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CZECH NATIONAL BANK

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Reviewed by: Peter Stella (Stellar Consulting LLC)
David Archer (Bank for International Settlemets)
Jaromír Baxa (Institute of Economic Studies, Charles University, Prague)
Jan Schmidt (Czech National Bank)

Project Coordinator: Michal Franta

Does Central Bank Financial Strength Matter for Inflation? An Empirical Analysis

Soňa Benecká, Tomáš Holub, Narcisa Liliana Kadlčáková and Ivana Kubicová*

Abstract

This paper analyses empirically the link between central bank financial strength and inflation. The issue has become very topical in recent years as many central banks have accumulated large financial exposures and the risk of losses has risen. We conclude that even though some estimates show a statistically significant and potentially non-linear negative relationship between several measures of central bank financial strength and inflation, this link appears rather weak and not as robust as suggested by the previous – very limited – literature. In general, other inflation determinants play a much more important and robust role.

JEL Codes: E31, E52, E58.

Keywords: Central bank financial strength, central bank independence, inflation, monetary policy, seigniorage.

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* Soňa Benecká, Czech National Bank, Monetary and Statistics Department (sona.benecka@cnb.cz); Tomáš Holub, Czech National Bank, Monetary and Statistics Department (tomas.holub@cnb.cz), corresponding author; Narcisa Liliana Kadlčáková, Czech National Bank, Monetary and Statistics Department (narcisa.kadlcakova@cnb.cz); Ivana Kubicová, Czech National Bank, Monetary and Statistics Department (ivana.kubicova@cnb.cz).
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Nontechnical Summary

This paper analyses empirically if there is a link from central bank finances to inflation. There is no consensus on this issue in the academic literature. On the one hand, there are papers arguing that a central bank's financial weakness can lead to "policy insolvency". On the other hand, some authors argue that central bank financial strength is just one of many features of the monetary policy institutional set-up, and that its link to inflation is far from straightforward. In terms of country case studies, one can find examples in both directions, too. There are historical examples of countries where central bank financial weakness has led to clear problems, but there are also central banks – including the Czech National Bank – that have successfully delivered price stability for many years irrespective of their negative equity.

The empirical literature on this issue is so far very limited. One notable exception is the paper by Klüh and Stella (2008). The authors of this paper found a relatively stable and robust negative relationship between central bank financial strength and inflation, but at the same time suggested that only a relatively strong impairment of the central bank's balance sheet would result in a significant worsening of inflation performance. Another recent contribution is Adler et al. (2012), which suggests that central bank financial strength can be a statistically significant factor explaining large negative interest rate deviations from a forward-looking Taylor rule.

The present paper uses a panel of more than 100 countries between 2002 and 2009 to analyse the link. It applies five alternative measures of central bank financial strength, related to both their balance sheets and their profit-and-loss accounts, to deal with the difficulty in finding a universally accepted proxy due to the significant differences in central bank accounting and buffering methods, as well as due to the economically uncertain best definition of their financial strength. Several econometric techniques are used to achieve comparability with the previous research and to check the robustness of the results.

Several structural determinants of inflation are employed as control variables. In particular, the level of economic development, capital account openness, a fixed exchange rate regime and an inflation targeting framework are found to be associated with lower inflation. The impact of the inflation targeting framework appears particularly strong and stable across model specifications. The global price of oil has a substantial effect on inflation worldwide, with the expected positive sign.

The paper finds in a few cases a statistically significant negative relationship between some measures of central bank financial strength and inflation. Nevertheless, the results lack robustness with respect to the choice of alternative measures of financial strength and the econometric technique. At the same time, the relationship – if there is any – is found to be non-linear, with only substantial financial weakness being associated with higher inflation. There is also some evidence (using pooled OLS estimation) that the link exists only for those countries which enjoy the lowest level of central bank legal independence and/or exhibit relatively high inflation rates. In general, the explanatory power of central banks' financial strength indicators is rather weak, while other inflation determinants seem to play a more important and robust role.

1. Introduction and Motivation

The issue of whether central banks' finances affect their policy performance has been relevant for the Czech National Bank, as well as for several other central banks in catching-up economies that have experienced negative equity in the last decade. More recently, this issue has also become topical for advanced economies, as their central banks have increased their financial exposures considerably as a result of anti-crisis measures (Buiter, 2008; Stella, 2009), and some of them – especially the Swiss National Bank in 2010 (see Jordan, 2011) – have already experienced financial losses.

The answer to this question is neither easy nor uncontroversial. There are numerous historical examples – typically associated with fiscal or quasi-fiscal operations – when central bank financial weakness has become so serious that the pursuit of monetary policy objectives has been clearly affected. Nonetheless, for most central banks financial losses or even negative equity have no direct implications for their performance. A central bank can hardly become illiquid in the domestic currency, as it is its monopoly issuer, so it can continue to service its liabilities smoothly even with negative equity. Moreover, central banks are typically not subject to standard bankruptcy procedures, and zero is thus not a legally binding constraint for their equity. Finally, the right to collect seigniorage (i.e. monetary income) means that central banks' actual financial strength typically goes well beyond their accounting equity.

However, it is argued that central banks' finances could have an impact on their policy pursuit and outcomes due to "soft" considerations, such as political independence, credibility and reputation. A government can try to limit the autonomy of a loss-making central bank, as the losses do have long-term fiscal implications (reduced net transfers of dividends to public budgets) and their origins may be viewed as controversial. To avoid such negative consequences, a central bank may abstain from potentially loss-generating activities in the first instance, or try to improve its finances by allowing higher inflation once the losses have occurred.

There are several quotes by policymakers that are often used to illustrate that central banks do indeed care about their finances. Fukui (2003), the former Governor of the Bank of Japan (BoJ), is often mentioned in this context. He stressed that: "The (above) cases of actual behavior of some central banks indicate that central banks' concern with the soundness of their capital base might not be grounded purely in economic theory but may be motivated rather by the political economic instincts of central bankers…." More recently, Governor Shirakawa (2010) also discussed the issue of potential central bank losses in relation to the BoJ's Asset Purchase Program introduced in October 2010, even though in his speech he explained that ultimately prominence had been given to the policy goals and not to financial considerations. Another statement which is cited rather frequently (see, for example, Stella and Lönnberg, 2008) is by Francisco de Paula Gutierrez, President of the Central Bank of Costa Rica: "We, the central bank, have a negative net worth…and this remains our greatest challenge."[1] The link between policy objectives and financial considerations was also mentioned in recent speeches by Bini-Smaghi (2011), a member of the ECB's Executive Board, and by Governor Fischer (2011) of the Bank of Israel in the context of FX

[1] Central Banking, Vol. XV, No. 4, May 2005.

reserves accumulation.[2] The issue was also discussed by Jordan (2011), Vice Chairman of the Swiss National Bank.

The political-economy considerations could thus be very important. But at the same time their relevance is likely to depend very much on other aspects of the institutional design of each central bank. The impact of central bank finances on policy performance may thus be far from straightforward and linear. It is therefore ultimately an empirical question whether any such link exists, and – if it does – how strong it is, and whether it can be offset by other institutional or economic features.

Unfortunately, the empirical evidence on these crucial questions is scarce. In fact, we are aware of just two papers that investigate the issue using standard econometric methods (Klüh and Stella, 2008; Adler, et al., 2012). In our paper, we extend the analysis of Klüh and Stella (2008) and explore the robustness of their results using a broader and more recent data sample, enriching the set of variables approximating the financial strength of central banks, and employing some alternative control variables and econometric techniques.

The paper is organized as follows. Section 2 provides a literature review related to central banks' financial issues and their impact on policy performance. Section 3 defines the data to be used in the empirical analysis, describes the recent evolution of central banks' financial strength ratios, and provides a simple correlation analysis of these ratios with inflation. It is followed in Section 4 by regression estimation outcomes using several econometric techniques and in Section 5 by some (further) robustness checks focusing mainly on the (non-)linearity of the relationship analysed. Finally, Section 6 summarizes and concludes.

2. Literature Review

A general overview of the literature focusing on the origins of losses, discussing the intertemporal solvency of central banks and modelling their balance sheets has been presented already in Cincibuch et al. (2008; 2009). Many useful general references can also be found in a recently published book edited by Milton and Sinclair (2011). In the present paper, we thus limit ourselves to reviewing specifically those papers that have explicitly discussed the link from central bank finances to policy pursuit, with an emphasis on empirical work.

The debate goes back – at least – to two seminal papers from the 1990s, which were to a large extent affected by the preceding experience with central bank quasi-fiscal operations, especially during the Latin American debt crisis of the 1980s. Fry (1993) claimed that central banks' (quasi-)fiscal activities undermine both their independence and ultimately also their monetary policy objectives, as the resulting losses must eventually be covered by an expansion of central bank money. Stella (1997) also argued that a large negative net worth of a central bank was likely to compromise its independence and interfere with its policy objectives and in particular with price stability. More recently a similar line of reasoning was followed, for example, in Sims (2004),

[2] "In the case of pressures for appreciation, the central bank has to balance the net costs of holding additional reserves against the benefits of preventing unwanted appreciation. This is a complicated calculus…"

Bindseil et al. (2004), Stella (2005) and Ize (2005). Stella and Lönnberg (2008) condensed these ideas into the expression "policy insolvency", as opposed to "technical insolvency", to describe situations in which central banks' policies become affected by their financial weakness. Policy insolvency can occur only in cases where central bank finances are severely distressed, rather than on the margin, implying potentially strong non-linearity in the relationship. The source of the loss may also be crucial, with fiscal abuse of central banks likely to have the most detrimental consequences.

