The role of central bank independence on optimal taxation and seigniorage*

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Abstract

Should inflation be thought of as "just another tax?" The theoretical basis for doing so dates back to Phelps (1973) and has been greatly refined ever since. Since optimal taxation minimizes the deadweight loss by equalizing the marginal distortions of all available taxes, including the inflation tax, a key distinctive theoretical implication obtained by these models is that inflation and tax rates have a positive relationship. While theoretically appealing, empirical studies find virtually no support for this key implication.

We show that, considering the role of central bank independence (CBI), it is possible to reconcile the main theoretical implications of models of optimal taxation and seigniorage with the empirical evidence. Different degrees of CBI capture the extent to which monetary policy is effectively controlled by the fiscal authority. Our model generates three testable implications: i) if CBI is low, the optimal relationship between inflation and tax rates is positive, ii) such relationship is a decreasing function of the degree of CBI, and iii) the relationship is negative for high levels of CBI. We show that these hypotheses hold for alternative measures of tax policy, seigniorage, and CBI as well as after controlling for several macroeconomic performance, ideology, political instability, governance, and economic structural/development factors.

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> The ability of the government to finance expenditures by issuing money is the 'seigniorage' associated with its sovereign monetary monopoly. Both explicit and implicit taxes are distortionary. The distortion of the inflation tax is the diversion of resources or loss of utility associated with the scarcity of money, already mentioned. But there are also distortions in explicit taxes; lump-sum taxes are not available. *The problem is to optimize the choice of taxes, given the necessity of government expenditure. This formulation correctly connects the money-supply process to the government budget. (Emphasis added)*
>
> Tobin (1986, page 11)

1 Introduction

Should inflation be thought of as "just another tax?" The theoretical basis for doing so dates back to Phelps (1973). Influenced by early theories of optimal taxation in public finance (e.g. Wicksell, 1896; Ramsey, 1927; Boiteux, 1956; Musgrave, 1959), Phelps (1973) was the first to point out that if lump-sum taxation is not available, optimal taxation minimizes the deadweight loss by equalizing the marginal distortions of all available taxes, including the inflation tax.[1]

This argument was further developed and refined by Marty (1976), Siegel (1978), Drazen (1979), Chamley (1985), Tobin (1986), Mankiw (1987), Grilli (1988), Poterba and Rotemberg (1990) and Chari and Kehoe (1999), among others. Typically using a neoclassical framework with different model structures and functions for money, the underlying question of these papers is how to optimally finance a certain level of public spending. These studies typically assume a benevolent government that chooses the rates of taxation and inflation to minimize the present value of the distortionary social cost of raising revenue, and that marginal distortions of taxation and seigniorage are increasing in the underlying rates. Given this framework, a key distinctive theoretical implication obtained by these models is that inflation and tax rates have a positive relationship. That is to say, the optimum policy requires "some" use of each of the available distorting taxes, including the inflation tax, in order to reduce the extent to which any of the others must be used.

While theoretically appealing, empirical studies find virtually no support for this key implication. Using United States data from 1952 to 1985, Mankiw (1987) finds a striking

[1] Inflation tax is a metaphorical representation of the economic disadvantage suffered by holders of money due to the inflationary effects of expansionary monetary policy, which acts as a hidden tax that subtracts value from those assets.

positive correlation between inflation and tax burden, measured by government revenue as a percentage of GDP. Subsequent studies suggest that this characterization generally fails to fit the experiences of both developed and developing economies (Roubini and Sachs, 1989; Poterba and Rotemberg, 1990; Edwards and Tabellini, 1991; Roubini, 1991). Roubini and Sachs (1989) find that for 12 out of 15 developed countries, there are no significant relationships, and, in 5 of the countries (France, Austria, Italy, Ireland and Denmark), the relationship is negative. Poterba and Rotemberg (1990) find a positive relationship for Japan and the United States, while the existence of such relationship is not found for France, the United Kingdom and West Germany. In a sample of 21 developing countries, Edwards and Tabellini (1991) find no statistically significant relationship for 17 countries and a statistically significant, but negative, relationship for 4 of them. Roubini (1991) rejects this key theoretical implication for most developing countries. In a sample of 92 developing countries he find that there is a positive and statistically significant relationship for only 15 of them, there is no statistically significant relationship for 37 economies and, notably, such relationship is statistically negative in 40 countries.

This puzzle is extremely relevant for at least two reasons. First, as described above, an important part of the theoretical macroeconomic literature has been built on these types of models. Second, given the absence of readily available cross-country data on tax rates, many empirical papers have relied upon the use of inflation tax as a proxy for tax policy (Talvi and Vegh, 2005; Kaminsky, Reinhart, and Vegh, 2004).

This paper shows that, considering the role of central bank independence (CBI), it is possible to reconcile the main theoretical implications of models of optimal taxation and seigniorage with empirical evidence. Previous studies assume that while government policy is executed by different agencies or branches, such as the fiscal authority and central bank, there is no independence of goals in each of these branches. "To the contrary, each agency is conceived... as calculating the actions it must take in full knowledge of those actions by the other agencies which are entailed by their concerted pursuit of specific government policy objectives" (Phelps, 1973, page 70). In other words, the fiscal authority and central bank fully cooperate toward the common objective of reducing overall excess burden of taxation.

While it is intrinsic to fiscal authority goals to minimize deadweight loss of taxation, it

is less obvious that revenue considerations of seigniorage are a key element in the positive theory of monetary policy. Using a simple optimal taxation and seigniorage model, we show that the optimal relationship between inflation and tax rates crucially depends upon the degree of CBI.

First, if CBI is low, the fiscal authority effectively controls monetary policy and, consequently, selects tax rates and inflation taking into account revenue and distortionary considerations. In this context, inflation can be rationalized as "just another tax." Equivalent to the current theoretical literature, inflation and tax rates are positively related. That is to say, what the current literature frames as full cooperation of the fiscal and monetary branches toward the common objective of reducing overall excess burden of taxation, we rationalize as a circumstance of low CBI where the fiscal branch captures the central bank.

On the contrary, if CBI is high, then central banks pursue their own monetary policy that is consistent with a certain implicit or explicit inflation target. In this case, inflation and tax rates have a negative relationship. This occurs because an increase in the level of inflation by the monetary authority increases seigniorage revenues. The latter reduces the pressure to collect revenues via regular taxation, optimally inducing the fiscal authority to reduce the tax rate. Lastly, taking into account the theoretical implications associated with these two extreme levels of CBI, we also show that the optimal relationship between inflation and tax rates is a decreasing function of the degree of CBI. That is to say, the optimal relationship between inflation and tax rates becomes less positive or more negative for higher degrees of CBI.

We test the predictions of the model using a sample of 89 countries for the period 1970-2009 and alternative measures of CBI, tax policy, and seigniorage. We first proxy CBI using the yardstick de facto measure which relies on the turnover rate of central bank governor (Cukierman, 1992; Cukierman et al, 1992). The basic presumption of this de facto measure is that, at least above some threshold, a more rapid turnover of central bank governors indicates less CBI. Frequent replacement of the central bank governor may reflect the removal of those who challenge the government which, in turn, also gives political authorities the "opportunity to pick those who will do their will" (Cukierman et al, 1992, page 363). This de facto measure has been frequently used when focusing on the developing

world, where there tends to be an important difference between legal frameworks and actual practices. We complement this analysis using legal measures like the ones developed by Cukierman et al (1992) and Jácome and Vázquez (2008). As is tradition in this literature, we use tax burden defined as the ratio of government revenues to GDP (to proxy tax rates) and inflation (to proxy for inflation tax). We also present complementary evidence using a novel dataset on value-added tax rates for 40 countries (to proxy tax rates) and seigniorage revenues, calculated as the change in reserve money as percentage of GDP. Our findings strongly support our model's predictions, even after controlling for several macroeconomic performance, ideology, political instability, governance, and economic structural/development variables.

Our findings shed light on some the weaknesses of a traditional and important theoretical macroeconomic literature that builds upon the optimal use of regular taxes as well as the inflation tax to finance public spending. It also cautions an important empirical literature related to developing countries which relies on inflation rates to proxy for taxation policy. Our argument increases in practical relevance in recent times. Indeed, Figure 1 shows that CBI has increased, particularly since the 1990s. Legal and de facto measures of CBI support a similar institutional profile over time, as evidenced by increases in legal measures of CBI as well as reductions in the turnover rate of central bank governor (which is associated with more de facto CBI) since early-mid 1990s. In other words, in a context of high CBI (as the one observed since early-mid 1990s) one does not expect inflation tax to be a fiscal policy tool.

The paper proceeds as follows. Section 2 develops a simple optimal taxation and seigniorage model which generates three key testable theoretical implications regarding the role of CBI on optimal taxation and seigniorage: i) if CBI is low, the optimal relationship between inflation and tax rates is positive, ii) the optimal relationship between inflation and tax rates is a decreasing function of the degree of CBI, and iii) the optimal relationship between inflation and tax rates is negative for high levels of CBI. We then turn to the empirical analysis and present the data in Section 3. Section 4 performs a preliminary analysis using a non-parametric approach. Section 5 turns to regression analysis. Section 6 complements our basic regression analysis controlling for potential omitted variable concerns. We consider several macroeconomic performance, ideology, political instability,

governance, and economic structural/development factors. Section 7 tests the robustness of our findings using alternative measures of tax policy, seigniorage, and CBI. In Section 8 we present final remarks.

2 Model

This section develops a simple optimal taxation and seigniorage model close in spirit to the work initiated by Phelps (1973). However, unlike previous models, we analyze the role of central bank goal independence.

