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) it is negative for high levels of CBI. We show that these hypotheses hold for alternative measures of tax rates, groups of countries, and macroeconomic theories regarding the determination of the level of inflation.

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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.

[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.

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 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 built on this type 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 (Cooley and Hansen, 1995; Talvi and Végh, 2005; Kaminsky, Reinhart, and Végh, 2005).

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 the 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 goal independence 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 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 the 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.

If CBI is high, however, inflation is set by the central bank and is essentially divorced from fiscal considerations. 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 three predictions of the model by calculating the relationship between inflation and tax rates for alternative levels of CBI. To this effect we use both non-parametric – as in de Haan and Zelhorst (1990) – and regression analysis and a sample of 89 countries for the period 1970-2009. As is tradition in this literature, we proxy tax rates using the tax burden (i.e. ratio of government revenues to GDP). We proxy CBI using the turnover rate of central bank governors, which became the yardstick de facto measure of CBI after the seminal papers of Cukierman (1992) and 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).[2]

We find that for low levels of CBI (i.e. high turnover rates of central bank governors) inflation and tax burden are positively related; this correlation decreases as CBI increases, and for high levels of CBI (i.e. low turnover rates of central bank governors) the relationship becomes negative.

We also perform three robustness checks. First, we present complementary evidence using a novel dataset on value-added tax rates for 33 countries for the period 1970-2009. Second, we test whether our findings are general across countries or if they only apply to a particular group of countries, such as developed or developing. Third, we test whether our empirical results are robust to relevant macroeconomic theories regarding the determination of the level of inflation including cost-push as well as fiscal and financial distress arguments. Our main findings strongly hold for alternative measures of tax rates, groups of countries, and fiscal and macroeconomic conditions.

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 non-parametric analysis. Section 5 turns to regression analysis. In Section 6 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 con-

[2] We use this de facto measure as opposed to alternative legal measures of CBI because of the weak link between legal and actual independence derived from low levels of rule of law and transparency, especially in developing countries (Cukierman, 1992; Cukierman et al, 1992).

sisting 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 Végh 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).[3]

2.1 Private agent

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

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

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

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

where 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. $k > 0$).

[3]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.

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).[4] 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

[4] 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.

words, under high CBI (low CBI) the central bank does (does not) enjoy goal independence.[5] If independent, the central bank aims to minimize the deviation of inflation from an implicit or explicit target ($\widetilde{\pi}$)[6,7]

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

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 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 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[8]

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

Proposition 2 *If CBI is high, inflation and 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

[5] 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).

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

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

[8] Appendix 7.1.1 shows this derivation.

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[9]

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

Proposition 3 *The optimal relationship between inflation and 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 way . Solving the model, we obtain[10]

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

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

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

[9] Appendix 7.1.2 shows this derivation.
[10] Appendix 7.1.3 shows this derivation.

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 annual panel dataset consists of inflation, tax rates and CBI data.[11] The sample comprises 26 advanced and 63 developing countries for the period 1970-2009.[12] We obtain inflation data from Global Financial Data.

We use two alternative measures of tax rates. On one hand, as has been tradition in this literature, we use the tax burden, which is proxied by the percentage of government revenues to GDP. We obtain this dataset for 89 countries from Kaminsky, Reinhart and Végh (2004) and Global Financial Data. On the other hand, we built a novel value-added tax (VAT) rates dataset. 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.[13] Unlike personal and corporate taxes, which have several tax rates, this single-rate feature allows the researcher to clearly asses 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.[14] For some economies this tax is one of the most valuable taxes in terms

[11] Appendix 7.2 shows all definitions and sources of data.

[12] 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.

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

[14] These 40 countries are Argentina, Austria, Belgium, Bulgaria, Canada, Cyprus, Czech Republic, Dominican Republic, Ecuador, Egypt, El Salvador, Estonia, Finland, France, Ger-

of tax collection (e.g. it comprises more than 55 percent of total revenues for Mexico). However, for others, this tax is less valued (e.g. it makes up less than 15 percent of total revenues for Japan), reducing the extent to which it is able to capture the stance of the overall tax policy. For this reason, we exclude from our empirical exercise regarding VAT tax rates, seven countries where the percentage of taxes on goods and services to total revenues is below one standard deviation from the sample mean.[15]

Table 1 shows the average and standard deviation of inflation, tax burden and VAT tax rate for each country in the sample. 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. Average and median tax burden is 27.7 and 26.7 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 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.

We use a de facto oriented measure of CBI 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). We use this de facto measure instead of alternative legal measures of CBI; this is due to the weak link between legal and actual independence, which derived from low levels of rule of law and transparency, especially in developing countries.

many, 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.

[15] The seven countries excluded, with their respective average percentage of taxes on goods and servicies to total revenues are: Canada (16.92), Egypt (16.87), Germany (20.86), Italy (21.74), Japan (14.29), Singapore (19.08) and Spain (20.25).

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).[16] This approach allows 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 has the highest turnover rate 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.

For robustness tests we also use the following data: bank crises from Kindleberger (2000) and Reinhart (2010), sovereign default from Reinhart (2010), IMF program from Reinhart (2010) and International Financial Statistics (IMF), and fiscal deficits from Kaminsky, Reinhart and Végh (2004) and Global Financial Data.

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

4 Non-parametric analysis

In this section we perform a non-parametric 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, $-1 \geqslant \rho_i \geqslant 1$. A value of $\rho_i = 1$ ($\rho_i = -1$) would indicate a 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.[17,18]

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.

We start by testing our three key theoretical implications using tax burden as a proxy for tax rate (Section 4.1). Sections 4.2 and 4.3 perform robustness checks using alternative measures of tax rates and samples of countries. Section 4.4 analyzes whether our empirical results are robust to relevant macroeconomic theories regarding the determination of the level of inflation, including cost-push as well as fiscal and financial distress arguments.

[17] 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.

[18] 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.

4.1 Benchmark results

This section tests the three key implications of our theoretical model: i) the optimal relationship between inflation and tax rates is negative for high levels of CBI (i.e. when TOR is low), ii) the optimal relationship between inflation and tax rates is a decreasing function of the degree of CBI or, alternatively, an increasing function of TOR, and iii) when CBI is low (i.e. TOR is high), the optimal relationship between inflation and tax rates is positive.

Figure 1 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 for tax rate. We strongly confirm the three key implications of our theoretical model. First, the optimal relationship between inflation and 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 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.

4.2 VAT tax rates

In this section we show complementary evidence to that presented in Section 4.1. For this purpose, we use a novel dataset of VAT tax rates for 33 countries. While the sample size is notably smaller, the general result holds.

