Non-linear effects of tax changes on output: The role of the initial level of taxation*

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Abstract

We estimate the effect of worldwide tax changes on output following the narrative approach developed for the United States by Romer and Romer (2010). We use a novel dataset on value-added taxes for 51 countries (21 industrial and 30 developing) for the period 1970-2014 to identify 96 tax changes. We then use contemporaneous economic records to classify such changes as endogenous or exogenous to current (or prospective) economic conditions. In line with theoretical distortionary and disincentive-based arguments – and based on the exogenous tax changes – we find that the effect of tax changes on output is highly non-linear. The tax multiplier is essentially zero under relatively low/moderate initial tax rate levels and more negative as the initial tax rate and the size of the change in the tax rate increase. Based on a global sample, these novel non-linear findings suggest that the recent consensus pointing to large negative tax multipliers in industrial countries, particularly in industrial Europe (e.g., Alesina, Favero, and Giavazzi, 2015), (i) is not a robust empirical regularity, and (ii) that those findings are mainly driven by high initial tax rates in these countries. We also show that the bias introduced by misidentification of tax shocks critically depends on the procyclical or countercyclical nature of endogenous tax changes. We evaluate the relevance of our arguments both for our global sample and for Romer and Romer's U.S. dataset.

JEL Classification: E32, E62, H20.

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1 Introduction

After the 2007-2008 Global Financial Crisis, fiscal multipliers – the effects of fiscal policy on aggregate output – have taken center stage in the policy world. Motivated early on by the policy focus on fiscal stimulus (to counter the economic recession that followed the crisis) and, more recently, by fiscal consolidation (due to increasing concerns about debt sustainability) studies estimating government spending multipliers and, to a lesser extent, tax multipliers have flourished.

The main challenge and point of contention among researchers has been how to address the possible endogeneity of fiscal policy or, put differently, how to identify exogenous fiscal policy shocks (i.e., changes in fiscal policy variables that are not directly or indirectly related to output changes). On the taxation front, which is the focus of this paper, there is an emerging consensus in the literature that the so-called narrative approach developed by Romer and Romer (2010) (henceforth RR) in their study of the United States is better suited to identifying exogenous tax policy shocks than the traditional approach pioneered by Blanchard and Perotti (2002) (hereafter BP). The BP approach imposes short-term restrictions in the context of structural vector autoregressions (SVAR). While changes in tax policy are allowed to contemporaneously affect output, it is assumed that it takes the government at least one quarter to respond to developments in the state of the economy. While appealing at first sight, this timing identifying strategy has been criticized on the basis that most changes in fiscal policy, including tax changes, are actually anticipated by agents (e.g., Ramey and Shapiro, 1998; Leeper, Walker, and Yang, 2008; Ramey, 2011; Auerbach and Gorodnichenko, 2012a; and Riera-Crichton, Vegh, and Vuletin, 2016). Moreover, and especially for large and sudden falls in output, it is not obvious that within-the-quarter economic developments do not affect tax policy. For example, during episodes of natural disasters, it is often the case that governments quickly respond by increasing or reducing taxes. The earthquakes in Ecuador (2016), Japan (2011), India (2001), and California (1989) are clear examples of the unsuitability of the BP timing assumption as tax responses occurred within 26, 47, 6, and 18 days following the earthquakes, respectively.[1]

In contrast, RR use narrative records, from Congressional reports to presidential speeches, to identify the principal motivation behind all major postwar tax policy actions in the U.S. The analysis of contemporaneous records enables RR to separate legislated tax changes into those enacted for reasons related to current or prospective economic conditions (i.e., endogenous to the business cycle) from those taken for reasons exogenous to the business cycle, including those motivated by long-run growth considerations (e.g., by a belief that lower taxes will raise output in the long run) and inherited deficit-driven tax changes (which reflect past economic conditions and budgetary decisions, not current or prospective ones). With this classification of tax changes in hand, RR

[1] See Appendix 1 for more details about the nature of these earthquakes, effects on GDP, as well as the tax policy responses.

analyze the behavior of output following exogenous tax changes. RR find that (i) tax hikes (cuts) lead to contractions (expansions) in economic activity, and (ii) misidentification of tax shocks (i.e., when using all tax changes à la BP) tends to underestimate the negative effect of tax changes on output. Interestingly, RR also find that the effect of tax changes on output varies depending upon the motivation for the exogenous tax change. While the tax multiplier associated with long-run growth considerations is negative (and virtually identical to that of a generic exogenous tax change), the multipliers of deficit-driven tax changes are essentially zero. For this reason, RR cautiously suggest that "tax increases to reduce an inherited deficit may be less costly than other tax increases."

Since RR's seminal work, several other studies have used the narrative approach for individual or multi-country analyses (in all cases, focusing *solely* on industrial economies, and mostly on industrial European countries). These studies find large negative tax multipliers, ranging between -2 and -5.[2] This recent consensus pointing to large negative tax multipliers, especially in industrial European countries, naturally entails important policy prescriptions. For example, as part of a more comprehensive series of papers focusing on spending and tax multipliers, Alesina, Favero, and Giavazzi (2015) point that "policies based upon spending cuts are much less costly in terms of short run output losses than tax based adjustments." A natural question is whether large negative tax multipliers are a robust empirical regularity and, if not, whether there are some underlying forces behind the observed difference in tax multipliers across countries or groups of countries. In order to answer this highly relevant academic and policy question, one would ideally need to conduct a study using a more global sample including industrial and, particularly, developing countries. To the best of our knowledge, there is no such a study. The main reason is surely the lack of data on legislated tax changes in developing countries, which is needed to capture the behavior of a tax policy instrument (i.e., a variable that is under the direct control of policymakers).[3] Furthermore, unlike the BP approach, the RR narrative approach poses a major challenge in terms of the sheer time needed to gather contemporaneous economic records to identify the motivation behind each

[2] Relying on the narrative approach for fiscal consolidation episodes and using a multi-country analysis, Alesina, Favero, and Giavazzi (2015) find, for a sample of 17 industrial countries, a tax multiplier of about -2 (after two years of the tax shock). Using a similar identification strategy, yet based on value-added tax rate changes, Riera-Crichton, Vegh, and Vuletin (2016) find for a sample of 14 industrial countries a tax multiplier of about -3.5 (after one year of the tax shock). Relying on the narrative approach for country-specific studies, RR, Cloyne (2013), Hayo and Uhl (2013), Gil, Marti, Morris, Perez, and Ramos (2017), and Pereira and Wemans (2013) find a tax multiplier of about -2.7, -2, -2.4, -2, and -1.7 (after two years of the tax shock) for the U.S, U.K, Germany, Portugal, and Spain, respectively. Also relying on a narrative approach, Pereira and Wemans (2013) and Gil, Marti, Morris, Perez, and Ramos (2017) find for Portugal and Spain even more negative tax multiplier for *indirect* taxation of about -2.7 and -5 (after two years of the tax shock), respectively.

[3] As discussed in RR and Mertens and Ravn (2014) for the case of the U.S. and Riera-Crichton, Vegh, and Vuletin (2016) for a sample of 14 industrial countries, cyclically-adjusted changes in tax revenues are often used as a proxy for discretionary changes in tax policy. While appealing in principle, the use of cyclically-adjusted revenues suffers from serious measurement error because it implicitly attributes any change in revenues not associated with the estimated change in the tax base to policymakers' discretionary behavior. As a result – and as shown in Riera-Crichton, Vegh, and Vuletin (2016) – tax multipliers estimated with cyclically-adjusted revenues yield misleading results.

tax change.

This paper takes on this challenge by focusing on 51 countries (21 industrial and 30 developing) for the period 1970-2014. Given the lack of readily-available data on average marginal individual and/or corporate income tax rates on a global scale, we focus our efforts on building a new series for quarterly standard value-added tax rates (henceforth VAT rates). We believe that this significant effort in collecting VAT rates is crucial for any study analyzing tax policy in Europe as well as in the developing world, where indirect/value-added taxation is the main tax revenue instrument.[4] VAT rates were obtained from various primary sources including countries' revenue agencies, national libraries, books, newspapers, tax law experts, and research and policy papers. We identify a total of 96 VAT rate changes in 35 countries (18 industrial and 17 developing). As sources for the narrative analysis, we use contemporaneous International Monetary Fund (IMF) documents, OECD Economic Surveys, and news articles to gather evidence on policymakers' intentions and primary motivation behind each VAT rate change.

While closely following RR's identification strategy, we also incorporate some new elements that arise due both the global nature of our sample of countries and the specific tax measure used. In particular, we allow endogenous tax changes to include countercyclical tax changes (as in RR) as well as procyclical tax changes. While the latter type of policy behavior is not found by RR in the U.S., it is of critical importance in the developing world as well as in many other industrial countries (particularly industrial European countries after the 2007-2008 Global Financial Crisis). When focusing on exogenous tax changes motivated by inherited fiscal factors, we consider inherited *deficit*-driven tax changes (as in RR) as well as inherited *debt*-driven tax changes. Since, over the last 60 years, the U.S. has not faced sustainability problems regarding the public debt, RR do not concern themselves with the latter case. As our analysis will show, however, this distinction has important implications in terms of the size of the tax multipliers in our sample.

Relying on our novel worldwide narrative approach, we find that, for the entire global sample, the tax multiplier reaches -1.7 after two years of the tax shock. This figure is, compared to the range of estimated tax multipliers depicted before, among the least negative ones. Interestingly, when splitting the sample into industrial European economies and the rest of countries, we find tax multipliers of -3.6 and -1.2, respectively. While the tax multiplier in industrial European economies is quite negative and statistically significant (in line with recent studies), it is about 3 times smaller (in absolute value) and borderline statistically significant for the rest of countries.

Motivated by this large difference in tax multipliers, the paper's main empirical contribution consists in evaluating the role of tax distortions and disincentives in generating non-linear effects of tax changes on output. Many different kinds of non-linearities have been found in the estimation

[4] When analyzing the impact of specific taxes, Barro and Redlick (2011) focus on the effect of individual income and social-security payroll taxes in the U.S. Mertens and Ravn (2013) analyze the effect of individual and corporate income taxes in the U.S. Riera-Crichton, Vegh, and Vuletin (2016) focus on the impact of VAT in 14 industrial countries.

of spending multipliers in recent years. In most cases, the non-linear effect of spending on output has been associated with the macroeconomic context in which spending decisions have taken place. Building upon different macroeconomic theoretical frameworks, recent empirical findings have shown that spending multipliers tend to be larger under fixed exchange-rate regimes (Ilzetzki, Mendoza, and Vegh, 2013), under low debt (Ilzetzki, Mendoza, and Vegh, 2013; Huidrom, Kose, and Ohnsorge, 2016), and in recessions (Auerbach and Gorodnichenko, 2012a,b; Riera-Crichton, Vegh, and Vuletin, 2015). Rather than focusing on the aforementioned macroeconomic-based non-linear effects, our paper focuses on the non-linear effects of tax changes on output generated by distortionary and disincentive-based arguments.[5]

Based on different types of macroeconomic models (which in turn rely on different mechanisms), the output effect of tax changes is expected to be small at low initial levels of taxation but exponentially larger when initial tax levels are high. Therefore, the distortions and disincentives imposed by taxation on economic activity are directly, and non-linearly, related to the level of tax rates. By the same token, for a given level of initial tax rates, larger tax rate changes have larger tax multipliers. These theoretical results are present, for example, in Jaimovich and Rebelo (2017) (hereafter JR) who show that such a non-linear mechanism may operate through heterogeneity in entrepreneurial ability and its disincentives to innovate and invest. We also propose an alternative explanation for such a non-linear effect, based on the role played by informality. For this purpose, we use a simple reduced-formed solution type of model, where both the formal and informal sectors have identical production functions. The existence of VAT (which is imposed only on the "formal" good, and not on the "informal" one) generates, in and of itself, an initial distortion in which workers are incentivized to work in the informal sector more than under the absence of such a tax. Therefore, the marginal productivity of formal workers is, in equilibrium, larger than that of informal ones. Under this situation, an increase in the VAT rate simply increases the initial distortion, raising the share of informality, and reducing total output. Moreover, larger increases in the share of informality and more profound falls in output are observed when the tax increase is implemented in a context of higher initial VAT rates. Naturally, while we exemplified the mechanism using an increase in the VAT rate, the same results hold for a reduction in the VAT rate.[6,7]

In line with theoretical distortionary and disincentive-based arguments, we find, using our novel

[5] As we will discuss later in Sections 5.6 and 6, macroeconomic-based non-linear effects are not behind the non-linear effects associated with distortionary and disincentive-based type of arguments.

