WP/16/234

IMF Working Paper

Tax Capacity and Growth: Is there a Tipping Point?

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INTERNATIONAL MONETARY FUND

WP/16/234

IMF Working Paper

Fiscal Affairs Department

Tax Capacity and Growth: Is there a Tipping Point?

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November 2016

Abstract

Is there a minimum tax to GDP ratio associated with a significant acceleration in the process of growth and development? We give an empirical answer to this question by investigating the existence of a tipping point in tax-to-GDP levels. We use two separate databases: a novel contemporary database covering 139 countries from 1965 to 2011 and a historical database for 30 advanced economies from 1800 to 1980. We find that the answer to the question is yes. Estimated tipping points are similar at about 12¾ percent of GDP. For the contemporary dataset we find that a country just above the threshold will have GDP per capita 7.5 percent larger, after 10 years. The effect is tightly estimated and economically large.

JEL Classification Numbers: H11, H26, O10, O43

Keywords: income per capita, taxation, development, multiple equilibria

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[1] We are grateful to David Lipton for inspiring the research question. We thank Sanjeev Gupta, Mick Keen, Abdel Senhadji, Bernardin Akitoby, Rossen Rozenov, Andrew Hodge, Marialuz Moreno Badia, Xavier Debrun, Vikram Haksar, Albert Touna Mama and Aart Kraay for helpful comments and discussion. We are also grateful to participants of the IMF Fiscal Affairs Department seminar for their useful suggestions. We thank Elijah Kimani for excellent research assistance.

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I. INTRODUCTION

Is there a minimum tax-to-GDP ratio associated with a significant acceleration in the process of growth and development? This paper proposes a new way to quantify the relation between taxes and growth by investigating the existence of a tipping point in tax-to-GDP levels. Tipping points can occur in environments characterized by multiple equilibria and are associated with sharp changes occurring around some threshold.

We use a novel contemporary database covering 139 countries and spanning the period 1965-2011. We combine the approaches taken by Card, Mas and Rothstein (2008) using regression discontinuity design methods with the threshold regression framework proposed by Hansen (1999) to provide new estimates of tax tipping points.

Our approach provides new empirical estimates that build on earlier work by Besley and Persson (2011, 2013, 2014a, 2014b). We go beyond the existing literature in two dimensions: (i) we rely on a much broader database, both in coverage of countries and years; and (ii) we use a non-linear model to flexibly estimate the reduced-form relation between tax levels and subsequent GDP growth. Specifically, we use a regression discontinuity design model to estimate a growth tipping point.

Our focus is on tax revenues as other sources of revenue have not been found to be closely related to economic development. Arezki et al. (2011) and IMF (2015) illustrate that countries that have an abundance of natural resources often show a record of relatively poor economic performance compared with non-resource-rich countries. In the case of foreign aid, there is no consensus on its effects on economic development. Some argue that official assistance has harmed poor countries throughout the years, while others believe that aid levels have been too low. Edwards (2014) provides a useful overview.

From a conceptual viewpoint we follow the path openned by Joseph Schumpeter in his famous paper *The Crisis of the Tax State* (Schumpeter, 1918). Schumpeter links state and tax so closely that he stresses that his expression "tax state" can be regarded as almost pleonastic. He emphasizes that taxes are not only associated with the historical origin of the state, they are also active in shaping it. In his view the organic development of taxation was associated with the organic development of other dimensions of the state. It is particularly important for our purposes to stress Schumpeter's distinction between taxes and other forms of government revenue. From the viewpoint of the *Tax State,* the dependence on revenues from patrimony or entrepreneurial activity is characteristic of an earlier stage of Public Finance development. For Schumpeter, the analysis of the consequences of taxation requires a long run perspective that allows for structural and self-reinforcing evolutionary dynamics to play out in full. These dynamics are not only economic but also social and political. We interpret Besley and Persson as bringing a similar perspective to contemporary research. We would like to place our contribution within this tradition.

The answer to the question with which we begin the paper is made difficult by the joint determination of GDP and the tax-to-GDP ratio. We want to investigate how tax-to-GDP is associated with subsequent growth. But it is also the case that GDP growth is associated with increases in the tax-to-GDP ratio. This may be rationalized, for example, in terms of the so-called Wagner's Law. In the process of economic development, the demand for public services increases faster than GDP, leading to an increased in government's expenditure-to-GDP ratio. Since these tend to be financed, at the margin, by taxation, a similar increase in the tax-to-GDP ratio ensues. We mitigate the issue by focusing on local effects, i.e. how small changes in taxes around a specific tipping point lead to potentially large change in subsequent growth, as opposed to estimating global relations such linear models. We also find that our local results are robust when controlling for the potential endogeneity of taxes.[2]

The paper is organized as follows. Section II provides a short selective review on the relevant literature on the relationship between taxation and economic development. It also discusses the intuition on how a small change in taxes can lead to large changes in GDP. Section III describes how we compiled our two databases—the contemporary database and the historical database. Section IV explains the methodology used and the empirical results obtained. Section V concludes.

II. TAXATION AND ECONOMIC DEVELOPMENT

A. How is taxation linked to greater economic development?

When studying the relationship between taxation and economic development, there is a strand of literature that focuses on how development influences the evolution of the tax system. The emphasis is on the economic constraints that influence the government's ability to impose a particular tax rate on a particular tax base. For example, Tanzi (1992) and Burgess and Stern (1993) find that countries with a higher share of agriculture and a lower share of imports-to-GDP tend to have lower taxation. Gordon and Li (2009) emphasize the link between taxation and formal finance. They argue that firms have incentives to evade taxes by conducting all business in cash in countries where the value from using the financial sector is more modest. In the same vein, Kleven, Kreiner, and Saez (2009) show that in more developed countries, firm size is sufficiently large to make third-party tax enforcement effective, as income witholding facilitates cross-checking of tax records between indviduals and firms. Others have argued that large informal sectors in poor economies are inherently hard to tax, as discussed in the survey by Joshi et al. (2014). La Porta and Shleifer (2014) discuss the desire to avoid taxes as an important motive for informality.

Access to forms of revenue other than taxes has also been associated with lower taxation. Jensen (2011) finds that a 1 percent increase in the share of natural resource rents in total government income is associated with a 1.4 percent lower share of taxation in GDP. Benedek et al. (2014) find a negative association between foreign aid and domestic tax revenues, particularly in low-income countries and in countries with relatively weak institutions.

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[2] We use the IV threshold model proposed by Caner and Hansen (2004). Results are available upon request.

Of course, there is another strand of literature that studies the influence of the tax system on the economy. Barro (1990) discusses how the economy can be made more productive when tax revenues are spent on public goods and investments. Barro and Sala-i-Martin (1992) show that, in endogenous-growth models, well-designed tax systems can minimize the efficiency losses imposed by taxes and can even raise the GDP growth rate. For sub-Saharan Africa, Ebeke and Ehrhart (2011) find that the instability of tax revenue leads to the instability in public investment and government consumption, and it also reduces the level of public investment. Seidel and Thum (2015) argue that stricter tax enforcement forces corrupt officials to reduce bribe demands, which makes market entry by private firms more attractive.

Several authors have augmented the standard approach, giving political and institutional factors a key role in the analysis of taxation and development. Most notably, Besley and Persson (2011, 2013, 2014a, 2014b) emphasize the broader concept of state capacity to stand for a range of capabilities that are needed for the state to function effectively. State capacity incorporates investment by the government in building three key dimensions: (i) *fiscal capacity*, by increasing collection of taxes, especially broad-based taxes, through stronger tax enforcement; (ii) *legal capacity*, which refers to market-supporting regulation, enforcement of contracts, and protection of property rights; and (iii) *collective capacity* by augmenting markets, mostly by supplying public goods. Besley and Persson (2011) also suggest that many determinants of state capacity are common across these dimensions. They carry out simple regression analyses for a cross-section of 111 countries to show the correlation between common factors (war, ethnic homogeneity, political stability, constraints on the executive) and measures of fiscal and legal capacity.

Building on Besley and Persson, Figure 1 illustrates the link between taxation and greater economic development. State capacity is shaped by the interaction between tax capacity, legal capacity, and public administration capacity. Tax capacity not only provides a stable and elastic source of revenue for the government to finance its activities, but a government with a larger stake in the economy through a developed tax system also has stronger motives to play a productive role in the economy. Public administration capacity refers to the government's effective and efficient use of public money.[3] This directly impacts the ability of governments to implement policy and deliver public services, which in turn influences citizens' trust in government. Legal capacity refers to the government's ability to secure private property rights. This includes legal infrastructure such as building the court system and registering property.

It is important to note that tax capacity, legal capacity, and public administration capacity are complements. Sustained improvements in tax collection do not occur in a vacuum. Building tax capacity requires investment in legal capacity, and vice versa. This is why we would expect tax, legal, and public administration capacity to be positively correlated with one another. These feedback loops can also give rise to multiple equilibria as noted for example in Besley and Persson (2013).

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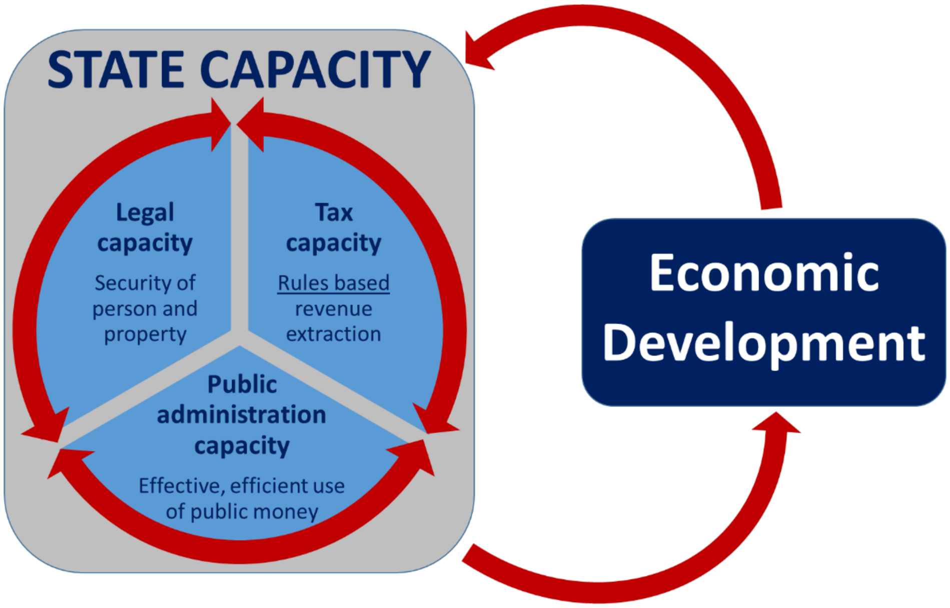
[3] For example, Pritchett (2000a) and IMF (2015) discuss how weaknesses in public investment management have resulted in inadequate returns to public investment in many countries.