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 VAT tax rates are used as proxy for tax rate. We strongly confirm the three key implications of our theoretical model. First, the optimal relationship between inflation and tax rates is negative when TOR is low (that is to say, when CBI is high). For example, for ρ_0 the relationship is negative and equal to -0.162. Such coefficient is statistically negative since $\left[\rho_0^-, \rho_0^+\right] = [-0.253, -0.067]$. The relationship between inflation and tax rate is statistically negative for TOR categories smaller than or equal to 0.2 ($\rho_{0.2}$). 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 $\rho_{1.14}$ the relationship is positive and equal to 0.726. Such coefficient is statistically positive since $\left[\rho_0^-, \rho_0^+\right] = [0.547, 0.842]$. The relationship between inflation and tax rate is statistically positive for TOR categories greater than or equal to 0.71 ($\rho_{0.71}$).

Similar to Section 4.1, if we did not distinguish between alternative TOR categories, the overall Spearman's rank correlation coefficient would be -0.193, with 95 percent confidence lower and upper bound intervals of -0.261 and -0.122. That is to say, when not differentiating across levels of CBI, we cannot reject the null that the relationship between inflation and tax rate is statistically negative. In other words, if we did not consider the role of CBI, our empirical findings would, as does most current empirical literature, reject the positive relationship implied by current models of optimal taxation and seigniorage.

4.3 Advanced vs. developing countries

In this section we test whether our findings from Section 4.1 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.[19]

Figures 3 and 4 show the same correlations as Figure 1 for developing and advanced countries, respectively.[20] Naturally, 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 1.28 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 1, the relationship is neither positive nor negative. For low levels of CBI (when TOR is higher than 1), developing countries show, as does Section 4.1, 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 Section 4.1 when CBI is low are mainly driven by the performance of developing countries.

Similar to the findings of Sections 4.1 and 4.2, 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 tax rate.

4.4 Macroeconomic theories regarding the determination of the level of inflation

In this section we test whether our findings are robust to some of the most common macroeconomic theories regarding the determination of the level of inflation. We consider cost-push and business cycle arguments, as well as those that link inflation with periods of fiscal and financial distress. It is important to remark that, while not modeled in our paper, these theories do not necessarily compete with ours. The propositions developed in Section 2.4 do not provide

[19] 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 1 percent significant level.

[20] 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.

implications regarding the level of inflation, but rather about its relationship with the tax rate. In other words, the positive (negative) relation between inflation and tax rate implied by our model in the case of low (high) CBI could, in principle, occur at high or low levels of inflation.

To fix ideas, suppose CBI is low and, consequently, the FA effectively uses both tax rate and inflation to finance a certain path of spending. An unanticipated sharp increase in government spending will increase the fiscal deficit at the given tax rate and inflation. Following the reasoning of our model, both tax rate and inflation will increase in order to equalize the burden of taxation, leaving the positive association between tax rate and inflation unaffected at naturally higher levels for each of them. In the following sections we test the orthogonality, independence, and robustness of our findings to common macroeconomic theories regarding the determination of the level of inflation.

4.4.1 Cost-push inflation

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).

Figure 5 shows the same type of correlations as Figure 1, using 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).[21] 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.

Similar to the findings in Sections 4.1, 4.2, and 4.3, if we did not distinguish between alternative TOR categories, the overall Spearman's rank correlation coefficient would be -0.329 with 95 percent confidence lower and upper bound intervals of -0.366 and -0.291.

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

4.4.2 Fiscal and financial distress

A well-established theory in macroeconomics is that fiscally dominant governments running persistent deficits have to finance those deficits sooner or later with monetization, ultimately increasing inflation (Sargent and Wallace, 1981). This view has been particularly 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 the central banks – increase the dependence on the inflation tax (Alesina and Drazen, 1991; Calvo and Reinhart, 2000; Calvo and Végh, 1999; Cukierman, 1992; Cukierman et al, 1992, Lohmann, 1992; Rogoff, 1985).

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." Last, but certainty not least, inflation is positively associated with fiscal deficits; the Spearman's rank correlation coefficient between inflation and fiscal deficit is 0.15 and statistically significant at a level of 1 percent.

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. Figures 6, 7, and 8 show that the empirical findings of Figure 1 hold after excluding observations associated with banking crisis, sovereign debt default, and IMF programs, even though these exclusions reduce the sample size by 4.05, 14.57, and 13.59 percent, respectively. Similar to the findings in Sections 4.1, 4.2, 4.3, and 4.4.1, if we did not distinguish between alternative TOR categories, the overall Spearman's rank correlation coefficient associated with Figures 6, 7, and 8 would be -0.370, -0.380, and -0.373, respectively. In all three cases we cannot reject a negative relationship between tax burden and inflation.

Figures 9 and 10 show the same correlations as Figure 1 when fiscal deficit as a percentage of GDP is above and below the overall sample's median value of 3.43 percent. The mean fiscal deficit as a percentage of GDP of the first group is 7.57 percent, in clear contrast with that of the second group, 0.45 percent. Such difference is statistically significant at a level of 1 percent. The main findings also hold for each subsample, implying that the optimal relationships between tax rate and inflation derived by the model hold for alternative levels of fiscal deficits. Similar to the findings of Sections 4.1, 4.2, 4.3, and 4.4.1, if we did not distinguish between alternative TOR categories, the overall Spearman's rank correlation coefficient associated with Figures 9 and 10 would be -0.357 and -0.358, respectively. In both subsamples we cannot reject a negative relationship between tax rate and inflation.

4.4.3 Business cycles

In this section we test whether the state of the economy, in particular its business cycle, could be driving the way CBI affects the relation between inflation and tax rate. Figures 11 and 12 show the same correlations as Figure 1 for "good" and "bad" times, respectively. The general results strongly hold for each subsample. Therefore, the stance in the business cycle does not affect differently the way in which CBI affects the relation between inflation and tax rate.

Similar to the findings of Sections 4.1, 4.2, 4.3, 4.4.1, and 4.4.2, if we did not distinguish between alternative TOR categories, the overall Spearman's rank correlation coefficient associated with Figures 11 and 12 would be -0.336 and -0.371, respectively. In both subsamples we cannot reject a negative relationship between tax rate and inflation.

To summarize, our main findings strongly hold for alternative measures of tax rates, groups of countries, and some of the relevant theories regarding the determination of the level of inflation. We support this assertion by i) using alternative measures of tax rates such as VAT tax rate, ii) checking for institutional and macroeconomic differences across advanced and developing countries, iii) modifying the inflation variable to control for external inflation/disinflation trends associated with external shocks such as oil prices, iv) reducing the influence of extremely stressful fiscal and financial events by excluding events associated with banking crises, sovereign debt defaults, and IMF programs, and v) splitting the sample according to level of fiscal deficit and stance in the business cycle.