Cargil (2005) argued that the BoJ had indeed taken its financial results into account in the preceding decade, claiming that this had become an undesirable policy constraint in practice, interfering with monetary policy and leading to suboptimal outcomes. On the other hand, Jeanne and Svensson (2007) developed a theoretical model in which they showed that a positive weight put by a central bank on its balance sheet might actually provide a welcome commitment device for escaping from a liquidity trap, as the desire to avoid negative equity makes the promised future money creation and exchange rate depreciation more credible.

There are also papers suggesting that the link between central bank finances and policy outcomes is not straightforward, and that other aspects are crucial, too. For example, Ueda (2004) wrote: "Summing up the experiences of insolvent central banks, my conclusion is that the maintenance of a sound balance sheet is, in general, neither a necessary nor a sufficient condition for fulfilling a central bank's responsibility, but there have been cases where an unhealthy balance sheet became a major obstacle to price stability." In a similar vein, Cukierman (2011) acknowledged the role of the central bank's capital for preserving its policy independence, but at the same time highlighted the importance of other institutional aspects, such as the range of central bank responsibilities and risks assumed, central bank independence, the exchange rate regime and the degree of fiscal responsibility. He stated that negative central bank capital does not *always* prevent the achievement of price stability, giving the Central Bank of Chile as an example.

The Czech National Bank (CNB) is another central bank that has been able to achieve price stability irrespective of its negative equity situation (other examples include Slovakia, Israel, Mexico and Thailand). This country case has been described by Frait (2005), Cincibuch et al. (2008, 2009) and Frait and Holub (2011), who stressed the non-inflationary nature of the CNB's accounting losses related to large FX reserves and assessed the bank's ability to get out of its negative equity situation in the future without resorting to faster price growth. On the other hand, Mandel and Zelenka (2009) partly disputed the benign view of the CNB's losses, arguing that these have real income and demand consequences.

Given this diversity of opinions as well as of country experience, it is in the end an issue for empirical investigation if central bank financial strength indeed affects policy performance. Unfortunately, systematic evidence in this area is rather scarce. At the same time, it focuses almost exclusively on one dimension of policy success, i.e. on the achievement of low inflation. This focus is justified on two grounds. First of all, price stability is typically considered the primary objective of monetary policy, and high inflation would thus be a clear sign of policy failure. Second, higher inflation is a way to boost seigniorage, meaning that there is a potentially straightforward "transmission" between a central bank's desire to overcome its financial weakness and policy outcomes. Nevertheless, central bank finances could be equally – or even more – important for other policy areas, such as financial stability and foreign exchange policy.

Some stylized facts showing that central bank financial weakness is empirically associated with higher inflation were provided in Stella (2003) and in several follow-up papers by the same author. He divided his sample of central banks in the years 1992, 1996 and 2002 into two groups based on his measure of financial strength, defined as the sum of capital and "other items net" (OIN; from the IFS IMF database) relative to total assets. "Weak" central banks were those for which this measure of financial strength was negative, while the ones in positive territory were called "strong". He found that mean inflation for the weak group was 26%, twice as high as for the strong group.[3] This difference was statistically significant at all standard confidence levels using the t-test.

Stella (2008; 2011) repeated this empirical work with more recent data and obtained very similar results. In particular, he used the data from 1992, 1997 and 2004, and found that inflation was on average 23.8% for the weak central banks and 11.2% for the strong ones, this difference again being significant at the 99% confidence level even after correcting for hyperinflationary outliers. He also mentioned a few country cases where inflation had fallen significantly after their central banks had been recapitalized.

Ize (2006) used a sample of 87 countries and divided them into "weak" and "strong" ones based on structural pre-transfer profits, i.e. their interest margin plus other structural net income minus operating expenditure. The weak (strong) central banks were those with negative (positive) structural profits in 2003. He found out that the average inflation rate was 9.5% for the weak central banks and 3.5% for the strong ones, although he did not formally test if this difference was statistically significant. He conjectured that the weak performers partly made up for their financial difficulties by following looser monetary policies, or alternatively that more inflationary environments allowed room for higher central bank expenditure and negative structural profitability.

The paper by Klüh and Stella (2008) was probably the first attempt to investigate the relationship between central bank financial strength and inflation econometrically, using a range of control variables to take into account other relevant inflation determinants. As it is the key starting point for our own analyses, we review this paper in detail. The authors used primarily a panel of 15 Latin American and Caribbean countries from 1987 to 2005. As a measure of central bank financial strength they chose four different proxies, one of them being the same balance sheet measure as in Stella (2003; 2008), and the other three being flow variables reflecting central bank profitability as a ratio to total assets (the return on average assets, ROAA) or to GDP (either in the current year or over the last 2–4 years). As control variables they employed world inflation, central bank independence (several alternative measures), fixed exchange rate regime, quality of institutions, GDP per capita, incidence of a banking crisis, and public budget deficit, which all turned out to be statistically significant in at least some versions of the estimates. In terms of econometric method, they proceeded from simple pooled OLS to fixed effects, and eventually also to Feasible Generalized Least Squares (FGLS). They concluded that there appeared to be a relatively stable negative relationship between central bank financial strength and inflation, which was moreover robust to the choice of the key explanatory variable, control variables and the econometric

[3] The median inflation performance was 10.1% for weak banks and 5.8% for strong banks.

technique.

As a further robustness check, Klüh and Stella (2008) used a cross-section of almost 100 countries with a smaller set of control variables, and found a negative relationship between their balance sheet measure of central bank financial strength ($CBFS_1$) and inflation. Looking deeper into the relationship, the authors concluded that only a relatively strong impairment of the central bank's balance sheet would result in a significant worsening of inflation performance, suggesting some non-linearity of the empirical link.

The most recent contribution to the literature is Adler et al. (2012). Unlike in the previous studies, the authors do not analyse the empirical impact of central bank finances on inflation, but instead focus on a measure of monetary policy constraint, which is defined as the deviation of actual interest rates from an estimated forward-looking Taylor rule. In other words, this study focuses on the link from central bank financial strength to monetary policy *actions*, rather than to monetary policy *outcomes*. Using a sample of 41 countries and applying both linear and nonlinear techniques, the authors find that central bank financial strength can be a statistically significant factor explaining large negative interest rate deviations from "optimal" levels. A set of robustness checks is also provided to support this conclusion.[4]

Similarly to Klüh and Stella (2008), we focus our econometric analysis on the link between central bank financial strength and inflation. Our own analysis, however, differs from theirs in several important respects, providing an in-depth robustness check of their results. First of all, we use a broader and more recent panel data sample covering 105 countries worldwide between 2002 and 2009. Second, we enrich the set of variables approximating the financial strength of central banks.[5] Third, we use some alternative control variables and employ econometric techniques better suited to our panel data set-up. Fourth, in some of our estimates we explore whether the strength of the relationship between central bank finances and inflation outcomes depends on the degree of legal central bank independence, conjecturing that with a high degree of independence a central bank is less exposed to the political-economy aspects of its financial situation.

[4] Ultimately, the critical point of this approach seems to be the reliability of Taylor rule estimates, i.e. avoiding misspecifications which would lead to spurious correlation of the residuals with central bank financial strength. For example, an exchange rate appreciation/depreciation shock directly lowers/increases the central bank's financial strength due to revaluation losses/gains on the FX reserves. At the same time, it exerts pressure for lower/higher inflation in the future, and thus for interest rate cuts/hikes at present. Lower/higher central bank financial strength is thus associated with lower/higher rates. Ideally, this would be captured by the estimated forward-looking Taylor rule, and the measure of monetary policy constraints would thus be unaffected, but this may be hard to achieve in practice in a study using a broad country sample.

[5] Two of the variables that we use – ROAA and $CBFS_1$ (see below) – are in line with Klüh and Stella (2008). The other three variables are unique to our analysis.

3. Proxies for Central Bank Financial Strength and Data Description

3.1 Measures of Central Bank Financial Strength

The empirical analysis of the link between central bank finances and inflation suffers from the difficulty of finding a suitable proxy for central bank financial strength. There are at least two crucial issues which complicate the situation. One of them is related to accounting, while the other is of an economic nature.

On the accounting side, there are significant differences among central banks concerning their valuation, accounting and buffering methods (see, for example, Stella, 2008). The extent to which central banks revalue their assets and liabilities and mark them to market varies greatly. At the same time, the degree to which (unrealized) revaluation gains or losses are passed to the profit-and-loss account and/or to equity is very differentiated. For example, there have been instances when unrealized revaluation losses have not been recognized as negative liabilities lowering central bank equity, but as positive revaluation "assets". The same profit-and-loss figure or the same equity measure can thus mean markedly different things for different central banks. Standard accounting concepts of financial strength, which may work reasonably well for commercial enterprises, may therefore not be ideal for central banks.[6] To partly overcome this problem, Klüh and Stella (2008) – following, for example, Stella (2003 and 2008) – instead used an indicator labelled $CBFS_1$, which represents the ratio of central bank capital plus other items net from the IMF's IFS database divided by total assets. A large ratio of other items net to total assets suggests, according to Klüh and Stella (2008), low central bank transparency and may hide some financial weakness not shown in the equity.