The strength of tax capacity depends crucially on social norms of compliance. Kiser and Levi (2015) emphasize that the more a government is effective and trustworthy, the more legitimacy it is likely to attain, and the more it will be able to elicit compliance without excessive monitoring or punitive action. Similarly, as proposed by Levi (1988), the government can achieve a high degree of quasi-voluntary compliance with the taxation system when citizens comply with taxation out of a combination of strategic and normative considerations. Strategic considerations refer to the calculation of the probability of being caught and the punishment involved. Normative considerations refer to a sense of fairness: the citizen believes that sufficient public goods are being provided in return for tax payments, and that others are also paying their fair share. A variety of other authors have also argued that creating a culture of compliance is central to raising revenue. For example, Gordon (1989) refers to individual morality, Posner (2000) to tax-compliance norms, and Torgler (2007) to tax morale. Social norms of compliance are in turn closely associated with a higher demand by citizens for accountable and transparent government, as argued by Moore (2007), Brautigam et al. (2008) and Ross (2004). These relationships are illustrated in Figure 2.

Figure 1. Complementarities in State Capacity



Finally, our paper can also be linked to the recent literature on growth accelerations (see for example Hausman et al. 2005, Pritchett 2000b and Berg et al. 2012). While the average effect on growth of crossing the tax-to-GDP tipping point isn't quite as high as the highest growth acceleration episodes considered in several of these studies[4], we find that average annual growth rates are higher by about 0.75 ppa over 10 years compared to countries that remain below the tipping point. This qualifies as an important and large driver of sustained growth

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[4] For example, Hausman et al. (2005) consider episode where GDP per capita growth rates increase by 2.5 ppa sustained over 8 years.

episodes in addition to several other variables that have been consistently associated with these episodes such as investment and trade, political regime changes and economic reform and equality of the income distribution (Hausman et al. 2005, Berg et al. 2012).

Figure 2. Tax Capacity, Social Norms, and Accountability

B. Tipping points: how can a small change in taxes lead to large changes in GDP?

As shown by Card et al. (2008), multiple equilibria can arise in settings where feedback loops occur among agents—when individual preferences depend on choices made by other agents. Importantly, the authors show how multiple equilibria can be identified in the data by estimating tipping points, i.e. cases where small changes in initial conditions give rise to large changes in outcomes.[5] Specifically, one can identify tipping points whenever the economy 'jumps' from one equilibrium to another. If taxpayers and policy makers' decisions were characterized by such strategic complementarities, it could in principle be possible to find cases where small changes in taxes lead to large changes in growth.

A shift in social norms can push a country out of a low tax compliance equilibrium into a high tax compliance equilibrium as discussed, for example, by Traxler (2010). Such enhanced tax capacity could then lead to a virtuous cycle in behavior and institutions that will have a positive impact on growth. The virtuous cycle could be triggered through several channels. Greater tax compliance enlarges the tax base, which can reduce the marginal cost of public funds. In turn, this enables greater spending by the government on state capacity building. An increase in cooperative behavior and trust can also make it easier to realize

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[5] A recent example applied to taxpayers' behavior is proposed by Traxler (2010).

agglomeration effects in production as more individuals and firms participate in formal markets. Furthermore, greater accountability from a larger pool of taxpayers can improve governance and help decrease corruption, further reducing barriers to market entry by firms and supporting economic growth (Murphy, Schleifer, and Vishny, 1993).

We argue that as countries approach and eventually exceed some revenue threshold, growth outcomes for these countries would then jump discontinuously. Card et al. (2008) demonstrate that tipping points can be identified and estimated through the use of regression discontinuity design (RDD) methods. We apply the approach to the relation between tax-to-GDP levels and subsequent GDP growth. In particular, we look for levels of tax-to-GDP around which we observe sharp changes in subsequent GDP growth rates. We interpret our findings as suggestive of the possible presence of multiple equilibria in tax compliance and capacity: small variations in tax levels around a tipping point can lead to economies jumping from one equilibrium to another. This in turn can lead to large differences in growth as some countries reach the high compliance/high growth equilibrium while others remain in the low compliance/low growth equilibrium.

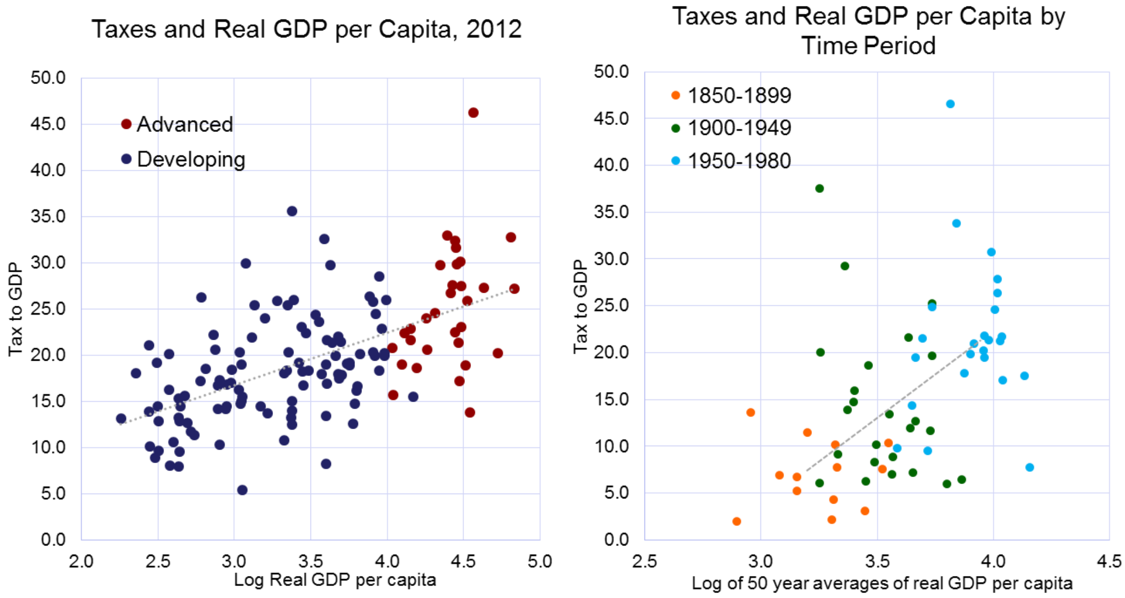
C. Stylized Facts

Stylized facts illustrate the relationship between tax capacity and economic development. Figure 3 shows the positive relationship between tax-to-GDP and real GDP per capita, using two separate samples of countries. Using a cross-section of data for 2012, the figure shows that higher income countries tend to raise more tax revenue as a share of GDP than lower income countries. Using historical time-series data going back to the 1800s for 30 countries, the figure shows a similar trend, where tax-to-GDP rise over time along with income levels. These findings are in line with the reading of Wagner's Law that we suggested earlier.

Figure 4 illustrates the complementarity between tax capacity and legal capacity. The figure shows that countries with higher tax revenue-to-GDP also tend to have stronger protection of property rights, as measured by a Fraser Institute indicator of legal structure and property rights. The figure also shows that higher tax-to-GDP is associated with higher quality of government policies and regulation, as measured by the Worldwide Governance Indicators.

Figure 5 illustrates the complementarity between tax capacity and public administration capacity. The figure shows a negative relationship between tax-to-GDP and a corruption index by Transparency International. This suggests that tax capacity is once again associated with greater government transparency and accountability. The figure also shows that countries with higher tax-to-GDP also tend to have stronger budget institutions, as measured by the Public Investment Management Efficiency (PIE-X) index.

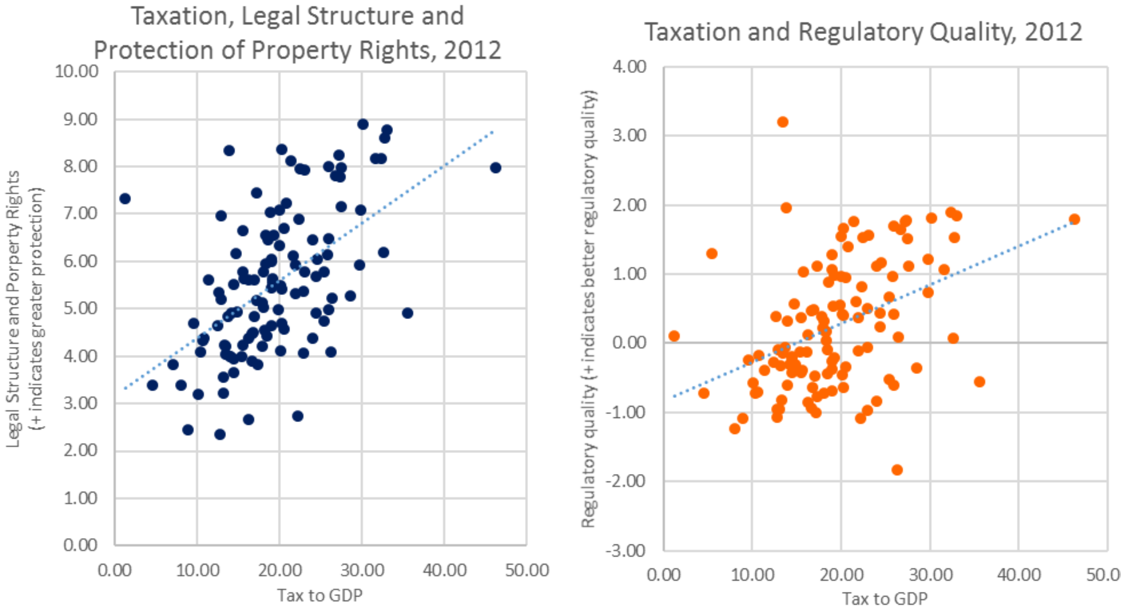
Figure 3. Tax to GDP and Income Levels


Taxes and Real GDP per Capita, 2012

Taxes and Real GDP per Capita by Time Period

Sources: International Historical Statistics, World Economic Outlook, and authors' estimates