[6] See Appendix 2 for details on the model. If the production functions of the formal and informal sectors allowed larger productivity in the formal sector than in the informal one (as it is frequently assumed based on firm level data evidence) and/or if there existed a segmentation in the labor market where formal workers were paid more than informal ones (as empirical evidence strongly suggests), the proposed mechanism as well as the output and informality implications would be further amplified.

[7] While different in the nature of the object under analysis (output versus tax burden), JR and our simple model based on the role played by the informal sector, also relate to a well-established public finance literature (e.g., Harberger, 1964a,b; Browning, 1975; Feldstein, 1995) which argues that the excess burden of taxation, or deadweight loss, associated with taxation is small at low tax rates, increases with higher tax rates, until, eventually, "a tax [is] imposed at so high rate that it eliminates the taxed activity." (Hines, 2007, p. 1).

worldwide narrative, that the effect of tax changes on output is indeed highly non-linear. Our empirical findings show that the tax multiplier is essentially zero under relatively low/moderate initial tax rate levels and more negative as the initial tax rate and the size of the change in the tax rate increase. Based on a global sample, these novel non-linear findings suggest that the large negative tax multipliers, especially in industrial Europe, are *not* a universal empirical regularity but are instead mainly driven by high initial tax rates for these countries. Moreover, for an important part of the world, especially in developing countries, where tax multipliers are virtually zero or slightly negative, the implied policy prescription could be the opposite of that of Alesina, Favero, and Giavazzi (2015).

The paper proceeds as follows. Section 2 outlines the conceptual framework that motivates our narrative analysis, which closely follows that of RR. However, unlike RR, we highlight the critical role of procyclical/countercyclical fiscal policy in determining the sign of the bias of the estimator of the effects of tax changes on output. Section 3 discusses our sample and data sources. Section 4 proceeds to identify the motivation behind all tax changes in our sample. We first discuss some general considerations and then classify all tax changes into endogenous and exogenous and, within each category, into various subcategories that will prove critical for the remainder of the study. We then turn to the econometric analysis. Section 5 first introduces our basic linear specification and then discusses our basic results, the biases introduced by misidentification of tax shocks, the role of expectations, and the mechanisms involved. We also show that while the tax multiplier in industrial European economies is quite negative and statistically significant (in line with recent studies), it is about 3 times smaller (in absolute value) and borderline statistically significant for the rest of countries. Section 6 shows, in line with theoretical distortionary and disincentive-based arguments, the existence of strong non-linear effects of tax changes on output. In particular, tax multipliers are essentially zero under relatively low/moderate initial tax rate levels and more negative as the initial tax rate and the size of the change in the tax rate increase. We also show that these non-linear effects are critical in explaining (i) the linear findings of Section 5 when estimating the tax multiplier for industrial Europe and the rest of countries, and (ii) the VAT or indirect tax multipliers calculated on country-specific studies using different empirical strategies. We also show further evidence that these non-linear effects are powerful in explaining (i) the different effect of tax changes on output observed depending upon the motivation of the exogenous tax change (e.g., like the one identified by RR when comparing the output effect of long-run growth versus inherited deficit-driven tax changes), (ii) the perceived (survey-based) extent to which taxes reduce the incentive to work and invest, and (iii) policymakers' tax plans to deal with the current need for increasing economic activity and addressing fiscal deficits. We also show that the same non-linear arguments are present in RR's sample. Section 7 provides some final thoughts.

2 Conceptual framework

This section outlines the conceptual framework that motivates our narrative analysis, which closely follows that of RR. However, unlike RR, we highlight the critical role of procyclical/countercyclical tax policy in determining the sign of the bias of the estimator of the effects of tax changes on output. We first lay out the basic set-up and then illustrate the possible biases.

2.1 Basic set-up

To fix ideas, let us use the simplest specification capturing how tax changes affect real GDP:

$$\Delta y_t = \alpha + \beta \Delta t_t^{all} + \varepsilon_t, \tag{1}$$

where y_t is the logarithm of real GDP (and Δy_t is thus the real GDP growth rate, expressed as the difference in logarithms), Δt_t^{all} represents all legislated tax rate changes expressed in percentage points, and ε_t is the stochastic error, with zero mean and variance σ_ε^2. Tax changes can be broken down into two types:

$$\Delta t_t^{all} = \Delta t_t^{exog} + \Delta t_t^{endog}, \tag{2}$$

where Δt_t^{endog} (*endog* stands for endogenous) are changes in tax rates enacted as a result of (i) current or prospective output growth differing from normal and/or (ii) other factors likely to affect output growth in the near future. In contrast, Δt_t^{exog} (where *exog* stands for exogenous) are changes in tax rates driven by reasons unrelated to developments likely to affect output in the near term. Therefore, while Δt_t^{exog} are orthogonal to ε_t (i.e., $cov(\Delta t_t^{exog}, \varepsilon_t) = 0$), Δt_t^{endog} are not (i.e., $cov(\Delta t_t^{endog}, \varepsilon_t) \neq 0$). As indicated by RR, examples of exogenous tax changes would be a cut in taxes (i) based on the belief that lower marginal rates will increase long-run growth or (ii) with the hope that lower revenues will eventually shrink the size of the government.

Let us now focus on endogenous tax changes. Without loss of generality, we can write Δt_t^{endog} as

$$\Delta t_t^{endog} = \gamma \varepsilon_t, \tag{3}$$

where $\gamma \lesseqgtr 0$ captures how endogenous tax changes respond to output shocks caused by factors other than taxes such as government spending, monetary policy, and terms-of-trade shocks, among many others. For example, suppose that a negative terms-of-trade shock reduces output (i.e., $\varepsilon_t < 0$). Policymakers may decide to reduce taxes to fight off such a recession (i.e., $\gamma > 0$), or they may be "forced" (due to the ensuing fall in fiscal revenues) to increase taxes (i.e., $\gamma < 0$).[8] More generally, countercyclical tax policies (aimed at smoothing out the business cycle) imply $\gamma > 0$; procyclical tax policies (which in principle tend to amplify output volatility) are captured by $\gamma < 0$; and acyclical tax policies (reflecting, on average, a non-systematic reaction of taxes to cyclical fluctuations) imply

[8] We should note that these endogenous tax changes are triggered by lower cyclical tax revenues and thus are not the result of inherited fiscal problems. This important distinction will be discussed in detail in Section 4.

$\gamma = 0$.

2.2 Biases in tax multipliers

Using equations (1)-(3), it is straightforward to show that there would be no bias if only exogenous tax changes were used to estimate (1). Formally, if we used Δt_t^{exog} (and not Δt_t^{endog}) to identify tax changes in equation (2), the bias associated with the OLS coefficient $\widehat{\beta^{exog}}$ (where $\widehat{\beta^{exog}}$ refers to the estimator for β in regression (1) when solely using Δt_t^{exog}) would be given by

$$Bias\ of\ \widehat{\beta^{exog}} \equiv E\left[\widehat{\beta^{exog}}\right] - \beta = \frac{cov(\Delta t_t^{exog}, \varepsilon_t)}{var(\Delta t_t^{exog})} = 0. \tag{4}$$

In contrast, if both Δt_t^{exog} and Δt_t^{endog} were used to identify tax changes as captured in equation (2), it is easy to show that the sign of the bias would depend on the sign of γ:

$$Bias\ of\ \widehat{\beta} \equiv E\left[\widehat{\beta}\right] - \beta = \frac{cov(\Delta t_t^{all}, \varepsilon_t)}{var(\Delta t_t^{all})} = \gamma \frac{\sigma_\varepsilon^2}{var(\Delta t_t^{all})}. \tag{5}$$

What would happen if $\gamma < 0$? Recall that $\gamma < 0$ implies that endogenous tax changes are procyclical. Then, $Bias\ of\ \widehat{\beta} < 0$, or $E\left[\widehat{\beta}\right] < \beta$. To fix ideas, suppose that $\beta < 0$ (indicating that higher taxes reduce output). Then, $E\left[\widehat{\beta}\right]$ would be even more negative. Why would that be the case? Suppose that there is a tax hike enacted in response to a decline in tax revenues triggered by a fall in output. If such a tax change was wrongly included in the estimation sample, such observation would be taken as evidence of a larger contractionary effect of tax increases on output (while it was actually the fall in output what caused the tax increase!).

What if $\gamma > 0$? When $\gamma > 0$, endogenous tax changes are countercyclical. Hence, $Bias\ of\ \widehat{\beta} > 0$, or $E\left[\widehat{\beta}\right] > \beta$. Suppose that $\beta < 0$; then $E\left[\widehat{\beta}\right]$ would be less negative (or even positive). Intuitively, the wrong inclusion of countercyclical tax changes (i.e., taxes increases during good times or tax reductions in bad times) would lead to an underestimation of the true effect of tax changes on output. Only in the case in which $\gamma = 0$ (reflecting, on average, a non-systematic response of taxes to output fluctuations) would there be no bias.

3 Narrative analysis: Sample and sources

As the conceptual framework makes clear, we need to identify the motivation behind each tax change (i.e., whether it was exogenous to the business cycle or not). To this effect, we first need to identify the size and timing of legislated tax changes, in terms of their announcement and implementation. As in RR, we proxy the announcement of tax rate changes by using the time of approval of the corresponding tax law. This section first discusses our sample and data sources and then proceeds to identify the motivation behind each tax change.

3.1 Sample

Our sample comprises 51 countries (21 industrial and 30 developing) for the period 1970-2014. Given the lack of readily-available data on average marginal individual and/or corporate income tax rates on a global scale, we focus our efforts on creating a new series for quarterly standard VAT rates, building on Vegh and Vuletin (2015) and Riera-Crichton, Vegh, and Vuletin (2016).[9] We believe that this significant effort in collecting VAT rates is crucial for any study analyzing tax policy in the developing world as well as in Europe, where indirect/value-added taxation is one of the main tax revenue instruments.[10]

Due to data availability, we use the standard VAT rate as a proxy for overall VAT policy. Such an approach could, in principle, raise concerns due to the omission of reduced VAT rates and/or exempted goods for some countries, as well as possible changes over time in the goods covered by the different rates. While data limitations prevent us from assessing the practical relevance of this concern for our whole sample of 51 countries, Vegh and Vuletin (2015) show, for a subset of 9 industrial countries, that these concerns are not warranted. First, the standard rate typically applies to most goods while reduced tax rates (if present at all) typically apply to a small subset of particular goods, including some food categories and child/elderly care. The average share of transactions covered by the standard VAT rate is about 75 percent of the total tax base. Second, the standard and average reduced VAT rates tend to be highly and positively correlated over time. In 80 percent of the countries, this correlation is larger than 0.5 and statistically significant at the one percent level. Third, the share of transactions covered by different statutory tax rates does not vary much over time in any given country. As a result, the standard VAT rate explains about 85 percent of the observed variability of the effective VAT rate (computed as the average of the different VAT rates weighted by their share in transactions as a percentage of the taxable base).[11]

3.2 Sources

The VAT rates were obtained from various primary sources, including countries' revenue agencies, national libraries, books, newspapers, tax law experts, and research and policy papers. In most cases, we were able to gather the complete time series of the VAT rate since its introduction. However, since our study focuses on the output implications of tax changes, we only use those tax changes for which we have real GDP data collected on a quarterly basis (as opposed to interpolated data). As discussed in detail in Ilzetzki, Mendoza, and Vegh (2013), relying on interpolated quarterly

[9] Vegh and Vuletin (2015) build a novel annual dataset of tax rates for 62 countries for the period 1960-2013 that comprises corporate income, highest personal income, and standard VAT rates. Riera-Crichton, Vegh, and Vuletin (2016) build a new quarterly standard VAT rate series for 14 industrial countries for the period 1980-2009.