To check the robustness of their results, Klüh and Stella (2008) also used three flow measures of central bank profitability relative either to overall assets or to GDP. A profitability measure (i.e. structural pre-transfer profits) was also used in Ize (2006). One clear advantage of such flow indicators may be data availability, especially as far as ROAA is concerned. The preferred indicator of Klüh and Stella (2008), denoted $CBFS_3$ and defined as the ratio of the central bank's income to GDP, had another advantage of having been scrutinized by IMF staff. In this case, the data availability was limited to 15 Latin American and Caribbean countries in 1987–2005, which constrained the number of observations significantly, but at the same time might have helped in terms of sample homogeneity. On the negative side, flow measures of financial strength are even more likely to suffer from the problem of accounting and buffering differences among central banks than balance sheet (i.e. stock) measures.[7] They also exhibit high time variation. Moreover, in

[6] Sometimes, non-standard accounting approaches are motivated by an effort to avoid the political-economy consequences of weak reported financial results. To the extent that it is these political-economy aspects that could adversely affect monetary policy outcomes, the accounting numbers could still play a role even if they are not a proper reflection of the underlying economic reality. In other cases, though, the accounting treatment may reflect a desire to build financial buffers in central banks' balance sheets, which would otherwise not be possible given the existing profit distribution rules. Here, the implicit belief is that the actual financial strength matters more than the reported financial figures. We thus consider it appropriate to use a range of financial strength measures, with some of them being closer to the officially reported numbers and others reflecting more closely the economic reality, and let the data tell which of these perform well empirically.

[7] For example, as regards unrealized valuation gains or losses, the extent to which they are taken to the P&L may differ greatly, while recording them completely outside equity is less common.

their case the issue of potential reverse causality may be more serious than for balance sheet measures, as higher inflation could directly and quickly improve the profitability of central banks via higher seigniorage.

From the economic point of view, central bank financial strength typically goes well beyond accounting equity. This is mainly due to the ability to collect seigniorage in the form of having an unremunerated liability – currency plus possibly non-interest-bearing bank reserves – that behaves as a kind of quasi-capital and can be invested in assets generating positive yields. To take this into account, Stella (2010) for example used a broader proxy for financial strength in which "currency is added to capital to obtain a superior measure of the ability of the central bank to generate seigniorage and finance its operational and quasi-fiscal expenditures". Bini-Smaghi (2011) also argued that "the seigniorage income expected for the future constitutes an implicit financial buffer that needs to be considered when assessing the economic capital of a central bank". On the other hand, central banks may also have assets with no or below-market yields, reflecting, for example, past bank bailouts, accounting treatment of unrealized valuation losses (see above) or non-genuine recapitalizations using non-interest-bearing government bonds. Ultimately, one could go as far as calculating the net present value of central banks (see, for example, Fry, 1993; Stella, 1997; Cincibuch and Vávra, 2001), but this is impractical for an empirical analysis covering a broad country sample.[8]

To partly deal with these issues, and as a robustness check, five alternative proxies for the financial strength of central banks are considered in this paper, referring both to their balance sheet situation and to their profitability. We use the BankScope database as our key data source, which covers a broad range of countries in a standardized manner. Moreover, in order to achieve some comparability of our results with Klüh and Stella (2008), we also use their measure of financial strength, $CBFS_1$, computed using data from the IMF's IFS database.

Balance Sheet Measures

1. The ratio of equity to total assets (ETA) indicates the relative proportion of a central bank's assets financed by its own resources. It is a natural benchmark to start with; although it may be too narrow for the central banking context, it is often used in policy debates[9] and thus deserves some attention – which it has not yet received – in empirical analysis. Source: BankScope

$$ETA = \frac{equity}{total\ assets}$$

This first indicator gives us a glimpse of how well central banks are capitalized, at least officially. Most of the countries have positive but relatively low ETA values. Still, there are between five and

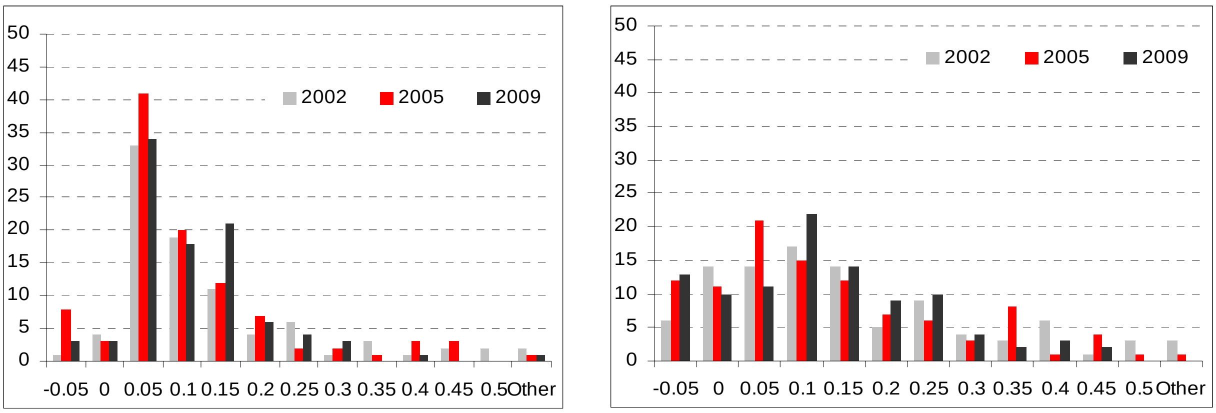
[8] One can also discuss intertemporal solvency and the long-run sustainability of central banks' balance sheets using the analytical approach from Ize (2005) and Cincibuch et al. (2009). However, this is also extremely difficult to do in practice for more than just a few central banks.

[9] See, for example, the ECB Convergence Report 2010, p. 239, or the quote of Francisco de Paula Gutierrez in Section 1.

fifteen countries with negative central bank equity from 2002 to 2009.[10] This represents between 5% and 10% of all countries for which the data is available. The distribution of countries according to ETA is shown in Figure 3.1 (left-hand part). As to the overall trends, the average ETA across our panel decreased from more than 10% in 2002 to 8% in 2009, suggesting some deterioration in the relative capital endowment of central banks (which may reflect both declining capital and growing assets).

Figure 3.1: Distribution of ETA and $CBFS_1$

ETA *$CBFS_1$*



Note: Number of countries in histograms.
Source: BankScope, IMF.

2. <u>The ratio of "broadly-defined" capital to total assets ($CBFS_1$)</u> based on Klüh and Stella (2008) is the sum of central bank capital and "other items net" (i.e. a residual item in the data) divided by total central bank assets. Source: IMF IFS

$$CBFS_1 = \frac{equity + other\ items\ net}{total\ assets}$$

This indicator (see Figure 3.1, right-hand panel) captures a broader definition of financial strength compared to ETA, as it also contains "Other items net" (OIN), which reflect – inter alia – specific accounting and reporting practices (see Stella, 2008). The number of countries with negative $CBFS_1$ has increased over time, while the share of countries with high financial strength ($CBFS_1$ of more than 30%) has dropped (Figure 3.1, right-hand part). As a result, the average $CBFS_1$ for our panel declined from more than 12% in 2002 to 6% in 2007, partially recovering to 9% in 2009. The contribution of OIN to this indicator and its evolution is shown in Figure 3.2 (left-hand panel), which suggests that the ratio of OIN to total assets has broadly stabilized and more than 80% of all countries now have a ratio close to zero.[11]

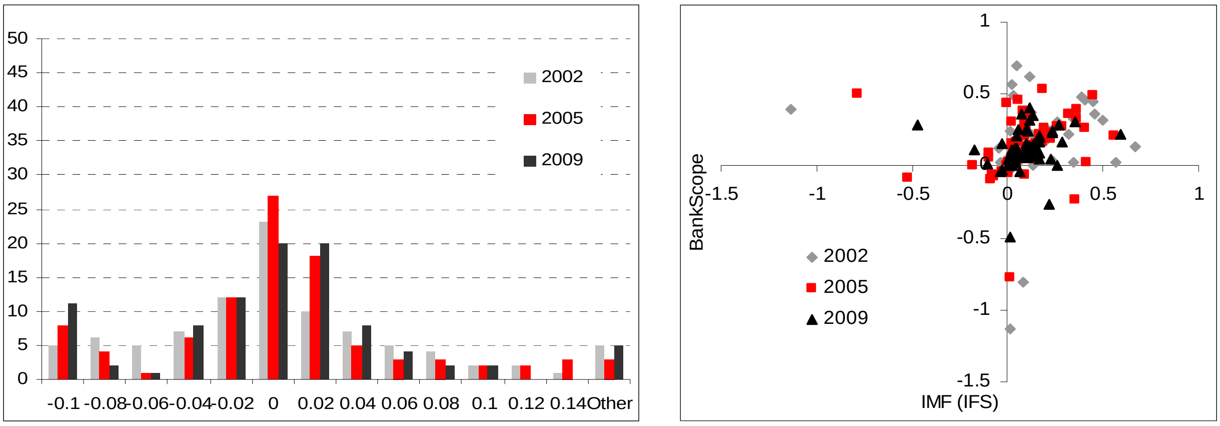
[10] The data must be interpreted with a degree of caution as the sample changes due to data availability issues. The IFS database presents a somewhat more stable sample.