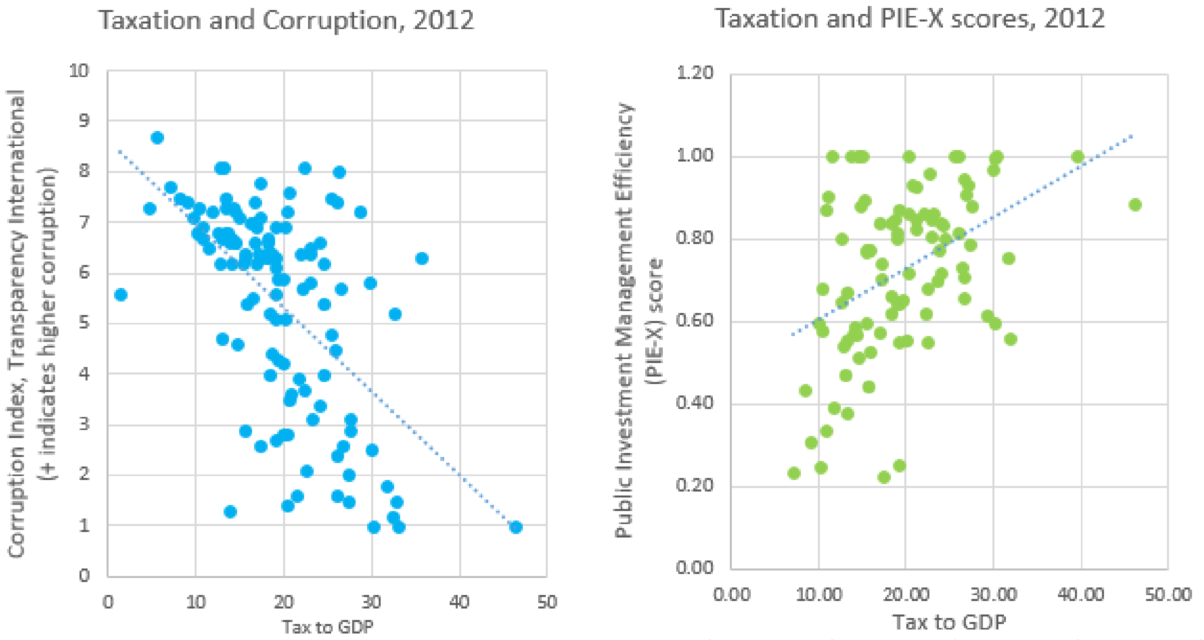
Figure 4. Tax Capacity and Legal Capacity, 2012


Taxation, Legal Structure and Protection of Property Rights, 2012

Taxation and Regulatory Quality, 2012

Sources: Fraser Institute, Worldwide Governance Indicators, World Economic Outlook.
Note: The Fraser Institute indicator for legal structure and property rights is the average across indicators of judicial independence, impartial courts, protection of property rights, military interference in the rule of law and politics, integrity of the legal system, legal enforcement of contracts, regulatory restrictions on the sale of property, reliability of police, and business costs of crime. The Worldwide Governance Indicator of regulatory quality reflects perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development.

Figure 5. Tax Capacity and Public Administration Capacity, 2012



Sources: Transparency International, Fiscal Affairs Department, World Economic Outlook
Note: Public Investment Management Efficiency (PIE-X) is an IMF tool that measures the relationship between the accumulated public capital stock per capita and various indicators of the quality of and access to infrastructure. The closer a country is to the efficiency frontier, the more efficient its public investment.

III. DATA

We rely on two independent databases for our analysis: a contemporary database and a historical database.

The contemporary database assembles a large unbalanced panel consisting of tax-to-GDP and real GDP per capita for 139 countries from 1965 to 2011. Data on tax-to-GDP ratios are collected from several sources. We combine, in order and when available, data on general or central government tax-to-GDP ratios from the following sources: (1) OECD; (2) Mansour (2014, 2015) for sub-Saharan African and MENA countries; (3) World Economic Outlook; (4) GFSM 1986 Historical Government Finance Statistics; and (5) the International Centre for Tax and Development's Government Revenue Dataset. Splicing is used to combine the different sources. Table 1 indicates the time period and number of countries available for each individual source.[6]

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[6] The IMF's World Revenue Longitudinal Data set (WoRLD) offers a similar compilation of government revenues with more detailed information by type of revenue starting in 1990. Our results are identical when using WoRLD data (available at http://data.imf.org/revenues).

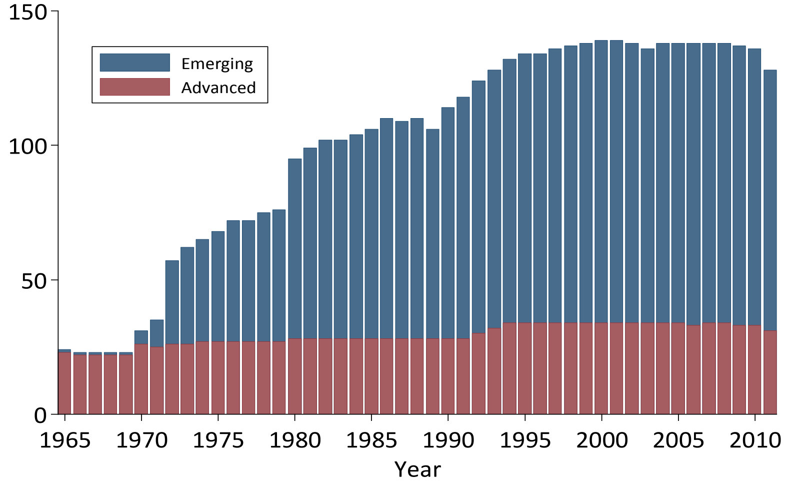
Table 1. Sources for Tax-to-GDP data

Database	Period	Countries
Tax-to-GDP (all sources)	1965-2011	139
1- OECD	1965-2011	47
2- Mansour (2014, 2015)	1980-2011	38
3- World Economic Outlook	1985-2011	77
4- GFSM 1986 Historical Government Finance Statistics	1970-2002	70
4- The International Centre for Tax and Development	1980-2010	40

To study growth across countries and over time, we use real GDP per capita at constant national prices, obtained the Penn World Tables 8.1 (Feenstra, Inklaar and Timmer, 2015).[7] Figure 6 shows the number of observations on tax-to-GDP available by year for advanced and developing countries. Figure 7 shows the distribution of tax-to-GDP and average annual real per capita GDP growth rates across the contemporary database.

The historical database is also an unbalanced panel consisting of tax-to-GDP ratios and real GDP per capita for 30 advanced countries between 1800 and 1980.[8] Data on tax-to-GDP is from the International Historical Statistics (Mitchell, 2003). Data on real GDP per capita (in GK$ 1990) is from the Maddison Project 2013 version. Figure 8 shows the number of observations on tax-to-GDP by year. Figure 9 shows the distribution of tax-to-GDP and average annual real per capita GDP growth rates across the historical database.

Figure 6. Contemporary Database: Number of Observations for Tax to GDP



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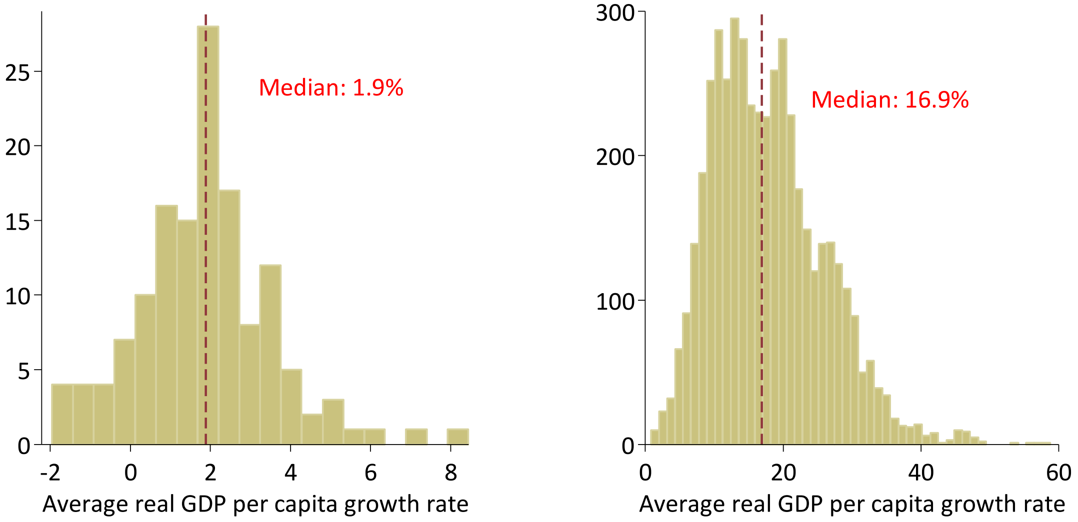
[7] We drop from our sample countries where natural resource rents, as measured in the World Development Indicators, exceeds 30 percent on average over the entire sample.

[8] Countries are: Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Israel, Italy, Japan, Korea, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovenia, Ireland, Spain, Sweden, Switzerland, United Kingdom, United States.

Figure 7. Contemporary Database: Distribution of Average Annual Real GDP per Capita Growth and Tax-to-GDP Ratios

Distribution of Average Annual Real GDP per Capita Growth Rate for Each Country, 1965-2011 (percent)

Distribution of Tax-to-GDP Ratios, 1965-2014 (percent)



Sources: Penn World Tables 8.1; OECD; Mansour (2014, 2015); World Economic Outlook; GFSM 1986; and the International Centre for Tax and Development's Government Revenue Dataset.
Note: Average annual real GDP per capita growth rate for each country is calculated with formula used by the Bureau of Economic Analysis (BEA), which is a variant of the compound interest formula (see http://www.bea.gov/faq/index.cfm?faq_id=463). Initial year is 1965 or earliest available for each country.

