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The Role of Political Institutions for the Effectiveness of Central Bank Independence

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Abstract

This paper empirically studies the impact of the quality of political institutions on the link between central bank independence and inflation. Making use of data on the evolution of central bank independence over time and controlling for possible nonlinearities, we employ interaction models to identify the conditions under which more central bank independence will enhance a country's inflation performance. Examining a cross-section of up to 69 countries, we are able to show that granting a central bank more autonomy does not necessarily lead to better inflation performance. To lower inflation by increasing independence, two conditions must be fulfilled: (1) The change in independence must be sufficiently large, and (2) the quality of the political institutions must be sufficiently high.

JEL-Code: E580, E020, E310.

Keywords: central bank independence, inflation, institutional quality, monetary policy.

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1 Introduction

In the last 30 years, academics and policymakers have shown increasing interest in the independence of central banks. Especially during the 1990s, many countries around the world adopted new central bank laws and granted their monetary institutions a greater degree of autonomy [see e.g., Cukierman (2008)]. In the European Union, the Maastricht Treaty has enabled the European Central Bank (ECB) to pursue monetary policy independent of national governments. The United Kingdom granted the Bank of England full autonomy in 1997 and many other countries followed suit. Figure 1 displays the evolution of central bank independence (henceforth: CBI) from the 1980s to 2003 for a sample of 69 countries, separately for OECD and non-OECD countries.[1] It is clear that the vast majority of central banks have become more independent.

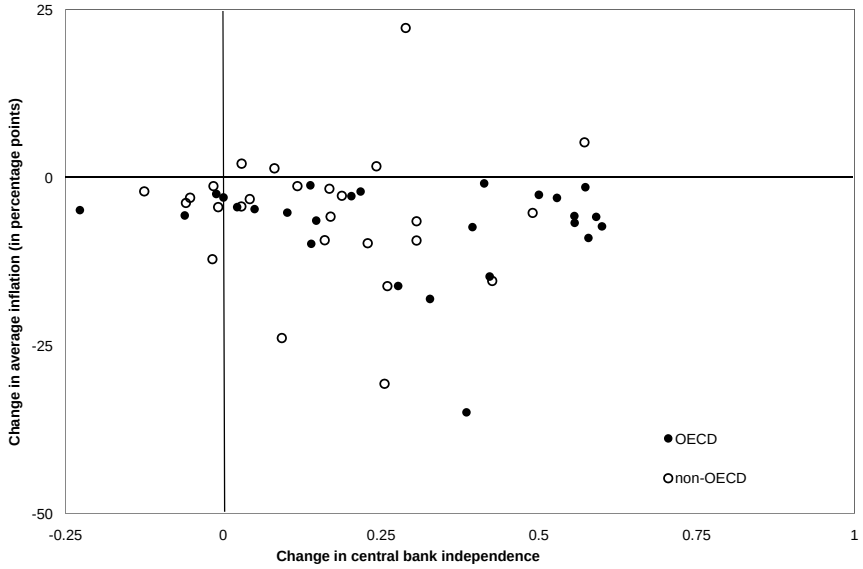

Figure 1: The evolution of central bank independence and inflation

At the same time, average inflation rates have decreased in almost all countries. This co-movement of independence and inflation has occurred in both OECD or non-OECD countries. As an example, OECD countries have on average experienced a reduction in average inflation by roughly 15 percentage points. CBI has on average increased by 0.30. However, the scatter-plot shows no clear negative relationship between the changes in CBI and the changes in inflation. In addition, the empirical literature on this issue casts doubt

[1] Indicators of central bank independence are taken from Cukierman et al. (1992) and Crowe and Meade (2007). Both indicators are based on the methodology of Cukierman et al. (1992), overlap for 69 countries and are normalized to the unit interval. Countries with inflation rates above 50% are excluded from the figure.

on the effectiveness of CBI for price stability. Although earlier studies primarily identify a negative link between CBI and inflation, especially in industrialized countries [see e.g., Grilli et al. (1991), Cukierman (1992) or Alesina and Summers (1993)], the results of more recent studies are rather ambiguous [see e.g., Eijffinger and de Haan (1996), Campillo and Miron (1997) or Klomp and de Haan (2010)]. The previous literature has made numerous attempts to explain the impact of CBI on inflation using different indicators of CBI, employing different sample periods and countries and controlling for all kinds of additional determinants of inflation. Surprisingly, comparatively few attempts have been made to study the conditions under which CBI can enhance a country's inflation performance. While many studies include a wide variety of control variables for inflation, the literature sparely addresses the interaction between certain control variables – e.g., the quality of political institutions – and CBI. In this paper, we argue that the quality of political institutions is an important determinant of the relationship between CBI and inflation.

From a theoretical point of view, increasing CBI helps to solve time-inconsistency problems by strengthening the reputation of monetary policy. However, indicators of CBI convey little information about the credibility of such an arrangement. To achieve the beneficial reputation effects of CBI, the established institutional design needs to be credible. High-quality political institutions might generally be associated with greater trust in governmental decisions and legal arrangements. As a result, the quality of institutions might be a positive determinant of the reputation effects of CBI. Chile and Venezuela provide helpful anecdotal evidence in support of our hypothesis. In the 1980s, both countries suffered from similarly high average inflation rates (21% and 20%). In addition, Chile and Venezuela increased the independence of their central banks to a similar extent (0.33 and 0.37).[2] However, whereas Chile established price stability in the first decade of the twenty-first century (with an average inflation rate of around 3%), the inflation problem in Venezuela persisted. The remarkably different inflation performance of these two countries may be reflected in discrepancies in institutional quality. If we measure institutional quality on the basis of political stability, rule of law or democratic accountability using the World Bank's governance indicators [Kaufmann et al. (2009)], Chile displays much higher institutional quality on average than does Venezuela (0.64 / 0.74 / 0.65 and 0.31 / 0.29 / 0.42). These differences may be crucial to the reputation of monetary policy design and hence to the effectiveness of CBI. We expect that institutional quality directly influences the marginal effect of CBI on inflation.

[2] Detailed data descriptions can be found in section 3.1 and in the appendix.

The main questions of our paper are as follows. Can we identify a relationship between CBI and inflation? If so, does the institutional quality of countries influence this relationship? How do institutional quality and CBI interact with each other?

To answer the above questions, we examine a dataset of up to 69 countries. Unlike in most of the literature, which primarily focuses on pure cross-section samples, we study the relationship between CBI and inflation by exploiting the time dimension of CBI data. Additionally, we allow for possible nonlinearities in the relationship between CBI and inflation. The impact of institutional quality on the marginal effect of CBI is studied by estimating interaction models. Our main findings can be summarized as follows. Institutional quality has a significant impact on the relationship between CBI and inflation. Increasing institutional quality is correlated with improved CBI effectiveness for a country's inflation performance. Our analysis reveals that granting a central bank more autonomy does not necessarily lead to better inflation performance. To lower inflation by increasing independence, two conditions have to be fulfilled: (1) The change in independence needs to be sufficiently large, and (2) the quality of institutions has to be sufficiently high.

This paper is organized as follows. Section 2.1 briefly discusses the theoretical and empirical literature on the relationship between CBI and inflation. In Section 2.2, we discuss the role of institutional quality in the effectiveness of CBI with regard to inflation performance enhancement. Section 3.1 describes the empirical methodology and the dataset. Section 3.2 presents the estimation results. A large number of robustness checks are presented in Section 3.3. Section 4 concludes.

2 Some theoretical considerations

2.1 The link between CBI and inflation

The theoretical rationale for central bank independence is based on the research on time-inconsistent policies [Kydland and Prescott (1977), Barro and Gordon (1983)]. Rogoff (1985) shows in his seminal paper that a society will see its welfare increase after appointing a conservative central banker and isolating monetary policy from political pressure. Hence, central bank independence in combination with a stronger focus on price stability helps to ease the inflationary bias. As a result, for a given degree of conservatism, CBI should be negatively related to inflation rates.

The empirical evidence backing the conventional view that central bank independence

helps to achieve low inflation is somewhat mixed. Eijffinger and de Haan (1996), Berger et al. (2001), Hayo and Hefeker (2008) provide excellent reviews of the empirical literature. One stylized fact that emerges from earlier studies is a negative relationship between CBI and the level of inflation, especially in industrialized countries. The results of more recent studies are rather inconclusive. For example, when high-inflation observations are excluded or certain control variables are included, the negative relationship is not very robust [see e.g., Sturm and de Haan (2001), Fuhrer (1997)]. A recent meta-regression analysis by Klomp and de Haan (2010) indicates omitted variable biases in previous empirical studies and shows that the findings are sensitive to sample periods and applied CBI indicators. In addition, some research casts serious doubt on the direction of causality and argues in favor of the endogeneity of central bank independence. For example, Posen (1995) shows that the degree of CBI is determined by the strength of financial sector opposition to inflation. This means that the direction of causality may run from inflation to CBI.

There may be various reasons for the ambiguous findings. First, there are no precise measures of CBI. Most existing studies make use of indices of statutory central bank independence [see e.g., Grilli et al. (1991), Cukierman (1992), Cukierman et al. (1992), Alesina and Summers (1993), Cukierman et al. (2002), Gutiérrez (2003), Jácome and Vázquez (2008), Carlstrom and Fuerst (2009), Arnone et al. (2009)]. A crucial argument against the use of such measures is that informal practices might differ substantially from formal rules. Particularly in developing and transition countries, there is a discrepancy between rules and practices [see e.g., Forder (1996, 1998), Berlemann and Nenovsky (2004)]. Fry (1998) shows that legal independence poorly reflects actual independence. Various attempts have been undertaken to measure actual independence. For example, the turnover rate developed by Cukierman (1992) is the most commonly used measure. Other measures are the survey indicator by Cukierman (1992) and the political susceptibility index by Cukierman and Webb (1995), as well as measures based on the estimation of central bank reaction functions [e.g., Eijffinger et al. (1996)]. However, most existing measures only capture some limited aspect of actual CBI.