5 Regression analysis

In this section we turn to regression analysis, which complements the analysis of Section 4. A clear advantage of regression analysis is that several control variables could be introduced simultaneously to address omitted variables concerns. As 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:

$$TAX_{it} = \alpha + \beta_1 \cdot INF_{it} + \varepsilon_{it}. \quad (12)$$

Similar to previous studies, we find that inflation and tax burden relates negatively (Table 3, column 1), which contradicts the key distinctive theoretical implication derived from current models of optimal taxation and seigniorage. Similar results are obtained if VAT tax rates are used (Table 3, column 4).

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

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

where (13) is similar to (12), but it also includes TOR and its interaction with INF. Table 3, column 2 strongly supports the predictions of our model using tax burden. First, when CBI is high – proxied by TOR=0 as extreme case – tax rate and inflation relate negatively (i.e., $\beta_1 < 0$). Second, when CBI is low – proxied by the maximun observed TOR value – tax rate and inflation relate positively. Last, the relationship between tax rate and inflation is a decreasing function of the degree of CBI or, alternatively, an increasing function ot TOR (i.e., $\beta_2 > 0$). Table 3, column 5 also strongly supports the predictions of our model using the novel VAT tax rate data.

Table 3, columns 3 and 6 allow for country fixed-effects. The previous results strongly hold. 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.

Similar in spirit to Section 4.4, columns 7 through 11 introduce alternative control variables one-at-a-time, which could potentially be at the roots of the way CBI affects the relation between inflation and tax rate. If this was the case, our previous regression analysis findings would be the result of omitted variables which relate to particular macroeconomic circumstances. In column 7 inflation is substituted for adjusted-inflation. Columns 8, 9, 10 and 11 introduce banking crisis, IMF programs, default episodes and real GDP cycle, respectively. Column 12 includes all factors at the same time and column 13 also allows for country-fixed effects. The main findings strongly hold; our results do not seem to be driven by omitted variables. This regression analysis supports and complements the non-parametric findings described in Section 4.

6 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.

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. For this purpose we built a novel VAT tax rates dataset. 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. Our main findings strongly hold for alternative measures of tax rates, groups of countries and macroeconomic theories regarding the determination of the level of inflation. 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.

7 Appendices

7.1 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

$$m_t = k \cdot c_{1t} = k \frac{1}{\lambda^{PA} (1 + k i_t)}, \tag{14}$$

$$c_{2t} = \frac{1}{\lambda^{PA} (1 + \theta_t)}, \tag{15}$$

where λ^{PA} is the is the Lagrange multiplier associated with the PA's budget constraint (2). Replacing (14)-(15) in (2) we obtain

$$\frac{1}{\lambda^{PA}} = \frac{r}{2}\int_0^{\infty} (y_t + g_t)\, e^{-rt} dt. \tag{16}$$

7.1.1 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 (14)-(16). Assuming that $\beta = r$ we obtain from optimal conditions

$$\frac{\theta_t}{1+\theta_t} = \frac{ki_t}{1+ki_t}. \tag{17}$$

From (17) it is clear

$$\frac{d\theta_t}{d\pi_t} = k\frac{(1+\theta_t)^2}{(1+ki_t)^2} > 0. \tag{18}$$

7.1.2 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 (14)-(16). Assuming that $\beta = r$ we obtain from optimal conditions

$$\frac{\theta_t}{1+\theta_t} = \Omega - \frac{i_t k}{1+ki_t}, \tag{19}$$

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 (19) it is clear

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

7.1.3 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 (17) and (19) to obtain

$$\frac{\theta_t}{1+\theta_t} = \alpha\Omega + (1-2\alpha)\,\frac{ki_t}{1+ki_t}. \tag{20}$$

From (20) it is clear

$$\frac{d\theta_t}{d\pi_t} = (1-2\alpha)\,k\frac{(1+\theta_t)^2}{(1+ki_t)^2} \gtrless 0, \tag{21}$$

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

7.2 Appendix of data

Inflation

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

Tax burden

Calculated as the percentage of general government revenues to GDP. Sources: Kaminisky, Reinhart and Végh (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.

Bank crises

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

Default

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

IMF program

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

Fiscal deficit

Calculated as the percentage of general government fiscal deficit to GDP. Sources: Kaminisky, Reinhart and Végh (2004) and Global Financial Data.

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).

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Table 1. Summary statistics. Inflation, tax burden and VAT tax rate.

