Standard rate in 2010	19	21	23	23	23
CP020: Alcoholic beverages, tobacco and narcotics	19	21	23	23	23
CP030: Clothing and footwear	19	21	23	23	23
CP040: Housing, water, electricity, gas and other fuels	19	21	23	23	23
CP050: Furnishings, households equipment	19	21	23	23	23
CP060: Health	19	21	23	23	23
CP070: Transport	19	21	23	23	23
CP080: Communications	19	21	23	23	23
CP090: Recreation and culture	19	21	23	23	23
CP120: Miscellaneous goods and services	19	21	23	23	23
Subject to Reduced rate in 2010	9	10	11	13	13
CP010: Food and non-alcoholic beverages					
CP011: Food	9	10	11	13	13
CP012: Non-alcoholic beverages	9	10	11	13	23
CP040: Housing, water, electricity, gas and other fuels					
CP044: Water supply and miscellaneous (50%)	9	10	11	13	13
CP045: Electricity, gas and other fuels	9	10	11	13	13
CP060: Health					
CP061: Medical products, appliances and equipment (50%)	9	10	11	13	6,5
CP062: Out-patient services (50%)	9	10	11	13	23
CP063: Hospital services (50%)	9	10	11	13	23
CP073: Transport services	9	10	11	13	13
CP094: Recreational and cultural services (50%)	9	10	11	13	13
CP110: Restaurants and hotels					
CP111: Catering services	9	10	11	13	23
CP112: Accommodation services	9	10	11	13	6,5
Subject to Super-reduced rate in 2010	4,5	5	5,5	6,5	6,5
CP090: Recreation and culture					
CP094: Recreational and cultural services (50%)	4,5	5	5,5	6,5	6,5
CP095: Newspapers, books and stationery	4,5	5	5,5	6,5	6,5
Excluded from the scope of VAT in 2010					
CP040: Housing, water, electricity, gas and other fuels					
CP044: Water supply and miscellaneous(50%)	excl.	excl.	excl.	excl.	13
CP060: Health					
CP062: Out-patient services (50%)	excl.	excl.	excl.	excl.	13
CP063: Hospital services (50%)	excl.	excl.	excl.	excl.	13
CP100: Education					
CP101: Pre-primary and primary education	excl.	excl.	excl.	excl.	excl.
CP102: Secondary education	excl.	excl.	excl.	excl.	excl.
CP103: Post-secondary non-tertiary education	excl.	excl.	excl.	excl.	excl.
CP105: Education not defined by level	excl.	excl.	excl.	excl.	excl.
CP120: Miscellaneous goods and services					
CP125: Insurance	excl.	excl.	excl.	excl.	excl.
CP126: Financial services n. e. c.	excl.	excl.	excl.	excl.	excl.

For exposition purposes, we only report the evolution of the 1-digit categories, e.g., CP020, for goods and services subject to the standard rate in 2010. All 2-digit categories that do not appear in the other sections, e.g., CP041, are subject to the default tax rates of the associated 1-digit category.

Table A2. Robustness analysis – Decomposition along the volatility of VAT compliance versus "developed" economies.

Panel A				
VAT compliance	(1)	(2)	(3)	(4)
GDP growth	-.006	.069	.092	.063
	(.160)	(.174)	(.175)	(.188)
GDP growth × High-volatility	.657***	.611***	.589***	.753***
	(.160)	(.171)	(.172)	(.181)
GDP growth × Industrial	.008	-.017	-.012	-.114
	(.168)	(.183)	(.182)	(.191)
Observations	558	485	485	392
Sectoral composition	No	Yes	Yes	Yes
Trade	No	No	Yes	Yes
Government expenditures	No	No	No	Yes
Panel B				
Tax compliance	(1)	(2)	(3)	(4)
VAT rate	-.089	-.154	-.136	-.374
	(.151)	(.168)	(.168)	(.229)
VAT rate × High-volatility	-.334**	-.311**	-.319**	-.225
	(.134)	(.143)	(.143)	(.209)
VAT rate × Industrial	-.044	.034	.023	.318
	(.112)	(.122)	(.123)	(.199)
Observations	558	485	485	392
Sectoral composition	No	Yes	Yes	Yes
Trade	No	No	Yes	Yes
Government expenditures	No	No	No	Yes

Significantly different than zero at * 90% confidence, ** 95% confidence, *** 99% confidence. Robust standard errors are reported between parentheses. All specifications include year- and country-fixed effects. VAT compliance is the yearly percentage change in VAT compliance. GDP growth is the yearly difference in GDP growth, measured in percentage points. See Section 2 for the definition of the *High-volatility* dummy.