Second, the literature often does not properly distinguish between conservatism and independence [e.g., Berger et al. (2001), Hayo and Hefeker (2002)]. According to the seminal work of Rogoff (1985), the inflationary bias depends on the combination of central bank independence and conservatism. Thus, the empirical evidence on the relation between CBI and inflation may be distorted when differing levels of conservatism are not taken into account.

Third, the time-dimension of central bank independence and inflation data has been widely neglected up until now. In earlier studies, this was primarily due to a lack of time-variant indicators of independence. A recent study by Crowe and Meade (2008) finds a significant negative relationship between CBI and inflation when exploiting the time dimension of the dataset but is unable to identify a significant link in a pure cross-section analysis. One reason for this result might be that exploiting the time dimension of the dataset may diminish possible omitted variable bias.

Fourth, the marginal effect of CBI on inflation may not be constant. Earlier studies find a significant relationship between CBI and inflation, but this is the case only for a sample of industrialized countries [e.g., Cukierman et al. (1992)]. Temple (1998) also shows that the effect of CBI on inflation disappears if higher inflation economies are included. He argues that one reason for this might be a nonlinear effect of CBI. However, to our knowledge, there are no studies so far that explicitly take nonlinear effects into account.

Fifth, existing empirical studies provide little evidence on the conditions under which CBI can have beneficial effects on inflation performance. While many studies include a wide variety of control variables for inflation, the literature sparely addresses the interaction between certain control variables – e.g., the quality of political institutions – and CBI. Two notable exceptions are the papers by Keefer and Stasavage (2003) and Hayo and Voigt (2008). We argue that the quality of political institutions is an important determinant of the link between CBI and inflation.

This paper mainly addresses the latter three issues. We follow a comparative-static approach to study the impact of institutional quality on the link between CBI and inflation and consider possible nonlinearities in the effect of independence. The first two issues; i.e., possible measurement problems of actual CBI and the distinction between conservatism and independence, are not the primary focus of our analysis. However, we try to address these issues in the robustness section of this paper.

2.2 The role of institutional quality

The quality of institutions matters in attempts to assess the link between CBI and inflation for various reasons. First, it is a determinant of inflation and thus a necessary control variable in estimations. For example, Campillo and Miron (1997) show that politically unstable countries have higher inflation rates and that CBI does not help to explain a country's inflation history. Second, political institutions might be a determinant of CBI.

For example, countries with good checks and balances grant their monetary institutions greater autonomy [e.g., Moser (1999), Keefer and Stasavage (2000) or Farvaque (2002)]. Hence, measures of the quality of institutions represent potential instruments for legal CBI that can be used to cope with endogeneity problems related to CBI and inflation [e.g., Crowe and Meade (2008)]. Third, and most importantly from our point of view, the quality of political institutions might directly influence the relationship between CBI and inflation. There is only little evidence on this issue. For example, Keefer and Stasavage (2003) show that the effectiveness of central bank independence in strengthening credibility and enhancing inflation performance is increased by the presence of multiple political veto players. Hayo and Voigt (2008) also find evidence that a significant relation between CBI and inflation only exists if checks and balances are sufficiently strong.

From a theoretical perspective, the relationship between CBI and inflation can be explained as follows. Increasing the level of CBI helps to solve time-inconsistency problems by enhancing the reputation of monetary policy. Hence, inflation expectations can be anchored at a low level, which helps to perpetuate price stability. However, to achieve the beneficial reputation effects of CBI, the institutional design needs to be credible. Whereas the most indicators of CBI primarily reflect information regarding the legal status quo of the central bank design, they hardly contain information on the credibility of such an arrangement. Even though independence prevents short-run monetary policy from being subject to political influence, the choice of a central bank design might still be susceptible to political pressure, which would prevent reputation building.

We argue that the quality of political institutions is crucial to the credibility of central bank design. High-quality political institutions might generally be associated with a higher level of trust in governmental decisions and legal arrangements. As a result, the quality of political institutions might be a positive determinant of the reputation effects of CBI. Aspects of institutional quality that we expect to be particularly important are the stability and effectiveness of the government and the bureaucratic system, democratic accountability and the rule of law. For example, in a democracy, any political action bears the risk of punishment by the voters. The opportunity for punishment increases the accountability of policy-makers. Under the assumption that central bank independence is socially beneficial [see Rogoff (1985)] greater democratic accountability makes it more costly for politicians to deviate from the socially preferred central bank design and thus increases the credibility of CBI. We also expect political stability to have an impact on the credibility of CBI. For example, frequent government changes may precipitate revisions to central bank design and

have a negative impact on the credibility of the legal design of monetary policy. However, even in an unstable government, the impact of government changes may be counteracted by the existence of a strong and high-quality bureaucratic system that can act as a shock absorber and minimize policy revision [see e.g., Busse and Hefeker (2007)]. Finally, the rule of law as a general indicator of trust in the legal system might also indirectly reflect the level of trust in government institutions, including the central bank.

For the reasons mentioned, we argue that institutional quality should not simply be used as a control variable in explaining inflation or as an instrument for CBI; rather, it should be directly linked to the marginal effect of CBI on inflation. Hence, our empirical strategy is to identify the impact of measures of the quality of political institutions on the relationship between CBI and inflation using interaction models.

3 Empirical analysis

3.1 Empirical specification and data

To address our research questions, we use the following procedure. First, we follow the approach used by Crowe and Meade (2008) and estimate the impact of the changes in CBI on the changes in inflation. Next, we control for possible nonlinearities in the marginal effect of CBI on inflation. Then, we incorporate different measures of the quality of political institutions as control variables and interact these measures with the change in CBI. Finally, we check the robustness of our findings.

Any analysis of the link between CBI and inflation is restricted by the availability of time-varying data on CBI. We use data on central bank independence provided by Cukierman et al. (1992) for the period 1980-1989 and the index by Crowe and Meade (2007) for the year 2003. Note that the indicators are comparable because both are based on the methodology developed by Cukierman et al. (1992). The two samples overlap for 69 countries. All definitions and data sources are provided in the appendix A.2. The sample countries are summarized in Table A.6.

As mentioned above, exploiting the time dimension may diminish possible omitted variable bias. In the simple linear version of our 'comparative-static' cross-section approach the estimation equation has the following form:

$$\Delta\pi_i = \alpha_0 + \alpha_1 \cdot \pi_{80/89,i} + \alpha_2 \cdot \Delta CBI_i + \epsilon_i, \tag{1}$$

where the dependent variable $\Delta\pi_i$ reflects the change in the average inflation rate between (1980-1989) and (1998-2007) in country i, i.e. $\Delta\pi = \pi_{80/89} - \pi_{98/07}$.[3] The variable $\pi_{80/89,i}$ represents average inflation in the first period (1980-1989) and controls for initial level effects. In the empirical analysis, we also make use of the inflation tax π^T as an alternative measure of inflation performance. The inflation tax (defined as $\pi^T = \pi/(1+\pi)$) is a commonly used measure in the unit interval, reflecting the depreciation rate of money and reducing the impact of hyperinflation observations as well as heteroscedasticity [e.g., Cukierman et al. (1992), Crowe and Meade (2008)]. The variable ΔCBI_i denotes the change in the indicator values of Crowe and Meade (2007) and Cukierman et al. (1992): i.e., $\Delta CBI = CBI_{98/07} - CBI_{80/89}$. Hence, it represents the evolution of CBI over time. According to the theoretical rationale for CBI, we would expect an increase in CBI ($\Delta CBI > 0$) to result in a decrease in inflation ($\Delta\pi > 0$, $\Delta\pi^T > 0$), which would correspond to a positive sign of the coefficient α_2.[4]

To control for possible nonlinearities, we extend equation (1) by a quadratic term for the change in independence ($(\Delta CBI)^2$), resulting in

$$\Delta\pi_i = \alpha_0 + \alpha_1 \cdot \pi_{80/89,i} + \alpha_2 \cdot \Delta CBI_i + \alpha_3 \cdot (\Delta CBI_i)^2 + \epsilon_i. \tag{2}$$

A positive value of α_3 would imply that the marginal effect of increasing CBI is positively related to the magnitude of CBI changes. A negative value of α_3 would imply that the marginal effect of increasing CBI is negatively related to the magnitude of CBI changes. Hence, large changes in CBI result in a disproportionate decrease (increase) in inflation relative to small changes. As shown in the results section below, we find evidence of nonlinearities. Hence, in the following, we use the quadratic specification of equation (2).

To analyze the impact of the quality of institutions on the CBI-inflation nexus, we specify the following interaction model:

$$\Delta\pi_i = \alpha_0 + \alpha_1 \cdot \pi_{80/89,i} + \alpha_2 \cdot \Delta CBI_i + \alpha_3 \cdot (\Delta CBI_i)^2 + \alpha_4 \cdot IQ_i + \alpha_5 \cdot IQ_i^2 + \alpha_6 \cdot (IQ_i \cdot \Delta CBI_i) + \epsilon_i, \tag{3}$$

where IQ_i is a measure of institutional quality. We use a wide variety of potential proxies for institutional quality, namely *democratic accountability*, *political stability*, *government effectiveness*, *regulatory quality*, *corruption*, *rule of law* and *freedom of press* from different data sources. The corresponding sources and definitions are described in the appendix A.2.

[3] The period from 1980 to 1989 coincides with the sample of the indicator by Cukierman et al. (1992). Because Crowe and Meade (2007) construct their indicator of CBI based on the legal status in the year 2003 we calculate average inflation rates for a comparable 10-year interval around that year (1998-2007).

[4] Note again that due to the definition of the variables, we expect a positive α_2 because the change in CBI is defined as $\Delta CBI = CBI_{98/07} - CBI_{80/89}$ but the change in the inflation is defined as $\Delta\pi = \pi_{80/89} - \pi_{98/07}$.