[11] Nevertheless, it may still be important to take OIN into account for the other 20% of central banks, as it might be exactly this group that exhibits a relationship between central bank financial weakness and inflation.

Besides the inclusion of OIN, another difference between $CBFS_1$ and ETA is the source of data, i.e. the IMF's IFS instead of BankScope. We can use this to check data quality and robustness. If we compare equity to total assets as reported by the IMF and BankScope, some important differences appear (see Figure 3.2, right-hand part), although they seem to have declined in recent years. This illustrates the importance of the data issues discussed above.

Figure 3.2: Distribution of OIN and a Database Comparison for the Equity Ratio

OIN / total assets *Equity / total assets*



Note: Number of countries in histogram.
Source: BankScope, IMF.

3. <u>The ratio of net non-interest bearing liabilities (NNIBL)</u> to total assets is given by equity plus the difference between other non-interest bearing liabilities and non-earning assets together with fixed assets, divided by total assets. Source: BankScope

$$NNIBL = \frac{equity + \text{non-interest bearing liabilities} - \text{non-earning assets} - fixed\ assets}{total\ assets}$$

This ratio is a broad measure which captures not just central bank capital, but also issued currency as a non-interest bearing liability, allowing the central bank to generate seigniorage. At the same time, assets that are not generating any yields (which could partly be "artificial" accounting items reflecting valuation losses, results of non-genuine central bank recapitalizations using non-interest bearing government bonds,[12] etc.) are subtracted. This is the measure of financial strength that we prefer from the economic point of view, as it should capture the overall earning potential of a central bank, even though it comes at the cost of somewhat reduced data availability.[13]

The distribution profile of NNIBL differs from the ETA distribution (compare the left-hand panels of Figures 3.1 and 3.3). As shown in Figure 3.3 (right-hand part), most countries have NNIBL values higher than ETA, while both indicators are positive. This reflects the fact that the components of NNIBL other than equity typically contribute positively to central bank financial

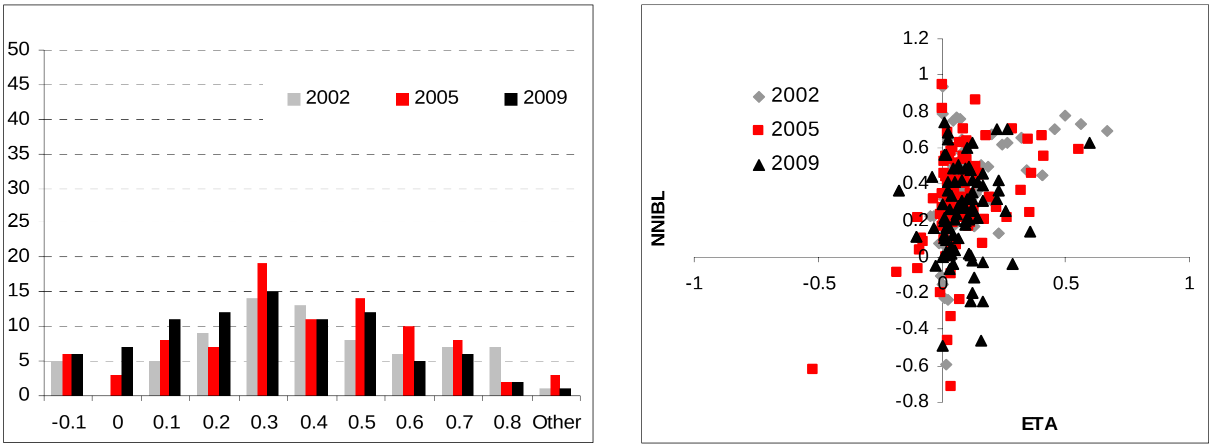
[12] Unfortunately, this measure cannot capture those cases where the government bonds are remunerated at artificially low interest rates, which was historically the case in many countries (e.g. Indonesia).

[13] The necessary items for computing NNIBL are not available in some cases (e.g. Israel, Costa Rica). Generally, our sample for NNIBL is smaller than for all other measures of central bank financial strength.

strength, mainly due to non-interest bearing liabilities, primarily representing currency in circulation. In some cases, these items more than outweigh the negative equity, resulting in a negative ETA being accompanied by a positive NNIBL.[14] However, there are also a few countries that have positive ETA but the other components draw their NNIBL into negative territory.

Figure 3.3: Distribution of NNIBL and its Comparison to ETA

NNIBL *NNIBL compared to ETA*



Note: Number of countries in histogram.
Source: BankScope, IMF.

Profitability measures

4. The return on average assets (ROAA) is the ratio of net income divided by average total assets. This ratio reflects net returns generated on central bank assets, and it is commonly used in the business world. Source: BankScope

5. The return on average equity (ROAE) is the standard ratio of net income divided by average equity. It measures the profitability of the central bank's own funds. Source: BankScope

Looking at the historical evolution of these central banks' profitability ratios, one can observe an increase after 2003, with a slight subsequent decline in 2009.[15] The share of countries with negative ROAA peaked in 2004 at 26%, while in 2008 and 2009 only 15% of the sample had a negative result (Figure 3.4). A majority of central banks have been achieving positive ROAA of up to 4%. ROAE has a more dispersed distribution, with some central banks achieving rather high values, reflecting relatively high profits in spite of the negligible equity that a central bank can achieve, mainly due to its ability to collect seigniorage.

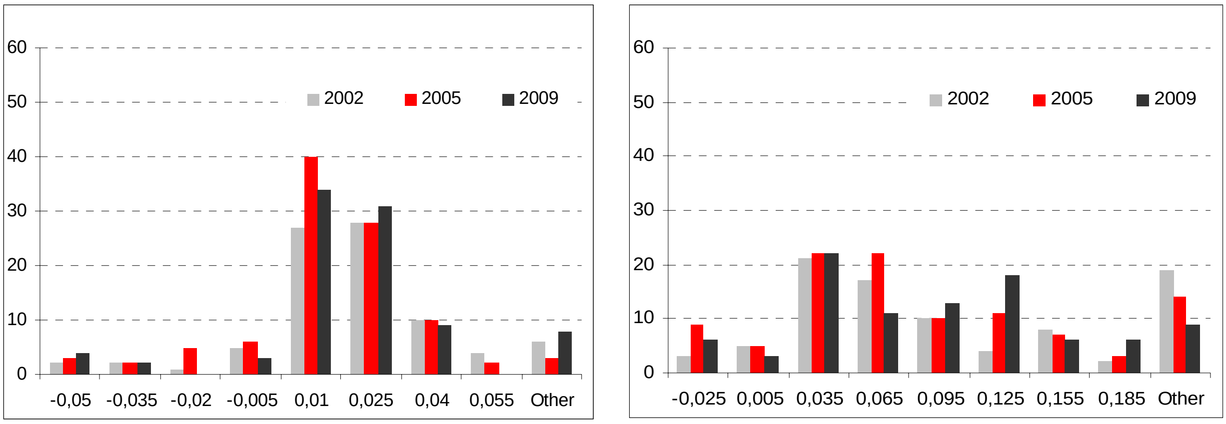
[14] This is the case of Turkey, Poland (in two years), Israel, the Czech Republic, Slovakia, Uruguay, Chile and Mexico.

[15] The average ROAA increased from close to zero in 2003 to 1.7% in 2008. This suggests a reversal of the declining trend in ROAA from 1995 to 2005 found by Klüh and Stella (2008).

The observed increase in ROAA probably reflects the increase in global interest rates between 2004 and 2008 amid rising global inflationary pressures in that period; note that this suggests a potential positive correlation between ROAA and inflation due to the reverse causality issue (see Section 4). The second important macroeconomic determinant of central bank profitability is the development of the exchange rate and the related revaluation gains/losses. We indeed found a weakly positive relationship between profitability and the percentage change in the exchange rate in our sample.

Figure 3.4: Return on Average Assets (ROAA) and Return on Average Equity (ROAE)

ROAA *ROAE*



Note: Number of countries in histograms.
Source: BankScope;

3.2 Cross-country Correlations between Central Bank Finances and Inflation Outcomes

Figure 3.5 presents pooled scatter plots linking our central bank financial strength measures with inflation.[16] In particular, monetary policy performance is measured as in Klüh and Stella (2008) by the rate of depreciation of purchasing power. The dependent variable d is defined as $d = \pi_t / (1 + \pi_t)$, where π is the annual inflation rate. The variable d is thus a rescaled measure of inflation that deals with hyperinflationary outliers.[17] As regards the financial strength proxy variables, they are lagged by one year to achieve consistency with the econometric analysis presented later on.