Table A3. Robustness analysis – Elasticities of VAT rates to VAT effective rates.

Panel A				
VAT compliance	(1)	(2)	(3)	(4)
VAT rate	-.442***	-.442***	-.437***	-.412***
	(.046)	(.050)	(.050)	(.069)
Observations	539	477	477	385
Sectoral composition	No	Yes	Yes	Yes
Trade	No	No	Yes	Yes
Government expenditures	No	No	No	Yes
Panel B				
Tax compliance	(1)	(2)	(3)	(4)
VAT rate	-.380***	-.288***	-.279***	-.190
	(.086)	(.105)	(.121)	(.127)
VAT rate × High-volatility	-.084	-.195*	-.201*	-.307**
	(.097)	(.118)	(.118)	(.147)
Observations	539	477	477	385
Sectoral composition	No	Yes	Yes	Yes
Trade	No	No	Yes	Yes
Government expenditures	No	No	No	Yes

Significantly different than zero at * 90% confidence, ** 95% confidence, *** 99% confidence. Robust standard errors are reported between parentheses. All specifications include year- and country-fixed effects, and controls for GDP growth. VAT compliance is the yearly percentage change in VAT compliance. VAT rate is the yearly percentage change in VAT effective rate. See Section 2 for the definition of the *High-volatility* dummy.

Table A4. Robustness analysis – Correlation between fiscal consolidations and default risk.

Δ Spread (10 yrs)	(1)	(2)
Δ Primary Balance	-0.120	-0.118
	(.031)	(.032)
Δ Primary Balance × High-volatility	0.084	0.075
	(.034)	(.036)
Observations	433	326
Country fixed-effects	Yes	Yes
Year fixed-effects	Yes	Yes
Basic controls	Yes	Yes
Extended controls	No	Yes

Robust standard errors are reported between parentheses. All specifications include year- and country-fixed effects. Units of observation are episodes of large fiscal consolidations (changes in fiscal surplus above 1% of output). The dependent variable is the change in 1-year bond spread and the explaining variable is the size of the fiscal consolidation. See Section 2 for the definition of the *High-volatility* dummy.

Table A5. Robustness analysis – Correlation between fiscal policy and output.

Panel A				
VAT effective rate	(1)	(2)	(3)	(4)
Cycle	-.381	-.333	-.343	-.347
	(.101)	(.111)	(.111)	(.104)
Observations	539	477	477	385
Fixed effects	Yes	Yes	Yes	Yes
Sectoral composition	No	Yes	Yes	Yes
Trade	No	No	Yes	Yes
Government expenditures	No	No	No	Yes
Panel B				
VAT effective rate	(1)	(2)	(3)	(4)
Cycle	-.183	-.218	-.226	-.205
	(.131)	(.136)	(.137)	(.125)
Cycle × High-debt	-.265	-.216	-.221	-.258
	(.143)	(.147)	(.147)	(.131)
Observations	523	466	466	385
Fixed effects	Yes	Yes	Yes	Yes
Sectoral composition	No	Yes	Yes	Yes
Trade	No	No	Yes	Yes
Government expenditures	No	No	No	Yes

Robust standard errors are reported between parentheses. All specifications include year- and country-fixed effects. The dependent variable is the change in VAT effective rate and the explaining variable is HP-filtered GDP per capita. See Section 5 for the definition of the *High-debt* dummy.