The basic structure of the model is straightforward. The small, open economy is inhabited by a representative private agent (PA) and a government consisting of a fiscal authority (FA) and a central bank (CB). To keep the model as simple as possible, we assume that agents are blessed with perfect foresight. Without loss of generality we assume that initial asset positions are zero. As in Lucas and Stokey (1983), there are two kinds of consumption goods, c_{1t} and c_{2t}. The first good, c_{1t} or "cash goods" can be purchased only with fiat currency previously accumulated. The second, c_{2t} or "credit goods" can be paid for with income contemporaneously accrued. Similar to Vegh and Vuletin (2011), the consumption of c_{2t} is subject to taxation, while the consumption of c_{1t} is not. These two goods are perfect substitutes in production, and, therefore, their relative price is one. Production is exogenous (i.e. there is an endowment y_t).[2]

2.1 Private agent

Without loss of generality, and in order to obtain analytical solutions, we assume that PA's preferences are logarithmic

$$\int_0^\infty \left[\ln\left(c_{1t}\right) + \ln\left(c_{2t}\right)\right] e^{-\beta t} dt, \tag{1}$$

[2]There are different ways of introducing two distortions into the model, one associated with regular taxation and the other related to inflation. The most obvious alternative would be to add leisure to the model, in which case an income tax would distort the consumption/leisure choice, and inflation, the allocation between consumption goods.

We prefer this alternative specification – with the "credit good" and "cash good" being taxed by a consumption tax and the inflation tax respectively – because it enables us to isolate the distortionary effects stemming from an exogenous income path. That is to say, we are able to isolate income from taxation decisions. While not modeled, the "cash good" that is non-taxed by a consumption tax and subject to the inflation tax could be thought of as the underground economy.

where $\beta > 0$ is the discount factor. The PA's intertemporal constraint is given by

$$\int_0^\infty (y_t + g_t)\, e^{-rt} dt = \int_0^\infty (c_{2t}\,(1+\theta_t) + c_{1t} + m_t i_t)\, e^{-rt} dt, \tag{2}$$

where g_t is the exogenous fiscal transfers to the PA, θ_t is the consumption tax on "credit goods," i_t is the nominal interest rate and m_t represents real money balances. $i_t \equiv r + \pi_t$, where r is the exogenous and constant real interest rate and π_t is inflation. We assume that the money demand is given by a simple cash-in-advance constraint à la Calvo (1987),

$$m_t \geqslant k \cdot c_{1t}, \tag{3}$$

where k is a positive constant (i.e. $k > 0$).

The PA's problem consists in choosing $\{c_{1t}, c_{2t}, m_t\}$ for all $t \in [0, \infty)$ to maximize (1) subject to (2) and (3) taking as given θ_t and π_t. Assuming that $\beta = r$ to avoid spending tilting, we obtain from optimal conditions

$$m_t = k \cdot c_{1t} = k \cdot c_{2t} \frac{1+\theta_t}{1 + k\,(r + \pi_t)}. \tag{4}$$

From (4) it is clear that an increase (decrease) in θ_t increases (decreases) the consumption of c_{1t} and the use of money in detriment (benefit) of the consumption of c_{2t}. This occurs because c_{2t} is subject to the consumption tax θ_t while c_{1t} is not. The use of money is tight to c_{1t} through the cash-in-advance constraint. Alternatively, an increase (decrease) in π_t increases (decreases) the consumption of c_{2t} in detriment (benefit) of the consumption of c_{1t} and the use of money. This occurs because c_{1t} is the "cash good" which implicitly pays the inflation tax because of the cash-in-advance constraint. On the other hand, c_{2t} is the "credit good," not subject to the cash-in-advance constraint and, therefore, not affected by the inflation tax.

2.2 Fiscal authority

We assume, as is convention in this literature, that the FA is benevolent. Her problem is to choose the optimal mix of distortionary taxes to finance exogenous fiscal transfers to

the PA (g_t).[3] The FA's intertemporal constraint is given by

$$\int_0^\infty (\theta_t c_{2t} + i_t m_t)\, e^{-rt} dt = \int_0^\infty g_t e^{-rt} dt, \tag{5}$$

which has the usual interpretation that the present value of expenditures must equal the present value of revenues associated with regular taxation (consumption tax in our model) and seigniorage.

2.3 Central bank

The CB can either have the power to decide the monetary policy (i.e. high CBI) or it can function as an agency of the fiscal branch, in which case monetary policy is effectively determined by the fiscal authority (i.e. low CBI). In other words, under high CBI (low CBI) the central bank does (does not) enjoy goal independence.[4] If independent, the central bank aims to minimize the deviation of inflation from a target ($\widetilde{\pi}$)[5,6]

$$\int_0^\infty (\pi_t - \widetilde{\pi})^2\, e^{-\beta t} dt. \tag{6}$$

2.4 Results

Using this simple model we formulate three key propositions regarding the influence of CBI on the optimal relationship between inflation (π_t) and tax rate (θ_t).

Proposition 1 *If CBI is low, inflation and the tax rate have a positive relationship.*

This relationship coincides with the theoretical implications developed by the current literature on optimal taxation and seigniorage. In those papers this is the natural result of a benevolent government that coordinates both fiscal and monetary policies to minimize the deadweight loss of distortionary taxation. We rationalize such framework as one in which the central bank does not enjoy goal independence (i.e. CBI is low). In this case

[3] The path of fiscal transfers to the PA is taken as exogenous to highlight the optimal taxation mix. Alternatively, we could think that there is an expenditure branch which sets the levels and compositions of transfers and which does not participate in financing decisions.

[4] Debelle and Fischer (1994) make a clear distintion between goal independence – the full delegation embodied, for example, in Rogoff's (1985) conservative central banker model – and instrument independence – the type of relationship suggested by agency models (Walsh, 1995).

[5] Since the analysis is conducted in a neoclasical framework, there is no role for countercyclical monetary policy.

[6] See, for example, Taylor (1993) and Clarida, Galí and Gertler (2000).

the FA effectively conducts fiscal and monetary policy; that is to say, she selects θ_t and π_t. Inflation can be rationalized as "just another tax," selected by taking into account revenue and distortionary considerations. Formally, solving the model, we obtain[7]

$$\frac{d\theta_t}{d\pi_t} = k\frac{(1+\theta_t)^2}{(1+ki_t)^2} > 0. \tag{7}$$

Proposition 2 *If CBI is high, inflation and the tax rate have a negative relationship.*

If CBI is high, the CB minimizes (6) by selecting π_t and the FA selects θ_t in order to finance the exogenous path of g_t. If π_t increases (decreases) optimally due to an increase (decrease) in $\widetilde{\pi}$, implicit revenues accrued from the inflation tax increase (decrease) as well. The latter reduces (increases) the pressure to collect revenues via regular taxation on consumption, which optimally induces the fiscal authority to reduce (increase) the use of distortionary taxation. That is to say, θ_t decreases (increases). For these arguments, inflation and tax rates have a negative relationship. In other words, inflation cannot be rationalized as "just another tax" because the CB, which enjoys goal independence, does not take into consideration the revenue and distortionary implications of inflation. Formally, solving the model, we obtain[8]

$$\frac{d\theta_t}{d\pi_t} = -k\frac{(1+\theta_t)^2}{(1+ki_t)^2} < 0. \tag{8}$$

Proposition 3 *The optimal relationship between inflation and the tax rate is a decreasing function of the degree of CBI.*

More generally, CBI can be thought of as the extent to which the CB determines monetary policy without interference from the fiscal authority. For this purpose, we define α as a proportion (i.e. $1 \geqslant \alpha \geqslant 0$) that measures the extent of CBI under which fiscal and monetary policies are determined. If $\alpha = 0$, CBI is low and if $\alpha = 1$ we are under the presence of high CBI. In other words, α captures the degree of CBI in a more continuous

[7] Appendix 9.1.1 shows this derivation.
[8] Appendix 9.1.2 shows this derivation.

way . Solving the model, we obtain[9]

$$\frac{d\theta_t}{d\pi_t} = (1-2\alpha)\, k \frac{(1+\theta_t)^2}{(1+ki_t)^2} \gtrless 0. \tag{9}$$

As shown in Propositions 1 and 2, the optimal relationship between inflation and tax rate crucially depends on the degree of CBI. If CBI is relatively high (i.e. $\alpha > 1/2$) the optimal relationship between inflation and tax rate is negative. If CBI is relatively low (i.e. $\alpha < 1/2$) the optimal relationship between inflation and tax rate is positive. If $\alpha = 1/2$ then inflation and tax rate are not related to each other.

More importantly, from (9), it is straightforward that

$$\frac{d\left(d\theta_t/d\pi_t\right)}{d\alpha} = -2k \frac{(1+\theta_t)^2}{(1+ki_t)^2} < 0, \tag{10}$$

which indicates that the optimal relationship between inflation and tax rate is a decreasing function of the degree of CBI. In other words, as CBI increases the optimal relationship between inflation and tax rate becomes less positive, or more negative.

3 Data

Our main annual panel dataset consists of alternative measures of tax policy, inflation tax, and CBI.[10] The sample comprises 26 advanced and 63 developing countries for the period 1970-2009.[11] As is tradition in this literature, we use as benchmark tax burden defined as the ratio of government revenues to GDP (to proxy tax policy) and inflation (to proxy for inflation tax). We obtain this dataset for 89 countries from Kaminsky, Reinhart and Vegh (2004) and Global Financial Data.

[9] Appendix 9.1.3 shows this derivation.

[10] Appendix 9.2 shows all definitions and sources of data.

[11] According to the IMF World Economic Outlook country classiffication, the advanced countries in the sample are Australia, Austria, Belgium, Canada, Cyprus, Czech Republic, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Japan, Korea, Netherlands, New Zealand, Norway, Portugal, Singapore, Spain, Sweden, Switzerland, United Kingdom and United States.