Country	Average inflation	Standard deviation inflation	Average tax burden	Standard deviation tax burden	Average VAT tax rate	Standard deviation VAT tax rate
Algeria	14.0	8.6	32.9	4.3		
Argentina	260.4	796.3	16.3	5.6	18.4	3.0
Australia	6.5	4.4	31.4	3.5		
Austria	4.2	2.3	48.7	3.8	18.9	1.4
Bangladesh	12.6	21.8	8.5	3.1		
Belgium	4.8	3.4	48.0	1.4	18.6	1.5
Bolivia	109.4	405.3	20.8	5.7		
Botswana	10.4	2.8	45.3	5.9		
Brazil	333.6	614.6	30.5	9.2		
Bulgaria	67.5	149.2	40.7	1.1	19.9	1.1
Canada	4.5	3.4	41.8	3.5	6.7	0.7
Cape Verde	3.7	3.9	32.7	4.5		
Chile	53.6	108.7	23.1	3.4		
China	7.2	9.2	15.3	2.9		
Colombia	20.0	7.2	21.7	4.0		
Costa Rica	17.2	16.1	11.2	2.6		
Cyprus	5.0	3.5	36.4	4.6	5.0	0.0
Czech Republic	4.5	3.2	42.5	5.1	20.9	1.6
Dominican Republic	14.7	16.3	15.5	2.0	11.6	3.6
Ecuador	27.3	22.3	18.3	5.6	8.2	2.3
Egypt	10.8	7.2	30.1	6.2	10.0	0.0
El Salvador	10.5	8.3	16.9	1.9	12.5	1.2
Estonia	75.7	223.2	37.7	2.6	17.2	2.5
Finland	6.8	4.9	46.9	3.8	22.0	0.0
France	6.2	4.3	46.3	4.6	19.2	1.6
Gambia The	12.2	11.3	25.1	3.9		
Germany	3.4	2.1	45.4	1.0	13.1	1.6
Ghana	37.6	34.4	15.1	5.9		
Greece	14.0	7.6	32.7	4.7	17.7	0.7
Guatemala	10.7	10.2	11.6	1.5	9.4	1.9
Haiti	13.9	11.9	8.7	2.2		
Honduras	12.0	8.5	20.8	3.9		
Hungary	10.2	9.3	44.0	2.0	24.1	2.0
Iceland	20.5	20.9	20.9	12.9		
India	8.2	6.0	18.0	1.0		
Indonesia	13.6	13.6	17.9	2.0		
Iran	17.9	10.1	25.7	9.2		
Ireland	8.3	6.7	36.9	3.3	22.3	2.9
Israel	52.6	92.9			15.7	2.4
Italy	9.6	6.5	40.4	5.3	16.3	3.1
Jamaica	18.9	15.4	25.3	5.6		
Japan	3.1	4.8	28.1	3.4	4.2	1.0
Jordan	7.0	7.4	26.9	7.1		
Kenya	13.3	10.2	26.6	2.9		
Korea	7.5	7.3	19.2	3.3	10.0	0.0
Latvia	10.1	10.5	36.1	2.2	18.0	0.0
Lithuania	18.0	45.9	34.3	2.0	18.1	0.3
Madagascar	15.0	12.5	12.9	2.1		
Malaysia	4.0	3.5	30.7	5.3		
Mauritius	10.0	8.1	21.9	1.6		
Mexico	29.4	34.2	22.3	3.2	12.8	2.5
Mongolia	61.2	97.6	30.1	5.9		
Morocco	5.9	3.8	23.8	2.4		
Mozambique	10.9	7.5	23.2	3.5		
Nepal	8.2	5.3	13.0	1.8		
Netherlands	4.2	3.0	51.2	2.6	17.5	1.8
New Zealand	7.4	5.9	34.5	3.5	12.1	0.9
Nigeria	25.7	20.2	24.8	7.1		
Norway	5.9	3.8	50.2	2.5		
Pakistan	8.9	6.6	17.0	1.9		
Paraguay	14.2	9.6	13.6	4.3	10.0	0.0
Peru	177.7	552.0	14.6	3.0		
Philippines	11.8	10.7	16.8	3.5		
Poland	54.1	144.0	40.2	2.3	22.0	0.0
Portugal	13.9	9.0	36.8	4.6	16.6	0.5
Romania	65.7	85.7	9.4	15.4	19.1	1.2
Rwanda	10.2	12.2	13.2	4.6		
Seychelles	3.7	4.2	48.0	5.2		
Singapore	2.9	5.4	27.8	6.3	4.2	1.6
South Africa	10.1	4.4	25.6	1.3	13.8	0.9
Spain	9.8	6.0	36.4	3.8	13.8	1.9
Sri Lanka	10.2	6.1	20.2	3.3		
Sudan	40.1	39.7	12.4	3.6		
Swaziland	12.0	4.9	28.9	2.2		
Sweden	5.6	4.0	59.6	2.0	22.4	3.4
Switzerland	2.9	2.7	35.6	2.4	7.3	0.5
Syrian Arab Republic	12.2	11.9	24.7	5.0		
Tanzania	19.7	15.4	16.3	2.6		
Thailand	5.7	5.2	16.7	1.6		
Trinidad and Tobago	9.2	5.4	29.8	3.7		
Tunisia	5.9	3.1	29.1	4.6		
Turkey	43.9	30.0	21.6	3.4	12.9	3.9
Uganda	46.6	62.5	12.8	4.8		
United Kingdom	6.5	5.8	39.2	2.0	14.9	3.5
United States	4.8	3.2	28.1	1.2		
Uruguay	43.7	33.1	27.9	3.5	19.4	4.1
Venezuela	25.4	23.7	27.5	3.9		
Zambia	61.5	50.5	25.3	2.9		
Zimbabwe	67.8	172.1	28.2	2.1		
Average	*27.1*	*48.7*	*27.7*	*3.8*	*14.9*	*1.6*
Median	*10.9*	*8.6*	*26.7*	*3.5*	*16.0*	*1.5*
Min	*2.9*	*2.1*	*8.5*	*1.0*	*4.2*	*0.0*
Max	*333.6*	*796.3*	*59.6*	*15.4*	*24.1*	*4.1*

Table 2. Summary statistics. Turnover rate of central bank governor and frequency of central bank governor replacement.