Figure 8. Historical Database: Number of Observations for Tax-to-GDP

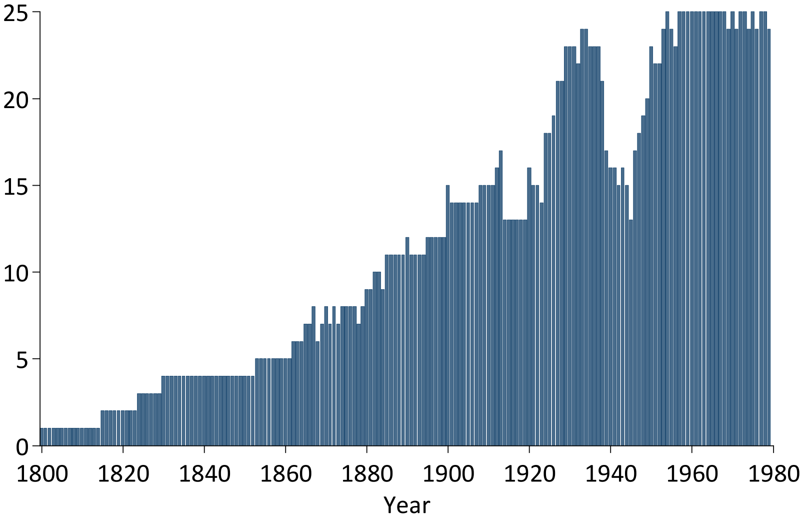
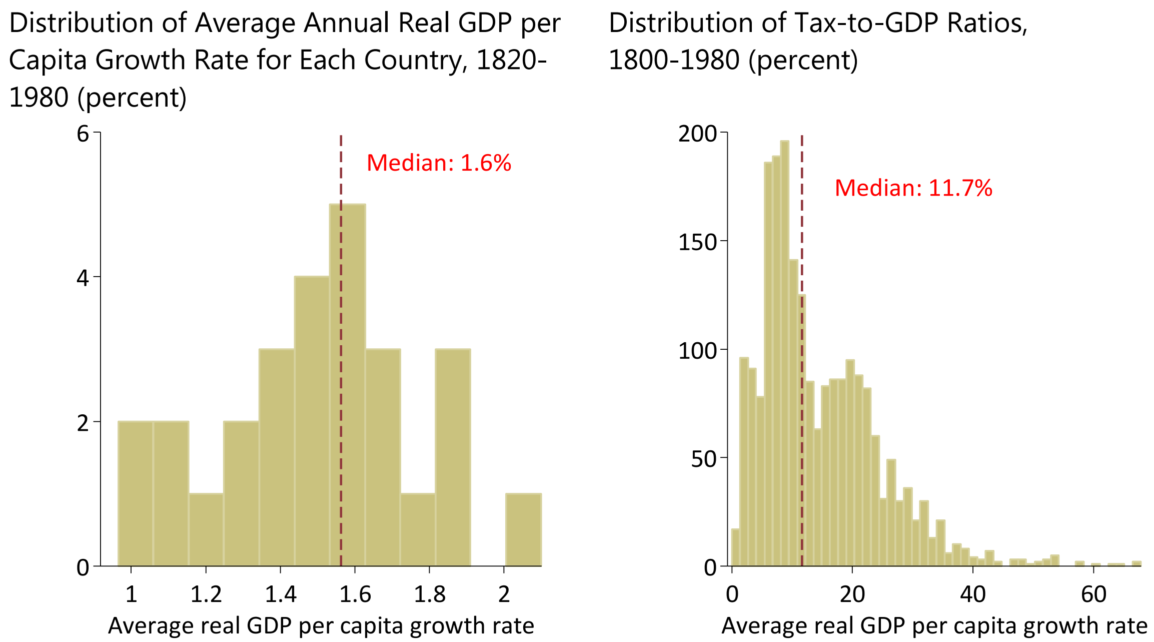


Figure 9. Historical Database: Distribution of Average Annual Real GDP per Capita Growth and Tax-to-GDP


Distribution of Average Annual Real GDP per Capita Growth Rate for Each Country, 1820-1980 (percent)

Distribution of Tax-to-GDP Ratios, 1800-1980 (percent)

Note: Average annual real GDP growth rate for each country is calculated with formula used by the Bureau of Economic Analysis (BEA), which is a variant of the compound interest formula (see http://www.bea.gov/faq/index.cfm?faq_id=463). Initial year is 1800 or earliest available for each country.

IV. EMPIRICAL APPROACH

A. Methodology

As in Card, Mas and Rothstein (2008) (CMR hereafter), we use a regression discontinuity design (RDD) to investigate the existence of a tipping point in tax-to-GDP ratios on GDP growth. Our approach entails estimating and testing both for the existence of an unknown threshold as well as measuring the impact of crossing this threshold on subsequent GDP growth for the average country in our sample.

Specifically, we model cumulative GDP per capita growth rate $\Delta GDPPC_{ct+j}$ in country c, year t over some horizon j as some function of the tax-to-GDP level tax_{ct}, which we allow to vary discontinuously at the unique unknown threshold value γ. We also include covariates X_{ct} as well as country and year fixed effects:

$$\Delta GDPPC_{ct+j} = \begin{cases} \alpha_l + f_l(tax_{ct} - \gamma) + X_{ct}\rho + \theta_c + \delta_t + \varepsilon_{ct} & \text{if } tax_{ct} \leq \gamma \\ \alpha_r + f_r(tax_{ct} - \gamma) + X_{ct}\rho + \theta_c + \delta_t + \varepsilon_{ct} & \text{if } tax_{ct} > \gamma \end{cases} \quad (1)$$

where $\Delta GDPPC_{ct+j} = \left(GDPPC_{ct+j} - GDPPC_{ct-1}\right)/GDPPC_{ct-1}$.

Equation (1) is closely related to threshold regression models, a widely-used class of non-linear models. Related applications in the context of cross-country growth studies include the estimation of thresholds effects for inflation (Khan and Senhadji 2001); fiscal deficits (Adam and Bevan 2005); and public debt levels (Chudik et al. 2015). The main difference between Equation (1) and threshold regressions is that we don't impose a continuous function around the threshold—as would be the case in a slope-shifting model—since we explicitly allow for a different intercept α_r at the point of discontinuity. We also don't constrain the relation between the dependent and independent variables to be linear to the left and right of the threshold. Instead, we use both parametric and non-parametric estimators to flexibly describe the relation between tax levels and subsequent GDP growth. For example, our main estimator relies on a fourth order polynomial in tax-to-GDP levels.[9]

Another key difference is that we are not so much interested in estimating the global relationship between taxes and growth—the specific shape of the functions $f_l(.)$ and $f_r(.)$ as in standard threshold regressions—but rather in measuring any discrete change in GDP growth occurring around the tax threshold. This local effect is given by the constant term α_r and specifically measures the difference in cumulative GDP growth rates immediately to the left and to the right of γ.

The advantage of this local approach is that uncovering unbiased estimates requires much less stringent assumptions than otherwise similar piecewise linear models. The usual explanation to motivate the use of RDD methods is that within a small neighborhood around the tipping point in which countries are likely to be similar, the position of an observation relative to the threshold is as good as randomly assigned. For example, countries only have so much control over the exact value of their tax-to-GDP levels so that if they are already close to the tax tipping point, they still cannot control perfectly whether they will be just below or just above it. In turn it is this random assignment that will determine 'treatment'. While we leave a fuller treatment of what exactly this treatment would involve—as discussed above this could imply a shift in social norms, increased tax and state capacity, increased demand for political accountability, etc.— to future research, we think there is still considerable value in estimating the reduced form relation between taxes and growth.

Finally, our focus on the effect of tax-to-GDP levels crossing the tipping point also motivates our use of both higher order polynomials and local regression methods, since these models allow us to be more flexible in estimating the relation between taxes and growth around the tipping point.

Equation (1) can also be re-expressed in a more compact way as

$$\Delta GDPPC_{ct+j} = \alpha_l + \beta D + f(tax_{ct} - \gamma) + X_{ct}\rho + \theta_c + \delta_t + \varepsilon_{ct} \qquad (2)$$

where $\beta \equiv \alpha_r - \alpha_l$, $D \equiv \mathbb{I}(tax_{ct} > \gamma)$ and $f(.) \equiv f_l(.) + D[f_r(.) - f_l(.)]$.

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[9] Using lower order polynomials in tax-to-GDP generates somewhat lower estimates of the effect of crossing the tipping point. Results are available upon request.

We follow the two-step approach proposed by CMR.[10] In the first step, we estimate a structural break in the relation between tax-to-GDP ratio and subsequent GDP growth, i.e. we find a level of tax above which GDP growth changes discontinuously. This candidate tipping point is found by setting the value of γ such that the R-squared of Equation (2) is maximized.[11] After establishing the statistical significance of the tipping point, the second step entails recovering the estimate for β using the usual RDD estimator, taking the value of γ as if it were known.

This two-step approach belongs to a class of estimators that converge to non-standard distributions (see for example Bai 1997, Hansen 1999 and Porter and Yu 2015). More specifically, conventional test statistics for the existence of a tipping point will tend to reject the null too often. We therefore follow the approach outlined in Hansen (1999) where a testing procedure is proposed that accounts for the non-standard properties of the threshold estimate $\hat{\gamma}$ from equation (2).[12]

While in principle the full model should be estimated in order to locate the tipping point, we find that it performs poorly over various growth horizons $\boldsymbol{j}$. Indeed, the threshold values that maximize the R-squared are not constant, but vary widely when using cumulative GDP growth over different time horizons as the dependent variable. Moreover, for most specifications we fail to reject the null hypothesis of no tipping point when using the full model.

Our interpretation of these facts is that including the full set of covariates leads to a loss of statistical power that is necessary to identify the tipping point. Moreover, in our view subsequent results on the effect of crossing the tipping point (Table 4 below) validate our approach since we show that the effect of crossing the tipping point is robust across all specifications, even though the identification of this tipping point might not be. While the use of the full model for both stages of the procedure would seem preferable, on balance we defend our approach because it allows to use of the available information to identify the tipping point. The results from the second stage are strongly suggestive that the procedure credibly identifies a structural break in the data occurring at the tipping point.

Therefore, we follow the approach taken in CMR and ignore covariates and fixed effects and approximate $\boldsymbol{f(tax_{ct} - \gamma)}$ by a constant function. This results in a more parsimonious specification which should nevertheless allow us to test for and estimate the effect of a candidate tipping point.[13] Indeed, if our first step simply identified an artefact of the data without any real

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[10] The paper uses regression discontinuity methods with unknown threshold to estimate tipping points in neighborhood racial composition in the United States.

[11] An alternative estimation framework that seeks to maximize $(\hat{\beta})^2$ directly is presented in Porter and Yu (2015). Results using both approaches are broadly similar when the local regression weights used are sufficiently large.

[12] CMR use an alternative approach. They randomly split their sample in two with a first sub-sample used to estimate the location of the threshold and the second sub-sample used to estimate the effect on the dependent variables of crossing this estimated threshold. We do not have enough observations to pursue this strategy.

[13] Results are robust to the inclusion of GDP per capita in the initial year.

effect on growth, our two-step estimation would yield small and statistically insignificant results of the effect of the tipping point on growth.

To find the value of the tipping point we estimate the following

$$\Delta GDPPC_{ct+j} = \alpha_l + \beta D + \varepsilon_{ct} \tag{2'}$$

where the variables and coefficients are defined as above.

Once we find the value $\hat{\gamma}$ that maximizes the R-squared of Equation (2′) through a grid search, we test the null hypothesis of no threshold, i.e.:

$$H_0: \quad \beta = 0$$

Hansen (1999) proposes to bootstrap a likelihood ratio test of H_0 based on the test statistic formed by the ratio of the sum of squared errors under both the null and the alternative:

$$F_1 = N\frac{S_0 - S_1}{S_1}, \tag{3}$$

where N is the sample size. The sum of squared residuals under the null (S_0) and the alternative (S_1) are obtained after estimating Equation (2′):

$$S_0 = \sum_{i=1}^{N}\left(\Delta GDPPC_{ct+j} - \tilde{\alpha}_l\right)^2 \quad \text{and} \quad S_1 = \sum_{i=1}^{N}\left(\Delta GDPPC_{ct+j} - \hat{\alpha}_l - \hat{\beta}D\right)^2.$$

The p-value of the test for the existence of a tipping point is then given by the number of times the bootstrapped iterations of F_1 exceed the actual statistic obtained from the sample. We reject H_0 in favor of the alternative if this p-value is smaller than some critical value.[14]

We restrict the grid search procedure by looking for the unique value of γ between 8 and 30 percent of GDP. In our full sample, this represents roughly the 5th and 95th percentile of the tax-to-GDP distribution. We also drop observations with tax-to-GDP levels below 5 percent and above 40 percent. There are few observations outside this range and they display high variance in GDP per capita growth rates, especially at the bottom. This data restriction also does not materially affect the search results. To find the value of the tipping point that maximizes the fit of Equation (2′), we perform a search over 2,500 quantiles.