[10] Indirect (value-added) taxes represent, on average, 43 (28) percent of total tax revenues in industrial countries and 47 (32) percent in the developing world.

[11] While the use of standard VAT rates is a good proxy for overall VAT tax policy, our narrative analysis will take into account the fact that, in some cases, changes in the standard VAT rate are intended to compensate for changes in the VAT base and/or VAT reduced rates.

data creates serious problems associated with measurement error. The coverage, which varies across countries, starts as early as 1970:Q1 and ends as late as 2014:Q4 (see column 1 in Table 1 for country-specific coverage).

As sources for the narrative analysis, we use contemporaneous International Monetary Fund (IMF) documents, OECD Economic Surveys, and news articles to gather evidence on policymakers' intentions and primary motivations for VAT rate changes. IMF documents include Staff Reports and Background Material for Article IV Consultations, as well as additional IMF country reports and publications such as Recent Economic Developments, Selected Issues, and Public Information Notices. IMF documents published prior to 1997 are available in digitalized hard copies at the IMF Archives in Washington, D.C., whereas documents from 1997 and onward are available at the IMF website. News articles were obtained from global media including BBC, Bloomberg News, EU Business, Financial Times, International Herald Tribune, Los Angeles Times, New York Times, Reuters, The Daily Mirror, The Daily Telegraph, The Guardian, The Independent, The Times, Wall Street Journal, and Xinhua News Agency as well as from individual countries' media outlets such as Mmegi (Botswana), National Post (Canada), The Globe and Mail (Canada), Prague Daily Monitor (Czech Republic), Intellinews-Czech Republic Today (Czech Republic), Irish Times (Ireland), The Belfast News Letter (Ireland), Sunday Business Post-Cork (Ireland), Baltic News Service (Latvia), The Southland Times (New Zealand), Sunday Star-Times (New Zealand), and El Pais (Spain).

4 Tax changes: Identifying motivation

This section explains the actual identification of tax changes. We first discuss some general considerations and then classify all the tax changes in our sample into endogenous and exogenous. Then, within each category, we further classify each change into various subcategories that will prove critical for the remainder of the analysis.

4.1 Identification strategy

We identify a total of 96 VAT rate changes in 35 countries (18 industrial and 17 developing). Given the time coverage of these 35 countries, there is, on average, a VAT rate change every 11 years with an average change (in absolute value) of 1.9 percentage points. The remaining 16 economies in our sample of 51 countries show no VAT rate change. Out of those 96 VAT rate changes, 60 occurred in industrial countries and 36 in developing ones.

As discussed in Section 2, and following RR's identification strategy, we separate VAT rate changes into (i) those taken as a result of current or prospective output growth differing from normal and/or in response to other factor(s) likely to affect output growth in the near future, which are called *endogenous*, and (ii) those taken for other reasons, which are called *exogenous*. Table 1 summarizes the classification of each of the 96 tax changes according to the scheme described below. A thorough analysis of each tax rate change, including the list of key country-specific references, is described in great detail in the Online Appendix. When applying these criteria – and as discussed by RR – we typically find substantial agreement across various sources on the nature of each tax change. When various motives come into the picture, we try to ascertain if one is given more weight than the others. The remainder of this section describes in great detail the nature of each classification category and discusses some illustrative examples. Table 1 characterizes each and every tax rate change identified in this study according to the classification strategy described below.

INSERT TABLE 1 *AND FIGURE* 1 *HERE*

4.2 Endogenous tax changes

As illustrated in Figure 1, we classify endogenous tax changes into two categories: (i) GDP-driven tax changes and (ii) offsetting tax changes.

- GDP-driven tax changes are those enacted by policymakers in response to deviations of (contemporaneous or prospective) output from trend. Clearly, such changes present a problem of reverse causality since we are trying to quantify the effect of tax changes on output.[12]

  In turn, GDP-driven tax changes may be countercyclical or procyclical:

  - Countercyclical tax changes: Tax changes aimed at stabilizing output around trend, which implies either cutting taxes in recessions or increasing taxes during booms. In our sample, the most common countercyclical tax change is a tax cut in response to a current or prospective recession with the aim of stimulating economic activity.[13] A clear example would be Thailand in 1999. After increasing the VAT rate from 7 percent to 10 percent during the Asian crisis in the summer of 1997, Thai authorities attempted to revive domestic demand by reducing the VAT rate back to 7 percent in March 1999. The IMF supported the stimulus package. "The package is an important step in facilitating economic recovery," said Reza Moghadam, the IMF representative in Thailand at the time.

    While less common, there are also cases in our sample in which tax rates were increased to restrain domestic demand and cool off economic activity. An example would be the tax hike implemented in Sweden in 1990 (with the VAT rate changing from 23.5 to 25 percent) that was intended to relieve pressure from very tight labor markets and wage increases.

[12] Of the 33 GDP-driven tax changes in our sample, 17 occurred in industrial countries and 16 in developing ones.

[13] In line with the findings in Vegh and Vuletin (2015), most countercyclical tax policy is to be found in industrial countries (5 out of 7 countercyclical tax changes in our sample occurred in industrial countries).

– Procyclical tax changes: Tax hikes (cuts) enacted in response to a current or prospective recession (boom).[14] The natural question is, of course, why would policymakers pursue a tax policy that would tend to amplify the underlying business cycle? In fact, procyclical tax policy falls under the more general phenomenon of procyclical fiscal policy (which would also include increasing government spending in booms and reducing it in recessions) that has been explored in detail in the literature. The most common explanations for such procyclical behavior have revolved around (i) political economy pressures that induce policymakers to loosen fiscal policy during booms and (ii) limited access to international credit markets in bad times, which forces policymakers to tighten fiscal policy.[15] While procyclical fiscal policies have been most common in developing countries, it has also been observed in several Eurozone countries since the Global Financial Crisis of 2007-2008.

  The most common procyclical tax change is a tax hike enacted in response to a current (or prospective) recession which has dramatically reduced tax revenues. In effect, particularly when large and/or sudden contractions in economic activity are involved, the increase in the fiscal deficit that results from a sharp fall in tax revenues often leads to an unsustainable public debt. In such circumstances, it is not uncommon for countries to face a sharp increase in borrowing costs or even lose access to international credit markets altogether, which leaves policymakers with no choice (other than defaulting) but to raise taxes.

  In practice, typical examples of procyclical tax changes have taken place as a direct result of sudden economic crises, including the increases (i) from 10 percent to 15 percent in Mexico (March 10, 1995) as a consequence of the Tequila crisis, (ii) from 18 percent to 21 percent in Argentina (March 16, 1995) as a consequence of the contagion effects of the Tequila crisis, (iii) from 7 percent to 10 percent in Thailand (August 5, 1997) as a consequence of the Asian financial crisis, (iv) from 10 percent to 12 percent in Ecuador (October 26, 1999) after the 1998-1999 Ecuadorean economic crisis, as well as (v) several tax hikes in Europe (Czech Republic, Finland, Greece, Hungary, Ireland, Latvia, Lithuania, Portugal, Romania, Spain, and the United Kingdom), during the 2008-2010 period, following the Global Financial Crisis.

  While less frequent, procyclical tax changes also include tax cuts made during buoyant economic times, when fiscal revenues are higher than normal due to the increase in the tax base (be it income or consumption). In such circumstances, policymakers may be subject to powerful political pressures to reduce taxes. A good example would be the

[14] We identified 26 procyclical tax changes (12 in industrial countries and 14 in developing ones).

[15] See, among others, Gavin and Perotti, 1997; Tornell and Lane, 1999; Kaminsky, Reinhart, and Vegh, 2004; Talvi and Vegh, 2005; Alesina, Campante and Tabellini, 2008; Frankel, Vegh, and Vuletin, 2013; Vegh and Vuletin, 2015; and Avellan and Vuletin, 2015.

VAT rate cut passed by France (March 1, 2000), when a stronger-than-expected fiscal position led to a reduction in the VAT rate from 20.6 percent to 19.6 percent.

We should note that, as Figure 1 indicates, procyclical tax changes are much more prevalent than countercyclical ones, with close to 80 percent (or 26 out of 33) of GDP-driven tax changes being procyclical. Moreover, procyclical tax changes are more common in the developing world than in industrial countries: while about 70 percent (or 12 out of 17) of GDP-driven tax changes are procyclical in industrial countries, this figure increases to close to 90 percent (or 14 out of 16) in developing economies.

- Offsetting tax changes are those intended to offset other factor(s) that would likely move output growth away from normal. More specifically, they involve standard VAT rate changes intended to offset the effect of changes in (i) government spending, (ii) other non-VAT taxes or (iii) the VAT base and/or VAT reduced rates.[16] Since these tax changes are, though indirectly, responding to changes in GDP, we have again a problem of reverse causality. As indicated in Figure 1, we identify 19 offsetting changes (13 in industrial countries and 6 in developing ones). The proportion of offsetting tax changes is roughly the same in industrial and developing countries, with 22 percent (or 13 out of 60) of total tax changes in industrial and 17 percent (or 6 out of 36) in developing countries.

  In line with the discussion in RR, contemporaneous IMF, OECD, and news articles often explicitly identify policymakers' intentions in this regard. However, even when that link was not made explicit, it is appropriate to classify these type of changes as endogenous. Specifically, we found the following cases:

  - In 4 cases, VAT rates were raised because government spending was increased. For example, after twelve years of armed conflict in El Salvador that ended in 1992, the new government of President Armando Calderon Sol increased the VAT rate from 10 percent to 13 percent on July 1, 1995 to help finance a "National Reconstruction Plan which will provide for the rehabilitation of damaged infrastructure [during the civil war] and the reintroduction of different segments of society into the economic mainstream," as stated by Mr. Fernandez, the IMF official at the time. In the same vein, Norway increased the VAT rate from 23 percent to 24 percent on January 1, 2001 to ensure no budgetary implications of an increase in spending on health and education.
  - In 11 cases, VAT rates were raised because other non-VAT taxes were reduced. In most cases, these VAT hikes were implemented to offset reductions in personal, corporate, and labor taxes aimed at increasing competitiveness and labor supply. For example, on June

[16] We include possible changes in other non-VAT taxes as well as changes in the VAT base and/or VAT reduced rates because the main tax series used in this study is the standard (as opposed to the effective) VAT rate.

18, 1979, the government of recently-elected Prime Minister Margaret Thatcher increased the VAT rate by 7 percentage points (from 8 percent to 15 percent) as part of a major tax reform intended to partially offset the impact of large cuts to marginal income tax rates.

  - In 4 cases, the VAT rate was reduced because the VAT base was broadened and/or VAT reduced rates were increased or eliminated. For example, on May 1, 2004, the Czech Republic reduced the standard VAT rate from 22 to 19 percent and shifted over 25 percent of the consumption basket of goods and services from the reduced to the standard VAT rate.