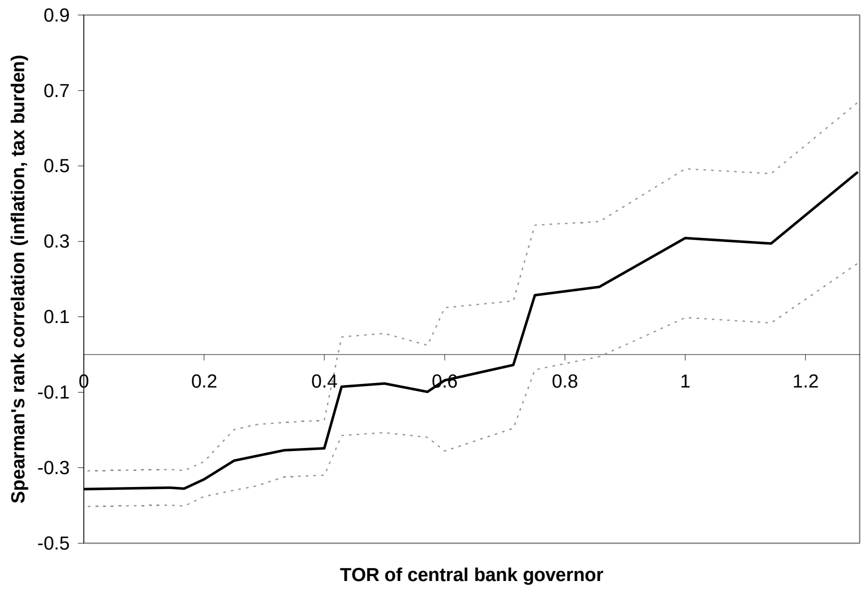
Country	Average TOR	Average frequency of central bank governor replacement	Standard deviation TOR
Algeria	0.21	4 years and 9 months	0.13
Argentina	0.80	1 year and 2 months	0.35
Australia	0.14	7 years and 4 months	0.05
Austria	0.20	5 years	0.09
Bangladesh	0.23	4 years and 4 months	0.12
Belgium	0.12	8 years and 2 months	0.07
Bolivia	0.60	1 year and 8 months	0.46
Botswana	0.19	5 years and 3 months	0.13
Brazil	0.61	1 year and 7 months	0.35
Bulgaria	0.20	4 years and 11 months	0.10
Canada	0.11	9 years and 5 months	0.06
Cape Verde	0.12	8 years and 4 months	0.08
Chile	0.42	2 years and 4 months	0.24
China	0.23	4 years and 5 months	0.09
Colombia	0.14	6 years and 11 months	0.10
Costa Rica	0.51	1 year and 11 months	0.30
Cyprus	0.06	16 years and 4 months	0.07
Czech Republic	0.18	5 years and 7 months	0.13
Dominican Republic	0.44	2 years and 3 months	0.21
Ecuador	0.82	1 year and 2 months	0.19
Egypt	0.21	4 years and 8 months	0.10
El Salvador	0.33	3 years	0.17
Estonia	0.17	6 years	0.10
Finland	0.15	6 years and 8 months	0.10
France	0.17	5 years and 9 months	0.08
Gambia The	0.17	5 years and 10 months	0.12
Germany	0.12	8 years and 1 months	0.10
Ghana	0.16	6 years	0.09
Greece	0.24	4 years and 2 months	0.14
Guatemala	0.46	2 years and 2 months	0.27
Haiti	0.55	1 year and 9 months	0.31
Honduras	0.22	4 years and 7 months	0.09
Hungary	0.17	5 years and 9 months	0.14
Iceland	0.09	11 years and 8 months	0.12
India	0.30	3 years and 3 months	0.12
Indonesia	0.16	6 years and 2 months	0.09
Iran	0.30	3 years and 3 months	0.15
Ireland	0.15	6 years and 8 months	0.06
Israel	0.14	6 years and 11 months	0.08
Italy	0.08	11 years and 10 months	0.09
Jamaica	0.26	3 years and 9 months	0.20
Japan	0.20	4 years and 11 months	0.07
Jordan	0.13	7 years and 5 months	0.09
Kenya	0.16	6 years and 1 months	0.10
Korea	0.38	2 years and 7 months	0.12
Latvia	0.22	4 years and 7 months	0.13
Lithuania	0.24	4 years and 1 months	0.26
Madagascar	0.12	8 years and 3 months	0.11
Malaysia	0.15	6 years and 9 months	0.11
Mauritius	0.09	11 years and 8 months	0.08
Mexico	0.12	8 years and 2 months	0.12
Mongolia	0.19	5 years and 1 months	0.10
Morocco	0.10	10 years	0.10
Mozambique	0.13	7 years and 7 months	0.12
Nepal	0.19	5 years and 4 months	0.07
Netherlands	0.06	17 years	0.07
New Zealand	0.15	6 years and 8 months	0.11
Nigeria	0.16	6 years and 3 months	0.13
Norway	0.12	8 years and 2 months	0.13
Pakistan	0.27	3 years and 7 months	0.16
Paraguay	0.33	3 years	0.31
Peru	0.38	2 years and 7 months	0.19
Philippines	0.18	5 years and 7 months	0.09
Poland	0.28	3 years and 7 months	0.24
Portugal	0.22	4 years and 5 months	0.11
Romania	0.12	8 years and 5 months	0.12
Rwanda	0.16	6 years and 4 months	0.12
Seychelles	0.14	7 years and 4 months	0.09
Singapore	0.12	8 years and 4 months	0.08
South Africa	0.09	11 years and 3 months	0.07
Spain	0.17	5 years and 9 months	0.08
Sri Lanka	0.16	6 years and 4 months	0.09
Sudan	0.26	3 years and 10 months	0.16
Swaziland	0.15	6 years and 9 months	0.12
Sweden	0.19	5 years and 2 months	0.13
Switzerland	0.14	7 years and 2 months	0.09
Syrian Arab Republic	0.15	6 years and 6 months	0.08
Tanzania	0.08	12 years and 6 months	0.09
Thailand	0.27	3 years and 8 months	0.12
Trinidad and Tobago	0.15	6 years and 8 months	0.11
Tunisia	0.22	4 years and 5 months	0.13
Turkey	0.29	3 years and 5 months	0.10
Uganda	0.20	4 years and 11 months	0.14
United Kingdom	0.11	9 years	0.07
United States	0.11	8 years and 8 months	0.11
Uruguay	0.36	2 years and 9 months	0.15
Venezuela	0.33	3 years	0.14
Zambia	0.28	3 years and 6 months	0.15
Zimbabwe	0.12	8 years and 1 months	0.06
Average	*0.22*	*4 years and 5 months*	*0.13*
Median	*0.17*	5 years and 9 months	*0.11*
Min	*0.06*	*17 years*	*0.05*
Max	*0.82*	*1 year and 2 months*	*0.46*

Table 3. Panel data regressions.

	Basic regressions						Regressions with control variables (dependent variable is tax burden)						
	Dependent variable is:						Control variable is:						
	Tax burden			VAT tax rate			$\pi^{adjusted}$	Bank crisis	IMF program	Default	GDP cycle	All controls	All controls
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
π	-0.006*** [-4.1]	-0.030*** [-5.4]	-0.007*** [-3.1]	-0.087 [-0.9]	-0.803* [-1.8]	-1.418*** [-6.4]	-0.028*** [-5.0]	-0.033*** [-5.6]	-0.031*** [-5.4]	-0.083*** [-6.8]	-0.062*** [-6.7]	-0.103*** [-6.8]	-0.021*** [-3.7]
$\pi \cdot TOR$		0.031*** [5.6]	0.004** [2.2]		0.858** [2.1]	1.180*** [5.9]	0.029*** [5.3]	0.037*** [5.8]	0.035*** [5.7]	0.089*** [7.0]	0.066*** [7.3]	0.110*** [7.1]	0.019*** [3.3]
$\pi \cdot TOR \cdot bank\ \ crisis$								0.031 [0.9]				-0.001 [-0.0]	-0.010 [-0.7]
$\pi \cdot TOR \cdot IMF\ \ program$									0.005 [0.2]			-0.082** [-2.5]	-0.009 [-0.8]
$\pi \cdot TOR \cdot default$										-0.084*** [-6.0]		-0.144*** [-5.4]	-0.021** [-2.1]
$\pi \cdot TOR \cdot GDP\ \ cycle$											-0.0003 [-0.1]	-0.017*** [-3.5]	-0.005*** [-3.0]
Estimator	OLS	OLS	FE	OLS	OLS	FE	OLS	OLS	OLS	OLS	OLS	OLS	FE
Observations	2148	2148	2148	737	737	737	2148	2148	2148	1681	2125	1658	1658

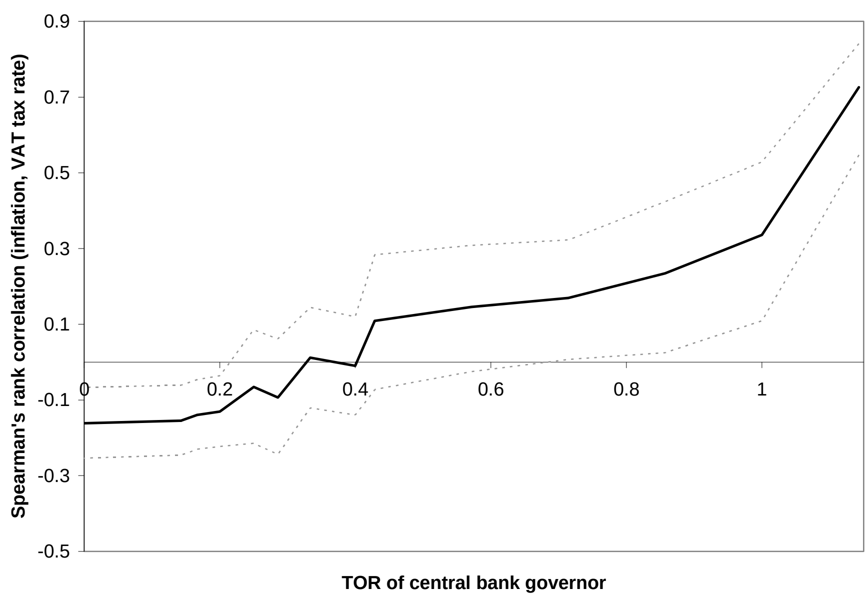
Note: See Appendix 7.2 for definition and source of variables. Constant term as well as those terms which do not interact with INF are not reported.