B. Results based on the contemporary database

Figure 10 below displays the R-squared from estimating Equation (2′) using different values of the thresholds and over various growth horizons. Unsurprisingly, a constrained version of Equation (2) has relatively little explanatory power for the overall variance of cumulative GDP

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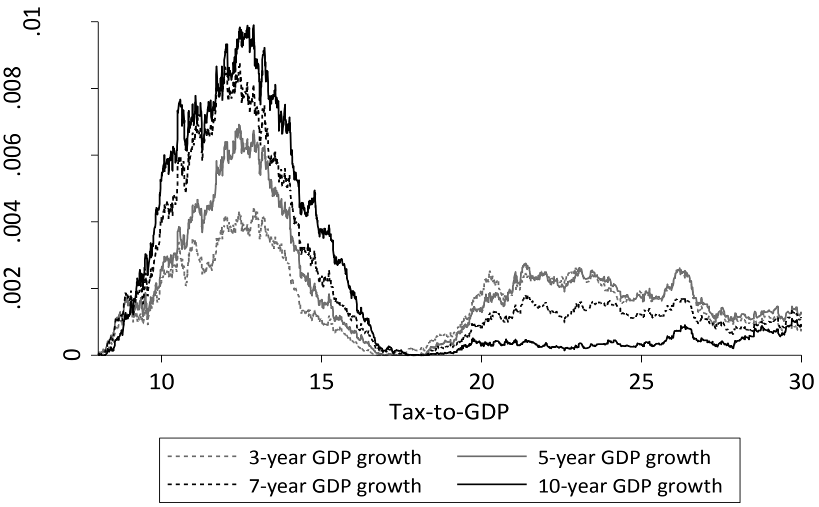
[14] The bootstrap procedure should also reflect the panel structure of the data. See Hansen (1999) and Wang (2015) for a detailed description of the bootstrapping procedure.

growth in our panel. The maximum R-squared reached is around 0.01 when using the 10-year cumulative growth rate as dependent variable. However, the figure clearly suggests the existence of a stable tipping point roughly halfway between 10 and 15 percent of GDP at all horizons considered. In all cases, the series show a unique maximum although they are not strictly single-peaked until 10 years. The threshold identified in Figure 10 is therefore a strong candidate for estimating a tipping point in tax-to-GDP levels.

Figure 10. Searching for a Tax Tipping Point at Different Horizons



The figure displays the R-squared from estimating Equation (2′) when setting the estimated threshold $\hat{\gamma}$ at different values between 8 and 30 percent of GDP. The series are obtained using different growth horizons j= (3, 5, 7, 10) for the dependent variable. See text for details.

Next we test whether this threshold is statistically significant using the bootstrap procedure proposed by Hansen (1999) and described above. The results are given in Table 2 below. The p-values of the estimated thresholds at all horizons are strongly statistically significant well below the one percent level.[15] This is consistent with the graphical evidence in Figure 10, which shows a high degree of curvature around the single peaks for all series.

Beyond testing for the existence of a threshold, we also calculate confidence intervals for our estimates so that we can assess how precisely to assign the structural break in GDP growth to a specific tax level. Hansen (1999) provides further guidance for doing so. The proposed method relies on a "no-rejection region" using the likelihood ratio statistic from Equation (3). Intuitively, the idea is to delimit the confidence interval around the estimated threshold $\hat{\gamma}$ to the range of values for which the difference between $S(\hat{\gamma})$ and $S_1(\gamma)$ does not exceed some critical value.[16]

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[15] As a robustness check, we also perform a similar bootstrap procedure using a cluster-robust Wald test statistic for H_0. The tipping point is significant at the 10 percent level at all horizons.

[16] See Hansen (1999) for further details and critical values. Seijo and Sen (2011) also propose a smooth bootstrap procedure. We find similar results with both methods, though confidence intervals using the smooth bootstrap tend to be larger.

Table 2. Testing for Statistical Significance of Tax Thresholds

Dependent variable: GDP per capita cumulative growth					
		3-year	5-year	7-year	10-year
Hansen test statistic					
p-value		0.000	0.000	0.000	0.000
F_1 statistic		17.8	26.2	30.9	30.8
Critical values:	10%	2.8	3.2	2.7	2.6
	5%	4.2	4.7	4.1	3.8
	1%	6.6	7.5	6.9	5.7

Note: The table presents test statistics for the null hypothesis of no threshold in tax-to-GDP. p-values and critical values are obtained by bootstrapping the individual test statistics 1000 times. See text for further details about the construction of individual test statistics.

The point estimates for the tax threshold are consistent with the graphical evidence presented in Figure 10 and are very stable across all horizons. The confidence intervals also show that these threshold values are very precisely estimated. For example, the tax-to-GDP threshold at the 10-year horizon has a point estimate of 12.88 percent and a 99 percent confidence interval ranging from 11.33 percent of GDP to 13.97 percent, less than 2.65 percentage points wide. The confidence intervals are somewhat wider for shorter time horizons. Because the confidence intervals do not rely on the usual Student or normal distribution assumptions, they are also not necessarily symmetric. The observed asymmetry derives from the specific shape of the series around their peak in Figure 10. In particular, the slopes of the series are steeper to the right of their respective maximum so that the upper bound of the confidence intervals will be closer to the estimated threshold than the lower bound.

Table 3. Estimated Tax-to-GDP Thresholds

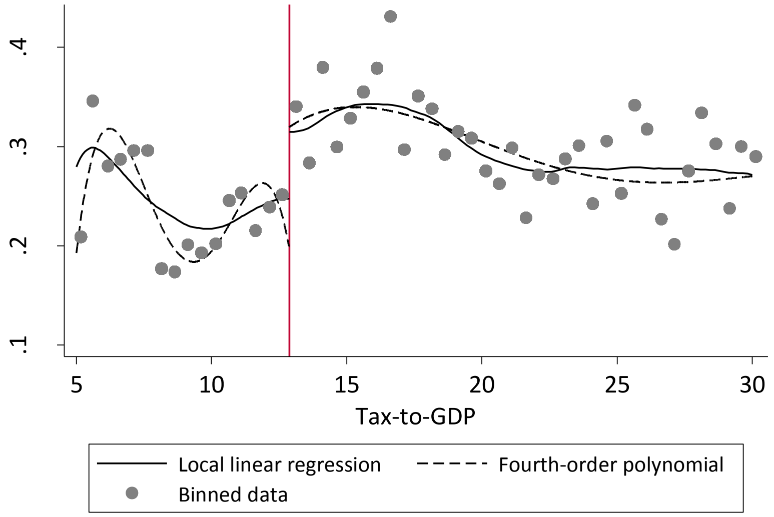
Dependent variable: GDP per capita cumulative growth					
		3-year	5-year	7-year	10-year
Tax-to-GDP threshold		12.88	12.42	12.45	12.88
Confidence intervals:					
No-rejection region	95%	[11.56; 14.01]	[11.70; 13.38]	[11.60; 13.05]	[11.62; 13.41]
	99%	[9.94; 14.19]	[11.40; 13.78]	[10.91; 13.51]	[11.33; 13.97]

Note: The table presents estimates for the tax-to-GDP threshold using the specification search for Equation (2′) described in the text. Confidence intervals are obtained by the "no-rejection region method. See text for details.

Another important feature of the two-step estimator we use is the fact that is it super-consistent, i.e. if one can reject the null, then the variance of the second step estimates does not need to be corrected for the sampling error of the estimated threshold $\hat{\gamma}$ (Hansen 2000). From Table 2, we know we can confidently reject the null hypothesis that there is no threshold, so we proceed with the regression discontinuity estimates from Equation (2) and use the naïve standard errors as if the value of γ was known.

The effect of crossing the tax-to-GDP threshold on subsequent growth can be clearly illustrated graphically. Figure 11 shows three estimators of the relation between tax levels and growth: (1) average cumulative GDP per capita growth over 10 years within bins of bandwidth equal to 0.5[17]; (2) predicted values from a local linear regression with bandwidth of 1.5; and (3) a global fourth-order polynomial in the level of tax-to-GDP fully interacted with the threshold variable. The figure shows clearly the effect of the threshold at the point of discontinuity around 12.88 percent of GDP: countries that are immediately to the left of the tipping point on average grow by around 20 to 25 percent in real terms over 10 years, or around 2 percent annually. Countries immediately to the right of the threshold grow by more than 30 percent over 10 years, or 2.8 percent annually. Both the local linear regression and the global fourth-order polynomial provide very similar point estimates of the treatment effect $\hat{\beta}$ at the point of discontinuity. It is also interesting to note that the relationship between tax-to-GDP and growth is very noisy at the bottom of the tax-to-GDP distribution. Right above the threshold, the relationship is smoother with a slight negative slope beyond 15 percent of GDP. Appendix Table A1 lists the years in which countries in the contemporary database cross the estimated threshold.

Figure 11. Impact of the Tax Threshold on 10-year Cumulative Growth



The scatter plot shows average GDP growth in 0.5-percentage-point bins. The solid line is a local linear regression fit separately on either side of 12.88 using an Epanechnikov kernel and a bandwidth of 1.5. The dashed line is a global fourth order polynomial estimated separately on either side of the tipping point. See text for further details.

This regression discontinuity figure can be reproduced for all horizons and shows consistently large treatment effects at the tax threshold.[18] We show instead the effect on growth of crossing the long-run discontinuity threshold of 12.88 percent for various time horizons. Figure 12 plots estimates $\hat{\beta}$ from Equation (2) excluding covariates and fixed effects, where we vary the end year j from 10 years prior to 15 years after the year we observe the tax to

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[17] Bins closest to the threshold contain over 140 country-year observations per bin.

[18] See Appendix Figures A1-A3 for estimates using cumulative growth over 3, 5 and 7 years.

GDP ratio. The function $f(tax_{ct})$ is estimated using a global fourth order polynomial. The figure also shows the 90 percent confidence intervals to assess the statistical significance of the point estimates across years.