B Complements on the production side

Equilibrium in the formal sector The equation characterizing the equilibrium number of formal entrepreneurs is:

$$\frac{\gamma_t - \theta\gamma_{t-1}}{1-\theta} = H\left[(1-\theta\beta)r_t + \theta\beta E_t H^{-1}\left(\frac{\gamma_{t+1}-\theta\gamma_t}{1-\theta}\right)\right],$$

Such equation admits a unique "stable" equilibrium if

$$h\left[R_t\right]\left[-E_t\frac{\theta^2\beta}{h\left(H^{-1}\left(\frac{\gamma_{t+1}-\theta\gamma_t}{1-\theta}\right)\right)} + (1-\theta)(1-\theta\beta)(1-\tau_t)a_t\gamma_t^{\frac{1}{\phi}-2}\left(\frac{1}{\phi}-1\right)\right] < 1. \quad \text{(C)}$$

We ignore the unstable equilibrium $H(0) = 0$, and we focus on the stable equilibrium with a positive number of entrepreneurs willing to work in the formal sector.

Formal sector and returns to the formal activity The equation characterizing the equilibrium number of entrepreneurs in the formal sector implicitly relates the size of the formal sector γ_t to the aggregate relative returns to the formal sector, and to z_t or τ_t in particular:

$$\frac{\partial\gamma_t}{\partial z_t} = \frac{(1-\theta)(1-\theta\beta)(1-\tau_t)\gamma_t^{\frac{1}{\phi}-1}h\left[R_t\right]}{1+E_t\frac{\theta^2\beta h[R_t]}{h(R_{t+1})} - (1-\theta)(1-\theta\beta)(1-\tau_t)z_t\gamma_t^{\frac{1}{\phi}-2}(\frac{1}{\phi}-1)h\left[R_t\right]},$$

and

$$\frac{\partial\gamma_t}{\partial\tau_t} = -\frac{z_t}{1-\tau_t}\frac{\partial\gamma_t}{\partial z_t}.$$

Tax receipts and output in equilibrium We write the tax receipts and the output net of taxes:

$$\begin{cases} t_t = \tau_t z_t \gamma_t^{\frac{1}{\phi}} \\ w_t = (1-\tau_t)z_t\gamma_t^{\frac{1}{\phi}} + \theta\int_{R_{t-1}}^{\infty} Rh(R)dR + (1-\theta)\int_{R_t}^{\infty} Rh(R)dR \end{cases}$$

Differentiating these expressions, we find that:

$$\begin{cases} \dfrac{\partial t_t}{\partial \tau_t} = z_t \gamma_t^{\frac{1}{\phi}} + \frac{z_t \tau_t}{\phi} \gamma_t^{\frac{1}{\phi}-1} \frac{\partial \gamma_t}{\partial \tau_t} \\ \\ \dfrac{\partial w_t}{\partial \tau_t} = -z_t \gamma_t^{\frac{1}{\phi}} + z_t(1-\tau_t)\frac{1}{\phi}\gamma_t^{\frac{1}{\phi}-1} \frac{\partial \gamma_t}{\partial \tau_t} - (1-\theta) R_t h(R_t) \frac{\partial R_t}{\partial \tau_t} \end{cases}$$

Using the fact that $(1-\theta)h(R_t)\frac{\partial R_t}{\partial \tau_t} = \frac{\partial \gamma_t}{\partial \tau_t}$, we get:

$$\begin{cases} \dfrac{\partial t_t}{\partial \tau_t} = z_t \gamma_t^{\frac{1}{\phi}} + \frac{z_t \tau_t}{\phi} \gamma_t^{\frac{1}{\phi}-1} \dfrac{\partial \gamma_t}{\partial \tau_t} \\ \\ \dfrac{\partial w_t}{\partial \tau_t} = -z_t \gamma_t^{\frac{1}{\phi}} + \left[(1-\tau_t)\frac{z_t}{\phi}\gamma_t^{\frac{1}{\phi}-1} - R_t\right] \dfrac{\partial \gamma_t}{\partial \tau_t} \end{cases}$$

These two expressions highlight the existing distortions exerted by taxes. Indeed, total output $w_t + t_t$ strongly depends on the transparency response $\frac{\partial \gamma_t}{\partial \tau_t} < 0$ as follows:

$$\frac{\partial (w_t + t_t)}{\partial \tau} = \left(\frac{z_t}{\phi}\gamma_t^{\frac{1}{\phi}-1} - R_t\right) \frac{\partial \gamma_t}{\partial \tau_t} < 0$$

Distortions also depend on the factor $\frac{z_t}{\phi}\gamma_t^{\frac{1}{\phi}-1} - R_t > 0$. In the case $\theta = 0$, this term simplifies and we get:

$$\frac{\partial (w_t + t_t)}{\partial \tau} = \tau_t \frac{z_t}{\phi} \gamma_t^{\frac{1}{\phi}-1} \frac{\partial \gamma_t}{\partial \tau_t} < 0$$

A low ϕ would be associated with high complementarity in the formal sector, and taxes would then be particularly distortive.