Figure 1. Evolution of Spearman's rank correlation between inflation and tax burden across alternative levels of TOR of central bank governor. +/- 95 percent confidence interval.



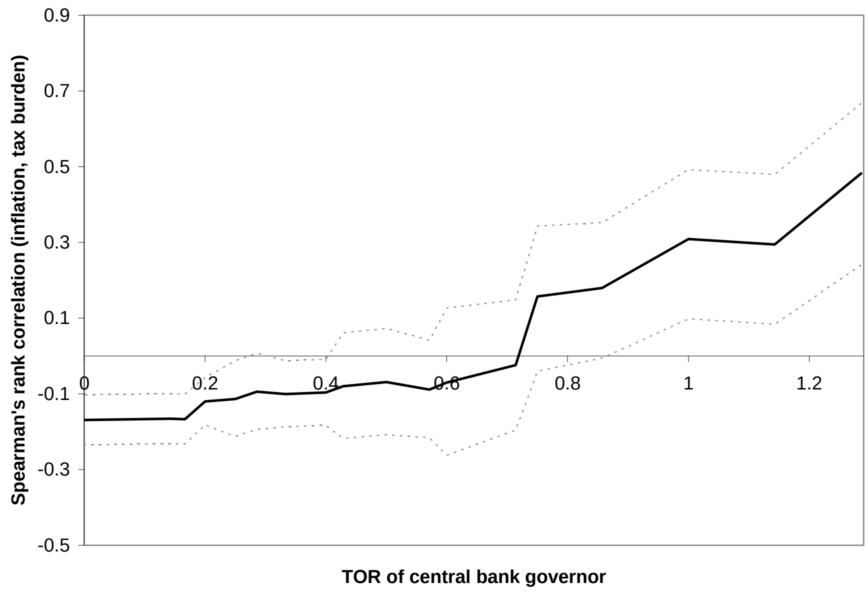
Note: 2148 observations.

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



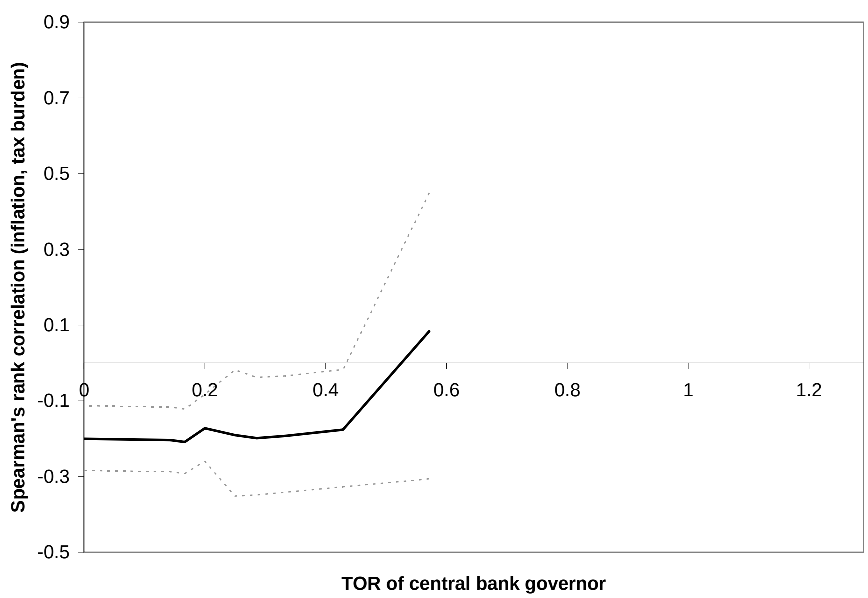
Note: 737 observations.

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



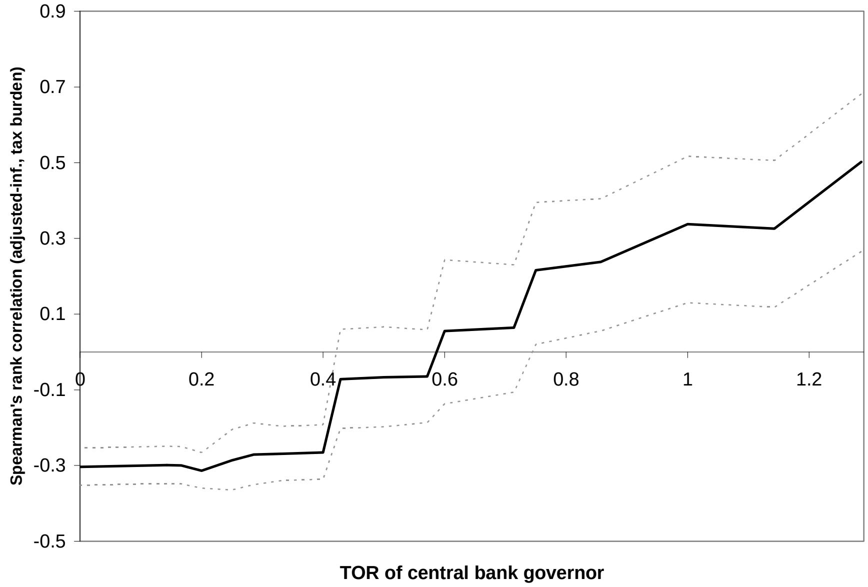
Note: 1512 observations.

Figure 4. Evolution of Spearman's rank correlation between inflation and tax burden across alternative levels of TOR of central bank governor. Advanced countries. +/- 95 percent confidence interval.