Figure 12 shows the effect of crossing the threshold on GDP over time. The marginal effect on growth increases smoothly over the first 10 years, then more sharply between years 10 and 13 before decreasing until 15 years after the year of observation. The difference between countries that are initially just to the left of the tipping point in year 0 and those immediately to the right is 12.36 percent after 10 years and 16.85 percent 15 years later. This implies that crossing the tax threshold adds about one percent to real annual GDP per capita growth for the next 10 to 15 years.

Another important feature of the approach is that it allows us to assess how countries on either side of the tipping point differ in terms of growth rates in the years that precede observation year 0. Finding systematic differences in growth rates for countries around the threshold prior to the base year would cast serious doubt on the identification of a causal effect of tax levels on growth. It is reassuring to find that no such pre-trend can be detected in the figure. While some individual point estimates are statistically different from zero, a joint test of the null that all pre-treatment coefficients are zero cannot be rejected at conventional levels (the p-value of the test is 0.23). The point estimates are also smaller in magnitude than the cumulative effect observed several years after the year of observation at year 0. Overall, this suggests that the growth pattern of countries that were just to the left and just to the right of the tipping point are very similar in the preceding years.

We also estimate the effect on GDP growth of crossing the tipping point in Equation (2) under various specifications to assess the robustness of our regression discontinuity estimate. Table 4 below presents the estimated coefficients for the tipping point β when only a global fourth-order polynomial in tax-to-GDP ratio fully interacted with the estimated tax-to-GDP threshold at 12.88 is used in column (1). Column (2) adds country and year fixed effects, while columns (3) to (7) add other variables typically used in cross-country growth regressions.[19]

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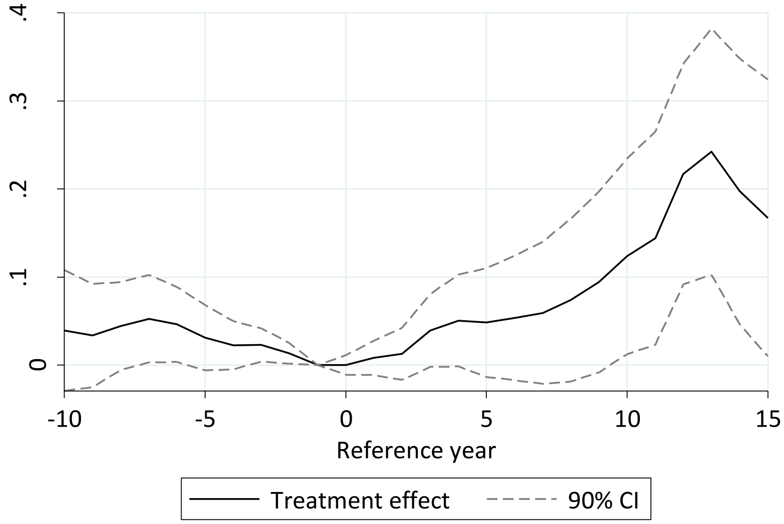
[19] See Hanushek and Woessmann (2015) for a recent example.

Figure 12. Impact of the Tax Threshold over Time



The figure plots estimate of β from Equation (2) estimated without covariates and fixed effects using cumulative growth over horizons ranging from 10 years prior to 15 years after the year in which we observe the tax-to-GDP ratio. Cumulative GDP per capita growth rates are calculated using year -1 as the base year. By construction they are 0 in that year. The figure also plots the 90 percent confidence intervals. Standard errors are clustered at the country level.

Column (1) reports the effect of the tax-to-GDP tipping point on cumulative GDP per capita growth after 10 years. The point estimate is equal to the vertical distance at the point of discontinuity shown in Figure 11. It is also equal to the point estimate reported in Figure 12 on the full dynamic effect of the tipping point on growth at the 10-year mark. It indicates that countries that are located immediately to the right of the tipping point of 12.88 percent of GDP are 12.36 percent larger in real per capita terms on average than countries that are immediately to the left. Adding country and year fixed effects reduces the estimated impact on cumulative growth considerably, to 6.86 percent. Unsurprisingly, the overall R-squared increases markedly from around 2 percent[20] to 69 percent, with a within R-squared of 13.2 percent.

For our preferred specification in column (3), we add real GDP per capita in the initial year. This increases the estimate of the impact of the threshold on growth, but only marginally, to 7.45 percent. The coefficient on GDP per capita itself is negative and strongly significant, reflecting the usual convergence result in growth regressions. The R-squared once again increases markedly to close to 74 percent for the overall and over 26 percent for the within R-squared.

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[20] The R-squared in column (1) is twice as large as the maximum R-squared displayed in Figure 10 because of the inclusion of the fully interacted fourth-order polynomial in tax-to-GDP level with the tax-to-GDP threshold.

Table 4. Estimating Growth Effects

Dependent variable: 10-year cumulative GDP per capita growth							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Tax-to-GDP threshold	12.355*	6.864**	7.450**	7.283**	6.852**	6.963**	7.717**
	(6.651)	(3.060)	(3.017)	(3.018)	(3.081)	(3.054)	(2.967)
GDP per capita			-3.127***				-2.972***
			(0.538)				(0.610)
Openness				7.644***			4.388*
				(2.762)			(2.474)
Capital per capita					2.395		-13.893
					(18.400)		(16.755)
Human capital index						-4.754	0.718
						(4.170)	(4.786)
Country and year FE	No	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3189	3189	3189	3189	3189	3189	3189
R-squared, overall	0.023	0.691	0.739	0.701	0.691	0.692	0.742
R-squared, within		0.132	0.266	0.159	0.132	0.135	0.275

Note: The table presents OLS results from Equation (2). The tax-to-GDP threshold is an indicator variable equal to one if the tax level exceeds the estimated tipping point of 12.88 percent of GDP. GDP per capita is at constant national prices expressed in thousands of 2005 US$. Capital stock and gross capital formation are expressed as a percent of GDP. Openness is the sum of imports and exports as a percent of GDP. Human capital index is based on years of schooling and returns to education. All data except tax-to-GDP ratios are taken from PWT 8.1. Coefficients from a fourth-order polynomial in tax-to-GDP fully interacted with the tax-to-GDP threshold, year and country fixed effects not shown. Standard errors clustered at the country level in parentheses. See text for details. * means p<10%, ** p<5%, *** p<1%.

In column (4) we replace GDP per capita with a variable reflecting the degree of openness of the economy. This variable is simply the sum of imports and exports-to-GDP. Once again, the coefficient for the tax-to-GDP threshold remains over 7 percent and the coefficient on the degree of openness is also large and highly statistically significant. In column (5), we add instead the total level of public and private capital per capita measured in 2005 US$. This leaves our main threshold estimate broadly unchanged compared to column (2) with the coefficient associated with capital not precisely estimated.

In column (6) we used human capital index as reported in the Penn World Tables. This leads to a slightly higher estimate of the effect of the tipping point on cumulative GDP growth, with the coefficient for the index itself not statistically significant.

Finally, in column (7) we include all control variables and fixed effects. The estimated coefficients in all cases except for the degree of openness and human capital remain broadly similar, including the estimated effect of the tax tipping point. Taken together, these results confirm that our RDD estimate of the tax threshold is quite robust to the inclusion of important determinants of growth.

Our analysis relies on a definition of tax revenues that excludes social security contributions. This definition follows the classification standard adopted in the IMF's 2014 Government Finance Statistics Manual. Unlike tax revenues, which are defined as compulsory and unrequited amounts payable to the government, social security contributions are typically associated with the expectation of future benefits. For this reason, associated revenues do not change the net asset position of the government and are not freely usable for consumption or investment.[21]

Exclusion of social security contributions from tax revenues also makes our two samples more comparable. While complete information is not available for all countries in the International Historical Statistics, comparison of the 1965-1980 time period, for which we have overlap of data across the main estimation sample and the IHS data, shows that *social security-exclusive* revenue series generally display higher correlation and more similar levels across the two samples than *social security-inclusive* revenue series.

Finally, using social security-inclusive tax revenue series yields similar but consistently lower results for the location of the tipping point. The estimates also vary more across growth horizons. At the 10-year horizon, we estimate a tipping point at 12.0 percent of GDP. The fact that we find a lower value for the tipping points is surprising given that mechanically one would expect a *higher* tax threshold when including social contributions. For countries with tax levels around the tipping point of 12.88 percent of GDP, social security contributions make up around 10 percent of tax revenues. Therefore, if social contributions were not related to subsequent economic growth, but were simply noise added to our tax series, one could expect a tipping point to be found at around 14 percent of GDP.

We also find that the effect on subsequent growth is negligible and statistically insignificant when using social security contribution-inclusive taxes and a value for the tipping point of 12.0 percent. However, when the tipping point for these series is defined as the sum of the contemporary database estimate of 12.88 percent of GDP *plus* the level of social security contributions, we recover almost exactly our main estimate of the effect of the tax threshold on subsequent GDP growth. We therefore conclude that adding social security contributions to the definition of tax revenues does not provide additional information on the location and effect of tax tipping points.

C. Results based on the historical database

One drawback of our contemporary database is that virtually all countries that were close to or crossed the tax-to-GDP threshold of 12.88 percent during our sample period are developing economies. Among OECD countries, only Spain and Turkey crossed this tipping point since 1965. In order to assess whether advanced economies that are now well above the threshold have also experienced similar tipping points during their development, we use historical data on tax revenue and GDP from the International Historical Statistics (Mitchell 2003). The starting year for the revenue and GDP series varies by country, but the longest series extends

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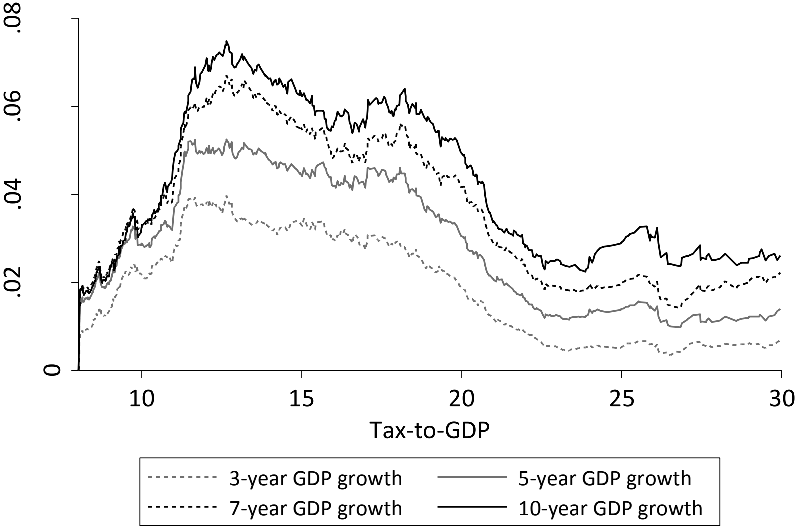
[21] It should be noted that the OECD's Revenue Statistics include social security contributions in total taxes.

from 1800, for the United States until 1980. Summary statistics for our historical dataset are given in Appendix Table A2.