The developing countries in the sample are Algeria, Argentina, Bangladesh, Bolivia, Botswana, Brazil, Bulgaria, Cape Verde, Chile, China, Colombia, Costa Rica, Dominican Republic, Ecuador, Egypt, El Salvador, Estonia, Gambia The, Ghana, Guatemala, Haiti, Honduras, Hungary, India, Indonesia, Iran, Jamaica, Jordan, Kenya, Latvia, Lithuania, Madagascar, Malaysia, Mauritius, Mexico, Mongolia, Morocco, Mozambique, Nepal, Nigeria, Pakistan, Paraguay, Peru, Philippines, Poland, Romania, Rwanda, Seychelles, South Africa, Sri Lanka, Sudan, Swaziland, Syrian Arab Republic, Tanzania, Thailand, Trinidad and Tobago, Tunisia, Turkey, Uganda, Uruguay, Venezuela, Zambia and Zimbabwe.

We complement our analysis using a novel dataset on value-added tax (VAT) rates for 40 countries (to proxy tax policy). We use this tax because it is one of the most important worldwide taxes in terms of tax collection. According to the World Development Indicators, taxes on goods and services represent more than 35 percent of total tax collection worldwide. Another key convenience of this tax is that it has a single standard rate.[12] Unlike personal and corporate taxes, which have several tax rates, this single-rate feature allows the researcher to clearly assess the stance on taxation policy. Using government agencies' websites, emails exchanged with those institutions and resources available online, we gather a novel dataset of VAT rates for 40 countries.[13] On the inflation policy side, we alternatively use seigniorage revenues calculated as the change in reserve money as percentage of GDP (Aisen and Veiga, 2006; Aisen and Veiga, 2008).

Table 1 shows the average of the tax burden, inflation, VAT rate, and seigniorage for each country in the sample. The average and median tax burden is 28 and 27.2 percent, respectively. The countries with the highest and lowest average tax burden are Sweden with 59.6 percent and Bangladesh with 8.5 percent. Average and median inflation is 27.1 and 10.9 percent, respectively. The countries with the highest and lowest average inflation rates are Brazil, at an astounding 333.6 percent and Singapore with 2.9 percent. The average and median VAT tax rate is 14.9 and 16 percent, respectively. The countries with the highest and lowest average VAT tax rates are Hungary with 24.1 percent and Singapore with 4.2 percent. The average and median seigniorage revenues are 1.2 and 1.1 percent, respectively. The countries with the highest and lowest average seigniorage revenues are Syrian Arab Republic with 3.9 percent and Sweden with 0.1 percent. The country coverage for tax burden and inflation is almost twice that of the VAT rate and seigniorage. Importantly, using a country-demeaned dataset, alternative measures of tax policy and inflation tax/seigniorage are quite related among themselves. The Spearman correlation between tax burden and VAT rates is 0.10 (and statistically different from zero at 99 confidence level). Similarly, the Spearman correlation between inflation and

[12] While many countries also have a reduced rate, they typically apply it to selected goods such as some foodstuffs and child and elderly care.

[13] These 40 countries are Argentina, Austria, Belgium, Bulgaria, Canada, Cyprus, Czech Republic, Dominican Republic, Ecuador, Egypt, El Salvador, Estonia, Finland, France, Germany, Greece, Guatemala, Hungary, Ireland, Israel, Italy, Japan, Korea, Latvia, Lithuania, Mexico, Netherlands, New Zealand, Paraguay, Poland, Portugal, Romania, Singapore, South Africa, Spain, Sweden, Switzerland, Turkey, United Kingdom and Uruguay.

seigniorage is 0.35 (and statistically different from zero at 99 confidence level).[14]

We use as a benchmark measure for CBI a de facto oriented measure which is based on the average turnover rate of central bank governors. Introduced by the seminal papers of Cukierman (1992) and Cukierman et al (1992), this measure quickly became the yardstick measure of de facto CBI (Cukierman and Webb, 1995; de Haan and Siermann, 1996; Al-Marhubi, 2000; Cukierman et al, 2002; Neyapti, 2003; Cukierman, 2008; Vuletin and Zhu, 2011). The basic presumption of this de facto measure is that, at least above some threshold, a more rapid turnover of central bank governors indicates less CBI. Frequent replacement of the central bank governor may reflect the removal of those who challenge the government which, in turn, also gives political authorities the "opportunity to pick those who will do their will" (Cukierman et al 1992, page 363).

The time interval used to calculate the average turnover rate of central bank governor varies across studies. Al-Marhubi (2000) and Temple (1998) use the average for the whole period under analysis, 1980-1995 and 1974-1994, respectively. Cukierman et al (1992) and de Haan and Kooi (2000) calculate decade averages, while Dreher et al (2008) use the averages or starting values for each lustrum. The use of very long time periods to calculate average turnover rate of central bank governor implicitly assumes that actual independence and institutional characteristics rarely change. On the contrary, the use of decades or lustrum allows for some moderate institutional change that seems to be consistent with some empirical evidence. For example, while central bank governors of Chile were replaced on average every 1 year and 3 months during the 1980s, they were replaced every 5 years – coinciding with the legal term of office – during the 1990s. While the use of decades or lustrum are more flexible by allowing for moderate institutional change, the use of fixed windows implicitly assumes that those changes only occur in arbitrary years; for example, the change occurs at the very beginning or at the very end of decades. On the contrary, the use of moving windows to calculate average turnover rate of central bank governor allows a more gradual and continuous institutional change. Taking these two dimensions into account, we use the 7-year centered moving average turnover rate of the change in the central bank governor (TOR).[15] This approach allows

[14] If the dataset was not country-demeaned, the Spearman correlations are 0.51 and 0.46 for tax policy and inflation tax/seigniorage measures, respectively. In both cases these correlations are statistically different from zero at 99 confidence level.

[15] Our results hold if the length of windows are moderately changed.

for a moderate and continuous institutional change.

Table 2 shows TOR averages as well as the associated average frequency of central bank governor replacement. The findings are consistent with previous studies in that the frequency of replacement in developing countries is much higher – almost two times higher – than it is in advanced economies. For example, Ecuador and Argentina have the highest turnover rates in the sample, with a central banker replaced, on average, every 1 year and 2 months. On the other side of the spectrum, Dutch governors are replaced, on average, every 17 years.

We also complement our analysis using a legal CBI measure (LVAW) initially created by Cukierman et al (1992) and later updated by Jácome and Vázquez (2008). This measure captures various legal CBI dimensions including (i) the process of appointment, dismissal, and term of office of the central bank governor, (ii) the autonomy regarding the formulation of policy, (iii) the objectives of the central bank, and (iv) the limitations on the availability of the central bank to lend to the public sector. Higher LVAW values are associated with higher legal CBI. The countries with the highest and lowest legal CBI are Germany with 0.69 and Poland with 0.10.

As noted by previous research, the relationship between TOR and LVAW is quite low. Indeed, the average LVAW is quite similar across advanced countries (0.38) and developing economies (0.40). Interestingly, when using country-demeaned dataset, alternative measures of CBI are quite related among themselves. The Spearman correlation between TOR and LVAW rates is -0.20 (and statistically different from zero at 99 confidence level). When the frequency of replacement of the central bank governor is high (i.e., high TOR and low de facto CBI), legal measures of CBI tend to decrease (i.e., low LVAW and low legal CBI). That is to say, when exploiting within country variability, these two CBI proxies are, indeed, moderately in sync.

For robustness tests we also use macroeconomic performance, ideology, political instability, governance, and economic structural/development data. For macroeconomic performance we use bank crises from Kindleberger (2000) and Reinhart (2010), IMF program from Reinhart (2010) and International Financial Statistics (IMF), sovereign default from Reinhart (2010), and GDP cycle based on authors' calculations using Kaminsky, Reinhart and Vegh (2004) and Global Financial Data. We also use ideology data from Database

of Political Institutions (DPI), political instability data from Cross-National Time-Series Data Archive (CNTS), governance data from International Country Risk Guide (ICRG), and economic structural/development data from World Development Indicators (WDI).

4 Preliminary analysis

In this section we perform a preliminary analysis regarding how the relationship between inflation and tax rates varies according to the level of CBI. From a methodological point of view we use a standard non-parametric approach, the Spearman's rank correlation coefficient. In particular,

$$\rho_i = 1 - \frac{6 \sum_{j=1}^{n} \left(R\left[\mathrm{INF}_j\right] - R\left[\mathrm{TAX}_j\right] \right)^2}{n\left(n^2 - 1\right)} \tag{11}$$

where ρ_i is the Spearman's rank correlation coefficient between inflation (INF) and tax rate (TAX) for the TOR category i. $R\left[\mathrm{INF}_j\right]$ and $R\left[\mathrm{TAX}_j\right]$ are the ranks of INF and TAX for observation j. The number of observations is represented by n. Naturally, $-1 \leqslant \rho_i \leqslant 1$. A value of $\rho_i = 1$ ($\rho_i = -1$) would indicate that INF and TAX are perfectly monotonically increasing (decreasing) related for TOR category i. For each ρ_i, the 95 percent confidence interval $\left[\rho_i^-, \rho_i^+\right]$ is also calculated using Fisher's z transformation.[16,17]

Because the Spearman's coefficient exploits the correlation in ranks as opposed to actual values, it has two distinct advantages with respect to alternative non-parametric correlation coefficients such as the Pearson's correlation. First, it is less sensitive to strong outliers that are in the tails of both INF and TAX. This seems particularly relevant considering the striking variation noted in Table 1. Second, the Spearman's coefficient is more flexible as it measures the relationship in a non-linear fashion. This is particularly relevant considering the non-linear nature of the expressions obtained in Section 2.4.