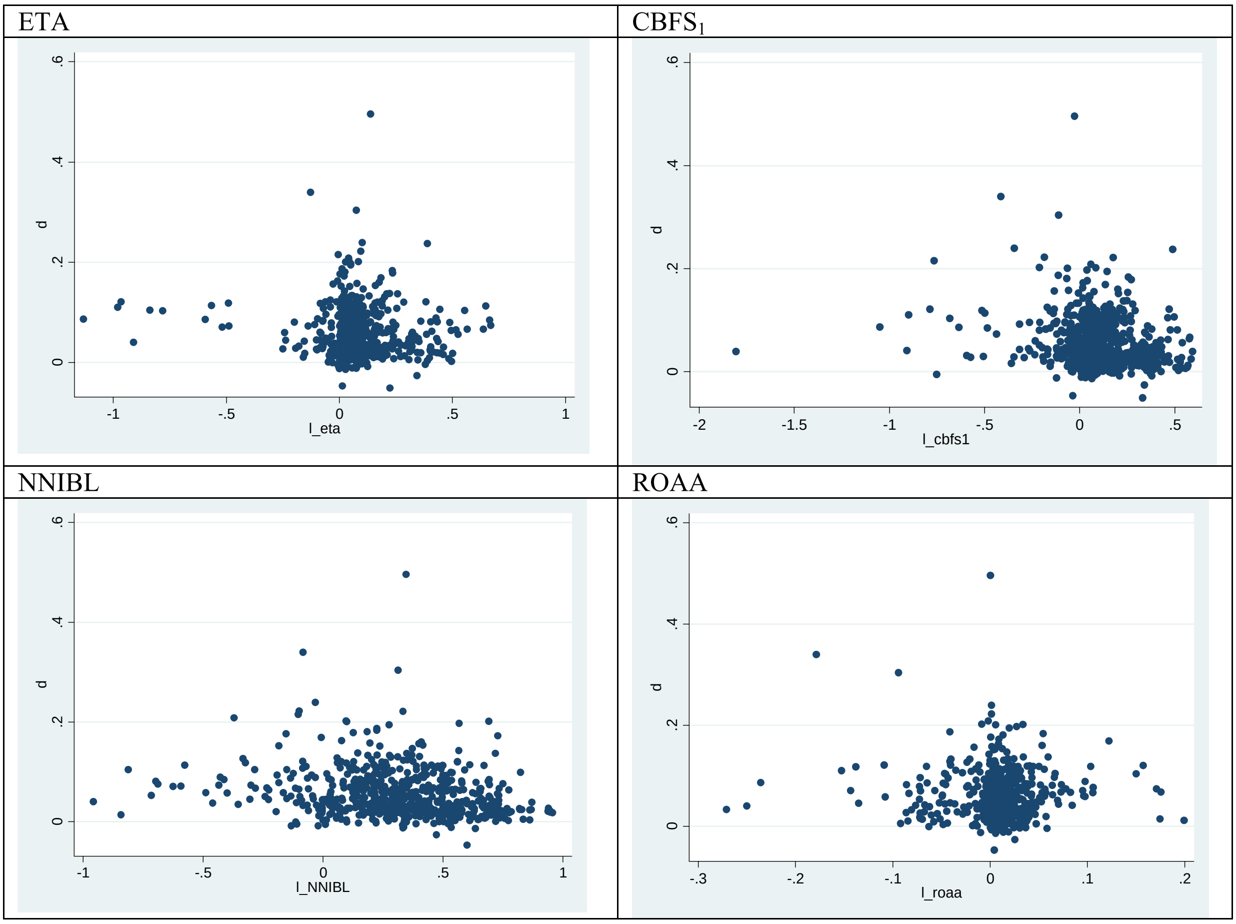
The scatter plots show that there is no apparent relationship between any of the financial strength ratios and the d variable. In the case of the ETA ratio, high inflation outcomes appear even in countries with positive equity in the preceding period, while there are some counties with negative central bank equity and modest inflation rates. It is true, however, that in countries with a negative equity ratio close to or above 0.5 in absolute terms, inflation is usually elevated at levels which are not consistent with price stability. Concerning the $CBFS_1$ measure of Klüh and Stella (2008), the results again do not show any clear correlation between central bank finances and inflation. In

[16] For the sake of brevity, we left out the scatter plot for ROAE, which was not very informative (see the low positive correlation with inflation in Table A.1.3 in Appendix 1), but it is available upon request.

[17] A logarithmic transformation of inflation was also used as a robustness check – see Section 5.

particular the correlation is only weakly and insignificantly negative at around -0.25 measured both by the standard correlation coefficient as well as by the Spearman correlation coefficient to account for the non-normal distribution of the variables analysed (Table A.1.3 in Appendix 1). There are countries that have achieved modest inflation rates even with a significantly adverse balance sheet situation. A similar level of negative correlation exists between the NNIBL variable and the rescaled measure of inflation *d*, i.e. it is between -0.2 and 0.25. The scatter plots and the correlation analysis also suggest no obvious relationship between the profitability measures and inflation.

Figure 3.5: Correlation of Lagged Financial Strength Indicators and Inflation (d)



Source: BankScope, IFS, own calculations (pooled samples; 2002–2009/2010), one-year lagged financial strength measures

4. Econometric Analysis

In this section we move on to an econometric analysis, which allows us to control for the impact of other variables on inflation and thus provides more reliable results than the bivariate correlation analysis presented above. In particular, we perform a panel data analysis of the relationship between central bank financial strength and inflation similar to Klüh and Stella (2008). Their model was tested primarily on a sample of 15 countries from Latin America and the Caribbean covering the period 1987–2005. At a later stage they extended the analysis to a larger cross section of countries (see Section 2). However, due to data limitations, the model specification in the latter case was less sophisticated and dealt with only a few structural determinants of inflation. In the present study, we use a specification similar to the more complex model of Klüh and Stella (2008), but extend the sample coverage to 105 countries, for which macroeconomic and central bank-specific information was collected. The period covered in this analysis extends from 2002 to 2009. Due to some missing observations the sample changes between individual regressions. The data description and summary statistics for the variables that we use are provided in Appendix 1.

For the sake of comparability, we start with a model similar to Klüh and Stella (2008) estimated by pooled OLS. At a later stage we address some panel data issues, such as unobserved country characteristics, endogeneity and the need to account for inflation inertia.

4.1 Structural Determinants of Inflation (Control Variables)

In this subsection we present the choice of structural inflation determinants – based on other studies' findings – which we use as control variables, together with the empirical results for our sample. A number of empirical studies explain cross-country differences in inflation using macroeconomic and institutional factors (e.g. Alfaro, 2005; Catao and Terrones, 2005; Cottarelli et al., 1998). The influence of political instability on inflation was studied by Aisen and Veiga (2005). A recent paper by Calderon and Schmidt-Hebbel (2008) employs a range of statistical methods to evaluate all possible non-monetary determinants of inflation. As this is the most comprehensive approach, we basically follow their choice of variables:

Price of oil: This has a substantial impact on production costs. In the dynamic model of Calderon and Schmidt-Hebbel (2008) the oil price gap was used. It can be considered a cyclical variable; in our simple framework it may well capture global shocks more generally. Klüh and Stella (2008) included world inflation as a global variable for their sample of Latin American and Caribbean countries. In contrast, we do not use world inflation as an explanatory variable in our global sample to avoid the endogeneity problem (i.e. the use of inflation on both the left-hand and right-hand sides of the equation).

Level of economic development: This is captured by real GDP per capita. The expected relationship is negative, i.e. more developed countries are expected to have lower inflation. This may be either due to a direct influence, related, for example, to the Balassa-Samuelson effect, or because the GDP per capita level could work as an indirect proxy for institutional quality (see Dollar and Kraay, 2003).[18]

Trade openness: The discussion of the link between trade openness and inflation goes back to the work of Romer (1993). He suggested that a negative link exists between inflation and trade openness, because trade openness would act as a "brake" (in the absence of central bank

[18] We also tried to include institutional variables directly, using an index of government efficiency or regulatory quality. High-quality institutions may prevent the financing of public debt via an inflation tax, thus guaranteeing low inflation. These variables are, however, closely correlated with GDP per capita and could therefore not be used simultaneously with it. The analysis confirmed that high-quality institutions are associated with better inflation performance. On the other hand, similarly to many previous studies we did not find any link between inflation and fiscal deficits. As these alternative choices of control variables did not significantly affect our main conclusions, they are not reported here, but they are available from the authors.

independence) on the gains obtained by an inflationary surprise by the government. A number of studies have found supportive evidence for this link. We capture trade openness in our analysis by the share of imports in GDP.

Capital account openness: This factor (see Chinn and Ito, 2008) was not fully discussed until recently, yet it can have the same disciplinary effect on monetary policy as trade openness. Moreover, financial integration lowers the cost of borrowing for the government, which might otherwise need to use seigniorage to finance its expenditure.

Exchange rate regime: The impact of the exchange rate regime choice on inflation was studied, for instance, by Levy-Yeyati and Sturzenegger (2001). It is usually assumed that inflation should be lower in countries with a fixed regime, as pegging is a way to escape high inflation. Again, it may have a disciplinary effect on the monetary authority, which is constrained to avoid expanding the monetary base excessively, as this would cause a balance-of-payments crisis. It also serves as a commitment device, influencing inflation expectations.