In equation (3), institutional quality interacts with the changes in CBI. The interaction model implies that the marginal effect of a change in CBI on inflation performance depends on the value of the conditioning variable institutional quality. In other words, a positive α_6 indicates that for a given ΔCBI, the marginal effect increases when IQ_i increases; i.e., the effectiveness of changes in CBI is larger for better institutions. To properly interpret the interaction terms, we must include the level of institutional quality IQ_i [see Brambor et al. (2006)]. As in the case of CBI, we allow for nonlinearities in the effect of institutional quality and include a quadratic term (IQ_i^2).[5] Based on equation (3), the marginal effect of a change in CBI on a change in inflation is given by

$$\frac{\partial \Delta\pi}{\partial \Delta CBI} = \hat{\alpha}_2 + 2\hat{\alpha}_3 \cdot \Delta CBI + \hat{\alpha}_6 \cdot IQ \tag{4}$$

and the corresponding confidence intervals can be derived using the estimated variance of the marginal effect:

$$\begin{aligned} \hat{\sigma}^2_{\frac{\partial \Delta\pi}{\partial \Delta CBI}} &= var(\hat{\alpha}_2) + 4(\Delta CBI)^2 \cdot var(\hat{\alpha}_3) + IQ^2 \cdot var(\hat{\alpha}_6) + 4\Delta CBI \cdot cov(\hat{\alpha}_2\hat{\alpha}_3) \\ &\quad + 2IQ \cdot cov(\hat{\alpha}_2\hat{\alpha}_6) + 4(IQ \cdot \Delta CBI) \cdot cov(\hat{\alpha}_3\hat{\alpha}_6). \end{aligned} \tag{5}$$

3.2 Empirical results

Results I

Table 1 displays the results regarding the link between the change in CBI and the change in inflation not considering the impact of the quality of institutions (see equations (1) and (2)).[6] Column (1) presents the estimation results for equation (1). We are able to explain a large proportion of the variance in the change in inflation (adj. R^2 of 82%). As expected, the initial level of inflation is highly significant. The positive sign of coefficient α_1 indicates that the decrease in inflation is higher in countries with poor initial inflation performance. Contrary to our expectations, the coefficient of ΔCBI is negative. Note that this implies that increasing CBI is associated with an increase in inflation. However, the coefficient does not turn out to be significant in this specification. In column (2), we use the inflation tax π^T as a measure of inflation performance. The qualitative results are unchanged. According to the estimations of the simple specification in equation (1), increasing the independence of a central bank does not seem to come along with enhanced inflation performance.

[5] The results below indeed indicate that nonlinearities seem to be particularly relevant for *government effectiveness*, *rule of law*, *regulatory quality* and *corruption*

[6] In Table 1, we compute White standard errors [White (1980)]. Standard test indicate heteroscedasticity (results available upon request). However, the sample is rather small and the statistical properties of the White estimator are quite uncertain in such samples. Therefore, we also display the results based on ordinary standard errors in Table A.1 in the appendix.

Table 1: Results of equation (1) and (2).

	Dependent variable: Change in inflation ($\Delta\pi$) or inflation tax ($\Delta\pi^T$)					
variable	(1)	(2)	(3)	(4)	(5)	(6)
constant	-0.307	-0.042***	-0.132	-0.036***	-0.035***	-0.019**
	(-1.25)	(-3.89)	(-0.92)	(-3.89)	(-3.30)	(-2.23)
$\pi_{80/90}$	1.014***	– – –	1.019***	– – –	0.865***	– – –
	(67.96)		(50.46)		(7.15)	
$\pi^T_{80/89}$	– – –	0.924***	– – –	0.947***	– – –	0.802***
		(19.77)		(18.40)		(7.58)
ΔCBI	-0.733	-0.038	-4.471	-0.237*	-0.264**	-0.135**
	(-0.95)	(-1.14)	(-1.03)	(-1.99)	(-2.50)	(-2.46)
$(\Delta CBI)^2$	– – –	– – –	7.007	0.368*	0.467**	0.218**
			(1.03)	(1.92)	(2.18)	(2.52)
No. observ.	69	69	69	69	62	62
adj. R^2	0.81	0.78	0.81	0.79	0.65	0.72
F-statistic	146.78***	123.38***	97.85***	85.56***	38.78***	53.56***

All columns with odd numbers refer to the change in inflation and all columns with even numbers refer to the change in inflation tax. In columns (5) and (6) all countries which experienced an absolute change in inflation of more than 200 percentage points are excluded. All t-statistics are reported in parentheses. Estimates are based on White heteroscedasticity-consistent standard errors. Significance levels are reported as follows: * for a 10%, ** for a 5% and *** for a 1%-significance-level.

Columns (3)-(6) display the results of the estimation of the nonlinear specification in equation (2). The results in column (3) and (4) are based on an estimation using the complete sample of 69 countries. With the change in inflation rates as the dependent variable (column (3)), only the initial level turns out to be significant. However, the estimation results on the basis of the inflation tax (column (4)) now differ heavily. The constant and the initial level are highly significant. As in the linear specification, the coefficient of ΔCBI is negative but now becomes significant at the 10%-level. The coefficient of the quadratic term $(\Delta CBI)^2$ is significantly positive; i.e., the marginal effect of increasing CBI on changes in inflation is positively related to the magnitude of CBI changes. Hence, countries with large changes in CBI seem to have, on average, experienced a disproportionate change in their inflation tax relative to countries with small changes.

The difference in the results between inflation and inflation taxes indicates that the insignificance in column (3) are due to an outlier bias of high inflation observations. In columns (5) and (6) we, thus, exclude the seven countries which experienced an increase or a decrease in inflation of more than 200 percentage points. The results are now similar to those in column (4). As a consequence, we control for the outlier effect in the remainder of the paper. Smoothing the change in the inflation performance using inflation taxes seems to

be the adequate procedure which allows to keep all cross section information and which is also in line with much of the empirical literature.

Even if the coefficients of ΔCBI and $(\Delta CBI)^2$ are significant, the overall marginal effect might be insignificant. Table 2 presents the marginal effect $\partial \Delta \pi^T / \partial \Delta CBI = \alpha_2 + 2 \cdot \alpha_3 \cdot \Delta CBI$ based on equation (2) for the specification with the entire sample in column (4).

Table 2: Marginal effect of change in CBI on change in inflation tax.

ΔCBI	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8
$\partial \Delta \pi^T / \partial \Delta CBI$	-0.164*	-0.090*	-0.017	0.057	0.131	0.204*	0.278*	0.351*

Estimates are based on White heteroscedasticity-consistent standard errors. Significance levels are reported as follows: * for a 10%, ** for a 5% and *** for a 1% significance-level. The variance of the marginal effect is given by $\hat{\sigma}^2 = var(\hat{\alpha}_2) + 4 \cdot (\Delta CBI)^2 \cdot var(\hat{\alpha}_3) + 4 \cdot \Delta CBI \cdot cov(\hat{\alpha}_2 \hat{\alpha}_3)$.

Table 2 reveals that for small changes in independence, the marginal effect is significantly negative. Only for changes in CBI above 0.54, we are able to identify a significantly positive relation between an increase in independence and inflation performance.[7]

Although we were not able to identify a significant relationship between CBI and inflation in the linear specification, controlling for possible nonlinearities reveals that CBI might be negatively related to inflation performance when there are large variations in CBI. Due to the empirical relevance of the nonlinearities, we continue to use the quadratic specification.

Results II

To analyze the impact of the quality of institutions on the link between CBI and inflation, we estimate the interaction model specified in equation (3). The estimates for two measures of institutional quality (*democratic accountability* and *political stability*) from the *International Country Risk Guide* (ICRG) dataset [PRS-Group (2007)] as well as for different specifications are displayed in Table 3. In addition, Table A.3 in the appendix shows the estimates (i) for other institutional quality measures (*government effectiveness*, *rule of law*, *regulatory quality*, *corruption* and the *freedom of press*) and (ii) for different data sources (ICRG, World Bank and Freedom House data).[8]

[7] Note, that we cannot interpret causality on the basis of the results in Table 2 since CBI may be endogenous. In section 3.3, we also control for possible endogeneity problems. Also, we might still face omitted variable bias in this specification due to the lack of control variables.

[8] See description of data in the appendix A.2. Furthermore, Table A.2 in the appendix replicates Table 3 on the basis of ordinary standard errors.

Table 3: Results for Democracy Accountability and Political Stability (alternative specifications)