We replicate the estimation procedure outlined above with our historical database. Specifically, we perform a grid search over the values of revenue-to-GDP between 8 and 30 percent which maximizes the fit of Equation (2′) for various time horizons. The R-squared are plotted in Figure 13. Similar to what we found with our contemporary database, there appears to be a stable threshold not far from 12½ percent of GDP.

We perform the same tests for the existence of a threshold on the historical data. Consistent with the visual evidence from Figure 13, we once again strongly reject the null hypothesis of no threshold. We do not report the statistics in the interest of space, but once again the p-values for both Hansen's F_1 statistic are well below 0.01. We report in Table 5 the values of the estimated revenue threshold at 3, 5, 7 and 10 year horizons. We also report the "no-rejection region" bootstrapped confidence intervals. Remarkably at all horizons, the estimated value of the revenue-to-GDP threshold is 12.65 percent of GDP. This is very close to the estimated threshold we found using our contemporary database.

Figure 13. Searching for a Tax Tipping Point at Different Horizons, Historical Database



The figure displays the R-squared from Equation (2′) when setting the estimated threshold $\hat{\gamma}$ at different values between 5 and 30 percent of GDP using the historical database. The series are obtained using different growth horizons j = (3, 5, 7, 10) for the dependent variable. See text for details.

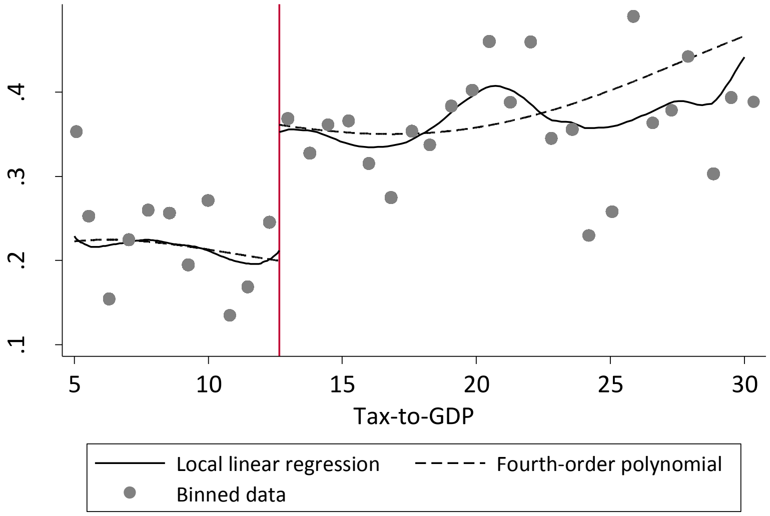
In Figure 14, we plot the effect of the revenue threshold on subsequent 10-year growth rates. Similar to our main results presented in Figure 11, we observe a sharp increase in average cumulative GDP per capita growth rates just above the estimated revenue threshold of 12.65 percent. This average growth rates remain higher than those observed at the lower end of the revenue-to-GDP range, although the estimates are noisier than what we had in our estimation using the contemporary database. This results suggest that advanced economies underwent a similar structural break in revenue levels and that this changes occurred at strikingly similar revenue levels than those observed for developing economies, Appendix Table A3 lists the years in which countries in the historical database cross the estimated threshold.

Table 5. Estimating Tax Revenue-to-GDP Thresholds, Historical Database

Dependent variable: GDP per capita cumulative growth					
		3-year	5-year	7-year	10-year
Tax-to-GDP threshold		12.65	12.65	12.65	12.65
Confidence intervals:					
"No-rejection region"	95%	[12.51; 12.81]	[11.37; 12.85]	[12.25; 12.84]	[12.24; 12.82]
	99%	[11.24; 12.94]	[11.28; 14.07]	[12.17; 13.72]	[12.17; 12.85]

Note: The table presents estimates for the tax-to-GDP threshold using the specification search for Equation (2) described in the text. Confidence intervals are obtained by the "no-rejection region method. See text for details.

Figure 14. Impact of the Tax Threshold on 10-year Cumulative Growth, Historical Database

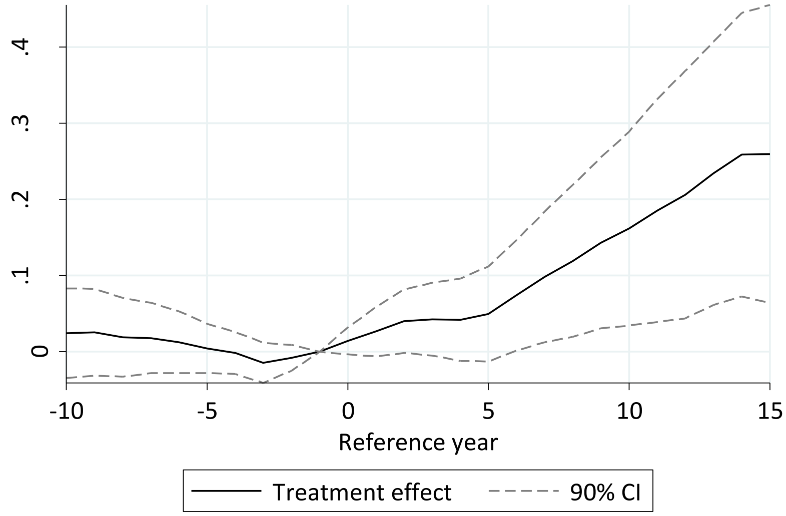


The scatter plot shows average GDP growth in 0.75-percentage-point bins. The solid line is a local linear regression fit separately on either side of 12.65 using an Epanechnikov kernel and a bandwidth of 1.5. The dashed line is a global fourth order polynomial with intercept shift at the estimated tipping point. See text for further details.

Finally, we present the dynamic effect of the tax-to-GDP threshold at 12.65 percent in Figure 15. Similar to our main findings, the impact of the threshold on subsequent growth is roughly constant throughout the first 5 years following the year of observation. There is then a further increase over the following 5 years so that after 10 years the cumulative effect on real GDP per capita growth is around 16 percent, very close to the effect we estimate on the contemporary database. This effect also keeps increasing so that the estimated long run effect of the threshold after 15 years is around 25 percent higher cumulative growth for countries immediately to the right of the threshold compared to countries immediately to the left. This point estimate is somewhat larger than the effect we found using the contemporary database, although the 90 percent confidence bands are quite large as well and include the value of 16.85 we found in the main sample.

Finally, we assess the robustness of the results obtained from the historical data by successively including country and year fixed effects as well as GDP per capita in the base year. The results are presented in Table 6 below.

Figure 15. Impact of the Revenue Threshold over Time, Historical Database



The figure plots estimates of β from Equation (2) estimated without covariates and fixed effects using cumulative growth over horizons ranging from 10 years prior to 15 years after the year in which we observe the tax-to-GDP ratio. Cumulative GDP per capita growth rates are calculated using year -1 as the base year. By construction they are zero in that year. The figure also plots the 90 percent confidence intervals. Standard errors are clustered at the country level.

The point estimate in column (1) is once again equal to the vertical distance in Figure 14 and the point estimated plotted at the 10-year mark in Figure 15. It represents the impact of the tax-to-GDP tipping point on subsequent growth for advanced economies. The specification in column (1) only includes a fourth-order polynomial with an intercept shift at the point of discontinuity. This specification differs slightly from our main estimates in that we do not estimate the polynomial separately on both sides of the tipping point as doing so leads to very imprecise results. Nevertheless, the effect on growth at almost 16 percent in real GDP per capita terms is statistically significant and very similar to what we found in the main sample.

In column (2) we add both country and year fixed effects. Doing so reduces the estimated effect of the tax-to-GDP tipping point to slightly over 5 percent, about one third of the result in column (1). The effect on growth is also no longer statistically different from zero. This is somewhat to be expected as the historical database is a highly unbalanced panel so that including year fixed effects removes much of the cross-sectional variation in the earlier years of the panel. The smaller sample size also reduces statistical power and makes it more difficult to estimate coefficients with enough precision. Finally, in column (3) we add real GDP per capita in the base year. The coefficient for the tax-to-GDP threshold decreases even further to around 2.5 percent. Once again, the point estimate is no longer statistically significant.

Table 6. Estimating Growth Effects, Historical Database

Dependent variable: 10-year cumulative GDP per capita growth

	(1)	(2)	(3)
Tax-to-GDP indicator	15.957**	5.440	2.535
	(7.189)	(6.515)	(5.714)
GDP per capita			-14.139***
			(2.847)
Country and year FE	No	Yes	Yes
Observations	1593	1593	1593
R-squared, overall	0.084	0.655	0.655
R-squared, within		0.436	0.585

Note: The table presents OLS results from Equation (2). The Tax-to-GDP threshold is an indicator variable equal to one if the tax level exceeds the estimated tipping point of 12.65 percent of GDP. GDP per capita taken from the Maddison project expressed in 1990 international dollars. Coefficients from a fourth-order polynomial in tax-to-GDP with intercept shift at the estimated tax-to-GDP threshold, year and country fixed effects not shown. Standard errors clustered at the country level in parentheses. See text for details. * means p<10%, ** p<5%, *** p<1%.

While these robustness checks are not fully definitive in part due to the smaller sample size of the historical database, overall we conclude that the historical results provide an important check on our main results. Taken together, these findings strongly suggest a common threshold to both advanced and developing economies in the tax-to-GDP level.

V. CONCLUSION

Is there a minimum tax-to-GDP ratio associated with a significant acceleration in the process of growth and development? In order to answer this question we rely on data from two separate databases: a novel contemporary database covering 139 countries from 1965 to 2011 and a historical database for 30 advanced economies from 1800 to 1980. Our empirical methodological draws on CMR by following a two-step approach. In the first step we find the tipping point and document its statistical significance. In the second step we take the threshold value as if it were know and estimate the impact of crossing the tipping point on growth. We also document that the effect on growth is robust to the inclusion of a number of additional covariates and fixed effects.

Using the contemporary dataset we find, from the first step in our procedure, that once the tax-to-GDP level of the average country in our sample reaches around 12.88 percent, its real GDP per capita increases sharply and in a sustained manner over several years. The tipping point is statistically signignificant and tightly estimated. From the second step, we find that, according to our preferred specification, a country just above the threshold will have real GDP *per capita* around 7.5 percent larger, after 10 years, than an otherwise similar country just below it. This effect is tightly estimated and economically large. In this specification we control for country and time fixed effects as well as for the initial level of GDP per capita.