Monetary policy regime: Empirical evidence (see, for example, Batini, et al., 2005) shows that adopting an inflation targeting regime tends to reduce inflation.[19] In our study we use a dummy variable that takes the value of 1 if the country used inflation targeting during that year.

The regression results for our control variables using several alternative estimation techniques[20] are presented in Table A.2.1 in Appendix 2. As can be seen, the overall explanatory power of the empirical models is relatively low, but the coefficients typically have the expected signs and are in most cases statistically significant. The level of economic development lowers inflation, and so does economic openness, which is found to work more strongly via the capital account rather than trade openness. Introducing a fixed exchange rate regime tends to lower inflation. The same is true for introducing an inflation targeting framework, this effect being statistically significant, rather strong (around three percentage points) and stable. Our analysis thus confirms previous findings on the empirical benefits of inflation targeting in terms of achieving price stability. The results for trade openness vary depending on the econometric method; in the pooled OLS they are insignificantly negative, while under the fixed effect estimation the impact is surprisingly significantly positive, i.e. increasing trade openness is associated with higher inflation. This may reflect the conditions in fast-growing countries, where development strategy is usually a combination of export-led growth, a fixed exchange rate regime and higher inflation. The global price of oil has a substantial effect on inflation worldwide with the expected positive sign.

[19] On the other hand, according to de Carvalho Filho (2011), during the recent financial crisis "inflation targeting countries lowered nominal and real interest rates more sharply than other countries; were less likely to face deflation scares; and had sharp real depreciations without a relative deterioration in their risk assessment by markets". In other words, inflation fell less during the crisis for the inflation targeting countries, which could reverse the coefficient sign for the inflation targeting dummy. However, our data sample is dominated by the pre-crisis period, which was indeed confirmed by the empirical estimates – see below.

[20] We started with OLS regression with robust standard errors to get results comparable with previous studies, and added clustering to get even more reliable estimates of the standard errors. Then we used panel data fixed effects, as well as random effects. The test of over-identifying restrictions (orthogonality conditions) for panel data estimation favours the fixed effects estimator. As the random effects turned out to be inconsistent, we do not use them further in the paper. As for OLS, we continue in the remaining text with an analysis based on clusters to achieve better estimates of the standard errors. The presence of heteroskedasticity and autocorrelation is supported by standard tests, but we deal with this issue at a later stage.

Moreover, these results for our control variables are generally quite stable and robust across the models presented below.

4.2 Central Bank Financial Strength and Inflation

In the second step we extend our basic models to include the proxy indicators of central banks' financial strength from Section 3. The crucial econometric issue here is potential endogeneity (reverse causality). In particular, higher inflation may increase central banks' financial strength via higher seigniorage. This could lead to a positive correlation of the two variables being detected, with the causality running in the opposite direction than the link we are interested in. To cope with this, our key explanatory variables are lagged by one year, as in the above example higher inflation should precede and not follow higher central bank financial strength. We are aware that this may not be a perfect solution, as for some sources of shocks the temporal pattern could be different; for instance an exchange rate depreciation shock improves the central bank's finances almost immediately due to revaluation gains on FX reserves, while inflation is likely to increase with a time lag due to a gradual exchange rate pass-through. Nonetheless, this approach is in line with the previous research. At a later stage, we also address the endogeneity problem using the GMM method.

Starting with the pooled OLS method (see Table 4.1), we found that $CBFS_1$ and NNIBL have a significantly negative coefficient. The result for $CBFS_1$ is thus consistent with the previous findings of Klüh and Stella (2008), and our own proxy variable NNIBL performs equally well in this context. On the contrary, the other three measures of central bank financial strength turned out to be statistically insignificant.

Table 4.1: Estimation Results Using the Pooled OLS Method

	$CBFS_1$	**NNIBL**	**NNIBL/CBI**	**ETA**	**ROAA**	**ROAE**
Price of oil	0.048*** (0.0102)	0.05*** (0.0115)	0.048*** (0.0092)	0.054*** (0.01)	0.0573*** (0.01)	0.0587*** (0.0103)
Real GDP per capita	-0.0004 (0.0003)	-0.001** (0.0002)	-0.001* (0.0003)	-0.0004 (0.0003)	-0.0007*** (0.0002)	-0.0007*** (0.0002)
Trade openness	-0.0093 (0.0084)	-0.0079 (0.0077)	-0.0034 (0.0104)	-0.0112 (0.0089)	-0.0089 (0.0068)	-0.0082 (0.0071)
Cap account openness	-0.006*** (0.0024)	-0.007*** (0.0024)	-0.006** (0.003)	-0.007*** (0.0024)	-0.0053** (0.0023)	-0.0053** (0.0023)
Fixed regime	-0.0169** (0.0077)	-0.0184** (0.0076)	-0.0127 (0.0089)	-0.0182** (0.008)	-0.0175** (0.0069)	-0.018** (0.0072)
Inflation targeting	-0.031*** (0.0068)	-0.031*** (0.0068)	-0.026*** (0.0078)	-0.031*** (0.0069)	-0.0278*** (0.0066)	-0.0273*** (0.0068)
Constant	0.066*** (0.0102)	0.069*** (0.011)	0.063*** (0.01)	0.0603*** (0.0103)	0.0583*** (0.0093)	0.0572*** (0.0097)
$CBFS_1$ (t-1)	**-0.0322**** **(0.0133)**					
NNIBL (t-1)		**-0.0196**** **(0.0093)**				
NNIBL (t-1) /CBI			**-0.0132**** **(0.0055)**			
ETA(t-1)				0.0007 (0.0205)		
ROAA (t-1)					-0.0783 (0.0672)	
ROAE (t-1)						-0.0003 (0.0016)
Observations	711	625	465	705	684	672
R2 (adj)	0.25	0.28	0.29	0.24	0.27	0.27
F	20.29	23.45	9.26	20.24	20.04	19.94

Note: Dependent variable is *d*. Standard errors in parentheses. Statistical significance is marked by *** at 1%, ** at 5% and * at 10%.

Moreover, Table 4.1 also shows a significantly negative coefficient for the interaction term between NNIBL and legal central bank independence (CBI). Our hypothesis was that a higher degree of independence could shield a central bank from the political-economy consequences of its financial performance and thus weaken the link between central bank financial strength and inflation. However, only the interaction term NNIBL/CBI turned out to be statistically significant in the pooled OLS (the other insignificant estimates are provided in Appendix 2, Table A.2.2). The analysis thus provides only weak and non-robust empirical support for the idea that central banks with a higher degree of independence might be able to care less about their balance sheets in pursuing their policy goals. This issue is explored further in Section 5.

The OLS method is used here mainly for the sake of comparability with the previous research. Nevertheless, standard statistical tests suggested several econometric issues that need to be addressed in our panel data set-up. These include the presence of unobserved country characteristics, non-normality of residuals, the presence of heteroskedasticity and autocorrelation, as well as the potential endogeneity (reverse causality) problem. We deal with these issues below using three alternative econometric techniques, which can at the same time be viewed as a robustness check of the results presented so far.

In the first step, Table 4.2 presents an estimate using the panel data fixed effects technique to capture unobserved country characteristics. These were identified as statistically significant using the standard statistical tests of fixed effects. It can be seen that the $CBFS_1$ variable loses its statistical significance when the fixed effects are included, and the same is true for the interaction term NNIBL/CBI. Moreover, there are now three variables with a significantly positive coefficient, which is contrary to expectations: NNIBL, ETA and ROAA. The estimated positive coefficient for ROAA is contrary to the findings of Klüh and Stella (2008). This may reflect the reverse causality problem discussed at the beginning of this sub-section. Note that the fixed effects panel estimation is likely to put more weight than the pooled OLS on the time dimension of the data, as a large part of the cross-sectional variation is captured by the estimated fixed effects. Presumably the reverse causality may appear more strongly in this time dimension than in the cross-sectional one. While countries with higher central bank financial strength according to some proxy measures may have lower inflation in the cross-section, increasing financial strength may be associated with higher inflation in the time dimension. As a matter of fact, the fixed effects yield consistently higher estimated coefficients for all our measures of central bank financial strength in Table 4.2 than the pooled OLS in Table 4.1.