	Dependent variable: Change in inflation tax							
	–Political Stability–				–Democratic Accountability–			
variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
constant	-0.185**	0.120	-0.660*	-0.063	-0.286*	0.100	-1.027***	-0.220
	(-2.64)	(0.54)	(-1.87)	(-0.24)	(-1.69)	(0.56)	(-3.76)	(-1.14)
$\pi^T_{80/89}$	1.014***	1.074***	1.271***	1.113***	0.984***	1.051***	1.024***	1.108***
	(16.57)	(18.59)	(8.49)	(20.82)	(19.63)	(23.26)	(11.85)	(17.63)
ΔCBI	-0.353	-0.425**	-0.630**	-0.297	-0.536*	-0.604**	-0.561***	-0.472
	(-1.64)	(-2.05)	(-2.17)	(-0.57)	(-1.82)	(-2.34)	(-3.04)	(-0.79)
$(\Delta CBI)^2$	0.279*	0.292**	0.119*	0.577	0.172	0.139	0.034	0.162
	(1.79)	(2.25)	(1.90)	(0.84)	(1.58)	(1.44)	(0.52)	(0.34)
IQ	0.495*	0.268	0.615	0.638	0.893	0.621	2.674***	1.090*
	(1.87)	(1.26)	(1.22)	(1.68)	(1.37)	(1.60)	(4.38)	(1.85)
$(IQ)^2$	-0.375	-0.125	-0.513	-0.418	-0.717	-0.388	-1.908***	-0.973*
	(-1.55)	(-0.62)	(-1.14)	(-1.01)	(-1.26)	(-1.39)	(-4.25)	(-1.93)
$IQ \times \Delta CBI$	0.272	0.434*	0.795*	-0.102	0.577	0.748**	0.680***	0.589
	(1.13)	(1.76)	(2.11)	(-0.13)	(1.62)	(2.26)	(3.18)	(0.60)
$GDP_{80/89}$	– – –	0.007	0.015*	0.013	– – –	0.005	0.004	0.006
		(0.90)	(1.83)	(0.51)		(0.86)	(0.85)	(0.49)
$GDPpc_{80/89}$	– – –	-0.014	0.030	-0.003	– – –	-0.024	0.004	-0.001
		(-0.57)	(1.02)	(-0.09)		(-1.18)	(0.25)	(-0.05)
$TRADE_{80/89}$	– – –	-0.043*	0.018	-0.056	– – –	-0.042**	0.006	-0.037
		(-1.85)	(0.89)	(-1.10)		(-2.62)	(0.54)	(-1.39)
ΔGDP	– – –	0.077	-0.097	0.080	– – –	0.110	0.021	0.031
		(0.99)	(-1.05)	(0.79)		(1.43)	(0.41)	(0.35)
$\Delta GDPpc$	– – –	-0.015	0.153	-0.007	– – –	-0.047	-0.032	0.093
		(-0.17)	(1.36)	(-0.05)		(-0.51)	(-0.46)	(0.87)
$\Delta TRADE$	– – –	-0.137**	-0.022	-0.160	– – –	-0.133***	-0.003	-0.145**
		(-2.37)	(-0.88)	(-1.37)		(-2.95)	(-0.08)	(-2.07)
$PEGGED$	– – –	0.018	-0.006	0.022	– – –	0.019	0.005	0.024
		(1.33)	(-0.63)	(0.85)		(1.35)	(0.66)	(0.70)
East Asian	– – –	0.027	– – –	– – –	– – –	0.045	– – –	– – –
		(0.75)				(1.13)		
Latin American	– – –	0.012	– – –	– – –	– – –	0.004	– – –	– – –
		(0.36)				(0.12)		
Sub-Saharan	– – –	-0.084	– – –	– – –	– – –	-0.097*	– – –	– – –
		(-1.38)				(-1.92)		
No. observ.	69	68	30	38	69	68	30	38
adj. R^2	0.84	0.90	0.92	0.87	0.90	0.92	0.97	0.89
F-statistic	59.22***	37.45***	26.98***	20.21***	65.68***	49.41***	65.63***	24.79***

Estimates are based on White heteroscedasticity-consistent standard errors. All t-statistics are reported in parentheses. Significance levels are reported as follows: * for a 10%, ** for a 5% and *** for a 1% significance-level.

Columns (1) to (4) show the estimation results for the measure of *political stability*. Columns (5) to (8) display the results for the measure of *democratic accountability*. The results of the baseline specification (equation (3)) are shown in columns (1) and (5). Relevant control variables, as proposed by Campillo and Miron (1997), are considered in columns (2) and (6).[9] We add the initial levels of (log)GDP ($GDP_{80/89}$), (log)GDP per capita ($GDPpc_{80/89}$) and the (log)trade volume relative to GDP ($TRADE_{80/89}$) as a proxy for openness. Different from Campillo and Miron (1997), we additionally include the change of the latter three variables since we follow a comparative-static approach in this paper [see Crowe and Meade (2008)]. The level of GDP is included to control for country size effects,

[9] See detailed data description in the appendix. Note, that in this case Serbia is excluded from the sample because data is not available for all control variables. Due to data restrictions we do not include the debt ratio.

the GPD per capita controls for various structural disparities as differences in the financial sector, technologies or optimal inflation [see Campillo and Miron (1997)]. According to Romer (1993), openness should be negatively related to average inflation. Surprise expansion of monetary policy is less beneficial in open economies because real exchange rate depreciations that come along with monetary expansion are more harmful in such countries. Furthermore, we account for the fact that monetary policy may have been restricted by the exchange rate system. By pegging its currency, a country can import inflation and may then experience a decrease in inflation that cannot be attributed to central bank design. Using a classification by Caramazza and Aziz (1998), we include a dummy for countries that are either classified as "pegged" or "limited flexible" ($PEGGED$).[10] We also incorporate dummies for Sub-Saharan, East Asian and Latin American countries to control for regional effects.

The remaining four columns address the issue that previous studies prevalently identified a significant relationship between CBI and inflation for industrialized countries only. One reason might be that legal CBI is a precise measure of factual CBI only in such countries. There is some evidence that de facto central bank behavior heavily deviates from de jure rules in developing and transition countries [Forder (1996, 1998), Berlemann and Nenovsky (2004)]. Therefore, we split the sample in OECD (columns (3) and (7)) and non-OECD countries (columns (4) and (8)).[11]

Again, the initial level turns out to be highly relevant in all specifications. In column (1), the coefficient of ΔCBI is negative but insignificant. The coefficient of the quadratic term $(\Delta CBI)^2$ is significant at the 10% level, indicating that the marginal effect of increasing CBI on changes in inflation is positively related to the magnitude of CBI changes. The coefficient of the political stability measure is significantly positive. More institutional quality seems to be associated with a higher decrease in inflation tax over time. However, the coefficient of the quadratic term is negative which implies that the disinflationary benefits of high institutional quality decrease in the level of institutional quality. But this effect is not found to be significant in this specification (p-value of 0.13). The coefficient of the interaction term $IQ \times \Delta CBI$ has the expected positive sign, but is insignificant. This is also true for the measure of *democratic accountability* in column (5). However, adding the control variables in columns (2) and (6) has a major impact on the significance of the

[10]Because most changes in central bank design occurred in the 1990s, we use the classification by Caramazza and Aziz (1998), which refers to 1997.

[11]Note, that further splitting the sample, e.g. to analyze transition countries, would leave us with a very scarce number of observations. We also address the issue of a deviation of factual from legal CBI by using turnover rates of central bank presidents in the robustness section 3.3.

parameters. In particular, the coefficient of the interaction term becomes significant. On the basis of the results in columns (2) and (6) we find evidence in favor of our hypothesis that institutional quality matters for the link between CBI and inflation.[12] Since robustness test reveal that including control variables yields the most stable results across different specifications, we continue to do so in the remainder of the paper.[13] With respect to the control variables, we only find evidence in favor of the hypothesis that openness is inversely related to inflation. The coefficients of both the level and change of openness turn out to be significantly negative.

The evidence in favor of a significant link between institutional quality and CBI effectiveness only seems to hold for highly developed countries. Analyzing the subsample of OECD countries in columns (3) and (7) reveals that the interaction term remains significant and is even larger than in the complete sample. For non-OECD countries (columns (4) and (8)), we are not able to identify a significant impact of institutional quality on the effectiveness of CBI. As mentioned above, this might be due to the fact that legal CBI is not a good proxy for factual CBI in developing and transition countries.

The interaction model asserts that the effect of ΔCBI on $\Delta\pi^T$ depends on the value of the conditioning variable institutional quality (IQ). We now calculate the marginal effects and the corresponding confidence intervals on the basis of equations (4) and (5). To illustrate how the marginal effect of the CBI change on the change in the inflation tax varies with institutional quality, the marginal effect is plotted in Figure 2. The figure displays the marginal effect for the specification in column (2). The solid black line denotes the marginal effect for $\Delta CBI = 0.5$. Confidence bands for the 10%-significance level are included. To compare the marginal effects for different levels of ΔCBI, we insert thin grey lines reflecting the marginal effect for $\Delta CBI = 0.3$ and $\Delta CBI = 0.7$.

Figure 2 reveals that the slope of the marginal effect is positive; i.e., more political stability improves the effectiveness of CBI. Furthermore, a larger (smaller) change in CBI shifts the marginal effect upwards (downwards). The shift in the marginal effect induced by higher values of ΔCBI is statistically significant because the coefficient of the quadratic term is significant. For $\Delta CBI = 0.5$, the marginal effect is negative but insignificant in case of low political stability. The cutoff value of political stability (i.e., the value for which $\partial\Delta\pi^T/\partial\Delta CBI = 0$) is 0.31. The marginal effect is statistically significant with 90%

[12] Table 4 presents more evidence in favor of this hypothesis. In most specifications and for most institutional quality measure, the interaction term is significantly positive.

[13] See robustness section 3.3.

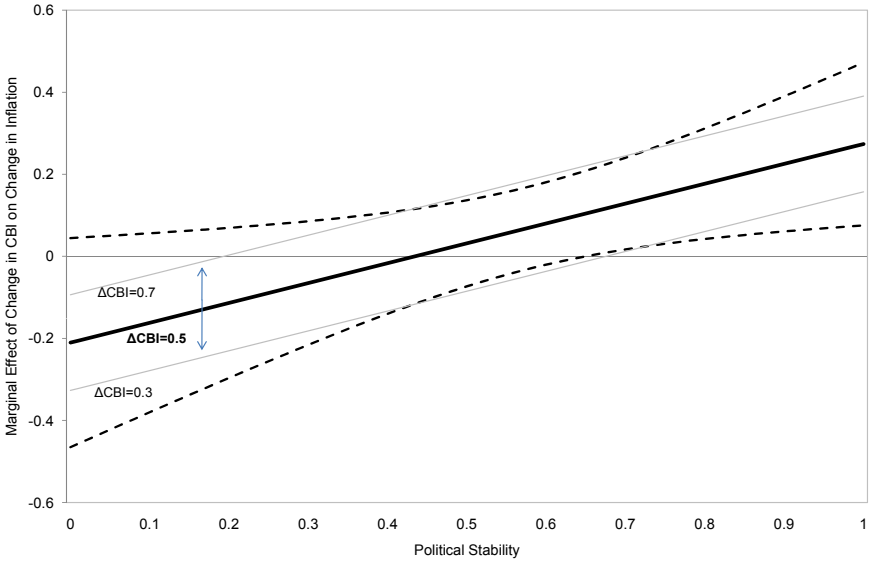

Figure 2: Marginal effect of ΔCBI on $\Delta\pi^T$: Political Stability.