Figure 2 shows the Spearman's rank correlation coefficients for each TOR level (i.e. ρ_i) as well as the 95 percent confidence interval $\left[\rho_i^-, \rho_i^+\right]$ when using tax burden as a proxy

[16] At least ten observations are needed in order to calculate confidence intervals (i.e. $n \geqslant 10$). Because some TOR categories do not have such number of observations we include, for the calculation of ρ_i, not only the observations included in such TOR category but, when possible, the observations associated with the two immediately smaller and bigger TOR categories.

[17] We do not calculate the Spearman's rank correlation coefficient for TOR categories bigger than 1.29 and 1.15 for tax burden and VAT tax rates, respectively, due to few observations.

for tax rate. We strongly confirm the three key implications of our theoretical model. First, the optimal relationship between inflation and the tax rate is negative when TOR is low (that is to say, when CBI is high). For example, for ρ_0 (i.e. the Spearman's rank correlation coefficient associated with TOR=0) the relationship is negative and equal to -0.357. Such coefficient is statistically negative since $\left[\rho_0^-, \rho_0^+\right] = [-0.403, -0.308]$. The relationship between inflation and the tax rate is statistically negative for TOR categories smaller than or equal to 0.4 ($\rho_{0.4}$). Second, the optimal relationship between inflation and tax rates is a decreasing function of the degree of CBI or, alternatively, an increasing function of TOR. Third, the optimal relationship between inflation and tax rates is positive when TOR is high, or in other words, when CBI is low. For example, for $\rho_{1.28}$ the relationship is positive and equal to 0.482. Such coefficient is statistically positive since $\left[\rho_0^-, \rho_0^+\right] = [0.241, 0.667]$. The relationship between inflation and tax rate is statistically positive for TOR categories greater than or equal to 1 (ρ_1).

Interestingly, if we did not differentiate between alternative TOR categories, the overall Spearman's rank correlation coefficient would be -0.367 with 95 percent confidence lower and upper bound intervals of -0.403 and -0.330. That is to say, when not distinguishing across levels of CBI, we cannot reject the null that the relationship between inflation and tax rate is statistically negative. Our findings indicate the relevance of CBI considerations when understanding optimal taxation and seigniorage. By considering the influence of CBI, we are able to reconcile the main theoretical implications of models of optimal taxation and seigniorage with the empirical evidence.

4.1 Advanced versus developing countries

We now explore whether our findings from Figure 2 are general across economies or if they only apply to a particular group of countries such as developed or developing. This is particularly important considering the institutional and macroeconomic differences across these two groups of countries. For example, the average inflation of developing countries is more than five times higher than it is in advanced economies.[18] Figure 3 shows the same correlations as Figure 2 for developing and advanced countries separately.[19] Naturally,

[18] We cannot reject the null hypothesis that the mean inflation of developing countries (37.10 percent) is statistically higher from that of advanced ones (6.57 percent) at the 1 percent significant level.

[19] We used the Country Composition of World Economic Outlook Groups provided by the International Monetary Fund to split the sample of countries into advanced and developing ones.

advanced economies do not have as high levels of TOR (i.e. low levels of CBI) as do developing countries. The highest TOR category for advanced countries is 0.57, as opposed to 1.57 for developing economies. More importantly, the general results hold for both groups of countries. For high levels of CBI (when TOR is smaller than 0.4) both groups of countries show negative relationships between inflation and tax rate. For TOR levels ranging between 0.4 and 0.86, the relationship is neither positive nor negative. For low levels of CBI (when TOR is higher than 0.86), developing countries show, as does Figure 2, a positive relationship between inflation and tax rate. The implications derived from the theory work similarly for both groups of countries. However, because most advanced countries do not have low levels of CBI, the findings obtained in Figure 2 when CBI is low are mainly driven by the performance of developing countries.

Similar to the findings of Figure 2, if we did not distinguish between alternative TOR categories, the overall Spearman's rank correlation coefficients for developing and advanced countries would be -0.179 and -0.232, respectively. In both cases we cannot reject a negative relationship between inflation and the tax rate.

5 Regression analysis

In this section we turn to more rigorous regression analysis. As did Mankiw (1987), Edwards and Tabellini (1991), and Roubini (1991), we start by estimating the following kind of regressions, without taking into account the role of CBI:[20]

$$TAX_{it} = \alpha + \beta_1 \cdot INF_{it} + \varepsilon_{it}. \tag{12}$$

Similar to previous studies, we find that inflation and the tax burden relates negatively (Table 3, column 1), which contradicts the key distinctive theoretical implication derived from current models of optimal taxation and seigniorage.

Second, we test the predictions of our model regarding the role of CBI. For this purpose we consider the following specification:

$$TAX_{it} = \alpha + \beta_1 \cdot INF_{it} + \beta_2 \cdot INF_{it} \cdot TOR_{it} + \beta_3 \cdot TOR_{it} + \varepsilon_{it}, \tag{13}$$

[20] Similar results are obtained if we use INF as the dependent variable and TAX as the independent variable. Results are not shown for brevity.

where (13) is similar to (12), but it also includes TOR and its interaction with INF. Using OLS, Table 3, column 2 strongly supports the predictions of our model. First, when CBI is high – proxied by TOR=0 as extreme case – the tax rate and inflation relate negatively (i.e., $\beta_1 < 0$). Second, when CBI is low – proxied by the maximum observed TOR value – the tax rate and inflation relate positively. Lastly, the relationship between the tax rate and inflation is a decreasing function of the degree of CBI or, alternatively, an increasing function of TOR (i.e., $\beta_2 > 0$).

Table 3, columns 3 to 5 allow for country fixed-effects. Column 3 shows that the previous results strongly hold after including country fixed-effects. In other words, our empirical findings are not related to omitted variables that are idiosyncratic to each country and constant over time. Indeed, such results are obtained from within country variability. Since tax policy is persistent over time, we also include the lagged tax burden in the right-hand side of equation (13). We estimate this dynamic panel data model using the system-GMM (Arellano and Bover, 1995; Blundell and Bond, 1998) to avoid well-known inconsistency problems (Arellano and Bond, 1991). Column 4 shows that the previous results strongly hold even after accounting for country fixed-effects and dynamics.[21] While country fixed-effects controls for omitted variables that are idiosyncratic to each country and constant over time, inflation rates reduced significantly in many countries around the world during the 1990s and the 2000s. To ameliorate concerns regarding our findings being driven by what is occurring during a particular period of time, Column 5 also includes decade dummies.[22] Our findings remain strong to this consideration. To summarize, our results strongly hold to the inclusion of country fixed-effects, dynamics, and decade dummies.

6 Controlling for macroeconomic, ideology, political instability, governance, and economic development factors

In this section we test whether our findings are driven by some omitted macroeconomic performance, ideology, political instability, governance, or economic structural/development factors. For this purpose, we introduce (in a cumulative fashion) alternative control vari-

[21] For brevity and to keep the focus of our study we do not report the coefficients of the lagged variable. In all regressions this coefficient is about 0.70 and extremely significant (with t-statistic values always higher than 10).

[22] Similar results are obtained if a linear trend is use instead.

ables which could potentially be at the roots of the way CBI affects the relation between inflation and tax policy. In all cases we use dynamic panel data regressions with decade dummies like the one used in Table 3, column 5. To fix ideas, when evaluating the implications of controlling for variable x, we consider the following specification:

$$\begin{aligned} TAX_{it} &= \alpha + \beta_1 \cdot INF_{it} + \beta_2 \cdot INF_{it} \cdot TOR_{it} + \beta_3 \cdot TOR_{it} + \beta_4 \cdot x_{it} + \\ &\quad + \beta_5 \cdot x_{it} \cdot INF_{it} + \beta_6 \cdot x_{it} \cdot INF_{it} \cdot TOR_{it} + \beta_7 \cdot x_{it} \cdot TOR_{it} + \varepsilon_{it}, \quad (14) \end{aligned}$$

where (14) is similar to (13), but it also includes x as well as its simple and combined interactions with TOR and INF.

6.1 Macroeconomic factors

We begin our analysis by testing whether our results are robust to some of the most common macroeconomic theories regarding the determination of the level of inflation: cost-push and business cycle arguments, as well as those that link inflation with periods of fiscal and financial distress.

Table 4, column 1 accounts for cost-push inflation arguments. Cost-push inflation is caused by a drop in aggregate supply, which may be due to natural disasters or increased prices of key inputs, such as oil (Loungani and Swagel, 2001; Hamilton and Herrera, 2004; Catão and Terrones, 2005). Table 4, column 1 is equivalent to that of Table 3, column 5 but uses adjusted-inflation instead of inflation, where adjusted-inflation is defined as the difference between inflation and world inflation, which is proxied by the inflation rate of G7 countries. This alternative measure controls for external inflation/disinflation trends associated with external shocks such as changes in oil prices (Jácome and Vázquez, 2008; Vuletin and Zhu, 2011).[23] The relevance of our central findings strongly hold when using this alternative measure of inflation. In other words, even after controlling for cost-push inflation arguments our main implications withstand.

A well-established theory in macroeconomics is that fiscally dominant governments running persistent deficits must finance those deficits sooner or later with monetization, ultimately increasing inflation (Sargent and Wallace, 1981). This view has been partic-

[23] Similar results are obtained if the percentage change in price of oil is used instead of world inflation.

ularly relevant in the literature of developing countries, which has long recognized that intermittent and limited access to external borrowing, frequent bailout of fragile financial systems prone to crisis, and weak institutions – especially central banks – increase the dependence on the inflation tax (Rogoff, 1985; Alesina and Drazen, 1991; Cukierman, 1992; Cukierman et al, 1992; Lohmann, 1992; Calvo and Reinhart, 2000; Calvo and Vegh, 1999).