Table 4.2: Estimation Results Using the Fixed Effects Panel Method

	$CBFS_1$	**NNIBL**	**NNIBL/CBI**	**ETA**	**ROAA**	**ROAE**
Price of oil	0.04*** (0.0143)	0.048*** (0.0148)	0.038*** (0.0117)	0.052*** (0.0121)	0.0492*** (0.0135)	0.0509*** (0.0138)
Real GDP per capita	-0.001*** (0.0002)	-0.001 (0.0008)	-0.001 (0.0008)	-0.001*** (0.0002)	-0.001 (0.0008)	-0.001 (0.0008)
Trade openness	0.1136** (0.0468)	0.1098** (0.0511)	0.0943*** (0.0326)	0.0984** (0.0416)	0.0991** (0.0435)	0.0951** (0.043)
Cap account openness	-0.01 (0.0091)	-0.014 (0.0102)	-0.011* (0.0064)	-0.012 (0.0089)	-0.0115 (0.0081)	-0.0105 (0.0081)
Fixed regime	0.0009 (0.0079)	0.003 (0.0088)	0.0074 (0.0079)	0.0012 (0.0073)	0.0006 (0.0076)	0.0024 (0.0071)
Inflation targeting	-0.025*** (0.0091)	-0.037*** (0.0093)	-0.035*** (0.0073)	-0.025*** (0.0077)	-0.0279*** (0.0097)	-0.0264** (0.0124)
Constant	0.005 (0.021)	-0.001 (0.0238)	0.016 (0.0206)	0.0015 (0.02)	0.0089 (0.0222)	0.0082 (0.0219)
$CBFS_1$ (t-1)	-0.004 (0.025)					
NNIBL (t-1)		**0.0266** (0.013)**				
NNIBL (t-1) /CBI			-0.0034 (0.0051)			
ETA(t-1)				**0.055* (0.0292)**		
ROAA (t-1)					**0.0709* (0.0371)**	
ROAE (t-1)						0.0005 (0.0011)
Observations	711	625	465	705	684	672
R2 (within)	0.13	0.16	0.20	0.16	0.15	0.15
F	11.24	13.60	12.56	13.78	13.33	12.48

Note: Dependent variable is *d*. Standard errors in parentheses. Statistical significance: *** at 1%, ** at 5% and * at 10%.

We address the endogeneity (reverse causality) later on, but before moving to that let us explore another econometric issue. Statistical tests confirm the presence of heteroskedasticity and autocorrelation, which we have so far ignored to provide estimates comparable to the earlier literature. A modified Wald test for groupwise heteroskedasticity in the fixed effect regression model was performed and in all cases the heteroskedasticity was significant.[21] The Wooldridge test for autocorrelation in the panel data for our preferred set of variables showed that serial correlation was present.[22] Klüh and Stella (2008) used Feasible Generalized Least Squares (FGLS) regression to deal with these features. However, this method is suitable only for panels with few countries and a long time span, and is thus clearly not appropriate in our case as our panel covers 105 countries and has a short time dimension of eight years only. Moreover, it tends to produce downward-biased standard error estimates. Therefore we re-estimated our model using a different method, namely a linear regression with panel-corrected standard errors (PCSE) that included a common AR(1) factor and was adjusted for panel heteroskedasticity. The results are presented in Table 4.3, which shows that the estimated AR(1) coefficient is relatively high at around 0.5, in line with the generally strong inflation persistence found in many studies.

[21] For example, the test for ROAA gave Chi2 (105) = 53,350 and Prob>chi2 = 0.0000, suggesting strong heteroskedasticity.

[22] The test yielded F-values that in all cases implied a zero probability of the null hypothesis of no first order autocorrelation.

Table 4.3: Estimation Results Using the PCSE Method with a Common AR(1) Term

	$CBFS_1$	**NNIBL**	**ETA**	**ROAA**	**ROAE**	**$CBFS_1$**
Price of oil	0.078*** (0.0214)	0.0789*** (0.0196)	0.086*** (0.0195)	0.0843*** (0.0186)	0.0854*** (0.0181)	
Price of oil (growth)						0.0517*** (0.0101)
Real GDP per capita	-0.0005*** (0.0001)	-0.0007*** (0.0002)	-0.0006*** (0.0001)	-0.0007*** (0.0002)	-0.0007*** (0.0002)	-0.0005*** (0.0001)
Trade openness	-0.0038 (0.0093)	-0.0016 (0.0082)	-0.0065 (0.0089)	-0.0028 (0.0083)	-0.0029 (0.0076)	-0.0031 (0.0102)
Cap account openness	-0.0066*** (0.0013)	-0.0072*** (0.0014)	-0.0067*** (0.0013)	-0.0059*** (0.0016)	-0.0062*** (0.0018)	-0.0069*** (0.0013)
Fixed regime	-0.0162*** (0.0042)	-0.0188*** (0.0041)	-0.0167*** (0.0043)	-0.0171*** (0.0048)	-0.0171*** (0.0049)	-0.0129*** (0.0042)
Inflation targeting	-0.0274*** (0.0063)	-0.0269*** (0.0062)	-0.0271*** (0.0066)	-0.0253*** (0.0056)	-0.0254*** (0.0053)	-0.022*** (0.0072)
Constant	0.046*** (0.0152)	0.0451*** (0.0147)	0.0387*** (0.0148)	0.04*** (0.0134)	0.0401*** (0.0132)	0.0777*** (0.0092)
$CBFS_1$ (t-1)	-0.0182 (0.0119)					**-0.0216* (0.0118)**
NNIBL (t-1)		0.0005 (0.0111)				
ETA (t-1)			0.0312 (0.0212)			
ROAA (t-1)				0.027 (0.0581)		
ROAE (t-1)					-0.0002 (0.0012)	
Observations	711	625	705	684	672	711
R2	0.25	0.27	0.27	0.29	0.29	0.28
Wald chi2	98.52	102.81	91.23	90.65	88.80	90.21
Common AR(1)	0.50	0.47	0.52	0.52	0.52	0.56

Note: Dependent variable is *d*. Standard errors in parentheses. Statistical significance: *** at 1%, ** at 5% and * at 10%.

The impact of changing the estimation method is substantial. There are now no statistically significant results for the central bank financial strength indicators in Table 4.3 if our standard set of control variables is used. The only indicator that is worth discussing in more depth is $CBFS_1$, as it has the expected negative sign and is not too far away from statistical significance. We thus performed some further robustness checks for $CBFS_1$, which suggest that this variable could reach at least a weak significance level with slightly modified control variables. This is illustrated in the last column of Table 4.3, where the annual change in the price of oil is used instead of its level. While the rest of the model remains largely unaffected by this small change, the $CBFS_1$ variable becomes significant at the 10% probability level.

Previous estimations suggest that (i) significant autocorrelation is present in the error terms of panel models, advocating the use of a dynamic model for inflation; (ii) the residuals have a non-normal distribution; and (iii) the reverse causality between inflation and central bank financial strength might not be sufficiently resolved in some models by lagging the left-hand-side variable by one year. To address these three issues simultaneously, we estimate a dynamic model for inflation of the Blundell-Bond type, based on the generalized method of moments (GMM).[23] The Blundell-Bond GMM estimation method is particularly suited to our case given that our panel satisfies the assumptions usually made in this context: (a) small time and large cross-country dimensions; (b) the presence of endogenous explanatory variables; (c) fixed effects; and (d) heteroskedasticity and autocorrelation in the idiosyncratic errors.

The model specification is similar to those presented above, except that the first lag of inflation and time dummies are also included as explanatory variables and that contemporaneous (not lagged) values for central bank financial strength variables are considered. The time dummies weaken the effect of the potential cross-sectional correlations, and their incorporation into the model is strongly recommended in the GMM set-up.[24] The model is estimated by the System GMM method, using orthogonal transformations and a two-step estimation with the Windmeijer correction and collapsed instruments. The System GMM approach simultaneously estimates the transformed and level equations and it is the preferred alternative (vis-à-vis difference GMM – the Arellano-Bond estimator) when the dependent variable is suspected to be close to a random walk. The number of lagged GMM instruments was in all cases adjusted in order to obtain p-values for the Hansen tests in the range 0.1–0.25 (see Roodman, 2006, footnote 24). We model lagged inflation as a predetermined variable, which means that it is assumed to be influenced by lagged errors but not by contemporaneous ones, and the central bank financial strength proxies as endogenous variables, influenced by both lagged and contemporaneous errors.

The results of the System GMM estimation are presented in Table 4.4. The only significant coefficient is for ROAA, and has the expected negative sign, which is a difference compared to all previous results presented in this paper, but is in line with the findings of Klüh and Stella (2008). This suggests that the System GMM method may effectively deal with the reverse causality (endogeneity) issue for this variable. On the other hand, the coefficients of all other central bank financial strength proxies are not significant, and with the exception of ETA (which is negative and statistically significant at least for some sub-samples – see Section 5) they are all positive.

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[23] A description of the Arellano-Bond and Blundell-Bond GMM estimators and guiding principles concerning their implementation within Stata are provided by Roodman (2006). The paper is available at http://www.cgdev.org/content/publications/detail/11619.

[24] The estimated coefficients of the time dummies are not reported here for the sake of brevity. However, in all regressions the time dummies that were not dropped due to collinearity had strongly significant coefficients.