confidence for values of political stability above 0.50.[14]

Finally, we summarize the interaction terms for a number of different specifications and measures of institutional quality in Table 4 to illustrate which aspects of political institutions are particularly relevant to the effectiveness of CBI. The interaction term directly quantifies the impact of institutional quality on the link between inflation and independence. In addition to *democratic accountability* and *political stability* Table 4 also contains the results for different institutional quality measures, namely *government effectiveness*, *rule of law*, *regulatory quality*, *corruption* and *freedom of press*. Moreover, Table 4 displays the results of two different data sources, (1) ICRG and (2) world bank data. Only the data quantifying the *freedom of press* is taken from FreedomHouse (2008). We also perform a number of robustness checks by estimating various specifications. Specification (A) is based on estimates using the complete sample and the specification as in equation (3) without additional control variables. In (B) control variables as in columns (2) and (6) of Table 3 are included. To test whether our findings are driven by the richest or poorest countries, we drop countries that belong to the richest and poorest 5% in the sample in specification (C). In (D), we exclude countries with average annual inflation rates above 50% in one of the sample periods (1980-1989, 1998-2007) to address the findings by Sturm and de Haan (2001) on the effect of high-inflation observations. As a last robustness check, we use ICRG data on internal conflicts to drop the 10% of the countries with the strongest

[14]Figures A.1 and A.2 in the appendix graphically show the calculated marginal effects based on ordinary standard errors [column (2) in Table A.2] and for *democratic accountability* [column (6) in Table 3]. The results are very similar.

internal conflicts (such as civil war, terrorism and civil disorder) in (E). The significance is analyzed using both ordinary and heteroscedasticity resistent standard errors [White (1980)].

Table 4: Overview of the interaction term coefficient for various specifications and institutional quality measures

		Dependent variable: Change in inflation tax						
Spec.	Data	-Pol. Stab-	-Democr. Acc.-	-Gov. Eff.-	-Rule of Law-	-Req. Qual.-	-Corr.-	-Fr. of Press-
(A)	(1)	0.28*/	$0.17/^{++}$	$0.42^{*}/^{++}$	0.18/	$0.55^{**}/^{+++}$	$0.35^{*}/^{+}$	$0.45/^{++}$
	(2)	$0.40^{*}/^{+}$	$0.58^{*}/^{++}$	0.25/	0.18/		0.30*/	
(B)	(1)	$0.40^{*}/^{+}$	$0.75^{**}/^{+++}$	$0.41^{*}/^{++}$	$0.39/^{+}$	$0.49^{**}/^{+++}$	$0.39^{**}/^{++}$	$0.57^{**}/^{+++}$
	(2)	0.64/	$0.66^{*}/^{++}$	$0.43^{**}/^{++}$	$0.47/^{+}$		$0.40^{**}/^{++}$	
(C)	(1)	0.15/	$0.26^{*}/^{+}$	$0.18^{**}/^{++}$	0.17/	$0.27^{**}/^{++}$	$0.18^{**}/^{++}$	$0.21^{***}/^{++}$
	(2)	0.35/	$0.28^{**}/^{+}$	$0.32^{***}/^{+++}$	$0.25^{*}/^{+}$		0.16**/	
(D)	(1)	$0.57^{**}/^{++}$	$0.86^{**}/^{+++}$	$0.40^{*}/^{+}$	$0.48^{*}/^{+}$	$0.47^{*}/^{++}$	$0.42^{*}/^{+}$	$0.57^{**}/^{+++}$
	(2)	1.09/	$0.66^{*}/^{++}$	$0.49^{*}/^{++}$	$0.61^{*}/^{++}$		$0.40^{**}/^{+}$	
(E)	(1)	0.22/	$0.59^{*}/^{+}$	$0.36/^{+}$	0.35/	0.31/	$0.39/^{+}$	$0.50^{*}/^{++}$
	(2)	0.43/	$0.57/^{+}$	$0.43/^{+}$	$0.53/^{+}$		0.31*/	

The table contains the coefficients of the interaction term. Significance levels are reported as follows: * for a 10%, ** for a 5% and *** for a 1% significance-level (for estimates using White standard errors) / $^{+}$ for a 10%, $^{++}$ for a 5% and $^{+++}$ for a 1% significance-level (using ordinary standard errors). (A) is based on estimates using the complete sample and the specification as in equation (3) without additional control variables, (B) includes control variables as in columns (2) and (6) of table Table 3, (C) drops high-inflation countries with an annual average inflation above 50% in (1980, 1989) or (1998, 2007), (D) excludes the highest and lowest 5% in income per capita, and (E) leaves out the 10% of countries with the strongest internal conflicts (ICRG-data). (1) is based on ICRG-data and (2) is based on data of institutional quality from the world bank. Only the data quantifying the *freedom of press* is taken from FreedomHouse (2008).

We can summarize the findings as follows. The interaction term is positive in all 10 specifications and for each measure of institutional quality; i.e., increasing institutional quality occurs along with improved effectiveness of CBI in terms of inflation performance. Not surprisingly, the evidence does not differ substantially for different measures of institutional quality; this can be explained by the strong correlation between the different measures. In any event, on the basis of Table 4, we can cautiously conclude that *democratic accountability*, *government effectiveness*, *corruption* and the *freedom of press* seem to matter most to CBI effectiveness.

The analysis in this section has revealed that granting a central bank more autonomy does not necessarily lead to better inflation performance. To be able to lower inflation by increasing independence, two conditions must be fulfilled: (1) The change in independence must be sufficiently large, and (2) the quality of institutions must be sufficiently high.[15] Based on the specification in column (2) of Table 3, the data for our sample countries imply that only 13 countries (around 19%) are characterized by a combination of ΔCBI

[15]The evidence of the robustness section 3.3 indicates that endogeneity of CBI is a negligible problem. Hence, we are able to interpret the results in this section as causation.

and a level of political stability for which a decrease in the inflation tax can be partially attributed to innovations in central bank design.

3.3 Robustness

We perform a number of robustness checks by estimating different specifications and addressing endogeneity issues as well as data problems to verify that the results are stable. The qualitative results do not change no matter which specification or estimation procedure is used.

First, we test whether the significance of parameters is driven by the use of robust standard errors [White (1980)]. Even though standard tests indicate heteroscedasticity, the statistical properties of the White estimator are quite uncertain in such small samples. Tables A.1 and A.2 in the appendix replicate Tables 1 and 3 using ordinary standard errors. The significance seems to be independent of the method of computing standard errors, in particular in the specifications including all control variables.

Second, Table A.2 in the appendix shows the estimates (i) for other institutional quality measures (*government effectiveness*, *rule of law*, *regulatory quality*, *corruption* and the *freedom of press*) and (ii) for different data sources (ICRG, World Bank and Freedom House data). The results are very similar to those in Table 3, which is not surprising, since the employed measures of institutional quality are highly correlated.

Third, as often addressed in the literature, the degree of CBI may be endogenous and, for example, could depend on the national inflation history. Hence, the change in CBI might, to some extent, be related to the initial level of inflation tax. To address a possible endogeneity bias in our main results, we perform the following procedure: in the first step, we verify that the initial level of inflation is a determinant of the change in independence by estimating

$$\Delta CBI_i = \beta_0 + \beta_1 \cdot \pi^T_{80/89,i} + \beta_2 \cdot CBI_{80/89,i} + \beta_3 \cdot IQ + \upsilon_t \tag{6}$$

where a significant β_1 indicates endogeneity. For all applied institutional measures, the parameter turns out to be significantly positive. As an example: in the specification with *democratic accountability*, the coefficient is ($\beta_1 = 0.26$) and significant at the 1%-level. It seems that countries with poor initial inflation performance adjust central bank laws more substantially. Not surprisingly, the parameter β_2 is significantly negative; i.e., countries with a higher initial level of independence experience smaller changes in CBI. In the second

step, we use the residuals υ_t as an instrument variable for the change in CBI and estimate equation (3) using Two-Stage Least Squares. The residuals seem to be a suitable instrument because they can be interpreted as the fraction of the change in independence that is not determined by inflation history. The residuals are not correlated with the initial level of inflation ($\pi^T_{80/89,i}$) but are strongly correlated with the change in CBI; i.e, a bivariate correlation of 89% (91%) for *democratic accountability* (*political stability*). The results indicate that endogeneity is not a major difficulty in our estimation. The results based on similar specifications as those in Table 3 are displayed in Table A.4 of the appendix and confirm our previous findings. Consequently, we interpret our results as causation, not only as correlation. Sufficiently large changes in CBI seem to lead to inflation performance enhancement.

We estimate a number of additional specifications, the results of which are displayed in Table A.5 in the appendix. The basis for these estimations is the specification in column (6) of Table 3; i.e., with *democratic accountability* and all control variables.[16] In column (1), we use standard year-on-year inflation rates as dependent variable. The qualitative results remain unchanged. In column (2), we leave out the initial level of the inflation tax since, unsurprisingly, the initial level effect explains most of the change in the inflation tax. The results reveal that quite a large proportion of the variance in the inflation tax change can still be explained by the remaining variables (adj. R^2 of 34%). In column (3), we address the issue that the absolute change in CBI and inflation tax might be a biased proxies when trying to measure the true link between CBI and inflation, because they are limited to the unit interval. As a robustness check we base the estimation on the relative changes in CBI and inflation tax. The results, however, remain virtually unchanged. As shown above, the change in CBI is likely to depend on its initial level which might distort the empirical evidence on the link between CBI and inflation. Similar to the two-stage procedure to control for endogeneity between CBI and inflation, we use the residuals of equation (6) as an adjusted measure of the change in CBI. The results are shown in column (4). In column (5), we add an interaction term between the change in CBI and (log)GDP per capita to test whether the effectiveness of CBI is higher or lower in richer countries. The interaction term turns out to be significantly negative without substantially altering the level and significance of the coefficients of interest. Only the coefficient of ΔCBI is now positive (but insignificant). The significant interaction implies that, when controlling for different political institutions, richer countries are characterized

[16]Note, that the control variables are not reported. The results are also robust for other specifications and are available from the authors upon request.

by lower effectiveness of innovations in central bank design. The interaction term might to some extent capture additional determinants of the effectiveness of CBI which go beyond political institutions. For instance, richer countries might also have a long history of price stability which in fact may be due to higher degrees of conservatism. Since conservatism and CBI matter for inflation performance, innovations in CBI may not be as relevant for inflation when the degree of conservatism is already high. In column (6), we make use of turnover rates of central banks presidents as provided by Crowe and Meade (2007). As we have explained earlier, indices of legal CBI might not be good proxies for factual CBI, in particular in developing and transition countries. However, turnover rates which aim at a direct measurement of factual CBI only capture one aspect of CBI. We also loose 10 observations due to data availability. On the basis of turnover rates, we are not able to identify a significant relation between the effectiveness of CBI and the quality of political institutions.