4.3 Exogenous tax changes

Following RR's identification strategy, exogenous tax changes are those *not* made in response to (i) current or prospective output different from normal or (ii) other factors likely to affect output contemporaneously or in the near future. In other words, exogenous tax changes do not present a problem of reverse causality because, according to the historical narrative, they should be uncorrelated with contemporaneous output or output in the near future. Such tax changes would thus be legitimate right-hand variables in a regression of output on tax changes. In fact, as a check on the accuracy of our historical narrative, we will show in Section 5 that exogenous tax changes are not Granger-caused by GDP fluctuations. We identify a total of 44 exogenous tax changes (30 in industrial countries and 14 in developing ones).

In turn, exogenous tax changes are classified into those motivated by long-run growth considerations or enacted in response to inherited fiscal factors:

- Long-run growth. As indicated by RR, this type of tax change responds to the belief that a tax cut will raise output in the long run by unleashing supply-side forces related to labor, capital, or, more generally, a more efficient use of resources. Such tax change is thus aimed at raising long-run growth, as opposed to responding to cyclical output fluctuations.

  In total, we find 9 tax changes motivated by long-run growth considerations, representing 20 percent of exogenous tax changes. For example, Canada's economy was operating close to potential and performing strongly during the mid-2000s. Yet, both in 2006 and in 2008, the government reduced the VAT rate by 1 percentage point each time to promote long-term growth according to several news articles and IMF's assessments.

- Inherited fiscal factors. These are tax changes that respond to either (i) fiscal deficits inherited from the past and thus determined by past actions (as opposed to fiscal deficits caused by current or prospective conditions) or (ii) a stock of public debt that is viewed as unsustainable if current deficits persist.[17] The critical point is that in neither case the change in the tax rate responds to the current (or prospective) state of the economy but rather to past actions that may have caused a fiscal deficit to be viewed as too large or a stock of public debt that has come to be seen as unsustainable. Such tax changes are thus exogenous to the current state of the business cycle.[18] In general, the identification of this type of tax changes is clear from the used sources. In the rare cases where different sources disagree, we err on the safe side and exclude potentially legitimate observations.

In our sample, a clear example of tax changes motivated by inherited fiscal deficits can be found in Switzerland in 1999 and 2001, when VAT rates increased from 6.5 to 7.5 percent and from 7.5 to 7.6 percent, respectively. After running primary budget surpluses for much of the 1980s, a prolonged period of economic stagnation during 1991-1996 (with average GDP growth rates of only 1 percent) caused the primary deficit to steadily increase, reaching about 2 percent of GDP in 1997 and 1998. While low by international standards, the rapid growth in the fiscal deficit during the first half of the 1990s caused concern among the public. In June 1998, voters approved a constitutional amendment requiring the federal government to balance the budget by 2001. Annual deficit ceilings were imposed and an additional, more stringent constitutional amendment was planned for 2001. The VAT tax increases of 1999 and 2001 were thus a response to such legal/constitutional demands. Clearly, these tax changes responded to what was viewed as a large inherited fiscal deficit rather than to current economic conditions.

Examples of tax changes caused by inherited public debt can be found in Belgium in 1992 and 1996, when the VAT rate increased by 0.5 percentage points each time. According to the IMF Staff Report SM/92/206 for the 1992 Article IV Consultation for Belgium "[i]n the late 1970s and early 1980s, a combination of domestic political developments, attempts to cushion the effects of the oil price shocks, and international recession led to double-digit fiscal deficits (as ratios to GNP) and massive increases in government debt. The general government deficit (excluding net lending) peaked at over 13 percent of GNP in 1981. Despite a steady reduction in the deficit, the debt ratio rose for most of the decade, and general government debt net of short-term financial assets reached 124 percent of GNP in 1988.[...] Policy since the mid-1980s has been guided by the goal of first stabilizing and then reducing the public debt ratio.[...] However, after stabilizing in 1990, it rose once again to 124 percent of GNP in 1991.[...] The agreement reached in December 1991 at Maastricht on economic and monetary union (EMU)

[17] Since, over the last 60 years, the U.S. has not faced sustaninability problems regarding the public debt, RR do not concern themselves with the latter case.

[18] Occasionally, fiscal packages aimed at dealing with inherited fiscal factors include not only tax increases but also cuts in government spending. To this effect, government spending will be used as a control in our empirical specifications. If we also included changes in corporate tax rates and/or the highest personal income tax rate, results would not be affected. Unfortunately, as discussed before, we do not have the average marginal personal tax rate. Results are not shown for brevity's sake.

among EC countries requires countries proceeding to the third stage of EMU to have general government fiscal deficits that do not exceed 3 percent of GDP, unless due to temporary and exceptional circumstances, and general government debt ratios that are at most 60 percent of GDP, or else declining at a satisfactory pace."

Other examples of tax changes triggered by inherited public debt are those that took place in Europe (Hungary, Ireland, Italy, Netherlands, Poland, Portugal, and the United Kingdom) as a result of debt sustainability concerns, particularly during the 2011-2014 period. Unlike the tax hikes enacted during the early stages of the Global Financial Crisis, which were triggered by a large and sudden fall in economic activity, these more recent tax hikes were mainly motivated by debt-sustainability concerns driven by past economic conditions and budgetary decisions, rather than by current developments.

5 Linear estimations

Having identified and classified all the tax changes in our sample, we can now proceed to the econometric analysis. This section first introduces our basic linear specification and then discusses our basic results, the biases introduced by misidentification, the role of expectations, and the mechanisms involved. Then, we also show that while the tax multiplier in industrial European economies is quite negative and statistically significant (in line with recent studies), it is about 3 times smaller (in absolute value) and borderline statistically significant for the rest of countries.

5.1 Basic specification

As has been the norm in the literature, this section estimates the linear effect of tax changes on output. We proceed in two steps. First, we estimate the effect of tax rate changes on economic growth using the single-equation approach proposed by Jorda (2005) and Stock and Watson (2007), which is based on linear "local projections" (LP). Second, we derive an expression for the tax multiplier as a function of our estimated regression coefficient.

The use of LP provides several advantages over the traditional SVAR methodology pioneered by BP. Specifically, LP (i) can be estimated by single-regression techniques (least-squares dummy variables, LSDV, in our case), (ii) are more robust to potential misspecifications, and (iii) can easily accommodate highly non-linear and flexible specifications that may be impractical in a multivariate SVAR context (a feature that will prove crucial later in the paper).

In our basic linear specification, the cumulative response of output growth at the horizon h is estimated based on the following regression

$$\begin{aligned} \Delta y_{i,t+h} \quad = \quad & \alpha_{i,h} + \beta_h \Delta t_{i,t}^{exog} + \lambda_h(L)\Delta y_{i,t-1} + \psi_h(L)\Delta t_{i,t-1}^{all} + \phi_h(L)\Delta g_{i,t-1} + \\ & + \varrho_h T_h + \upsilon_h T_h^2 + \mu_{i,t,h}, \end{aligned} \tag{6}$$

where subscripts i and t denote country and time, respectively, α_i is the country fixed effect, T and T^2 are the linear and quadratic trends, y and g are the logarithm of real GDP and real government spending, respectively, Δy and Δg measure the respective growth rates (expressed as the difference in logarithms), tax rate changes (Δt^{exog} and Δt^{all}) are expressed in percentage points, and μ is the error term.[19] Unlike the SVAR specification, the estimated coefficients contained in the polynomial lags $\lambda_h(L)$, $\psi_h(L)$, and $\phi_h(L)$ are not used directly to build the impulse response function (IRF) values but only serve as controls, "cleaning" the β_h coefficients from the dynamic effects of output and the effects of past changes in government spending and tax rates.[20,21] For this reason, the tax rate changes serving as controls include all tax rate changes (i.e., Δt^{all}). In contrast, the tax rate changes used to identify the effect on output have to be exogenous in nature (i.e., Δt^{exog}). It is important to note that, in this LP approach, each step in the cumulative IRF is obtained from a different individual equation. Defining $\Delta y_{i,t+h}$ as the accumulated output growth from $t-1$ to $t+h$ (i.e., $\Delta y_{i,t+h} \equiv y_{i,t+h} - y_{i,t-1}$), the cumulative IRF values are obtained directly from the β_h estimated coefficients at each time horizon h. Therefore, each coefficient β_h represents the step in the cumulative IRF at a forward time h and is read as the accumulated response of output growth to a one percentage point increase in the tax rate.

While conceptually appropriate, a drawback of using tax rate changes as the independent variable in equation (6) is that the estimated coefficients β_h do not correspond to the usual tax multiplier discussed in the literature, which measures the effect of a $1 change in tax revenues on the level of GDP. In other words, the coefficients β_h link the change in GDP to the change in the tax rate and not in the tax revenue. Following Barro and Redlick (2011, pp. 80-81), the tax multiplier at time horizon h is then computed exploiting the typical relationship between tax revenues and the tax rate[22]

$$Tax\ multiplier\ (h) = \frac{\beta_h}{e \cdot \rho_h + \beta_h \cdot I}, \tag{7}$$

where I captures the relationship between real VAT revenue and real output, e measures the relationship between I and the VAT rate t, and ρ_h captures how permanent is the initial tax shock at

[19] In all of our regression analyses, we use robust Driscoll and Kraay (1998) standard errors to correct for potential heteroskedasticity, autocorrelation in the lags, and error correlation across panels. Given concerns about the non-normal distribution of tax rate changes (which are zero most of the time) and small sample considerations, standard errors are computed using bootstrap techniques. In particular, standard errors are calculated from the average of 10,000 draws of the coefficient vector from a multivariate normal distribution with mean and variance-covariance matrix equal to the point estimates and variance-covariance matrix of the regression coefficients.

[20] We use four lags (i.e., $L = 4$). The selection of four lags balances the need to account for a sufficiently long structure of lags in order to study the effect of tax changes on output as well as to preserve most of our tax rate changes. Unfortunately, as we move towards longer lag structures, we are forced to drop some data points. Having said that, our results for the case of eight and twelve lags remain almost the same as in the four-quarter specification. Figures showing the multipliers for the eight- and twelve-lag estimations are not shown for the sake of brevity.

[21] We control for government spending for the reasons discussed in Section 4. However, not doing so does not affect our results. As also discussed in Section 4, if we also included changes in corporate tax rates and/or the highest personal income tax rate, results would not be affected. Unfortunately, as discussed before, we do not have the average marginal personal tax rate. Results are not shown for brevity's sake.

[22] See Appendix 3 for the derivation of the next two expressions.

time horizon h.[23]

Using a first-order approximation of (7), the standard error of the tax multiplier can be written as

$$Tax\ multiplier_{SE}\ (h) = \frac{e \cdot \rho_h}{(e \cdot \rho_h + \beta_h \cdot I)^2} \beta_h^{SE}, \tag{8}$$

where β_h^{SE} is the standard error of coefficient β_h. We now proceed to use this methodology to estimate the size of the tax multiplier, which will be reported, as is typical in the literature, with one-standard-error bands.

5.2 Basic results

Using specification (6) as well as equations (7)-(8), Figure 2 shows the estimated tax multipliers at different time horizons when using exogenous legislated tax rate changes (Panel A) and all legislated tax rate changes (Panel B).[24] As discussed in Section 2, the use of all (as opposed to exogenous) legislated tax rate changes is subject to misidentification.

INSERT FIGURE 2 *HERE*

The multiplier using exogenous legislated tax rate changes is consistently and significantly negative, indicating that tax hikes reduce economic activity while tax cuts increase it (see Panel A in Figure 2). Specifically, the multiplier is -1.1 ($t = -2.3$) on impact and becomes more negative with longer horizons until reaching -1.7 ($t = -1.5$) after eight quarters. Notice that while negative and larger than one in absolute value, this latter tax multiplier of -1.7 is on the lower side (in absolute value) when comparing it with recent evidence solely based on industrial countries which, in turn, points to quite negative tax multipliers ranging between -2 and -5.