A phase diagram We now show how the *interaction* of imperfect tax enforcement and limited commitment affects the government dynamic choices in a stylized phase diagram. For the sake of exposure, we assume that the government can choose partial default, i.e., $D_t \in [0, 1]$. The Lagrangian of the dynamic program is:

$$\mathcal{L}(s_t) = u\left(w_t - D_t\delta\right) + \beta E_t v(s_{t+1}) - \lambda_t\left[(1-D_t)b_t - q_{t+1}b_{t+1} - t_t + g_t\right]$$
$$-\mu_t \left\{ \frac{\gamma_t - \theta\gamma_{t-1}}{1-\theta} - H\left[(1-\theta\beta)\left(z_t\gamma_t^{\frac{1}{\phi}-1} - \frac{t_t}{\gamma_t}\right) + \theta\beta E_t H^{-1}\left(\frac{\gamma_{t+1} - \theta\gamma_t}{1-\theta}\right)\right]\right\}$$

where $w_t = z_t\gamma_t^{\frac{1}{\phi}} - t_t + \theta\int_{R_{t-1}}^{\infty} R dH(R) + (1-\theta)\int_{R_t}^{\infty} R dH(R)$.

Letting λ_t and μ_t denote the shadow prices associated with the first and second constraints, the solution to this program verifies the following system—as long as there is no default in period t (first-order conditions with respect to b_{t+1}, t_t and γ_t):

$$\begin{cases} \lambda_t \left[\frac{\partial q_{t+1}}{\partial b_{t+1}} + q_{t+1}\right] = \beta E_t \left[(1 - D_{t+1})\lambda_{t+1}\right] \\ \lambda_t = u^{'}(w_t) + \mu_t \frac{1-\theta\beta}{\gamma_t} h(R_t) \\ u^{'}(w_t)\frac{\partial w_t}{\partial \gamma_t} + \beta E_t \frac{\partial v_{t+1}}{\partial \gamma_t} + \lambda_t \frac{\partial q_{t+1}}{\partial \gamma_t} b_{t+1} = \mu_t \left[\frac{1}{1-\theta} - h(R_t)\frac{\partial R_t}{\partial \gamma_t}\right] + \beta E_t \mu_{t+1} \left[-\frac{\theta}{1-\theta} + h(R_{t+1})\frac{\partial R_{t+1}}{\partial \gamma_t}\right] \end{cases}$$

The first equation can be written as the following dynamic Euler equation:

$$\beta E_t \left[(1 - D_{t+1})(\lambda_{t+1} - \lambda_t)\right] = \frac{\partial q_{t+1}}{\partial b_{t+1}} \lambda_t \tag{6}$$

The second and third equations can be re-arranged as follows:

$$E_t[\mu_{t+1} - \mu_t] = F(\eta_t, \lambda_t) \tag{7}$$

Equation (6) describes a contracting path for the marginal utility of consumption (weighted by distortions) as long as the government does not default, and the contraction rate depends on the elasticity of spread to debt. In other words, a government facing default risk optimally chooses an increasing consumption path as long as shocks along this path do not lead to a default.

We can analyze the dynamic evolution of government choices, in expectations, in a phase diagram (λ_t, μ_t) (see Figure 5). The quantity λ_t is the shadow price associated with the budget constraint. The quantity μ_t is the dynamic distortion cost associated with imperfect tax enforcement.