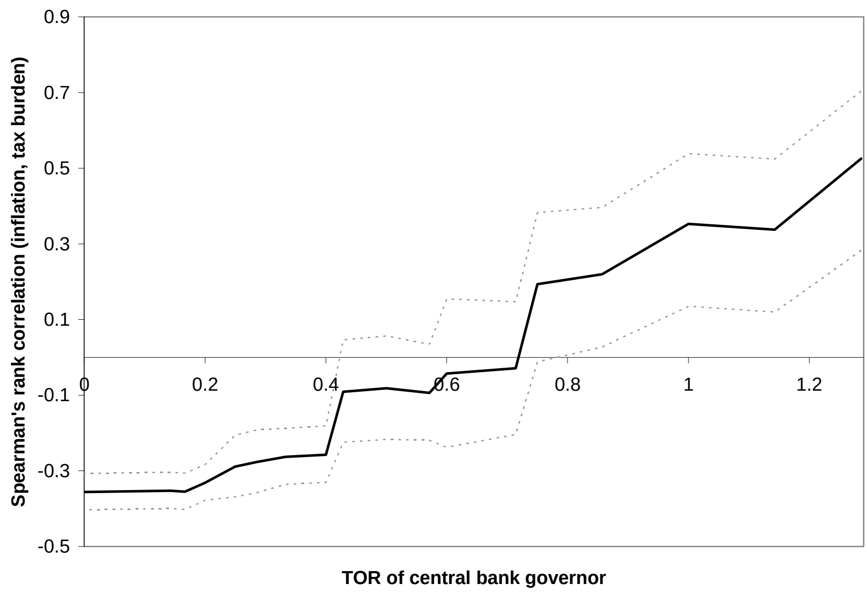
Note: 636 observations.

Figure 5. Evolution of Spearman's rank correlation between adjusted-inflation and tax burden across alternative levels of TOR of central bank governor. +/- 95 percent confidence interval.



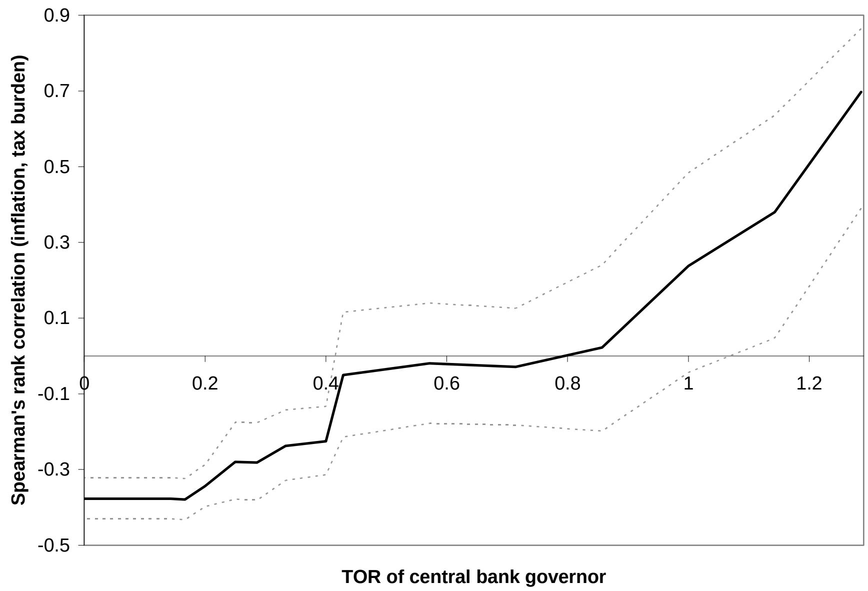
Note: 2148 observations.

Figure 6. Evolution of Spearman's rank correlation between inflation and tax burden across alternative levels of TOR of central bank governor. Non-banking crisis observations. +/- 95 percent confidence interval.



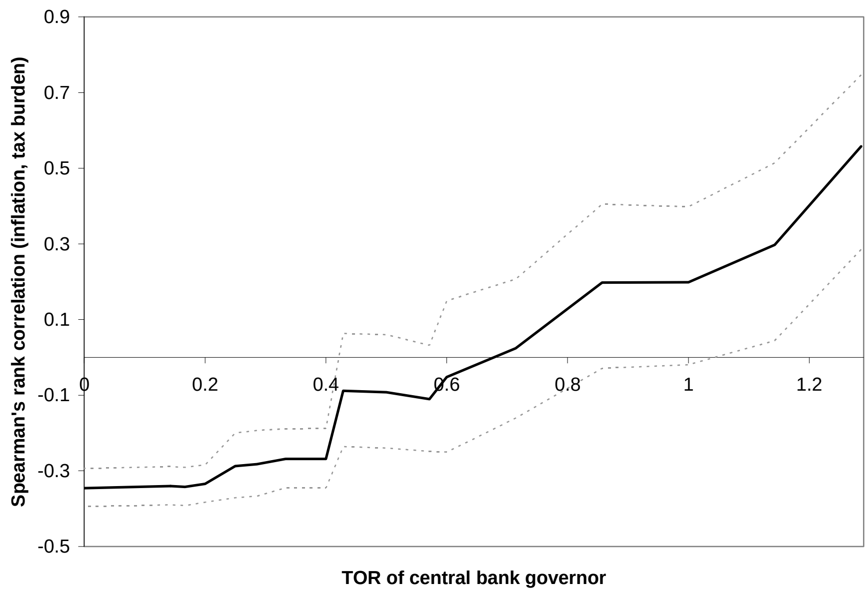
Note: 2061 observations.

Figure 7. Evolution of Spearman's rank correlation between inflation and tax burden across alternative levels of TOR of central bank governor. Non-default observations. +/- 95 percent confidence interval.



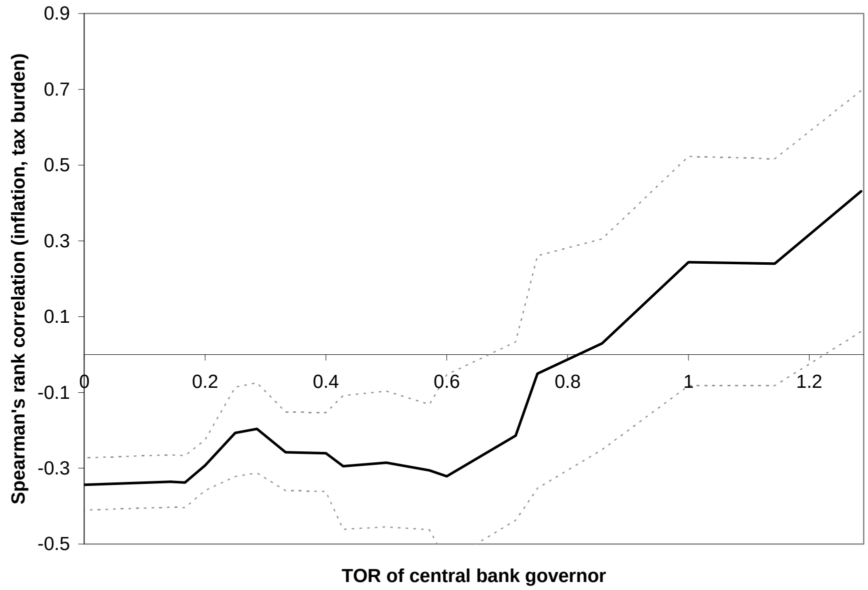
Note: 1436 observations.