What happens when using all legislated tax rate changes? That is to say, when solely relying on the BP identification strategy? Panel B in Figure 2 shows that when using all legislated tax rate changes, the tax multiplier obtained is even more negative, particularly in the long run. Indeed,

[23] See Appendix 3 for details. We use the sample average values of e (39 percent) and of I (6.2 percent) for our tax multiplier calculations. While there is some variation across countries, the variability is fairly small. The standard deviations of e and I are 8 and 1.8 percent, respectively. The estimated ρ_h for different time horizons h ranges between 0.99 (for ρ_1) to 0.91 (for ρ_8). Out of the 44 exogenous cases (i) in only 5 cases there is a tax change within two-year period and (ii) there is no tax change within one-year period. This latter evidence coupled with close to one values of ρ_h points that most VAT rate changes are, by and large, of permanent nature.

[24] Jorda's LP method does not consistently dominate the standard SVAR method for calculating impulse responses of endogenous variables with contemporaneous effects. Since Jorda's LP does not impose any restrictions linking the impulse responses at h and $h+1$, estimates can display an erratic behavior due to the loss of efficiency. Additionally, as the horizon increases, one loses observations from the end of the sample. Finally, the impulse responses sometimes display oscillations at longer horizons. Comparing Jorda to a standard SVAR and a dynamic simulation, Ramey (2016) finds that the results are qualitatively similar for the first 16 quarters. For longer horizons, however, Jorda's LP method tends to produce statistically significant oscillations not observed in the other two methods. For these reasons, and to err on the safe side, we report estimates until 8 quarters after fiscal and GDP shocks. Similar results would be obtained if we reported estimates until 12 quarters after fiscal and GDP shocks.

after eight quarters, the multiplier is -2.5 ($t = -3.3$), which is about 50 percent larger (in absolute value) than that obtained when using only exogenous tax changes.

5.3 Biases due to misidentification

Why is the multiplier using all tax changes more negative than that based on properly identified exogenous tax changes? In other words, what is the nature of the bias associated with the misidentification? As discussed in Section 2, the bias arises because of the wrongful inclusion of endogenous – and, on average, procyclical – tax changes in the set of tax changes used to estimate tax multipliers. Doing so yields the wrong conclusion that tax multipliers are more negative than they are. For example, a tax increase enacted in response to a fall in output (i.e., an endogenous and procyclical tax change) would wrongly imply a larger contractionary effect of tax hikes on output (i.e., a typical problem of reverse causality).

Indeed, Figure 3 shows the IRF of tax changes to a GDP shock. Panel A shows that endogenous tax changes respond, on average, procyclically to GDP shocks. In other words, tax rates increase (decrease) in response to a negative (positive) GDP shock. In sharp contrast, Panel B indicates that exogenous tax changes do not respond to a GDP shock. This offers, of course, a strong validation of our narrative-based identification strategy because it shows that exogenous tax changes are indeed unrelated to past output fluctuations.[25,26]

INSERT FIGURE 3 *HERE*

We have thus established that endogenous tax changes are, on average, procyclical. But how about different sub-types of endogenous changes? Figure 4 shows the results for GDP-driven tax changes (Panel A) and offsetting changes (Panel B). Panel A shows that tax changes identified as GDP-driven are, on average, procyclical. On the other hand, Panel B shows that offsetting tax changes (for which we do not have a prior in terms of how they would react to a GDP shock) tend to react little to GDP shocks.[27] In other words, the procyclical profile illustrated for endogenous

[25] As Figure 3 makes clear, we evaluate the effect of a GDP shock on tax rates after one quarter. When focusing on exogenous tax rate changes –and given our identification strategy– it would not be correct to allow a GDP shock to contemporaneously affect the tax rate. This is not the case when focusing on endogenous tax rate shocks which, in principle, could react to contemporaneous developments in economic activity. However, to maintain the symmetry in our analysis (i.e., not to have results depending upon the inclusion or not of the aforementioned lagged reaction), we evaluate the impulse response functions, for both exogenous and endogenous tax rate changes, allowing for a GDP shock to affect tax rates only after a quarter. Similar results, showing an even more pronounced procyclical profile, are observed if we allow a GDP shock to contemporaneously affect endogenous tax rate changes. Results are not shown for the sake of brevity.

[26] The response of subtypes of exogenous legislated tax changes (i.e., long-run growth, inherited fiscal factors, as well as inherited deficit- and debt-driven) to a GDP shock taken one-at-a-time also shows, like Panel B in Figure 3, an unresponsive profile. These results further validate our narrative-based identification strategy. Results are not shown for brevity.

[27] Specifically, the response is, on average, about two tenths (in absolute value) of that observed for GDP-driven changes and, for most time horizons, not statistically significant.

tax changes (see Panel A in Figure 3) is driven by the procyclical response of GDP-driven changes (see Panel A in Figure 4) and not by offsetting tax changes (see Panel B in Figure 4). Moreover, Panels C and D show that GDP-driven procyclical and countercyclical tax changes (identified based on the narrative approach) are indeed so, respectively, which further validates our narrative-based identification.

INSERT FIGURE 4 *HERE*

It is worth noting that our logic for the type of biases introduced by considering endogenous tax changes helps to explain some of RR's key results for the U.S. In effect, let us consider Figure 5, taken from RR, which shows that the sign of the bias introduced by using all tax changes (dashed line) vis-à-vis exogenous tax changes (solid line) is the opposite of that of Figure 2. That is to say, misidentification relying on the use of all tax changes as a measure of a tax shock would lead, for the U.S., to an *underestimation* of the true tax multiplier. Why? Because endogenous tax changes in the U.S. are, following RR classification, strongly countercyclical. In fact, RR identify (i) no procyclical tax change, (ii) that about one third of all U.S. tax changes (or 30 out of 84) are endogenous, and (iii) that 37 percent of those endogenous changes (or 11 out of 30) are countercyclical in nature (while the remainder 19 out of 30 are offsetting tax changes).

INSERT FIGURE 5 *HERE*

5.4 The role of expectations

In deriving our measure of tax multipliers, the date of tax changes corresponds to the date in which tax changes were actually implemented. Expectations, however, could also matter. As discussed in RR and Alesina, Favero, and Giavazzi (2015), announcements may lead to anticipation effects of tax changes. To explore this issue, Figure 6 shows the density function of the number of days between passage and implementation of exogenous tax rate changes. The lag between passage and implementation is relatively short, with a median lag of about 57 days (i.e., less than a quarter).

In order to control for possible anticipation effects arising from announcements, we follow RR's strategy of adding to our previous specification, given by equation (6), a "news" term and its corresponding lags. Formally,

$$\begin{aligned}\Delta y_{i,t+h} \quad = \quad & \alpha_{i,h} + \beta_h \Delta t_{i,t}^{exog} + \kappa_h \Delta \text{News}_{i,t} + \lambda_h(L)\Delta y_{i,t-1} + \psi_h(L)\Delta t_{i,t-1}^{all} + \\ & + \phi_h(L)\Delta g_{i,t-1} + \varrho_h T_h + \upsilon_h T_h^2 + \mu_{i,t,h}, \end{aligned} \tag{9}$$

where the variable "News" represents the expected tax rate change at the time of the official passage of the law. Figure 7 then shows the response of output to the passage of the law as well as to its implementation. Interestingly, Panel A in Figure 7 shows that, at the time of the passage of the law, output does not react much. Most importantly for our purposes, estimates of the tax multiplier itself remain robust.

INSERT FIGURES 6 *AND* 7 *HERE*

5.5 Transmission mechanism

We have found that exogenous tax increases (decreases) have a strong contractionary (expansionary) effect on output. We now focus on the mechanisms involved by evaluating the response of aggregate components of GDP, informality, as well as labor-related variables. Panel A in Figure 8 shows that, naturally, increases (decreases) in the VAT rate reduce (increase) consumption as it is the first obvious distortionary margin through which such a tax is expected to operate. Interestingly, yet no much surprising if one considered more general equilibrium implications of VAT rate changes (for example, associated with changes in consumption), Panel A also shows that increases (decreases) in the VAT rate reduce (increase) investment. This last evidence is in line with JR theoretical implications. Note, that consumption falls more than investment. Increases (decreases) in the VAT rate increase (reduce) net exports. This evidence is consistent with the so-called fiscal devaluations.

When focusing on labor variables, Panel B in Figure 8 shows that increases (decreases) in the VAT rate reduce (increase) employment (see solid line). This is not surprising considering that output also falls (increases) to a VAT rate hike (cut). More interestingly, Panel B also shows that increases (decreases) in the VAT rate reduce (increase) the labor force participation rate (see dashed line). Why? Because the increase (decrease) in the VAT rate calls for an increase (decrease) in inflation (see dotted line) which, coupled with nominal wage rigidities, reduces (increases) real wages (see dotted line with solid circles).[28] Panel B also shows that increases (decreases) in the VAT rate increase (reduce) the size of the informal economy (expressed as share of GDP). This last evidence is in line with our alternative proposed theoretical mechanism.[29] In sum, increases (decreases) in the VAT rate reduce (increase) the incentives to consume as well as those to invest, work, and be part of the formal sector.

INSERT FIGURE 8 *HERE*

5.6 Industrial Europe versus rest of countries

As discussed in the Introduction, since RR seminal contribution, a growing series of studies (especially with focus on industrial Europe) have found large (in absolute value) negative tax multipliers, ranging between -2 and -5 (after two years of the tax shock). Motivated by this growing consensus for this group of countries, Figure 9 shows the results when splitting our global sample into

[28] See Carroll, Cline, and Neubig (2010) for a comprehensive literature review about the impact of VAT rate changes on inflation, real wages, and labor supply.

[29] Interestingly, the effect of changes in the VAT rate on informality is present in both in industrial and developing countries. Results are not shown for the sake of brevity.

industrial European economies (Panel A) and the rest of countries (Panel B). After two years of the tax shock, we find tax multipliers of -3.6 ($t = -2.0$) and -1.2 ($t = -0.6$), respectively. While the tax multiplier in industrial European economies is quite negative and statistically significant (in line with recent studies, lying virtually in a midpoint between -2 and -5), it is about 3 times smaller (in absolute value) and borderline statistically significant for the rest of countries.

INSERT FIGURE 9 HERE

The difference observed in the size of tax multipliers just depicted naturally raises the question of why would this be the case. Specifically, why are tax multipliers more negative in industrial European economies (in line with recent studies) than those observed elsewhere? One possibility could be, for example, that the macroeconomic context associated with different tax changes varies across these groups of countries which, in turn, could affect the size of the multiplier. While it proves impossible to consider all potential factors, we cannot reject the null hypothesis that the prevalence of fixed exchange-rate regimes, public debt as a percentage of GDP, and the stance of the business cycle is the same in tax changes for industrial European and the rest of countries.[30] While, in principle, we cannot rule out other plausible considerations, we show in the next section that this need not be the case and that a simpler explanation could simply rely on non-linear distortionary and disincentive-based effects of tax rates on output.

6 The non-linear effect of tax changes on output

As discussed in the Introduction, and based on different types of macroeconomic models, the output effect of tax changes is expected to be small at low initial levels of taxation but exponentially larger (in absolute value) when initial tax levels are high. Therefore, the distortions and disincentives imposed by taxation on economic activity are directly, and non-linearly, related to the level of tax rates. By the same token, for a given level of initial tax rates, larger tax rate changes have larger tax multipliers.

In this section, we first show that these non-linear theoretical arguments are actually present empirically, and then that they can also explain (i) the linear findings of Section 5 when estimating the tax multiplier for industrial Europe and the rest of countries, and (ii) the VAT or indirect tax multipliers calculated on country-specific studies using different empirical strategies. We also show further evidence that these non-linear effects are powerful in explaining (i) the different effect of tax changes on output observed depending upon the motivation of the exogenous tax change (e.g., like the one identified by RR when comparing the output effect of long-run growth versus inherited deficit-driven tax changes), (ii) the perceived (survey-based) extent to which taxes reduce

[30] Results are not shown for the sake of brevity.

the incentive to work and invest, and (iii) policymakers' tax plans to deal with the current need for increasing economic activity and addressing fiscal deficits. We also show that the same non-linear arguments are present in RR's sample.