Our data supports these well-established findings. First, the level of inflation is negatively related to CBI; the Spearman's rank correlation coefficient between inflation and TOR is 0.29 and statistically significant at a 1 percent level. Second, the level of inflation is much higher during periods of i) banking crisis (four times higher), ii) sovereign debt default (almost seven times higher), and iii) when countries have IMF programs (almost two times higher); than in "tranquil times." Important for the robustness of our theoretical arguments, our main empirical findings hold after taking into account these macroeconomic theories regarding the determination of the level of inflation (Table 4, columns 2 to 4).

We now test whether the state of the economy, in particular its business cycle, could be driving the way CBI affects the relationship between inflation and tax policy. Table 4, column 5 augments our regression by also including the GDP cycle. Our main empirical findings withstand. To summarize, our main findings strongly hold controlling for some of the relevant theories regarding the determination of the level of inflation.

6.2 Ideology factors

While our theoretical model does not theoretically articulate the role of ideology factors, the sign of the relationship between inflation and tax policy could also reflect political ideology. For example, it has been generally reported that left-wing parties are associated with greater public spending than others, and hence are likely to strengthen the investigated link under high CBI. To control for this possibility, we use ideology data from Database of Political Institutions (DPI). Table 4, column 6 includes a dummy variable that equals one when the party orientation of the executive chief is right. Column 7 also includes a dummy variable that equals one when the party's platform of the executive chief is nationalist. After controlling for ideology arguments our main implications withstand.

6.3 Political instability factors

There is an important literature that finds that political instability is an important determinant of inflation, seigniorage and budget deficits (Edwards and Tabellini, 1991; Roubini, 1991; Cukierman, Edwards, and Tabellini, 1992; Aisen and Veiga, 2006 and 2008). One could then think that political instability could affect de facto CBI, as greater turnover of governments may lead to greater turnover of central bank governors if each new government appoints a new central bank governor. If this was the case, some of the effects currently attributed to CBI may be actually be driven by the degree of political instability. To control for this possibility, we use political instability data from Cross-National Time-Series Data Archive (CNTS). Table 4, column 8 includes changes in effective executive (Δeffective executive). This variable measures the number of times in a year that effective control of executive power changes hands.[24] Column 9 also includes major cabinet changes. This variable measures the number of times in a year that a new premier is named and/or 50% of the cabinet posts are assumed by new ministers. Finally, column 10 includes a broader measure of political instability based on a combined index of domestic conflict which includes elements such as assassinations, strikes, guerrilla warfare, government crises, purges, riots, revolutions, and anti-government demonstrations. In all cases our main results strongly hold to the inclusion of political instability factors.

6.4 Governance factors

One could also argue that it is not high CBI but simply good governance that may be leading to our results. To control for this possibility, we use governance data from International Country Risk Guide (ICRG). In particular we use, bureaucracy quality which measures the institutional strength and quality of the bureaucracy, and investment profile which is an assessment of factors affecting the risk to investment that are not covered by other political, economic and financial risk components (such as contract viability/expropriation, profits repatriation, and payment delays). Table 4, columns 11 and 12 show that our main empirical implications withstand.

[24] Such a change requires that the new executive be independent of his predecessor.

6.5 Economic structural/development factors

As discussed in Edwards and Tabellini (1991) and Aisen and Veiga (2006, 2008), a set of economic structural/development variables that reflect characteristics of the countries may affect their capacity to control inflation and rely on regular taxation. First, it has been argued that governments with a large agricultural sector will tend to rely more heavily on taxes with low administering cost, such as seigniorage and trade taxes. Second, it has been typically argued that the use of regular taxes on foreign trade increases with a country's openness because it is easier to tax international trade. Last, it has also been argued that it is easier to tax urban populations than rural populations. Table 4, column 13 controls by the importance of agriculture (measured as the share of value added of agriculture in GDP), column 14 includes the importance of trade (measured as imports plus exports as share of GDP), and column 15 also controls for the degree of urbanization (measured as share of urban population in total population). In all cases our main results strongly hold to the inclusion of economic structural/development factors.

To summarize, the main findings obtained in section 5 strongly hold; our results do not seem to be driven by omitted variables. This extended regression analysis also supports and complements the preliminary findings described in Section 4.

7 Alternative measures of tax policy, seigniorage, and central bank independence

In this section we test the robustness of our findings using alternative measures of tax policy, seigniorage, and CBI. Table 5 estimates are similar to the regression of Table 4, column 15 (i.e., it includes the lagged dependent variable as a regressor, country fixed-effects, decade dummies as well as all control variables used in section 6).

Instead of inflation, Table 5, column 1 uses seigniorage revenues (% of GDP) calculated as the change in reserve money as percentage of GDP. Even though the sample of countries shrink almost in half, our main empirical implications withstand. In column 2, we use adjusted inflation (as in Table 4) but we proxy tax policy using the VAT rate (instead of the tax burden). Our main results strongly hold even though our sample is also reduced

almost in half.[25,26]

We now use an alternative CBI measure. In particular, we use legal CBI (LVAW) instead of a de facto CBI (TOR). In particular, Table 5, columns 3 and 4 are equivalent to Table 4, column 15 and Table 5, column 1 but using LVAW instead of TOR. Our main empirical implications strongly withstand.

To summarize, the main findings obtained in sections 4, 5, and 6 strongly hold; our results are also robust to alternative measures of tax policy, seigniorage, and CBI.

8 Conclusions

The current theoretical literature initiated by Phelps (1973) and developed further by Marty (1976), Siegel (1978), Drazen (1979), Chamley (1985), Tobin (1986), Mankiw (1987), Grilli (1988), Poterba and Rotemberg (1990) and Chari and Kehoe (1999), among others, predicts that inflation and tax rates should be positively correlated. That is to say, the optimum policy requires "some" use of each of the available distorting taxes, including the inflation tax, in order to reduce the extent to which any of the others must be used.

While theoretically appealing, empirical studies find virtually no support for this key implication (Roubini and Sachs, 1989; Poterba and Rotemberg, 1990; Edwards and Tabellini, 1991; Roubini, 1991). In many studies, inflation and tax rates are not found to be statistically related to each other and, more strikingly, in many cases they have been found to be negatively correlated.

This paper solves the puzzle by reasonably considering the role of CBI. A key assumption of current theoretical literature is that while government policy is executed by different agencies or branches, such as the fiscal authority and central bank, there is no goal independence for each of these branches. In other words, the fiscal authority and central bank fully cooperate towards the common objective of reducing overall excess burden of taxation. While it is intrinsic for fiscal authority goals to minimize deadweight loss of taxation, it is less obvious that revenue considerations of seigniorage are a key element in positive theory of monetary policy.

[25] While we have VAT rate data for 40 countries, we only have other relevant macroeconomic, ideology, political instability, governance, and economic structural/development variables for 33 countries.

[26] When using the VAT rate and seigniorage, the sign of our main findings hold but their significance is significatively reduced. This occurs because the size of our sample is significatively affected; it reduces to just 12 countries.

Using a simple optimal taxation and seigniorage model, we show that the optimal relationship between inflation and tax rates greatly depends upon the degree of CBI. First, if CBI is low, the fiscal authority effectively controls the monetary policy and, consequently, she considers inflation as "just another tax." Equivalent to current theoretical literature, but due to different arguments, inflation and tax rates are positively related. In those papers their relationship is the natural result of a benevolent government that coordinates both fiscal and monetary policies to minimize the deadweight loss of distortionary taxation. We rationalize such framework as one in which the central bank does not enjoy goal independence; i.e. CBI is low. We also show that the optimal relationship between inflation and tax rates is a decreasing function of the degree of CBI and that, if CBI is high, inflation and tax rates have a negative relationship. The latter occurs because an increase in the level of inflation (which increases seigniorage revenues) reduces the pressure to collect revenues via regular taxation, optimally inducing the fiscal authority to reduce the tax rate.

Our three theoretical implications are confirmed using a non-parametric as well as a regression analysis approach for a sample of 89 countries over the period 1970-2009. We find that for low levels of CBI, inflation and tax rates are positively related; such correlation decreases as CBI increases. We also find that for high levels of CBI, the relationship becomes negative. We show that these hypotheses hold for alternative measures of tax policy, seigniorage, and CBI as well as after controlling for several macroeconomic performance, ideology, political instability, governance, and economic structural/development factors. We also find that when not distinguishing among levels of CBI, the relationship between inflation and tax rates is negative across the board. That is to say, we show that if CBI arguments are not considered, the evidence does not support the key implication offered by current theoretical literature. However, by considering the role of CBI, we are able to reconcile theory with empirics.