4 Conclusions

From a theoretical perspective, increasing CBI helps to solve the time-inconsistency problem and should therefore improve countries' inflation performance. However, empirical evidence supporting this conventional view is somewhat inconsistent. In this paper, we argue that one reason for the ambiguous results might be that the conditions under which CBI helps to maintain stable prices have been widely neglected in the literature. We argue that the quality of political institutions is an important determinant of the relationship between CBI and inflation.

The main questions of the paper were as follows. Can we identify a relationship between CBI and inflation? If so, does the institutional quality of countries influence this relationship? How do institutional quality and CBI interact with each other?

Two empirical results should be stressed. First, in exploiting the time dimension of the data, we are not able to identify a significant linear relationship between changes in CBI and changes in inflation. However, we find evidence of a nonlinear relationship between the variables. We are able to provide some evidence that the marginal effect of increasing CBI on changes in the inflation tax is positively related to the magnitude of CBI changes. Therefore, we conclude that only sufficiently large changes in CBI improve inflation performance. Second, we find strong evidence that institutional quality has a significant impact on the relationship between CBI and inflation. Institutional quality seems to improve CBI

effectiveness in influencing inflation performance. The estimation results clearly indicate that for a given change in CBI, the marginal effect increases with institutional quality.

The analysis has revealed that granting a central bank more autonomy does not necessarily lead to better inflation performance. To lower inflation by increasing independence, two conditions have to be fulfilled: (1) the change in independence must be sufficiently large and (2) the quality of institutions must be sufficiently high. Furthermore, institutions and variations in CBI seem to be (imperfect) substitutes. Our analysis also helps us to understand the mixed results in the previous empirical literature. Institutional quality is an important determinant of the relationship between CBI and inflation and should not be neglected in academic and political debates on monetary policy.

Our sample period covers the 'great moderation' which is characterized by a widespread downturn in economic volatility [Stock and Watson (2002)]. Also, inflation (persistence) is significantly reduced [Cogley et al. (2010)]. Besides 'good luck', the 'great moderation' is also attributable to improved monetary policy [Summers (2005)]. In line with this evidence, our results indicate that innovations in central bank design, e.g. more independent central banks, are one determinant of the 'great moderation'.

The results in this paper have to be interpreted with some caution. Due to the lack of reliable and time-varying data of actual CBI and conservatism, any analysis on the basis of legal indicators of CBI face a possible bias through measurement problems. However, when restricting the sample to OECD countries, in which legal CBI should be better proxy for actual CBI than in developing and transition countries, the evidence in favor of the effectiveness of CBI and the relevance of institutional quality is even stronger. If conservatism would have increased in many countries, we would overestimate the marginal effect of CBI changes on inflation changes. The robustness analysis has revealed that the qualitative results remain stable when at least indirectly controlling for different levels of conservatism.

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A Appendix

A.1 Further results

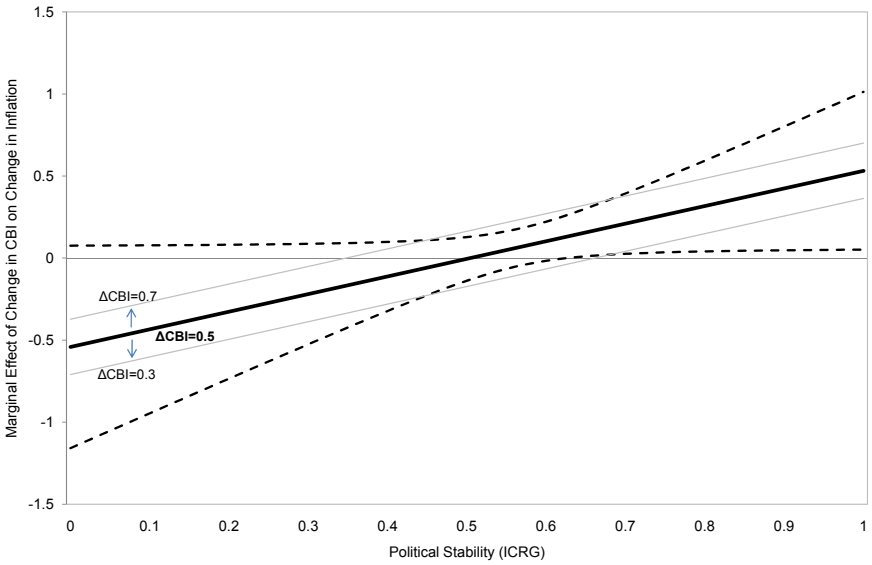

Figure A.1: Marginal effect of ΔCBI on $\Delta\pi^T$: Political Stability (ordinary standard errors)

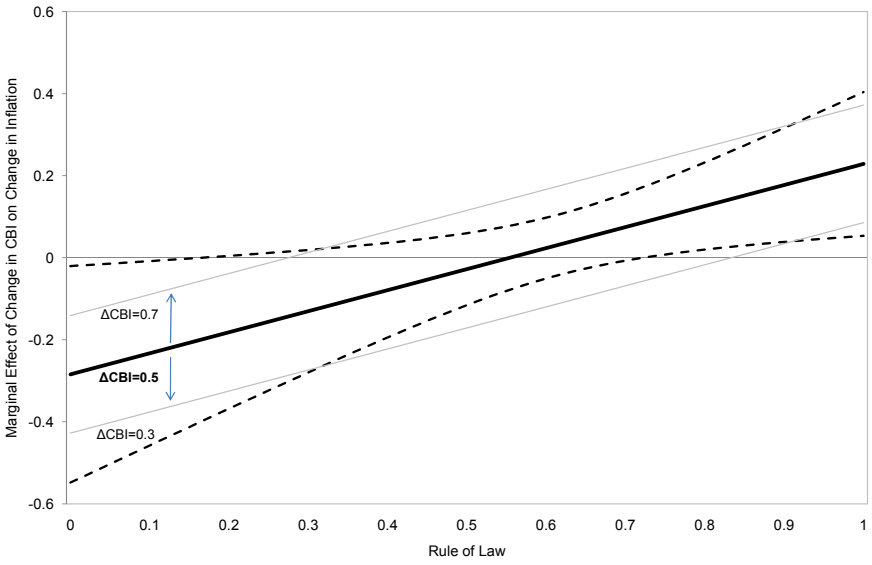

Figure A.2: Marginal effect of ΔCBI on $\Delta\pi^T$: Democratic Accountability

Table A.1: Results of equation (1) and (2) (ordinary standard errors).

	Dependent variable: Change in inflation ($\Delta\pi$) or inflation tax ($\Delta\pi^T$)					
variable	(1)	(2)	(3)	(4)	(5)	(6)
constant	-0.307	-0.042**	-0.132	-0.036*	-0.035	-0.019
	(-0.51)	(-2.28)	(-0.21)	(-1.92)	(-0.98)	(-1.47)
$\pi_{80/90}$	1.014***	– – –	1.019***	– – –	0.865***	– – –
	(17.07)		(17.04)		(10.78)	(12.63)
$\pi^T_{80/89}$	– – –	0.924***	– – –	0.947***	– – –	0.802***
		(15.53)		(15.73)		(12.63)
ΔCBI	-0.733	-0.038	-4.471	-0.237*	-0.264	-0.135*
	(-0.39)	(-0.72)	(-0.98)	(-1.85)	(-1.11)	(-1.69)
$(\Delta CBI)^2$	– – –	– – –	7.007	0.368*	0.467	0.218
			(0.90)	(1.70)	(1.16)	(1.60)
No. observ.	69	69	69	69	62	62
adj. R^2	0.81	0.78	0.81	0.79	0.65	0.72
F-statistic	146.78***	123.38***	97.85***	85.56***	38.78***	53.56***

All columns with odd numbers refer to the change in inflation and all columns with even numbers refer to the change in inflation tax. In columns (5) and (6) all countries which experienced an absolute change in inflation of more than 200 percentage points are excluded. All t-statistics are reported in parentheses. Estimates are based on ordinary standard errors. Significance levels are reported as follows: * for a 10%, ** for a 5% and *** for a 1%-significance-level.