6.1 Multipliers for different levels of initial tax rates

We will first evaluate how the effect of tax rate changes on output depends upon the initial level of the tax rate. For this purpose, we modify our linear specification (6) as follows:

$$\begin{aligned}\Delta y_{i,t+h} &= \alpha_{i,h} + \beta_h \Delta t_{i,t}^{exog} + \delta_h \left[\Delta t_{i,t}^{exog} \cdot t_{i,t-1}^{all}\right] + \gamma_h t_{i,t-1}^{all} + \psi_h(L)\Delta t_{i,t-1}^{all} \\ &\quad + \lambda_h(L)\Delta y_{i,t-1} + \phi_h(L)\Delta g_{i,t-1} + \varrho_h T_h + \upsilon_h T_h^2 + \mu_{i,t,h}, \qquad (10)\end{aligned}$$

where the only differences are the introduction of the initial tax rate level interacting with the changes in the tax rate and, naturally, the term associated with the initial tax rate for control purposes.[31,32]

Panel A in Figure 10 shows the estimated tax multipliers after two years, evaluated at different initial levels of tax rates. The black line shows a clear non-linear effect of tax changes on output depending on the initial level of the tax rate. While the multiplier is virtually zero at low/moderate levels of initial tax rates (i.e., for initial tax rate levels lower than 14 percent), it becomes statistically significant and increasingly negative with higher initial tax rates. In other words, the fall (increase) of output associated with raising (reducing) revenues by \$1 tends to be zero for low levels of initial tax rates and becomes larger as the initial tax rate increases. For example, multipliers reach -3.8 ($t = -2.1$) when starting at an initial tax rate of 22 percent. For comparison purposes, the grey line in Figure 10 reports the tax multiplier obtained based on the linear specification (6), which takes a value of -1.7 ($t = -1.5$).

INSERT FIGURE 10 *HERE*

This evidence strongly supports distortionary and disincentive-based arguments regarding a non-linear effect of tax rate changes on economic activity, with essentially zero effects under relatively low/moderate initial tax rate levels and much larger effects as the initial level of tax rates increases. The policy implications of this non-linear dimension are clearly important. While countries in need of higher tax rates might be able to do so without hurting economic activity too much when starting at low/moderate levels of tax rates, the economy will inevitably suffer when taxes are

[31] In this non-linear specification, the tax multiplier defined in expression (7) becomes *Tax multiplier* $(h) = [\omega_h] / [e \cdot \rho_h + \omega_h \cdot I]$, where $\omega_h \equiv \beta_h + \delta_h \cdot t^{all\ *}$ and $t^{all\ *}$ represents the initial tax rate level at which the multiplier is evaluated. Similarly, the standard error of the tax multiplier defined in expression (8) becomes $Tax\ multiplier_{SE}$ $(h) = \left[e \cdot \rho_h \cdot \omega_h^{SE}\right] / \left[(e \cdot \rho_h + \omega_h \cdot I)^2\right]$, where ω_h^{SE} is the standard error of ω_h.

[32] Similar results are obtained if one used the overall tax burden instead of the initial tax rate level. Results are not shown for the sake of brevity.

increased at higher initial tax rate levels. By the same token, reductions in tax rates will increase output considerably only when starting with high initial tax rate levels (i.e., there will be no output benefits of cutting taxes when tax rates are low to begin with).

6.2 Multipliers for different initial levels of tax rates and sizes of tax changes

We now consider the effect on output depending upon both (i) the initial level of the tax rate (as analyzed in the previous Subsection) and (ii) the size of the tax rate change. Figure 11 shows that, conveniently for identification purposes, there is no systematic relation between these two dimensions. In other words, the initial tax rate level does not condition, on average, the size of the tax rate changes.

To evaluate the joint effect, we expand specification (10) to also include the effect of the size of the tax change:

$$\begin{aligned}\Delta y_{i,t+h} \quad = \quad & \alpha_{i,h} + \beta_{1_h} \Delta t_{i,t}^{exog} + \beta_{2_h} \left(\Delta t_{i,t}^{exog\,+}\right)^2 - \beta_{2_h} \left(\Delta t_{i,t}^{exog\,-}\right)^2 \\ & + \beta_{3_h} \left(\Delta t_{i,t}^{exog}\right)^3 + \delta_{1_h} \left[\Delta t_{i,t}^{exog} \cdot t_{i,t-1}^{all}\right] + \delta_{2_h} \left[\left(\Delta t_{i,t}^{exog\,+}\right)^2 \cdot t_{i,t-1}^{all}\right] \\ & - \delta_{2_h} \left[\left(\Delta t_{i,t}^{exog\,-}\right)^2 \cdot t_{i,t-1}^{all}\right] + \delta_{3_h} \left[\left(\Delta t_{i,t}^{exog}\right)^3 \cdot t_{i,t-1}^{all}\right] + \gamma_h t_{i,t-1}^{all} \\ & + \psi_h(L) \Delta t_{i,t-1}^{all} + \lambda_h(L) \Delta y_{i,t-1} + \phi_h(L) \Delta g_{i,t-1} + \varrho_h T_h + \upsilon_h T_h^2 + \mu_{i,t,h}, \qquad (11)\end{aligned}$$

where $\Delta t^{exog\,+}$ and $\Delta t^{exog\,-}$ refer to positive (i.e., increases) and negative (i.e., reductions) exogenous tax changes, respectively. Unlike linear specification (6) and non-linear specification (10), specification (11) includes non-linear terms of the tax changes themselves.[33] In particular, we include quadratic and cubic terms.[34,35] Raising tax changes to the power of an even number (quadratic in our case), combined with the fact that some tax changes are positive while others are negative, poses a challenge that was not present in specifications (6) or (10). Since raising any tax change to the power of two always delivers a positive number, any proposed specification should

[33] In specification (10), the non-linear effect of tax changes is the result of interacting tax changes with the initial tax rate levels. Tax changes themselves (i.e., term $\beta_1 \Delta t^{exog}$) as well as tax changes interacting with the initial tax rate levels (i.e., term $\delta \left[\Delta t^{exog} \cdot t^{all}\right]$) both entered in a linear way.

[34] Since theory does not point to a specific non-linear form, nested models' tests (using F-tests) support the selection of a cubed specification. Comparing linear (i.e., restricted) and squared (i.e., unrestricted) models, both offer the same predicting power at all time horizons (in our case h). While a cubed specification is more powerful than a squared or linear one at most time horizons, adding a term of exogenous tax changes to the fourth power does not yield additional explanatory power (particularly after a year of the tax shock). Hence, for parsimonious considerations, a cubed specification is used. Similar tax multipliers are obtained if terms to the fourth power are also included. Results are not shown for the sake of brevity.

[35] In this non-linear specification, the tax multiplier defined in expression (7) becomes $Tax\ multiplier\ (h) = [\varphi_h] / [e \cdot \rho_h + \varphi_h \cdot I]$, where $\varphi_h \equiv \beta_{1_h} + \beta_{2_h} \cdot \Delta t^{exog\,*} + \beta_{3_h} (\Delta t^{exog\,*})^2 + \delta_{1_h} \cdot t^{all\,*} + \delta_{2_h} \left[\Delta t^{exog\,*} \cdot t^{all\,*}\right] + \delta_{3_h} \left[(\Delta t^{exog\,*})^2 \cdot t^{all\,*}\right]$. The terms $\Delta t^{exog\,*}$ and $t^{all\,*}$ represent the change in the tax rate (expressed positively for convenience) and the initial tax rate level, respectively, at which the multiplier is evaluated. Similarly, the standard error of the tax multiplier defined in expression (8) becomes $Tax\ multiplier_{SE}\ (h) = \left[e \cdot \rho_h \cdot \varphi_h^{SE}\right] / \left[(e \cdot \rho_h + \varphi_h \cdot I)^2\right]$, where φ_h^{SE} is the standard error of φ_h.

differentiate increases in tax changes from reductions. Not doing so would imply, in terms of this quadratic term, that both increases and reductions in tax rates have the same effect on output. This is naturally not a concern when focusing on the linear term associated with the tax change (i.e., $\beta_1 \Delta t^{exog}$) or when raising tax changes to the power of an odd number (e.g., $\beta_3 \left(\Delta t^{exog}\right)^3$). In these cases, the sign of the tax change would be maintained. Obviously, this would not be an issue if the empirical specification under consideration dealt with the non-linear effect of a variable expressed in levels (as opposed to its change). To deal with this challenge in a manner that allows us to use the entire set of exogenous tax changes, specification (11) constrains the quadratic coefficient associated with $\Delta t^{exog\ -}$ to be that of $\Delta t^{exog\ +}$ with the opposite sign.[36,37]

Panel B in Figure 10 shows the estimated tax multipliers after two years, evaluated at alternative initial tax rate levels and sizes of tax changes. The results clearly support our previous findings. Blue color area in Panel B represents a statistically zero tax multiplier. We can see that the most negative multipliers occur for high levels of both the initial tax rate and the size of the tax rate change. In other words, the fall (increase) of output associated with increasing (reducing) revenues by $1 (i) tends to be zero for low levels of initial tax rates and when small tax changes are involved and (ii) increases as the initial tax rate and the size of the tax change become larger. Hence, the evidence shows that the output effect of tax increases is highly non-linear, in line with distortionary and disincentive-based theoretical predictions. In other words, the linear tax multiplier of -1.7 ($t = -1.5$) obtained in Subsection 5.2 can be rationalized, through the eyes of this novel evidence, as a "weighted average" of tax multipliers ranging between extreme cases of (i) statistically zero tax multipliers for low levels of initial tax rates and when small tax changes are involved and (ii) quite negative tax multipliers (e.g., reaching -5, or dark red colors in Panel B in Figure 10) for high levels of both the initial tax rate and the size of the tax rate change.

These findings have important policy implications given that the initial level of taxes varies greatly across countries and thus so will the potential output effect of changing tax rates. Figure 12 shows that given countries' current VAT rate, the tax multiplier could be statistically zero (light blue color), or moderate to high (yellow, orange, and red colors).[38] For example, such tax increases would cause virtually no effect on GDP in countries with low tax rates such as Angola, Costa Rica, Guatemala, Nigeria, and Paraguay. In contrast, the same tax increase (decrease) would

[36] If we allowed the quadratic coefficient associated with $\Delta t^{exog\ -}$ to differ from that associated with $\Delta t^{exog\ +}$, we could not reject the null hypothesis that both coefficients are statistically the same (but with different signs) at any horizon level. If we allowed all coefficients (linear, quadratic, and cubed) associated with $\Delta t^{exog\ -}$ to differ from those associated with $\Delta t^{exog\ +}$, we could not reject the null hypothesis that all coefficients associated with positive and negative changes are statistically the same at any time horizon (in the case of the linear and cubed coefficients with the same sign and in the case of the quadratic coefficients with opposite signs). Results of these tests are not shown for the sake of brevity.

[37] Similar results would be obtained if the quadratic terms were excluded from specification (11). Results are not shown for the sake of brevity.

[38] While any out-of-sample exercise should be taken with a grain of salt, it is important to note that our estimates are based on a global sample with VAT rates ranging from 3% to 25% and the current (i.e., 2018's) countries' VAT rates used to build Figure 12 range between 5% and 27%.

cause output to fall (increase) in countries with relatively high VAT rates including some emerging markets like Argentina and Uruguay and, especially, in many industrial European countries.

INSERT FIGURE 11 *AND* 12 *HERE*

6.3 Non-linearity in action I: Industrial Europe versus rest of countries and further country-specific evidence

So far, Subsections 6.1 and 6.2 show that the aforementioned non-linear arguments regarding the effect of tax changes on output matter a great deal when determining the size of the tax multiplier. But do the differences in the initial tax rate levels and/or the respective sizes of the tax changes observed in industrial European and the rest of countries actually help explain some of the differences in tax multipliers (based on linear estimations) identified in Subsection 5.6?