We also use a historical database, for 30 countries, going at most back to 1800. The historical dataset allows the estimation of the tipping point for advances economies, as most of them were already above the estimated threshold in 1965, when the contemporary database starts. Remarkably, from the first step, we find a statistically significant threshold in government tax revenue at 12.65 percent of GDP, very close to our result using contemporary data. The tipping point is also tightly estimated. The threshold impact on subsequent growth is also economically relevant, although not statistically significant, once time and country fixed effects are introduced. While we lack the statistical power to find fully robust results on subsequent growth in the historical sample, the coincidence of the threshold found in both databases, raises the possibility that such a threshold is an invariant feature in the process of development. Hence our answer to the initial question: "Is there a tipping point in the relation between tax capacity and growth?" is yes!

From the estimates we obtained we think it is reasonable to assume a tax-to-GDP tipping point at about 12 ¾ percent of GDP. As we said such threshold is likely associated with changes in social norms of behavior and state capacity. Given that tax-to-GDP ratio are volatile we think it is reasonable to interpret our findings as in line with the standard recommendation to countries with low tax-to-GDP levels to aim for levels about 15 percent.

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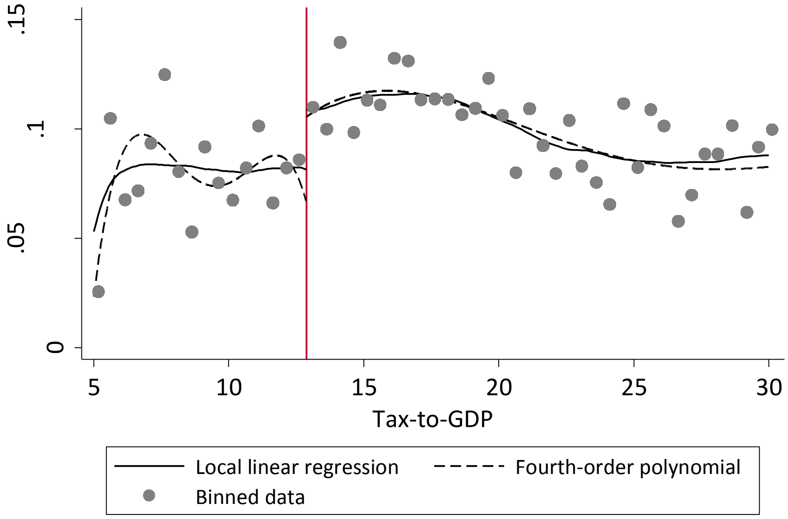
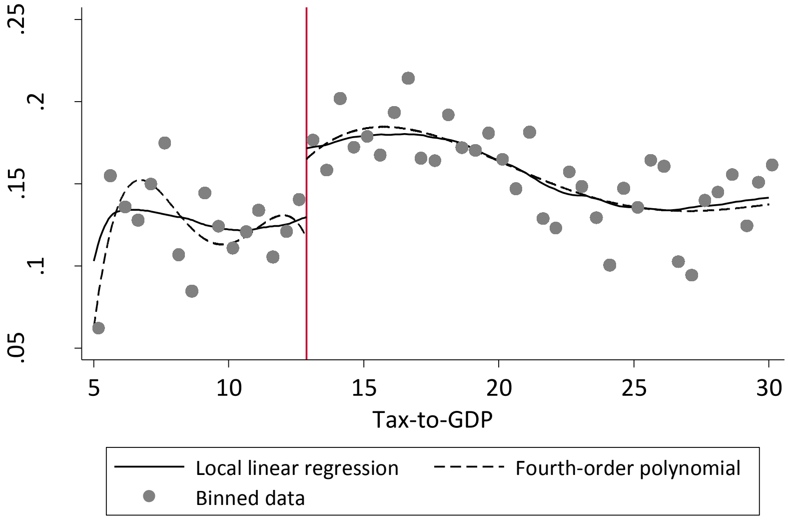
Appendix

Figure A1. Impact of a Tax Threshold on 3-year Cumulative Growth



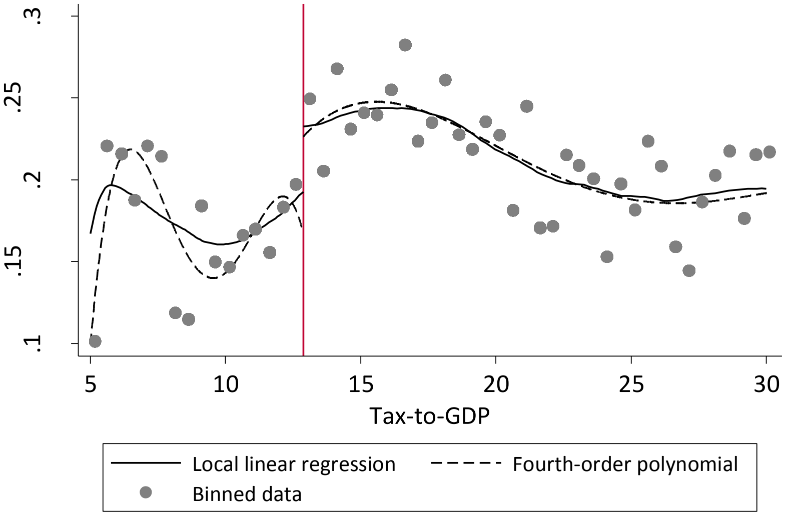
The scatter plot shows average GDP growth in 0.5-percentage-point bins. The solid line is a local linear regression fit separately on either side of 12.88 using an Epanechnikov kernel and a bandwidth of 1.5. The dashed line is a global fourth order polynomial estimated separately on either side of the estimated tipping point. See text for further details.

Figure A2. Impact of a Tax Threshold on 5-year Cumulative Growth



The scatter plot shows average GDP growth in 0.5-percentage-point bins. The solid line is a local linear regression fit separately on either side of 12.88 using an Epanechnikov kernel and a bandwidth of 1.5. The dashed line is a global fourth order polynomial estimated separately on either side of the estimated tipping point. See text for further details.

Figure A3. Impact of a Tax Threshold on 7-year Cumulative Growth



The scatter plot shows average GDP growth in 0.5-percentage-point bins. The solid line is a local linear regression fit separately on either side of 12.88 using an Epanechnikov kernel and a bandwidth of 1.5. The dashed line is a global fourth order polynomial estimated separately on either side of the estimated tipping point. See text for further details.

Table A1. Tipping Point Crossing, Contemporary Database

Year in which country last crossed the tax-to-GDP threshold of 12.88 percent of GDP

Country	Years crossed 12.88 percent tax-to-GDP threshold					
Albania	1993	1998				
Argentina	1993					
Armenia	1997					
Bangladesh	2011					
Benin	1981	1999				
Bhutan	2010					
Bolivia	2000	2002	2004			
Burkina Faso	2011					
Burundi	1978	1994	2000	2010		
Cabo Verde	1982	1992				
Cambodia	2004	2007				
Cameroon	1976	1980	1998	2000		
Chad	1977	2006	2010			
China	2001					
Colombia	2001					
Comoros	1992	1997	2003			
Costa Rica	1974	1983	1996	1998	2000	
Cyprus	1979					
Dominica	1977					
Dominican Republic	2001	2004				
El Salvador	2006	2010				
Gambia, The	1980	1984	1987	2004	2006	
Georgia	2004					
Ghana	2003	2010				
Greece	1966					
Guinea	1986	2005				
Honduras	1980	1984	1990			
India	1976					
Indonesia	1976	1990	1994	1997	1999	2008
Jordan	1975	1988				
Kenya	1981	1988	1994			
Korea	1974					
Kyrgyz Republic	2002					
Lao P.D.R.	2009					
Lebanon	1996	2002				
Liberia	2006					

Year in which country last crossed the tax-to-GDP threshold of 12.88 percent of GDP (continued)

Madagascar	1974	2008		
Malawi	1978	1994	1997	2004
Maldives	1989	1991	2007	2011
Mali	1999	2002		
Mauritania	1996	2005		
Mexico	1983	1997	2000	
Mozambique	1987	2009		
Nepal	2010			
Niger	2008			
Panama	1983			
Paraguay	2011			
Peru	1994	2001	2003	
Philippines	1990	2005		
Portugal	1967	1976		
Senegal	1987	1990	1995	
Singapore	2007			
South Africa	1973			
Spain	1982			
Sri Lanka	1973	1976	2004	2010
Suriname	1972	1995		
Swaziland	1975	1977	1983	1988
São Tomé and Príncipe	1982	2004		
Tajikistan	2002			
Thailand	1974	1979		
Togo	1995	2003		
Turkey	1992			
Uruguay	1976	1980	1983	1985
Vietnam	1984	1988	1992	
Zambia	2010			
Zimbabwe	2010			

Table A2. Summary Statistics, Historical Database

Country	First year in sample	Mean tax-to-GDP	Mean GDP per capita	Mean GDP per capita growth
Australia	1824	13.4	5,077	2.32
Austria	1913	17.1	6,490	4.24
Belgium	1924	21.7	7,748	2.85
Canada	1870	14.5	7,995	2.59
Chile	1908	12.3	3,691	1.36
Czechoslovakia	1920	16	2,543	2.55
Denmark	1853	10.9	5,179	1.81
Finland	1882	14.9	4,020	2.63
France	1820	13.1	3,910	2.06
Germany	1872	10.3	5,170	3.10
Greece	1928	21.1	4,479	4.08
Hungary	1900	27.6	2,411	1.52
Israel	1950	46.6	6,548	4.75
Italy	1862	14.1	3,472	2.03
Japan	1885	32.6	3,353	3.85
Korea	1911	11.2	1,267	4.32
Mexico	1895	7.7	2,737	2.40
Netherlands	1900	16.8	6,629	2.00
New Zealand	1931	26.9	8,832	1.99
Norway	1865	10.5	4,289	2.52
Portugal	1950	14.4	4,544	4.84
Southern Ireland	1926	23.3	4,855	2.71
Spain	1901	9.3	3,435	2.71
Sweden	1881	12.4	5,502	2.38
Switzerland	1913	7.2	11,660	1.71
United Kingdom	1830	16.7	5,276	1.29
United States	1800	6.2	5,267	1.61

Notes: Data on tax-to-GDP ratio taken from IHS, GDP per capita taken from the Maddison project expressed in 1990 international dollars. See Bolt and van Zanden (2014) for methodology.

Table A3. Tipping Point Crossing, Historical Database

Country	Years crossed 12.65 percent revenue-to-GDP threshold				
Australia	1841	1892	1940		
Canada	1940				
Chile	1948	1951	1954	1957	1959
Czechoslovakia	1921				
Denmark	1854	1863	1946	1955	
Finland	1920	1934	1941		
France	1879	1920			
Germany	1934				
Italy	1883	1887	1918	1949	
Japan	1890	1895			
Korea	1960	1962	1965		
Netherlands	1917	1940			
Norway	1946				
Portugal	1956				
Sweden	1943				
United Kingdom	1916				
United States	1943				

Notes: Data on tax-to-GDP ratio taken from IHS.