Table A.2: Results for Democracy Accountability and Political Stability (ordinary standard errors)

	Dependent variable: Change in inflation tax							
	–Political Stability–				–Democratic Accountability–			
variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
constant	-0.185***	0.120	-0.660*	-0.063	-0.286***	0.100	-1.027***	-0.220
	(-3.05)	(0.76)	(-2.03)	(-0.27)	(-3.16)	(0.66)	(-3.64)	(-0.86)
$\pi^T_{80/89}$	1.014***	1.074***	1.271***	1.113***	0.984***	1.051***	1.024***	1.108***
	(17.54)	(17.19)	(8.46)	(12.44)	(17.67)	(19.49)	(12.13)	(13.98)
ΔCBI	-0.353*	-0.425**	-0.630**	-0.297	-0.536**	-0.604	-0.561*	-0.472
	(-1.89)	(-2.40)	(-2.78)	(-0.48)	(-2.64)	(-3.41)***	(-1.96)	(-0.79)
$(\Delta CBI)^2$	0.279	0.292*	0.119	0.577	0.172	0.139	0.034	0.162
	(1.44)	(1.72)	(1.24)	(0.82)	(0.92)	(0.94)	(0.47)	(0.31)
IQ	0.495**	0.268	0.615	0.638	0.893**	0.621**	2.674***	1.090
	(2.17)	(1.21)	(1.45)	(1.20)	(2.63)	(2.18)	(4.25)	(1.57)
$(IQ)^2$	-0.375	-0.125	-0.513	-0.418	-0.717**	-0.388	-1.908***	-0.973
	(-1.62)	(-0.58)	(-1.27)	(-0.89)	(-2.34)	(-1.54)	(-4.41)	(-1.52)
$IQ \times \Delta CBI$	0.272	0.434*	0.795**	-0.102	0.577**	0.748***	0.680*	0.589
	(1.17)	(1.99)	(2.72)	(-0.10)	(2.20)	(3.36)	(2.01)	(0.59)
$GDP_{80/89}$	– – –	0.007	0.015	0.013	– – –	0.005	0.004	0.006
		(0.85)	(1.48)	(0.69)		(0.75)	(0.92)	(0.46)
$GDPpc_{80/89}$	– – –	-0.014	0.030	-0.003	– – –	-0.024	0.004	-0.001
		(-0.79)	(1.04)	(-0.11)		(-1.67)	(0.22)	(-0.05)
$TRADE_{80/89}$	– – –	-0.043*	0.018	-0.056	– – –	-0.042**	0.006	-0.037
		(-1.94)	(0.91)	(-1.46)		(-2.10)	(0.50)	(-1.10)
ΔGDP	– – –	0.077	-0.097	0.080	– – –	0.110	0.021	0.031
		(1.08)	(-0.99)	(0.74)		(1.57)	(0.32)	(0.25)
$\Delta GDPpc$	– – –	-0.015	0.153	-0.007	– – –	-0.047	-0.032	0.093
		(-0.18)	(1.23)	(-0.05)		(-0.61)	(-0.37)	(0.67)
$\Delta TRADE$	– – –	-0.137***	-0.022	-0.160***	– – –	-0.133***	-0.003	-0.145***
		(-4.42)	(-0.68)	(-2.82)		(-4.96)	(-0.12)	(-3.02)
$PEGGED$	– – –	0.018	-0.006	0.022	– – –	0.019	0.005	0.024
		(0.92)	(-0.48)	(0.58)		(1.10)	(0.52)	(0.66)
East Asia	– – –	0.027	– – –	– – –	– – –	0.045	– – –	– – –
		(0.67)				(1.28)		
Latin America	– – –	0.012	– – –	– – –	– – –	0.004	– – –	– – –
		(0.38)				(0.13)		
Sub-Saharan	– – –	-0.084**	– – –	– – –	– – –	-0.097***	– – –	– – –
		(-2.43)				(-3.13)		
No. observ.	69	68	30	38	69	68	30	38
adj. R^2	0.84	0.90	0.92	0.87	0.85	0.92	0.97	0.89
F-statistic	59.22***	34.45***	26.98***	20.21***	65.68	49.41***	65.23***	24.79***

Estimates are based on ordinary standard errors. All t-statistics are reported in parentheses. Significance levels are reported as follows: * for a 10%, ** for a 5% and *** for a 1% significance-level.

Table A.3: Results for Political Stability and Democratic Accountability (TSLS-estimates)

	Dependent variable: Change in inflation tax							
	–Political Stability–				–Democratic Accountability–			
variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
constant	-0.182**	0.119	-0.470	-0.048	-0.287	0.110	-0.902***	-0.212
	(-2.33)	(0.57)	(-1.25)	(-0.16)	(-1.60)	(0.65)	(-3.25)	(-1.13)
$\pi^T_{80/89}$	1.017***	1.070***	1.234***	1.097***	0.983***	1.052***	1.03***	1.103***
	(17.39)	(18.11)	(8.55)	(19.88)	(21.20)	(22.08)	(10.82)	(17.44)
ΔCBI	-0.415**	-0.421**	-0.909***	-0.546	-0.535**	-0.552**	-0.751***	-0.513
	(-2.14)	(-2.15)	(-2.98)	(-0.68)	(-2.15)	(-2.14)	(-2.97)	(-0.71)
$(\Delta CBI)^2$	0.408*	0.255	0.149	0.841	0.209	-0.058	0.037	0.055
	(1.93)	(1.51)	(1.11)	(0.73)	(1.61)	(-0.29)	(0.49)	(0.09)
IQ	0.494*	0.263	0.728	0.472	0.894	0.627	2.505***	1.027*
	(1.83)	(1.13)	(1.70)	(1.33)	(1.35)	(1.59)	(3.98)	(2.01)
$(IQ)^2$	-0.382	-0.131	-0.685	-0.309	-0.717	-0.398	-1.836***	-0.951*
	(-1.59)	(-0.65)	(-1.73)	(-0.65)	(-1.26)	(-1.42)	(-3.97)	(-2.04)
$IQ \times \Delta CBI$	0.281	0.491**	1.175***	0.382	0.555*	0.832**	0.910***	0.836
	(1.34)	(2.24)	(3.19)	(0.35)	(1.80)	(2.61)	(3.10)	(0.74)
$GDP_{80/89}$	– – –	0.007	0.014	0.011	– – –	0.006	0.004	0.006
		(0.81)	(1.53)	(0.48)		(0.93)	(0.76)	(0.53)
$GDPpc_{80/89}$	– – –	-0.013	0.014	-0.001	– – –	-0.027	0.001	-0.002
		(-0.52)	(0.38)	(-0.03)		(-1.31)	(0.05)	(-0.11)
$TRADE_{80/89}$	– – –	-0.043*	0.016	-0.052	– – –	-0.039**	0.006	-0.032
		(-1.84)	(0.72)	(-1.05)		(-2.42)	(0.59)	(-1.17)
ΔGDP	– – –	0.082	-0.081	0.082	– – –	0.107	-0.003	0.019
		(0.97)	(-0.89)	(0.76)		(1.33)	(-0.05)	(0.21)
$\Delta GDPpc$	– – –	-0.021	0.110	-0.006	– – –	-0.045	-0.012	0.110
		(-0.21)	(1.01)	(-0.03)		(-0.48)	(-0.15)	(1.05)
$\Delta TRADE$	– – –	-0.140**	-0.027	-0.159	– – –	-0.131***	-0.000	-0.143**
		(-2.34)	(-0.86)	(-1.37)		(-2.97)	(-0.01)	(-2.11)
$PEGGED$	– – –	0.016	-0.004	0.023	– – –	0.019	0.007	0.028
		(1.19)	(-0.33)	(0.83)		(1.28)	(0.85)	(0.76)
East Asia	– – –	0.028	– – –	– – –	– – –	0.042	– – –	– – –
		(0.74)				(1.04)		
Latin America	– – –	0.010	– – –	– – –	– – –	-0.004	– – –	– – –
		(0.28)				(-0.11)		
Sub-Saharan	– – –	-0.087	– – –	– – –	– – –	-0.106**	– – –	– – –
		(-1.43)				(-2.10)		
No. observ.	69	68	30	38	69	68	30	38
adj. R^2	0.84	0.90	0.91	0.87	0.85	0.92	0.96	0.89
F-statistic	58.75***	37.15***	24.82***	19.83***	65.32***	47.56***	62.08***	24.51***

The TSLS-estimates are based on White heteroscedasticity-consistent standard errors. All t-statistics are reported in parentheses. Significance levels are reported as follows: * for a 10%, ** for a 5% and *** for a 1% significance-level.