9 Appendices

9.1 Appendix of proofs

The PA's problem consists in choosing $\{c_{1t}, c_{2t}, m_t\}$ for all $t \in [0, \infty)$ to maximize (1) subject to (2) and (3) taking as given θ_t and i_t. Assuming that $\beta = r$ we obtain from optimal conditions

$$m_t = k \cdot c_{1t} = k \frac{1}{\lambda^{PA}(1 + ki_t)}, \tag{15}$$

$$c_{2t} = \frac{1}{\lambda^{PA}(1 + \theta_t)}, \tag{16}$$

where λ^{PA} is the is the Lagrange multiplier associated with the PA's budget constraint (2). Replacing (15)-(16) in (2) we obtain

$$\frac{1}{\lambda^{PA}} = \frac{r}{2} \int_0^{\infty} (y_t + g_t) e^{-rt} dt. \tag{17}$$

9.1.1 Proposition 1

If CBI is low, the FA effectively selects $\{\theta_t, \pi_t\}$ for all $t \in [0, \infty)$ to maximize (1) subject to (5) and (15)-(17). Assuming that $\beta = r$ we obtain from optimal conditions

$$\frac{\theta_t}{1 + \theta_t} = \frac{ki_t}{1 + ki_t}. \tag{18}$$

From (18) it is clear

$$\frac{d\theta_t}{d\pi_t} = k \frac{(1 + \theta_t)^2}{(1 + ki_t)^2} > 0. \tag{19}$$

9.1.2 Proposition 2

If CBI is high, the CB selects $\{\pi_t\}$ for all $t \in [0, \infty)$ to minimize (6) and the FA selects $\{\theta_t\}$ for all $t \in [0, \infty)$ to maximize (1) subject to (5) and (15)-(17). Assuming that $\beta = r$ we obtain from optimal conditions

$$\frac{\theta_t}{1 + \theta_t} = \Omega - \frac{i_t k}{1 + ki_t}, \tag{20}$$

where $\Omega \equiv \left(2\int_0^{\infty} g_t e^{-rt}dt\right) / \left(\int_0^{\infty} (y_t + g_t)\, e^{-rt}dt\right) > 0$. From (20) it is clear

$$\frac{d\theta_t}{d\pi_t} = k\frac{(1+\theta_t)^2}{(1+ki_t)^2} < 0.$$

9.1.3 Proposition 3

Defining α as the proportion (i.e. $1 \geqslant \alpha \geqslant 0$) to which the policies are determined under the presence of an independent central bank, we can combine (18) and (20) to obtain

$$\frac{\theta_t}{1+\theta_t} = \alpha\Omega + (1-2\alpha)\frac{ki_t}{1+ki_t}. \tag{21}$$

From (21) it is clear

$$\frac{d\theta_t}{d\pi_t} = (1-2\alpha)\, k\frac{(1+\theta_t)^2}{(1+ki_t)^2} \gtrless 0, \tag{22}$$

$$\frac{d\left(d\theta_t/d\pi_t\right)}{d\alpha} = -2k\frac{(1+\theta_t)^2}{(1+ki_t)^2} < 0. \tag{23}$$

9.2 Appendix of data

Inflation
Inflation rate based on consumer price index. Source: Global Financial Data.

Seigniorage revenues (% of GDP)
Calculated as the change in reserve money as percentage of GDP. Source: International Finance Statistics (IFS-IMF).

Tax burden
Calculated as the percentage of general government revenues to GDP. Sources: Kaminisky, Reinhart and Vegh (2004) and Global Financial Data.

TOR
7-year centered moving average turnover rate of central bank governor. We call the heads of the central bank "governors" independent of whether their actual job title is governor, director or president. Source: Vuletin and Zhu (2011), Central Bank's websites, and emails exchanged with those institutions. Similar results are obtained if we use Sturm and de Haan (2001), Dreher et al (2008 and 2010).

LVAW
Legal central bank independence index. The potential range for the legal central bank independence is from 0 (minimal independence) to 1 (maximum independence). Sources: Until the year 1989 we use data from Cukierman et al (1992); since 1990 we use data from Jácome and Vázquez (2008).

Bank crises

Dummy variable equal to 1 if there is a systemic bank crises; 0 otherwise. Sources: Kindleberger (2000) and Reinhart (2010).

IMF program

Dummy variable equal to 1 if there is an IMF program; 0 otherwise. Source: Reinhart (2010) and International Financial Statistics (IFS-IMF).

Default

Dummy variable equal to 1 if there is a rated foreign sovereign default on bonds or banks; 0 otherwise. Source: Reinhart (2010).

GDP cycle

Real gross domestic product cycle. Real gross domestic product is defined as gross domestic product deflated by the GDP deflator. The cyclical component has been estimated using the Hodrick-Prescott filter. Source: World Economic Outlook (WEO-IMF) and International Financial Statistics (IFS-IMF).

Party ideology right

Dummy variable equal to 1 if party orientation is right; 0 otherwise. Party orientation with respect to economic policy, coded based on the description of the party in the sources, using the following criteria: Right: for parties that are defined as conservative, Christian democratic, or right-wing. Left: for parties that are defined as communist, socialist, social democratic, or left-wing. Center: for parties that are defined as centrist or when party position can best be described as centrist (e.g. party advocates strengthening private enterprise in a social-liberal context). Not described as centrist if competing factions "average out" to a centrist position (e.g. a party of "right-wing Muslims and Beijing-oriented Marxists"). Source: Database of Political Institutions (DPI).

Party nationalist

Dummy variable equal to 1 if party's platform is nationalist; 0 otherwise. Party is listed as nationalist in Europa, Banks, Political Handbook, or www.agora.com. A primary component of the party's platform is the creation or defense of a national or ethnic identity. Examples: parties that have fought for independence, either militarily or politically, from a colonial power; advocates persecution of minorities; is listed as "xenophobic" on the Agora website. Source: Database of Political Institutions (DPI).

Δ effective executive

Changes in effective executive. The number of times in a year that effective control of executive power changes hands. Such a change requires that the new executive be independent of his predecessor. Source: Cross-National Time-Series Data Archive (CNTS).

Major cabinet changes

The number of times in a year that a new premier is named and/or 50% of the cabinet posts are assumed by new ministers. Source: Cross-National Time-Series Data Archive (CNTS).

Domestic conflict index

Weighted domestic conflict measure. The specific weights being variable. As of October 2007 the values entered were: assassinations (25), strikes (20), guerrilla warfare (100), government crises (20), purges (20), riots (25), revolutions (150), and anti-government demonstrations (10). Source: Cross-National Time-Series Data Archive (CNTS).

Investment profile

This is an assessment of factors affecting the risk to investment that are not covered by other political, economic and financial risk components. The risk rating assigned is the sum of three subcomponents (contract viability/expropriation, profits repatriation, payment delays). Each with a maximum score of four points and a minimum score of 0 points. A score of 4 points equates to very low risk and a score of 0 points to very high risk. Source: International Country Risk Guide (ICRG).

Bureaucracy quality

The institutional strength and quality of the bureaucracy is another shock absorber that tends to minimize revisions of policy when governments change. Therefore, high points are given to countries where the bureaucracy has the strength and expertise to govern without drastic changes in policy or interruptions in government services. In these low risk countries, the bureaucracy tends to be somewhat autonomous from political pressure and to have an established mechanism for recruitment and training. Countries that lack the cushioning effect of a strong bureaucracy receive low points because a change in government tends to be traumatic in terms of policy formulation and day-to-day administrative functions. Source: International Country Risk Guide (ICRG).

Agriculture (% of GDP)

Agriculture, value added (% of GDP). Agriculture corresponds to ISIC divisions 1-5 and includes forestry, hunting, and fishing, as well as cultivation of crops and livestock production. Value added is the net output of a sector after adding up all outputs and subtracting intermediate inputs. It is calculated without making deductions for depreciation of fabricated assets or depletion and degradation of natural resources. The origin of value added is determined by the International Standard Industrial Classification (ISIC), revision 3. Note: For VAB countries, gross value added at factor cost is used as the denominator. Source: World Development Indicators (WDI).

Trade (% of GDP)

Sum of exports and imports of goods and services measured as a share of gross domestic product. Source: World Development Indicators (WDI).

Urban (% of population)

Urban population refers to people living in urban areas as defined by national statistical offices. It is calculated using World Bank population estimates and urban ratios from the United Nations World Urbanization Prospects. Source: World Development Indicators (WDI).

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Table 1. Summary statistics. Tax burden (as % of GDP), inflation, VAT rate, and seigniorage (as % of GDP).

Country	Average tax burden	Average inflation	Average VAT rate	Average seigniorage
Algeria	32.9	14.0		
Argentina	16.3	260.4	18.4	1.3
Australia	31.4	6.5		0.4
Austria	48.7	4.2	18.9	0.6
Bangladesh	8.5	12.6		0.9
Belgium	48.0	4.8	18.6	
Bolivia	20.8	109.4		2.6
Botswana	45.3	10.4		
Brazil	30.5	333.6		2.0
Bulgaria	40.7	67.5	19.9	
Canada	41.8	4.5	6.7	
Cape Verde	32.7	3.7		1.2
Chile	23.1	53.6		0.6
China	15.3	7.2		1.6
Colombia	21.7	20.0		1.6
Costa Rica	11.2	17.2		1.1
Cyprus	36.4	5.0	5.0	
Czech Republic	42.5	4.5	20.9	
Dominican Republic	15.5	14.7	11.6	2.1
Ecuador	18.3	27.3	8.2	
Egypt	30.1	10.8	10.0	
El Salvador	16.9	10.5	12.5	0.3
Estonia	37.7	75.7	17.2	
Finland	46.9	6.8	22.0	
France	46.3	6.2	19.2	
Gambia The	25.1	12.2		1.3
Germany	45.4	3.4	13.1	0.4
Ghana	15.1	37.6		
Greece	32.7	14.0	17.7	
Guatemala	11.6	10.7	9.4	1.2
Haiti	8.7	13.9		3.7
Honduras	20.8	12.0		2.6
Hungary	44.0	10.2	24.1	1.4
Iceland	28.3	20.5		0.5
India	18.0	8.2		
Indonesia	17.9	13.6		1.6
Iran	25.7	17.9		
Ireland	36.9	8.3	22.3	
Israel		52.6	15.7	
Italy	40.4	9.6	16.3	
Jamaica	25.3	18.9		0.4
Japan	28.1	3.1	4.2	
Jordan	26.9	7.0		1.1
Kenya	26.6	13.3		0.3
Korea	19.2	7.5	10.0	
Latvia	36.1	10.1	18.0	
Lithuania	34.3	18.0	18.1	1.0
Madagascar	12.9	15.0		
Madagascar	12.9	15.0		
Malaysia	30.7	4.0		1.5
Mauritius	21.9	10.0		
Mexico	22.3	29.4	12.8	0.9
Mongolia	30.1	61.2		
Morocco	23.8	5.9		
Mozambique	23.2	10.9		1.1
Nepal	13.0	8.2		0.2
Netherlands	51.2	4.2	17.5	
New Zealand	34.5	7.4	12.1	
Nigeria	24.8	25.7		
Norway	50.2	5.9		
Pakistan	17.0	8.9		
Paraguay	13.6	14.2	10.0	1.6
Peru	14.6	177.7		0.5
Philippines	16.8	11.8		1.1
Poland	40.2	54.1	22.0	0.8
Portugal	36.8	13.9	16.6	
Romania	22.5	65.7	19.1	
Rwanda	13.2	10.2		
Seychelles	48.0	3.7		
Singapore	27.8	2.9	4.2	
South Africa	25.6	10.1	13.8	0.6
Spain	36.4	9.8	13.8	
Sri Lanka	20.2	10.2		
Sudan	12.4	40.1		
Swaziland	28.9	12.0		
Sweden	59.6	5.6	22.4	0.1
Switzerland	35.6	2.9	7.3	0.6
Syrian Arab Republic	24.7	12.2		3.9
Tanzania	16.3	19.7		1.8
Thailand	16.7	5.7		
Trinidad and Tobago	29.8	9.2		0.7
Tunisia	29.1	5.9		
Turkey	21.6	43.9	12.9	2.4
Uganda	12.8	46.6		0.7
United Kingdom	39.2	6.5	14.9	0.3
United States	28.1	4.8		0.4
Uruguay	27.9	43.7	19.4	2.2
Venezuela	27.5	25.4		1.8
Zambia	25.3	61.5		1.3
Zimbabwe	28.2	67.8		
Average	*28.0*	*27.1*	*14.9*	*1.2*
Median	*27.2*	*10.9*	*16.0*	*1.1*
Min	*8.5*	*2.9*	*4.2*	*0.1*
Max	*59.6*	*333.6*	*24.1*	*3.9*
Countries with data	*89*	*90*	*40*	*46*