Table 2 points out that, indeed, this may be the case. Table 2 shows that tax changes in industrial European countries have initial VAT rates that are higher than those observed in other countries. The same is not true for the size of the tax changes, which are very similar. These differences suggest that the reason behind the more negative tax multiplier observed in industrial European countries relative to those of the rest of countries is that, typically, the former group of countries has higher initial tax rates. In fact, Figure 13 provides further evidence that these non-linear arguments are actually at work. The median value of the tax multipliers calculated for each group of countries, based on the non-linear specification (11), matches very well the tax multiplier for each group of countries estimated in a linear fashion in Subsection 5.6. Moreover, when focusing on current VAT rates and considering a one-percentage-point increase for the same group of countries used in Alesina, Favero, and Giavazzi (2015), we obtain a tax multiplier (after two years of the tax shock) of -2.4 (versus -2 in their analysis).[39]

To further test the power of our non-linear empirical findings, Figure 14 focuses on country-specific studies analyzing the impact of changes in VAT or indirect taxation (using different empirical strategies) and compares their results with our estimates. Solid grey bars show the tax multipliers from these external sources (mainly studies conducted by researchers working in ministries, central banks, and other non-government institutions) and dotted-filled bars show our non-linear estimates considering the initial level and the change in the VAT rate under consideration. Note that Figure 14 includes evidence for industrial economies as well as for developing countries (in particular, Colombia, Dominican Republic, and Peru using alternative empirical strategies).[40] The "match" between the solid and dotted-filled bars is truly remarkable, which further validates our non-linear arguments. Appendix 4 shows that, when relying on RR's U.S. dataset, the same type of non-linear

[39] For Canada, we use the sum of (i) the federal goods and services tax of 5 percent and (ii) the average provincial sales tax of 8 percent, which results in an average sales tax of about 13 percent. For the United States, we combine state and average local sales tax rates which results in an average of 6.5 percent.

[40] See notes of Figure 14 for details about sources and methodologies.

arguments are present.

INSERT TABLE 2 *AND FIGURES* 13 *AND* 14 *HERE*

6.4 Non-linearities in action II: Explaining the effects of different exogenous tax changes on output

As discussed in the Introduction, RR find that the effect of tax changes on output varies depending upon the motivation for the exogenous tax change. While the tax multiplier associated with long-run growth considerations is negative (and virtually identical to that of a generic exogenous tax change), the tax multiplier of deficit-driven tax changes is positive, yet statistically insignificant.[41] Figure 15 shows the findings by RR. Interestingly, we find similar evidence (see Figure 16). Panel A shows that the output effect of tax changes motivated by long-run growth is small in the very short run, but becomes more negative rapidly and reaches -3.2 ($t = -1.1$) after two years. In contrast, Panel B shows that tax changes motivated by inherited fiscal factors have a smaller effect on output (in absolute value), reaching just -1.3 ($t = -0.8$) after 2 years. In other words, tax changes motivated by long-run growth trigger a more negative effect on output than those driven by inherited fiscal factors, especially in the medium and long run. Interestingly, Panel C in Figure 16 shows that inherited deficit-driven tax multipliers have, like in RR's inherited deficit-driven motivated changes (see Panel A in Figure 15), point estimates which are typically positive, yet statistically insignificant. In contrast, tax changes motivated by inherited debt-driven changes are clearly negative (see Panel D in Figure 16). In particular, the multiplier is -2.4 ($t = -1.3$) after 2 years. In other words, the negative tax multiplier estimate associated with inherited fiscal factors (see Panel B in Figure 16) is driven by the negative response of output to inherited debt-driven tax changes (see Panel D in Figure 16) and not by the zero multiplier associated with inherited deficit-driven tax changes (see Panel C in Figure 16).

We now ask whether the differences in the initial tax rate levels and/or the respective sizes of the tax changes observed across different categories of exogenous tax changes actually help explain some of the differences in tax multipliers (based on linear estimations) shown in Figure 16.[42] Table 3 points out that, indeed, this may be the case. Panel A shows that tax changes motivated by long-run growth typically have initial VAT rates that are higher than those observed for inherited fiscal factors. The same is not true for the size of the tax changes, which are very similar. Panel B shows that inherited deficit- and debt-driven tax changes typically share similar initial tax rate

[41] Recall that, given the nature of tax changes in the U.S., RR do not include in their classification what we call inherited debt-driven tax changes

[42] Another possibility is that the macroeconomic context associated with different tax changes varies across different types of tax changes which, in turn, could affect the size of the multiplier. While it proves impossible to consider all potential factors, we cannot reject the null hypothesis that the prevalence of fixed exchange-rate regimes, public debt as a percentage of GDP, and the stance of the business cycle is the same in tax changes motivated by inherited fiscal factors and long-run growth.

levels, yet the size of the median tax change is two times larger for debt-driven tax changes than for deficit-driven ones. This last finding should not come as a surprise since debt-driven changes are motivated by fiscal sustainability and debt stock considerations requiring larger fiscal efforts than deficit-driven changes, which are solely motivated by fiscal flow shortcomings.

The abovementioned differences suggest that the reason behind the more negative tax multiplier observed for tax changes driven by long-run growth relative to those driven by inherited fiscal factors is that, typically, the former have higher initial tax rates. By the same token, the tax multiplier of debt-driven tax changes may be more negative than that associated with deficit-driven tax changes because the tax changes tend to be of greater size in the first group.

In fact, Figure 17 provides further evidence that these non-linear arguments are actually at work. The median value of the tax multipliers calculated for each tax change, based on the non-linear specification (11) and classified per exogenous tax change category, matches quite well the tax multiplier of each exogenous tax change category estimated in a linear fashion. Appendix 4 shows that, when relying on RR's U.S. dataset, the same type of non-linear arguments can, as in our sample, help explain the different response of output to tax changes motivated by long-run growth considerations relative to deficit-driven tax changes.

INSERT TABLE 3 *AND FIGURES* 15, 16, *AND* 17 *HERE*

6.5 Non-linearities in action III: How do taxes affect incentives to work and invest?

In this subsection, we analyze whether the non-linear distortionary and disincentive-based theoretical arguments and the empirical results obtained above are actually reflected on the *perceived* effect of taxes on incentives to work and invest. Based on a survey of a representative sample of business leaders in 142 countries, the Global Competitiveness Index elaborated by the World Economic Forum includes specific questions such as (i) "[i]n your country, to what extent do taxes reduce the incentive to work?" and (ii) "[i]n your country, to what extent do taxes reduce the incentive to invest?". Panels A and B in Figure 18 show the relationship between the VAT rate and the perceived effect of taxes on incentives to work and invest, respectively, for a sample of 123 countries for the year 2014.[43] Supporting our previous findings, the relationship is highly non-linear. While the perceived effect of taxes on the incentives to work and invest barely changes as VAT rates increase at low/moderate levels (approximately until the VAT rate reaches 14 percent), it falls rapidly for high levels of VAT rates.

INSERT FIGURE 18 *HERE*

[43] Figure 18 does not include 19 countries that, in spite of having Global Competitiveness Index data, lack a VAT scheme.

6.6 Non-linearities in action IV: It works in empirics, but does it work in policy?

In the recent past, two of the most pressing policy challenges faced by governments around the world have been (i) how to regain the lost economic growth of the 2000s and (ii) how to deal with larger and more persistent fiscal deficits (161 out of 191 countries had fiscal deficits in 2017 and 120 governments have plans for fiscal adjustment in 2018).[44,45] In this section, we evaluate the extent to which our non-linear findings are, in a broad sense, actually being taken into account by countries' fiscal authorities when dealing with these key challenges. If the tax multiplier is essentially zero for countries with relatively low/moderate initial tax rate levels, then their governments could contemplate conducting fiscal adjustments by raising tax rates and, consequently, revenues. By the same token, it would prove ineffective to reduce the VAT rate to increase economic activity. In contrast, if the tax multiplier is largely negative for countries with high initial tax rate levels, it would prove quite costly to mobilize revenues by increasing the VAT rate and quite beneficial to reduce such a rate to boost economic activity. Figure 19 shows the relationship between the VAT rate (as of November 2017) and the expected change in cyclically-adjusted revenues (as a percentage of GDP) between 2017 and 2018 (ΔCAR).[46]

The evidence is quite striking in that countries' fiscal authorities with low rates are, indeed, planning to boost revenues as part of their adjustment efforts, while countries with high tax rates are not only not planning to substantially increase revenues, but also trying to reduce such a burden. In fact, the expected change in cyclically-adjusted revenues (as a percentage of GDP) is (i) 0.4 percentage points (statistically significant at the 1 percent level) for countries with VAT rates between 6 and 13 percent (with 83 percent of these countries planning increases in ΔCAR), (ii) -0.15 percentage points (statistically not significant) for countries with VAT rates between 14 and 18 percent (with 45 percent of these countries planning increases in ΔCAR), and (iii) -0.52 percentage points (statistically significant at the 1 percent level) for countries with VAT rates between 19 and 27 percent (with 76 percent of these countries planning decreases in ΔCAR). Figure 20 shows the same regularity when solely focusing on the VAT. In other words, our non-linear findings work in empirics and help explain the behavior of countries' fiscal authorities.

INSERT FIGURES 19 *AND* 20 *HERE*

[44] For these purposes, a fiscal adjustment plan is identified as a situation where the overall fiscal balance (being it deficit or surplus) is expected to increase from 2017 to 2018.

[45] While the number of countries planning to conduct fiscal adjustment in 2018 represent about 63 percent (or 120 out of 191) of the total number of countries, their economies represent about 86 percent of global output.

[46] It is worth noting that the correlation between the VAT rate (as of November 2017) and the revenue (as a pecentage of GDP) for 2017 is 0.62 (statistically significant at the 1 percent level).

7 Final thoughts

This paper has estimated tax multipliers for a large group of countries following the narrative approach. Specifically, based on a novel dataset on VAT rates in 51 countries (20 industrial and 31 developing) and contemporaneous economic records and sources, we have identified 96 tax rate changes and classified them into endogenous and exogenous to current (or prospective) economic conditions. The analysis has made clear the critical importance of relying on a narrative approach as opposed to the much more common (due to its considerable ease of implementation) Blanchard-Perotti approach. In terms of the bias, the Blanchard-Perrotti approach tends to overestimate the size of the tax multiplier in our global sample due to the numerous tax changes that have responded procyclically to the business cycle. In contrast, the true effect of tax changes on output would be underestimated in advanced economies like the U.S. which typically follow countercyclical tax policies by increasing (cutting) taxes in good (bad) times.

When properly identified, we show, as in RR, that the tax multiplier is negative, indicating that tax hikes reduce economic activity and tax cuts boost output. Why? Because increases (decreases) in the VAT rate reduce (increase) the incentives to consume, invest, and work. However, we found – both for our global sample and for RR's U.S. dataset – that such "average" multiplier hides important non-linearities. In line with theoretical models, which are based on distortionary and disincentive-based type of arguments, we find that the tax multiplier is essentially zero under relatively low/moderate initial tax rate levels but markedly negative when initial tax levels are high. By the same token, for a given initial tax rate, larger changes in the tax rate have larger tax multipliers. These findings have important policy implications given that the initial level of taxes varies greatly across countries and thus so will the potential output effects of changing tax rates.

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Appendices

1 Responses of tax policy to several recent earthquakes

Ecuador 2016: On April 16, 2016, Ecuador suffered a severe earthquake (with a magnitude of 7.8). According to contemporaneous estimates, GDP was expected to fall about 1 percent as a consequence of the disaster, and reconstruction costs were estimated to be about 3 to 4 percent of GDP. On April 20, President Correa announced an increase of 2 percentage points in the VAT rate (from 12% to 14%). Congress approved the VAT increase on May 12 and it was implemented on June 1. The time elapsed between the natural disaster and the approval (implementation) of the tax change was 26 (46) days.