Table A.4: Results for alternative institutional quality measures

	Dependent variable: Change in inflation tax							
	–Government Effectiveness–		–Rule of Law–		–RQ–	–Corruption–		–FoP–
variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
constant	0.068	0.126	-0.060	0.134	-0.137	0.038	0.031	0.139
	(0.43)	(0.65)	(-0.44)	(0.49)	(-1.11)	(0.25)	(0.16)	(0.66)
$\pi^{T}_{80/89}$	1.051***	1.101***	1.065***	1.088***	1.024***	1.076***	1.030***	1.079***
	(24.95)	(19.09)	(22.84)	(19.31)	(23.38)	(22.66)	(21.15)	(18.33)
ΔCBI	-0.45**	-0.552**	-0.396*	-0.572	-0.459**	-0.455**	-0.471**	-0.642**
	(-2.01)	(-2.27)	(-1.71)	(-1.63)	(-2.27)	(-2.08)	(-2.30)	(-2.25)
$(\Delta CBI)^2$	0.281*	0.335*	0.247*	0.293*	0.192*	0.311**	0.316**	0.244*
	(1.95)	(1.87)	(1.88)	(1.74)	(1.68)	(2.15)	(2.31)	(1.71)
IQ	1.443***	-0.440	0.983**	-0.207	1.339***	0.884**	0.649***	0.096
	(3.06)	(-1.37)	(2.27)	(-0.64)	(4.51)	(2.14)	(3.27)	(0.61)
$(IQ)^2$	-0.825***	0.297	-0.592**	0.153	-0.850***	-0.547**	-0.419***	-0.103
	(-2.99)	(1.41)	(-2.18)	(0.75)	(-4.31)	(-2.09)	(-3.18)	(-0.82)
$IQ \times \Delta CBI$	0.406*	0.432**	0.392	0.474	0.493**	0.395*	0.405**	0.569**
	(1.85)	(2.11)	(1.62)	(1.43)	(2.31)	(1.91)	(2.07)	(2.16)
$GDP_{80/89}$	0.007	-0.001	0.011	-0.002	0.014***	0.006	0.004	-0.005
	(1.28)	(-0.17)	(1.48)	(-0.25)	(3.09)	(0.94)	(0.65)	(-0.76)
$GDPpc_{80/89}$	-0.059**	0.016	-0.030	0.009	-0.042***	-0.030	-0.013	0.007
	(-2.23)	(1.08)	(-1.39)	(0.48)	(-3.03)	(-1.39)	(-0.84)	(0.56)
$TRADE_{80/89}$	-0.034*	-0.046*	-0.027	-0.049	-0.010	-0.034*	-0.041*	-0.054**
	(-1.79)	(-2.00)	(-1.67)	(-1.61)	(-0.90)	(-1.77)	(-1.71)	(-2.09)
ΔGDP	0.097	0.013	0.065	0.016	0.064	0.046	0.052	-0.013
	(1.60)	(0.23)	(1.14)	(0.28)	(1.62)	(0.87)	(0.91)	(-0.25)
$\Delta GDPpc$	-0.130	0.121*	-0.057	0.090	-0.083	-0.011	-0.010	0.111*
	(-1.42)	(1.80)	(-0.69)	(1.38)	(-1.42)	(-0.16)	(-0.15)	(1.99)
$\Delta TRADE$	-0.128***	-0.106**	-0.122**	-0.113**	-0.102***	-0.119**	-0.146**	-0.113**
	(-2.72)	(-2.29)	(-2.60)	(-2.06)	(-3.95)	(-2.37)	(-2.43)	(-2.15)
$PEGGED$	0.023	0.014	0.022	0.011	0.028**	0.016	0.025	0.008
	(1.60)	(0.72)	(1.56)	(0.69)	(2.04)	(1.14)	(1.58)	(0.54)
East Asia	0.034	0.035	0.050	0.038	0.021	0.045	0.052	0.057
	(1.11)	(0.89)	(1.35)	(0.86)	(0.72)	(1.28)	(1.47)	(1.39)
Latin America	0.038	0.032	0.058	0.038	0.021	0.028	0.020	-0.008
	(1.19)	(1.00)	(1.48)	(0.99)	(0.74)	(0.87)	(0.68)	(-0.26)
Sub-Saharan	-0.088*	-0.064	-0.049	-0.056	-0.058*	-0.069	-0.087	-0.065
	(-1.80)	(-1.06)	(-1.15)	(-0.86)	(-1.85)	(-1.41)	(-1.50)	(-1.20)
No. observ.	68	66	68	66	68	68	66	68
adj. R^2	0.92	0.88	0.91	0.88	0.95	0.90	0.90	0.89
F-statistic	47.84***	32.10***	44.52***	29.92***	86.11***	39.28***	36.13***	34.44***

Estimates are based on White heteroscedasticity-consistent standard errors. All t-statistics reported in parentheses. Significance levels are reported as follows: * for a 10%, ** for a 5% and *** for a 1% significance-level. Abbreviations: RQ – Requlatory Quality; FoP – Freedom of Press.

Table A.5: Results for Democratic Accountability (robustness checks)

	Dependent variable: $\Delta\pi$, $\Delta\pi^T$ or $\Delta\pi^T/\pi_{80/89}$					
	–Democratic Accountability–					
variable	(1)	(2)	(3)	(4)	(5)	(6)
constant	10.173	0.767*	3.520	-0.040	0.014	-0.085
	(1.13)	(1.86)	(1.67)	(-0.29)	(0.09)	(-0.45)
$\pi_{80/89}$	0.997***	– – –	– – –	– – –	– – –	– – –
	(33.68)					
$\pi^T_{80/89}$	– – –	– – –	– – –	1.069***	1.038***	1.064***
				(23.09)	(22.72)	(19.68)
ΔCBI	-18.334	-0.870**	– – –	– – –	0.185	– – –
	(-1.45)	(-2.17)			(0.42)	
$(\Delta CBI)^2$	1.728	0.283	– – –	– – –	0.089	– – –
	(0.39)	(1.07)			(0.87)	
CBI-growth	– – –	– – –	-1.193*	– – –	– – –	– – –
			(-1.93)			
$(CBI\text{-}growth)^2$	– – –	– – –	0.015	– – –	– – –	– – –
			(0.79)			
$\Delta CBI\text{-}resid$	– – –	– – –	– – –	-0.555**	– – –	– – –
				(-2.48)		
$(\Delta CBI\text{-}resid)^2$	– – –	– – –	– – –	0.092	– – –	– – –
				(0.49)		
$\Delta TURNOVER$	– – –	– – –	– – –	– – –	– – –	-0.009
						(-0.03)
$(\Delta TURNOVER)^2$	– – –	– – –	– – –	– – –	– – –	0.002
						(0.02)
IQ	30.152	1.122	0.043	0.865*	0.483	1.080
	(1.22)	(1.29)	(0.01)	(1.94)	(1.33)	(1.36)
$IQ\times\Delta CBI$	26.070	1.122**	– – –	– – –	1.393**	– – –
	(1.50)	(2.25)			(2.53)	
$IQ\times CBI\text{-}growth$	– – –	– – –	1.772**	– – –	– – –	– – –
			(2.08)			
$IQ\times\Delta CBI\text{-}resid$	– – –	– – –		0.808**	– – –	– – –
				(2.58)		
$IQ\times\Delta TURNOVER$	– – –	– – –	– – –	– – –	– – –	0.086
						(0.22)
$(IQ)^2$	-18.984	-0.918	2.770	-0.402	-0.363	-0.625
	(-1.04)	(-1.22)	(0.44)	(-1.38)	(-1.38)	(-1.10)
$GDPpc_{80/89}\times\Delta CBI$	– – –	– – –	– – –	– – –	-0.130*	– – –
					(-1.79)	
Controls	yes	yes	yes	yes	yes	yes
No. observ.	68	68	68	68	68	58
adj. R^2	0.87	0.34	0.27	0.92	0.92	0.89
F-statistic	29.48***	3.31***	2.66***	47.68***	48.82***	28.89***

The estimates are based on White heteroscedasticity-consistent standard errors. All t-statistics reported in parentheses. Significance levels are reported as follows: * for a 10%, ** for a 5% and *** for a 1% significance-level. The estimation results for the control variables are not reported. In column (1), we use the change in year-on-year inflation rates ($\Delta\pi$) as dependent variable. In column (2), we drop the initial level of the inflation tax. In column (3), we use the relative change in CBI (*CBI-growth*) as an alternative measure of innovations in central bank design and relative change in inflation tax ($\Delta\pi^T/\pi_{80/89}$) as dependent variable. Column (4) displays the results of an estimation on the basis of an adjusted measure of the change in CBI derived from the residuals of equation (6) (*CBI-resid*). In column (5), we add an interaction term between the change in CBI and initial (log) GDP per capita ($GDPpc_{80/89}$). In column (6), we make use of turnover rates of central banks presidents as provided by Crowe and Meade (2007) ($TURNOVER$).

A.2 Data sources and description

Central bank independence (CBI) data

Data on legal central bank independence for the 1980s is taken from Cukierman et al. (1992). Crowe and Meade (2007) provide replications of the Cukierman et al. (1992)-index based on the IMF's database of central bank laws at the end of 2003. Values for both indicators are available for 69 countries which are listed below:

Table A.6: Sample Countries

Argentina, Australia, Austria, Bahamas, Barbados, Belgium, Bolivia, Botswana, Brazil, Canada, Chile, China, Colombia, Dem. Rep. Congo, Costa Rica, Denmark, Egypt, Ethiopia, Finland, France, Germany, Ghana, Greece, Honduras, Hungary, Iceland, India, Indonesia, Ireland, Israel, Italy, Japan, Kenya, South Korea, Lebanon, Luxembourg, Malaysia, Malta, Mexico, Morocco, Nepal, Netherlands, New Zealand, Nicaragua, Nigeria, Norway, Pakistan, Peru, Philippines, Poland, Portugal, Qatar, Romania, Serbia, Singapore, South Africa, Spain, Sweden, Switzerland, Tanzania, Thailand, Turkey, Uganda, United Kingdom, United States, Uruguay, Venezuela, Zambia, Zimbabwe

Inflation

Annual inflation data (percent per annum, variable π) is taken from the IMF *International Financial Statistics*. The inflation tax (π^T) is calculated on the basis of $\pi^T = \pi/(1+\pi)$. Inflation data for the relevant periods (1980-1989) and (1998-2007) is constructed using unweighted averages of the available inflation data at an annual frequency.[17]

Institutional quality data

In our empirical analysis we make use of seven proxies for institutional quality. We distinguish between *democratic accountability*, *political stability*, *government effectiveness*, *rule of law*, *regulatory quality*, *corruption* and *freedom of press*. The institutional quality measures are taken from the *World Bank's Governance Indicators* dataset [Kaufmann et al. (2009)], the *International Country Risk Guide* (ICRG) dataset [PRS-Group (2007)] and the Freedom House dataset [FreedomHouse (2008)]. The World Bank data are in annual frequency since 2002 and in biannual frequency for 1996-2000. We use the unweighted average in the period from 2000 to 2005. ICRG data is only available since 1984. Hence, we calculate the average values for the period from 1984 to 2005. With respect to the Freedom House data we apply the annual average in the period from 1980 to 2005. To better compare the different estimation results we rescale all measures to the unit interval. A value of 0 (1) represent the lowest (highest) institutional quality.

Other controls

Data for the GDP per capita, the population to calculate the level of GDP and the measure of openness are all in constant prices and taken from Heston et al. (2009) (Penn World Table Version 6.3, series label: *rgdpl*, *POP* and *openk*). The initial level of the three variables is calculated using unweighted averages for the period from 1980 to 1989. Changes are defined as the difference between the averages of the two periods (1980-1989) and (1998-2007). The classification of countries according to their exchange rate regimes is based on the work of Caramazza and Aziz (1998). Their classification refers to the year 1997 and seems adequate here since most revisions of central bank law occurred in the 1990s.

[17]Where data is not available we use data provided by the DSI (Data Service & Information) in the respective countries. In some countries inflation data is only available since 1981. In this case, the average annual inflation tax for the 1980s is calculated for the period from 1981 to 1989. For Nicaragua, due to data availability the inflation tax for the 1980s represents the average of the years 1989/1990.