Table 2. Summary statistics. Central bank independence.

Country	Average TOR	Average frequency of central bank governor replacement	Average LVAW
Algeria	0.21	4 years and 9 months	
Argentina	0.80	1 year and 2 months	0.53
Australia	0.14	7 years and 4 months	0.36
Austria	0.20	5 years	0.61
Bangladesh	0.23	4 years and 4 months	
Belgium	0.12	8 years and 2 months	0.17
Bolivia	0.60	1 year and 8 months	0.46
Botswana	0.19	5 years and 3 months	0.33
Brazil	0.61	1 year and 7 months	0.31
Bulgaria	0.20	4 years and 11 months	
Canada	0.11	9 years and 5 months	0.45
Cape Verde	0.12	8 years and 4 months	
Chile	0.42	2 years and 4 months	0.60
China	0.23	4 years and 5 months	0.29
Colombia	0.14	6 years and 11 months	0.44
Costa Rica	0.51	1 year and 11 months	0.56
Cyprus	0.06	16 years and 4 months	
Czech Republic	0.18	5 years and 7 months	
Dominican Republic	0.44	2 years and 3 months	
Ecuador	0.82	1 year and 2 months	0.68
Egypt	0.21	4 years and 8 months	0.49
El Salvador	0.33	3 years	0.62
Estonia	0.17	6 years	
Finland	0.15	6 years and 8 months	0.28
France	0.17	5 years and 9 months	0.25
Gambia The	0.17	5 years and 10 months	
Germany	0.12	8 years and 1 months	0.69
Ghana	0.16	6 years	0.31
Greece	0.24	4 years and 2 months	0.55
Guatemala	0.46	2 years and 2 months	0.68
Haiti	0.55	1 year and 9 months	
Honduras	0.22	4 years and 7 months	0.47
Hungary	0.17	5 years and 9 months	0.24
Iceland	0.09	11 years and 8 months	0.34
India	0.30	3 years and 3 months	0.34
Indonesia	0.16	6 years and 2 months	0.27
Iran	0.30	3 years and 3 months	
Ireland	0.15	6 years and 8 months	0.44
Israel	0.14	6 years and 11 months	0.39
Italy	0.08	11 years and 10 months	0.25
Jamaica	0.26	3 years and 9 months	0.41
Japan	0.20	4 years and 11 months	0.18
Jordan	0.13	7 years and 5 months	
Kenya	0.16	6 years and 1 months	0.44
Korea	0.38	2 years and 7 months	0.29
Latvia	0.22	4 years and 7 months	
Lithuania	0.24	4 years and 1 months	
Madagascar	0.12	8 years and 3 months	
Malaysia	0.15	6 years and 9 months	0.36
Mauritius	0.09	11 years and 8 months	
Mexico	0.12	8 years and 2 months	0.46
Mongolia	0.19	5 years and 1 months	
Morocco	0.10	10 years	0.14
Mozambique	0.13	7 years and 7 months	
Nepal	0.19	5 years and 4 months	0.18
Netherlands	0.06	17 years	0.42
New Zealand	0.15	6 years and 8 months	0.24
Nigeria	0.16	6 years and 3 months	0.48
Norway	0.12	8 years and 2 months	0.17
Pakistan	0.27	3 years and 7 months	0.21
Paraguay	0.33	3 years	0.49
Peru	0.38	2 years and 7 months	0.56
Philippines	0.18	5 years and 7 months	0.43
Poland	0.28	3 years and 7 months	0.10
Portugal	0.22	4 years and 5 months	0.44
Romania	0.12	8 years and 5 months	
Rwanda	0.16	6 years and 4 months	
Seychelles	0.14	7 years and 4 months	
Singapore	0.12	8 years and 4 months	0.29
South Africa	0.09	11 years and 3 months	0.25
Spain	0.17	5 years and 9 months	0.57
Sri Lanka	0.16	6 years and 4 months	
Sudan	0.26	3 years and 10 months	
Swaziland	0.15	6 years and 9 months	
Sweden	0.19	5 years and 2 months	0.29
Switzerland	0.14	7 years and 2 months	0.59
Syrian Arab Republic	0.15	6 years and 6 months	
Tanzania	0.08	12 years and 6 months	0.44
Thailand	0.27	3 years and 8 months	0.27
Trinidad and Tobago	0.15	6 years and 8 months	0.50
Tunisia	0.22	4 years and 5 months	
Turkey	0.29	3 years and 5 months	0.44
Uganda	0.20	4 years and 11 months	0.38
United Kingdom	0.11	9 years	0.29
United States	0.11	8 years and 8 months	0.48
Uruguay	0.36	2 years and 9 months	0.37
Venezuela	0.33	3 years	0.55
Zambia	0.28	3 years and 6 months	0.33
Zimbabwe	0.12	8 years and 1 months	0.20
Average	*0.22*	*4 years and 5 months*	*0.39*
Median	*0.17*	5 years and 9 months	*0.39*
Min	*0.06*	*17 years*	*0.10*
Max	*0.82*	*1 year and 2 months*	*0.69*
Countries with data		89	63

Table 3. Basic panel data regressions. Dependent variable: tax burden. Independent variable: inflation.

	(1)	(2)	(3)	(4)	(5)
π	-0.006***	-0.030***	-0.007***	-0.003*	-0.003*
	[-4.1]	[-5.4]	[-3.1]	[-1.9]	[-1.8]
$\pi \cdot$ TOR		0.031***	0.004**	0.003**	0.003*
		[5.6]	[2.2]	[2.0]	[1.9]
Estimator	OLS	OLS	FE	GMM	GMM
Includes lag of dependent variable as regressor	No	No	No	Yes	Yes
Includes country fixed-effects	No	No	Yes	Yes	Yes
Includes decade dummies	No	No	No	No	Yes
Observations	2148	2148	2148	2057	2057
Countries	88	88	88	88	88

Note: See Appendix 7.2 for definition and source of variables. Constant term as well as those terms which do not interact with π and TOR are not reported.