Japan 2011: On March 11, 2011, Japan suffered a "triple disaster" (earthquake-tsunami-nuclear meltdown), with an earthquake magnitude of 9.0. According to contemporaneous reports, the economic damages were estimated to be about 6 to 7 percent of GDP. The earthquake hit Japan's north-east section, responsible for 6% to 8% of the country's total production. On April 27, several "special" national tax laws were promulgated and became effective immediately. Also, an expected cut of 5 percentage points of the Japanese corporate tax rate (announced on December 2010 by the Prime Minister) was deferred as consequence of the earthquake. Therefore, the time elapsed between the natural disaster and the approval and implementation of tax changes was of 47 days.

India 2001: On January 26, 2001, India suffered a severe earthquake (with a magnitude of 7.7). According to contemporaneous reports, the economic damage was estimated to be about 0.8 percent of GDP. On February 1, the Cabinet imposed a nationwide 2 percent surcharge on both income and corporate taxes in order to help finance the reconstruction of the affected areas. Therefore, the time elapsed between the natural disaster and the tax change approval was 6 days.

California 1989: On October 17, 1989, California suffered a severe earthquake (with a magnitude of 6.9). According to contemporaneous reports, the economic damage was estimated to be about 1 percent of California's GDP. The Governor called for a Special Session to address the needs for earthquake relief to be held on November 2. On November 4, a package of legislation was approved including a one-year 0.25% surcharge to the State's sales tax. The tax increase became effective on December 1. Therefore, the time elapsed between the natural disaster and the approval (implementation) of the tax change was 18 (45) days.

2 Model

What follows is a simple general equilibrium reduced-formed-solution type of model which explains the non-linear effects of VAT on output based on distortionary and disincentive-based arguments originated by the presence of informality. The representative agent (RA) maximizes

$$W = \ln(c_{\text{formal}}) + \ln(c_{\text{informal}}),$$

by selecting the consumption of formal and informal goods, subject to the budget constraint

$$\pi + wL + T = c_{\text{formal}}\,(1+t) + c_{\text{informal}}p.$$

The variables w, L, p, t, and T are wages, total worked hours (which are assumed as given), relative price of the informal good in terms of the formal one, VAT rate (which is only paid by the formal good), and government's lump sum rebate (to avoid wealth effects of taxation).

There are two types of representative firms (RF), one in the formal sector ($\text{RF}_{\text{formal}}$) and the other one in the informal sector ($\text{RF}_{\text{informal}}$). $\text{RF}_{\text{formal}}$ and $\text{RF}_{\text{informal}}$ maximize profits

$$\begin{aligned} \pi_{\text{formal}} &= y_{\text{formal}} - wL_{\text{formal}}, \\ \pi_{\text{informal}} &= y_{\text{informal}}p - wL_{\text{informal}}, \end{aligned}$$

by selecting L_{formal} and L_{informal}, respectively. For simplicity, we assume that both $\text{RF}_{\text{formal}}$ and $\text{RF}_{\text{informal}}$ have identical production functions: $y_{\text{formal}} = (L_{\text{formal}})^{\beta}$ and $y_{\text{informal}} = (L_{\text{informal}})^{\beta}$, where $\beta < 1$ to have decreasing marginal returns. The government collects VAT to finance the lump sum rebate (i.e., $c_{\text{formal}}t = T$). In equilibrium, naturally, the goods and labor markets need to clear. Solving the RA and RF problems, we obtain[47]

$$\begin{aligned} y^{*}_{\text{formal}} &= [1/(2+t)]^{\beta}, \\ y^{*}_{\text{informal}} &= [(1+t)/(2+t)]^{\beta}. \end{aligned}$$

Therefore, note that for any $t > 0$, it is easy to show that

$$\begin{aligned} \frac{\partial y^{*}_{\text{formal}}}{\partial t} &= -\frac{\beta}{(2+t)^{\beta+1}} < 0, \\ \frac{\partial y^{*}_{\text{informal}}}{\partial t} &= \frac{\beta}{(2+t)^{\beta+1}}(1+t)^{\beta-1} > 0, \\ \Omega &\equiv \frac{\partial y^{*}_{\text{informal}}}{\partial t} - \frac{\partial y^{*}_{\text{formal}}}{\partial t} = \beta\frac{(1+t)^{\beta-1}}{(2+t)^{\beta+1}}\left[1-(1+t)^{1-\beta}\right] < 0, \end{aligned}$$

where Ω captures the total output effect of a change in t. In other words, for example, for a given increase in t, the increase in output in the informal sector (as firms hire more in this sector given that now it is less costly to produce informal goods relative to formal ones) would be smaller (in absolute terms) than the fall in output of the formal sector. Why? Because the existence of VAT

[47] Derivations are not shown for brevity. Only most relevant endogenous variables are presented, also for the sake of brevity.

taxation generates, in and of itself, an initial distortion in which workers are incentivized to work in the informal sector more than in the absence of such a tax. Therefore, the marginal productivity of formal workers is, in equilibrium, larger than that of informal ones. Under this situation, an increase in the VAT rate simply increases the initial distortion, reducing output of the formal sector (more productive in equilibrium) by a larger margin (in absolute terms) than the increase in output of the informal sector (less productive in equilibrium). These last effects, in turn, obviously increase the share of informality (i.e., increases $y^*_{\text{informal}}/y^*_{\text{formal}}$). Naturally, while we exemplified the mechanism using an increase in the VAT rate, the same results hold if a reduction in the VAT rate was used instead.

We now show that this effect is non-linear, in particular more (less) intense when starting with higher (lower) initial VAT rate levels. It is easy to show that $\Omega(t = t_{high}) < \Omega(t = t_{low}) < 0$, where $t_{high} > t_{low} > 0$. In other words, as the initial VAT rate starts at a higher level, and consequently at a larger initial distortion, the increase in the VAT rate operates generating a larger fall in output (and an increase in the share of informality) under a high initial VAT rate than under a low initial VAT rate. Moreover, it is easy to show that $\Omega(t = 0) = 0$. This last result further shows that for truly low levels of VAT rate (mathematically speaking $t = 0$), our distortionary and disincentive-based arguments virtually vanish.

The proposed mechanism as well as the output and informality implications would be further amplified if (i) the production functions of the formal and informal sectors allowed larger productivity in the formal sector than in the informal one (i.e., $y_{\text{formal}} = (L_{\text{formal}})^{\beta_{\text{formal}}}$, $y_{\text{informal}} = (L_{\text{informal}})^{\beta_{\text{informal}}}$, and $\beta_{\text{informal}} < \beta_{\text{formal}} < 1$), as it is frequently assumed based on firm level data evidence, and/or (ii) if there existed a segmentation in the labor market where formal workers were paid more than informal ones (i.e., $\pi_{\text{formal}} = y_{\text{formal}} - wL_{\text{formal}}\varepsilon$, where $1 > \varepsilon > 0$), as empirical evidence strongly suggests.

3 Computation of tax multiplier and standard error

The derivation of equation (7) is as follows. Recall that the multiplier for time horizon h is typically defined as $\Delta Y_h/\Delta R_h$, where R is the real VAT revenue, Y is the real output, $\Delta Y_h \equiv Y_{t+h} - Y_t$, and $\Delta R_h \equiv R_{t+h} - R_t$. Notice that $\Delta Y_h/\Delta R_h = (\Delta Y_h/Y)/(\Delta R_h/Y)$. From equation (6), $\Delta Y_h/Y = \beta_h \Delta t$. Therefore, $\Delta Y_h/\Delta R_h = \beta_h \Delta t/(\Delta R_h/Y)$. Since $R \equiv I \cdot Y$, then $\Delta R_h \approx Y \cdot \Delta I_h + I \cdot \Delta Y_h$. Further, given that $e \equiv I/t$ is taken as a constant, then $\Delta I_h = e \cdot \Delta t_h$. Hence, $\Delta Y_h/\Delta R_h = \beta_h \Delta t/(e \cdot \Delta t_h + I \cdot \beta_h \cdot \Delta t)$. Since $\Delta t_h \equiv \rho_h \cdot \Delta t$, then $\Delta Y_h/\Delta R_h = \beta_h/(e \cdot \rho_h + \beta_h \cdot I)$.

The derivation of equation (8) is as follows. From (7), $Tax\ multiplier = f(x)$, where $f(x) = x/(e \cdot \rho_h + x \cdot I)$. Using a first-order approximation, it follows that the $Tax\ multiplier$ evaluated around a equals $f(x) \approx f(a) + f'(a)(x-a) = f(a) + f'(x)\,x - f'(x)\,a$. Hence, the variance of the Tax multiplier equals $Var[f(x)] \approx 0 + [f'(x)]^2 Var(x) - 0 = [f'(x)]^2 Var(x)$. Evaluating $f(x)$ at β_h, $Var[Tax\ multiplier\ (h)] = [f'(\beta_h)]^2 Var[\beta_h]$. Hence, $Tax\ multiplier_{SE}\ (h) = f'(\beta_h) \cdot \beta_h^{SE}$. Using (7), it follows that $Tax\ multiplier_{SE}\ (h) = [(e \cdot \rho_h)/(e \cdot \rho_h + \beta_h \cdot I)^2] \cdot \beta_h^{SE}$.

4 Can non-linear distortion-based arguments explain the effects of different exogenous tax changes when using RR's sample?

In Section 6.4, we explained the effects of different exogenous tax changes based on non-linear arguments using our global sample and narrative strategy. This appendix analyzes whether the same type of non-linear arguments is present in RR's U.S. dataset and the extent to which they can explain the different response of output to tax changes motivated by long-run growth considerations relative to deficit-driven ones. In order to maintain the comparability with RR's study, we use their specification and econometric strategy. In particular, RR's basic specification is as follows:

$$\Delta y_t = \alpha + \sum_{i=0}^{12} \beta_i \Delta t_{t-i}^{exog} + \sum_{j=1}^{12} \gamma_j \Delta y_{t-j} + \mu_t, \tag{12}$$

where y is the logarithm of real GDP (and thus Δy measures the real GDP growth rate) and Δt^{exog} is RR's measure of legislated tax change.

First, we proceed as in Subsections 6.1 and 6.2 and evaluate whether the effect of tax changes on output depends upon the initial tax level and the size of the tax change. Using the same type of interaction strategy proposed in specifications (10) and (11), Panels A and B in Figure A1 show similar findings to those obtained before using a global sample. This evidence further supports that the output effect of tax increases is, as theoretically argued, highly non-linear and becomes more negative with the initial tax level and size of the tax change.

Second, we analyze whether the differences in the initial tax levels and/or the respective size of the tax changes across long-run growth and inherited deficit-driven tax changes may help explain the differences in tax multipliers identified by RR and reported in Section 6.4. Table A1 and Figure A2 are equivalent to Table 3 and Figure 13 from Section 6.4. Table A1 and Figure A2 also support that a key reason why RR's tax changes driven by long-run growth motivations have a more negative effect on output than that of inherited deficit-driven ones lies on the larger initial tax rates observed for the former group.

INSERT TABLE A1 AND FIGURES A1 AND A2 HERE

5 Data definitions and sources

We constructed quarterly seasonally-adjusted real measures of gross domestic product, government spending, consumption, investment, net exports, VAT revenue, employment, population, and inflation using data from Global Financial Data, Data Stream, International Financial Statistics, OECD-FRED, and Eurostat. Labor force is from International Labour Organization. Real wage data is solely available for OECD countries based on OECD data. The size of the informal sector (expressed as share of GDP) is from Medina and Schneider (2018), interpolated from annual to quarterly frequency.