Before describing the dynamics of the system in a phase diagram, please note that:

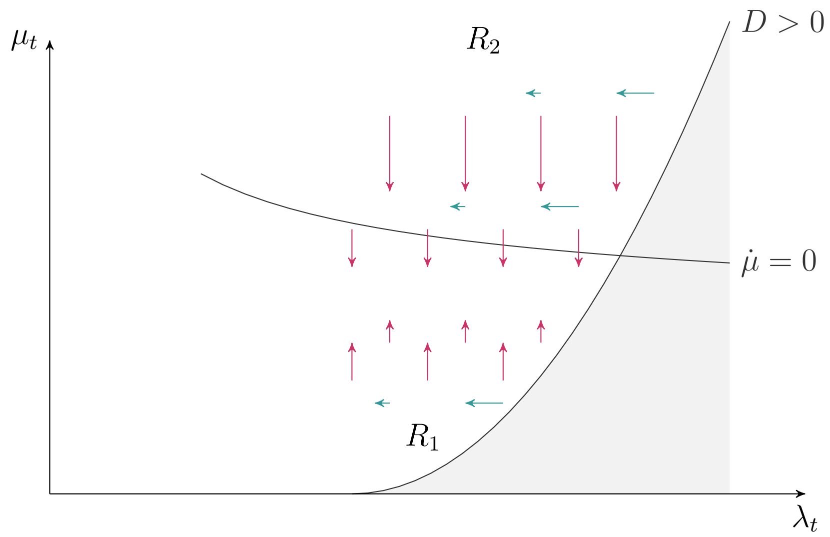
- The marginal utility of consumption $u^{'}(w_t)$ is a weighted average of the two shadow prices (λ_t, μ_t). The government internalizes the cost of the budget constraint in λ_t but also how current tax compliance will restrain its choices in the future.

- In the diagram (λ_t, μ_t) (see Figure 5), the optimal government program is such that λ_t is always decreasing in expectations (see Equation 6). It is strictly decreasing in areas where the elasticity of bond prices to debt is not equal to 0, i.e., $\frac{\partial q_{t+1}}{\partial b_{t+1}} < 0$, and stable otherwise.

- By contrast, μ_t may be decreasing or increasing in expectations, depending on the sign of $F(\mu_t, \lambda_t)$. When the government expects its choices to be more constrained in the future, the government is ready to transfer some of the distortions costs in the present and $E_t[\mu_{t+1} - \mu_t] < 0$. Instead, when the government expects its choices to be less constrained in the future, the government transfers some distortions costs to the future and $E_t[\mu_{t+1} - \mu_t] > 0$.

- These two equations describe the expected dynamics of the system along a *repayment* path. If we allow the government to default partially on its obligations, some partial default will occur as long as $\delta \leq \frac{\lambda_t}{u'(w_t)} b_{t+1}$. Default thus depends on debt but also on distortions as captured by the difference between λ_t and $u'(w_t)$. Intuitively, a default may be an efficient way to redistribute from households, who incur the default punishment δ, to the government.

Figure 5. Phase diagram for (λ_t, μ_t).



There are two regions with distinct dynamics in the phase diagram. In region R_1, $E_t[\mu_{t+1} - \mu_t] < 0$ and $E_t[(1 - D_{t+1})(\lambda_{t+1} - \lambda_t)] \leq 0$. In expectations, the marginal utility of consumption decreases over time and consumption increases over time. However, default may become more likely and the spread is not necessarily decreasing (*fiscal consolidation without consolidation*).

In region R_2, $E_t[\mu_{t+1} - \mu_t] > 0$ and $E_t[(1 - D_{t+1})(\lambda_{t+1} - \lambda_t)] \leq 0$. The default risk decreases and the economy drifts away from the default set. However, consumption may not increase over time: as the government expects to be unconstrained in the future, it transfers some of the current tax distortions to the future (*delayed fiscal consolidation*).

The *interaction* of imperfect tax enforcement and limited commitment plays an important role in these dynamics. When $\theta = 0$ (no dynamic role for tax enforcement), Equation (7) collapses to a static equation and the adjustments with respect to distortions are immediate. In such case, default risk can only decrease in expectations. When the government has perfect commitment, then $E_t\left[\lambda_{t+1}-\lambda_t\right]=0$ and the government perfectly smoothes consumption weighted by a distortion factor. Consumption may thus slightly decrease or increase depending on future expected distortions.