Table 4. GMM dynamic panel data regressions with decade dummies.
Dependent variable: tax burden. Independent variable: adjusted inflation.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
π	-0.003*	-0.006***	-0.006***	-0.013***	-0.024***	-0.074***	-0.075***	-0.081***	-0.074***	-0.076***	-0.149***	-0.133***	-0.144***	-0.109***	-0.180***
	[-1.9]	[-3.6]	[-3.7]	[-3.9]	[-6.3]	[-6.5]	[-6.5]	[-6.1]	[-5.4]	[-5.6]	[-5.4]	[-4.9]	[-4.4]	[-3.3]	[-3.1]
π · TOR	0.003**	0.008***	0.008***	0.012***	0.027***	0.073***	0.072***	0.077***	0.070***	0.066***	0.142***	0.149***	0.182***	0.126**	0.369***
	[2.0]	[4.4]	[4.4]	[3.7]	[6.7]	[6.7]	[6.5]	[6.2]	[5.3]	[4.9]	[5.0]	[3.6]	[3.5]	[2.2]	[3.5]
π · TOR · bank crisis		-0.037***	-0.037***	-0.042***	-0.053***	-0.031***	-0.040***	-0.039***	-0.040***	-0.039***	-0.041***	-0.045***	-0.028*	-0.024	-0.023
		[-4.5]	[-4.3]	[-5.1]	[-6.0]	[-3.3]	[-4.0]	[-3.6]	[-3.4]	[-3.3]	[-3.2]	[-3.1]	[-1.8]	[-1.6]	[-1.5]
π · TOR · IMF program			-0.008	-0.014**	-0.023***	-0.015*	-0.021**	-0.023***	-0.025***	-0.024**	-0.026**	-0.021*	-0.007	-0.010	-0.003
			[-1.2]	[-2.0]	[-3.1]	[-1.9]	[-2.6]	[-2.7]	[-2.6]	[-2.6]	[-2.3]	[-1.9]	[-0.6]	[-0.9]	[-0.3]
π · TOR · default				-0.011***	-0.030***	-0.075***	-0.066***	-0.068***	-0.062***	-0.065***	-0.064***	-0.056***	-0.076***	-0.043**	-0.047***
				[-3.2]	[-4.6]	[-7.4]	[-6.0]	[-5.6]	[-4.3]	[-4.6]	[-3.7]	[-3.6]	[-5.2]	[-2.5]	[-2.8]
π · TOR · GDP cycle					-0.005***	0.001	-0.001	-0.001	-0.002	-0.002	-0.001	-0.000	0.001	0.003	0.004*
					[-4.2]	[0.6]	[-0.7]	[-0.8]	[-1.1]	[-0.9]	[-0.3]	[-0.2]	[0.6]	[1.2]	[1.7]
π · TOR · party ideology right						-0.039***	-0.038***	-0.038***	-0.037***	-0.026***	-0.005	0.007	0.006	0.007	-0.001
						[-6.2]	[-5.8]	[-5.7]	[-5.4]	[-3.2]	[-0.3]	[0.3]	[0.2]	[0.2]	[-0.0]
π · TOR · party nationalist							-0.045**	-0.052***	-0.060**	-0.057**	-0.086***	-0.093***	-0.089***	-0.073*	-0.034
							[-2.2]	[-2.6]	[-2.5]	[-2.3]	[-3.1]	[-2.9]	[-2.7]	[-1.9]	[-0.8]
π · TOR · Δeffective executive								-0.002	-0.013	-0.010	-0.024*	-0.023*	-0.022	-0.024*	-0.035**
								[-0.3]	[-1.2]	[-0.9]	[-1.8]	[-1.7]	[-1.6]	[-1.7]	[-2.4]
π · TOR · major cabinet changes									0.012	0.010	0.025**	0.027**	0.020*	0.025**	0.031***
									[1.2]	[1.0]	[2.3]	[2.5]	[1.9]	[2.2]	[2.9]
π · TOR · domestic conflict index										-0.000	-0.000	-0.000	0.000	0.000	0.000**
										[-1.0]	[-0.4]	[-0.6]	[0.7]	[1.3]	[2.3]
π · TOR · investment profile											-0.017***	-0.020***	-0.013**	-0.014**	-0.019***
											[-3.6]	[-3.7]	[-2.0]	[-2.2]	[-2.7]
π · TOR · bureaucracy quality												-0.001	-0.013	-0.010	-0.003
												[-0.1]	[-0.8]	[-0.5]	[-0.2]
π · TOR · agriculture (% of GDP)													-0.005**	-0.008***	-0.015***
													[-2.4]	[-3.3]	[-4.9]
π · TOR · trade (% of GDP)														0.002***	0.003***
														[3.5]	[3.7]
π · TOR · urban (% of population)															-0.002**
															[-2.3]
Observations	2057	2057	2057	1609	1588	1150	1150	1110	1110	1110	869	869	821	817	817
Countries	88	88	88	69	69	60	60	58	58	58	57	57	56	56	56

Note: See Appendix 7.2 for definition and source of variables. Constant term as well as those terms which do not interact with π and TOR are not reported.

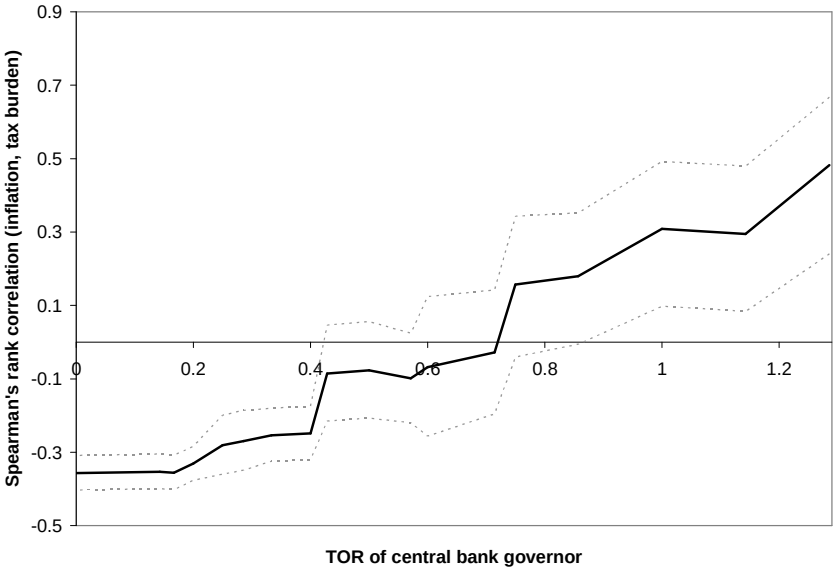
Table 5. GMM dynamic panel data regressions with decade dummies.

Dependent tax variable: Independent seign. Variable: CBI measure:	tax burden seigniorage (% of GDP) TOR	VAT rate adjusted inflation TOR	tax burden adjusted inflation LVAW	tax burden seigniorage (% of GDP) LVAW
	(1)	(2)	(3)	(4)
seign. var	-0.029* [-1.8]	-0.317*** [-4.4]	0.495*** [2.6]	0.135** [2.3]
seign. var · CBI	0.142*** [2.8]	0.861*** [3.4]	-1.407*** [-2.9]	-0.239** [-2.2]
seign. var · CBI · bank crisis	-0.072*** [-6.9]	-0.033 [-0.7]	0.017 [0.3]	0.036 [1.4]
seign. var · CBI · IMF program	-0.023*** [-3.1]	-0.027** [-2.5]	0.065 [1.5]	0.067*** [3.6]
seign. var · CBI · default	0.010 [1.3]	0.170*** [2.8]	-0.172* [-1.9]	-0.000 [-0.0]
seign. var · CBI · GDP cycle	0.007*** [5.1]	0.018*** [4.3]	-0.012 [-1.2]	-0.005 [-1.3]
seign. var · CBI · party ideology right	0.027** [2.3]	0.278*** [5.1]	0.059 [0.5]	-0.030 [-1.4]
seign. var · CBI · party nationalist	0.023 [1.3]	-0.186* [-1.8]	-0.455*** [-3.0]	0.019 [0.5]
seign. var · CBI · Δeffective executive	0.015** [2.0]	0.127*** [4.3]	0.153* [1.7]	0.007 [0.4]
seign. var · CBI · major cabinet changes	-0.016** [-2.5]	0.038* [1.7]	-0.215*** [-3.1]	0.029 [1.6]
seign. var · CBI · domestic conflict index	0.057** [2.1]	0.048 [1.2]	0.037 [0.4]	0.091 [1.5]
seign. var · CBI · investment profile	-0.001 [-0.2]	-0.041*** [-3.6]	-0.032 [-1.0]	0.006 [0.8]
seign. var · CBI · bureaucracy quality	-0.010 [-1.3]	-0.065** [-2.4]	0.014 [0.2]	-0.050*** [-3.9]
seign. var · CBI · agriculture (% of GDP)	-0.003 [-1.6]	-0.033*** [-4.7]	0.050*** [3.6]	-0.001 [-0.5]
seign. var · CBI · trade (% of GDP)	-0.000 [-1.1]	0.002* [1.7]	-0.005 [-1.6]	0.002*** [3.7]
seign. var · CBI · urban (% of population)	-0.001** [-2.5]	-0.006*** [-2.7]	0.017*** [4.0]	0.003*** [4.1]
Observations	352	418	346	198
Countries	29	33	40	18

Note: See Appendix 7.2 for definition and source of variables. Constant term as well as those terms which do not interact with π and TOR are not reported.

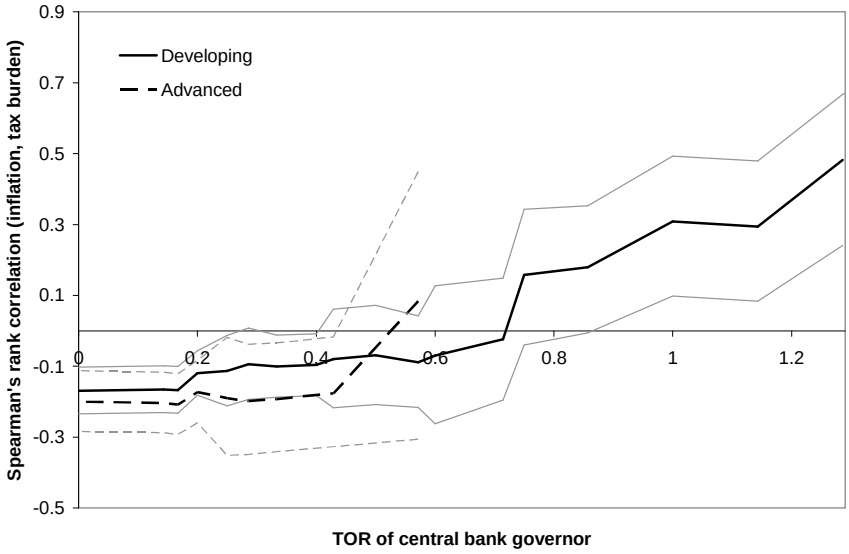
Figure 1. Evolution central bank independence measures over time. +/- 95 percent confidence interval.

Figure 2. Evolution of Spearman's rank correlation tax burden and inflation across alternative levels of TOR of central bank governor. +/- 95 percent confidence interval.



Note: 2148 observations.

Figure 3. Evolution of Spearman's rank correlation between inflation and tax burden across alternative levels of TOR of central bank governor. Developing vs. advanced countries. +/- 95 percent confidence interval.



Note: 1512 observations (for developing countries) and 636 observations. (for advanced countries).