Figure 8. Evolution of Spearman's rank correlation between inflation and tax burden across alternative levels of TOR of central bank governor. Non-IMF program observations. +/- 95 percent confidence interval.



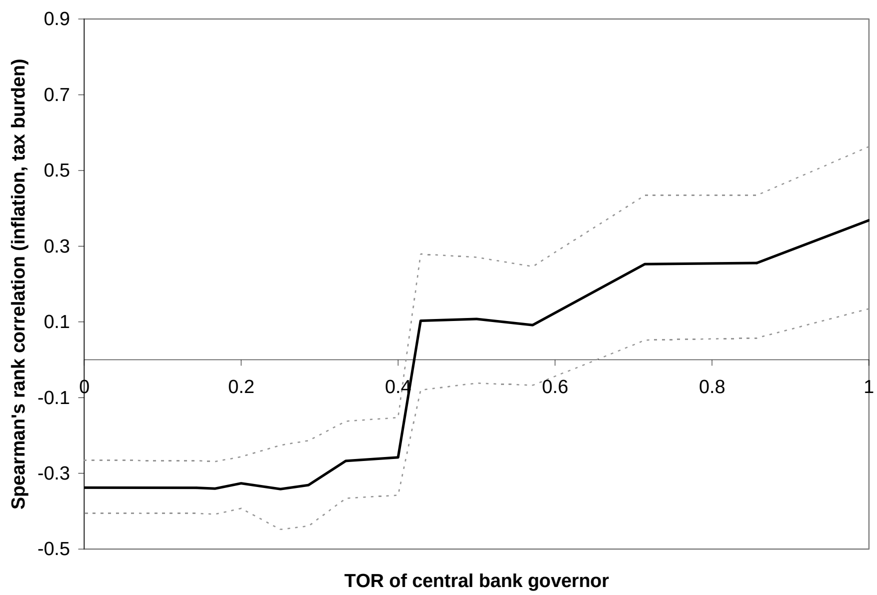
Note: 1856 observations.

Figure 9. Evolution of Spearman's rank correlation between inflation and tax burden across alternative levels of TOR of central bank governor. Observations with fiscal deficit as percentage of GDP above the median. +/- 95 percent confidence interval.



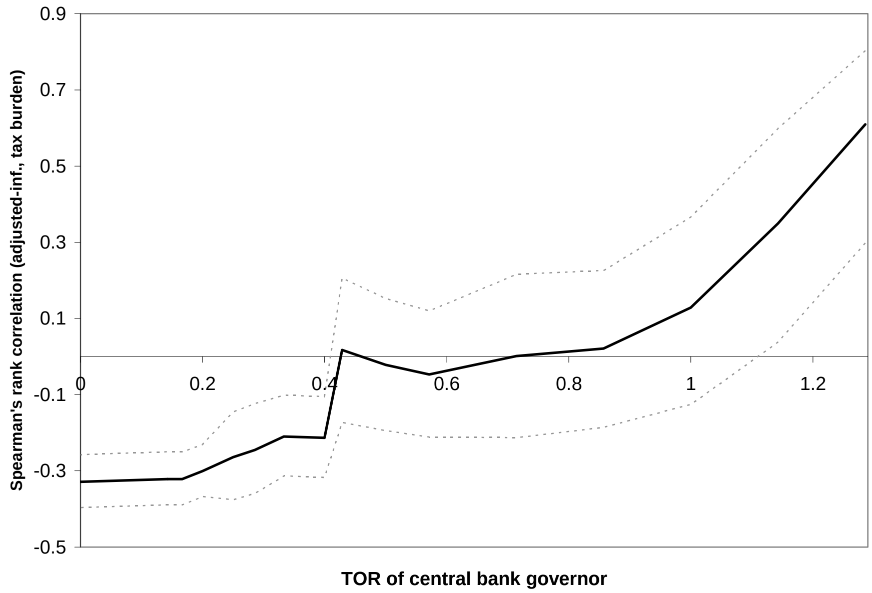
Note: 1041 observations.

Figure 10. Evolution of Spearman's rank correlation between inflation and tax burden across alternative levels of TOR of central bank governor. Observations with fiscal deficit as percentage of GDP below the median. +/- 95 percent confidence interval.



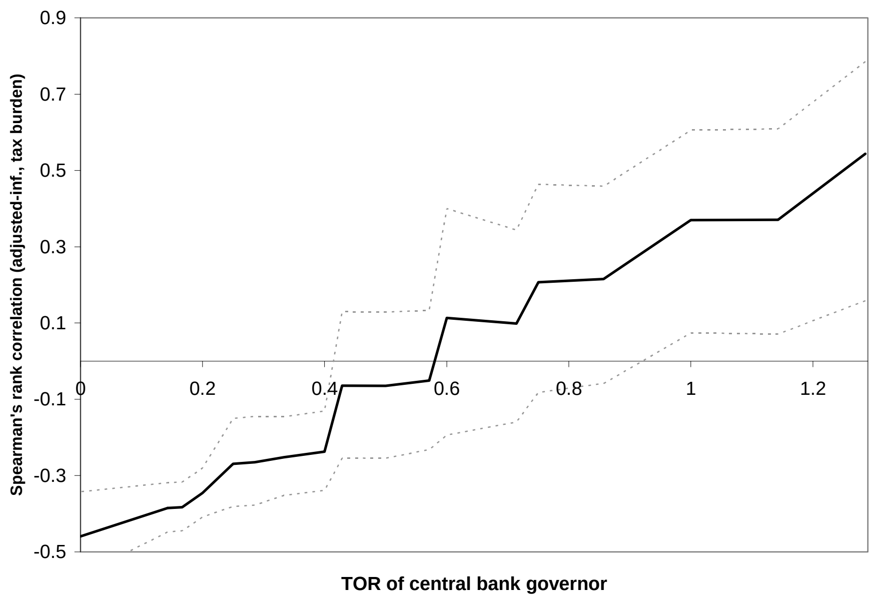
Note: 1040 observations.

Figure 11. Evolution of Spearman's rank correlation between inflation and tax burden across alternative levels of TOR of central bank governor. Observations with positive GDP cycles. +/- 95 percent confidence interval.



Note: 1044 observations.

Figure 12. Evolution of Spearman's rank correlation between inflation and tax burden across alternative levels of TOR of central bank governor. Observations with negative GDP cycles. +/- 95 percent confidence interval.



Note: 1081 observations.