Table 4.4: Estimation Results Using the System GMM Method

	$CBFS_1$	**NNIBL**	**ETA**	**ROAA**	**ROAE**
Price of oil	0.171*** (0.0162)	0.171*** (0.0168)	0.160*** (0.0150)	0.163*** (0.0157)	0.162*** (0.0151)
Real GDP per capita	-0.000255*** (7.11e-05)	-0.000415** (0.000182)	-0.000230 (0.000183)	-0.000419** (0.000176)	-0.000462*** (0.000155)
Trade openness	-0.00355 (0.00442)	-0.000604 (0.00533)	-0.00192 (0.00514)	-0.00301 (0.00426)	-0.00447 (0.00472)
Cap account openness	-0.00133 (0.00122)	-0.00209 (0.00139)	-0.00259* (0.00132)	-0.00240* (0.00135)	-0.00230* (0.00123)
Fixed regime	-0.00682** (0.00344)	-0.00915* (0.00465)	-0.00756* (0.00404)	-0.00900** (0.00411)	-0.00909** (0.00415)
Inflation targeting	-0.0108** (0.00436)	-0.0106* (0.00628)	-0.0149*** (0.00448)	-0.0157*** (0.00501)	-0.0145*** (0.00466)
Lagged dependent	0.577*** (0.0987)	0.518*** (0.112)	0.445*** (0.104)	0.452*** (0.107)	0.424*** (0.104)
Constant	-0.0945*** (0.0202)	-0.0889*** (0.0234)	-0.0702*** (0.0201)	-0.0692*** (0.0186)	-0.0686*** (0.0211)
$CBFS_1$	0.0128 (0.0243)				
NNIBL		0.0122 (0.0209)			
ETA			-0.0595 (0.0505)		
ROAA				**-0.280** (0.138)**	
ROAE					0.000197 (0.0103)
Observations	712	638	710	690	680
Maximum lag for GMM-style instruments	2	2	2	3	2
AR(1) (p-value)	0.006	0.013	0.004	0.010	0.026
AR(2) (p-value)	0.441	0.377	0.187	0.245	0.394
Hansen test (p-value)	0.133	0.117	0.182	0.0816	0.297
Difference-in-Hansen tests: (GMM instruments for levels)					
Hansen test excluding group (p-value)	0.156	0.222	0.080	0.116	0.146
Difference (p-value)	0.189	0.112	0.554	0.148	0.590

Note: Dependent variable is *d*. Standard errors in parentheses. Statistical significance: *** at 1%, ** at 5% and * at 10%.

To summarize, the empirical results for the link from central bank financial strength to inflation are not as robust as suggested by Klüh and Stella (2008). The estimates are sensitive in particular to the choice of key explanatory variable and the econometric technique. There is no financial strength indicator that performs best in our analysis across all econometric techniques. The two broader balance sheet measures of central bank financial strength, i.e. $CBFS_1$ and NNIBL, have the expected significantly negative coefficients in the pooled OLS regression, and the same is at least partly (depending on the chosen control variables) true for $CBFS_1$ using the PCSE method with a common AR(1) term. However, these results are not maintained with the panel data fixed effects estimations (significantly positive coefficients for $CBFS_1$ and NNIBL) and the System GMM method (insignificantly positive coefficients). On the other hand, ROAA has the expected negative and significant sign using the System GMM, but has a significantly positive coefficient with panel fixed effects and is insignificant for all the other econometric techniques. The other two measures representing the standard financial ratios used in the commercial world, i.e. ETA and ROAE, never achieve a significantly negative coefficient, suggesting that they may not perform well in the central banking context. In general, the explanatory power of central bank financial strength indicators for inflation appears rather weak, with other inflation determinants playing a much more important and robust role.

5. Further Robustness Checks (Recursive Estimations)

In the previous section, we already provided many robustness checks, looking mainly at the impact of alternative central bank financial strength proxies and estimation techniques. In this section, we explore the robustness issues further, examining how the relationship between alternative measures of central bank financial strength and inflation depends on the sample used for the estimation. The motivation for undertaking this analysis can be found both in theoretical literature, which suggests potential strong non-linearity (see Section 2), as well as in Klüh and Stella's (2008) empirical finding that the studied relationship may hold only when observations representing the financially weakest central banks are included in the sample. The criteria used for partitioning the data are inflation, the financial indicators themselves and central bank independence.

These robustness checks follow the "recursive" method of Klüh and Stella (2008). The first estimation is conducted based on a sample including only observations with the lowest inflation (between -5% and 2%). The estimation sample is sequentially enlarged by including observations with higher inflation rates, i.e. up to threshold values specified in each case. With regard to inflation outliers, our sample suffers far less from the nuisances found in Klüh and Stella (2008). We do not encounter episodes of hyperinflation of the order found in their study. The highest annual inflation rates in our sample are slightly above 100% (Angola in 2002–2003) and the remaining episodes of high inflation are predominantly below 50%.

A similar robustness check of the relationship between central bank financial indicators and inflation performance can be done with regard to the financial indicators themselves. Klüh and Stella (2008) argue that the relationship between inflation and central bank financial strength is likely to hold only if central banks with a more impaired balance sheet are included in the samples.

Following this approach, we estimate our regressions in a recursive way, moving along the distribution of the variables approximating central bank financial strength. The first regression starts with the 90th percentile of each financial strength measure, i.e. the sample containing the financially strongest 10% of the observations. In the second step, the next 10% of the observations are added to the sample and the regression is re-estimated. This procedure ends up with an estimation based on the entire sample, i.e. including the weakest central banks.

In a similar way, central bank independence can be used to differentiate our sample. The procedure is identical to the previous two cases; the only difference is that now the observations are classified according to the values of a central bank independence index, starting with the most independent central banks and then subsequently adding less and less independent cases (i.e. going from the highest values of the CBI index to the lowest ones).

The graphical results of all these recursive regressions are reported in Appendix 3. The figures presented there depict the evolution of the estimated coefficients and their 95% confidence intervals following the sequential expansion of the sample. The regressions are based on the model specifications contained in Tables 4.1 and 4.4 and estimated by two alternative methods: by pooled OLS as the basic method directly comparable to previous research and by the System GMM method, which we consider the most comprehensive one addressing all key econometric issues simultaneously.[25]

When the data is ordered according to the inflation criterion, the pooled OLS recursive regressions (see Figure A.3.1) show that the two balance sheet variables that we found significant in Section 4, i.e. $CBFS_1$ and NNIBL, have significantly negative coefficients at the 5% level starting from samples allowing up to 50% inflation rates. In other words, if one takes into account only observations with inflation rates below 25%, no significant relationship is found, but the relationship becomes significant if observations representing higher inflation rates are added into the sample.[26] We thus find evidence supporting Klüh and Stella's (2008) argument that central banks' weak financial stance can affect the policy outcome and cause higher inflation when countries with substantially high inflation rates are included in the sample. On the contrary, in the sample of countries with the lowest inflation (i.e. less than 2% inflation), a positive relationship between central bank financial strength and inflation is found for $CBFS_1$. In this group of countries greater financial strength is thus on the margin associated with higher inflation.[27] The other financial variables, i.e. ETA, ROAA and ROAE, stay consistently insignificant in the OLS regressions in relation to the policy outcome irrespective of the sample.

[25] These are at the same time the only two methods that yielded significantly negative coefficients for some central bank financial strength variables in Section 4 with our standard control variables. We also carried out recursive estimations using panel fixed effects and the PCSE method with a common AR(1) term, but the results were either significantly positive for some sub-samples (with the fixed effects) or insignificant in the majority of cases. They are thus not presented here due to space limitations, but are available upon request.

[26] At the 10% significance level, the coefficients become significant already in samples allowing up to 20% inflation for $CBFS_1$ and basically from 5% inflation for NNIBL (with the exception of the 7% and 25% thresholds).

[27] Note that this is opposite to the theoretical suggestion in Jeanne and Svensson (2007), in which a relatively weak balance sheet may actually work as a commitment device to avoid a deflationary trap, as the central bank has an incentive to follow an inflationary path to stay financially solvent.

The pooled OLS recursive regressions run by expanding the sample according to the central bank financial strength indicators (Figure A.3.3) offer mixed results. On the one hand, two indicators of capital strength ($CBFS_1$ and NNIBL) behave concordantly to the findings of Klüh and Stella (2008), as their coefficients become significantly negative at the 5% level only when the entire sample is used. This confirms the conclusion of Klüh and Stella (2008) that only a very strong impairment of central banks' balance sheets would induce a worsening of the policy outcome. On the other hand, the coefficients of ETA and ROAA are significantly positive for some sub-samples, suggesting that the reverse causality issue is potentially not limited to the fixed effects panel estimations, which it was indentified for in Section 4.

Turning to central bank independence (Figure A.3.5), the coefficient of $CBFS_1$ is consistently negative in the pooled OLS estimation, but is not significant in the sub-sample of the most independent central banks. As regards NNIBL in the pooled OLS, we find coefficients converging to significantly negative values only once the least independent central banks are added to the sample, which is in line with our hypothesis presented in Section 4. The other three central bank financial strength variables display insignificant coefficients over the entire range considered.

When the System GMM method is used (Figure A.3.2), ROAA and ETA achieve significantly negative coefficients already in sub-samples including observations with inflation up to 15% (in the case of ROAA) or up to 5% (in the case of ETA). Moreover, this outcome persists over a relatively large range of the inflation scale, although the statistical significance disappears for ETA when rather high inflation rates are included. We thus find no significant non-linearity when the sample is sorted according to the inflation rate. On the other hand, when the data is partitioned according to the financial strength indicators (Figure A.3.4), the ROAA coefficient becomes significantly negative only when the financially weakest observations are included in the sample, and the same is true for relatively weak values of ETA (although not the most extreme ones). This suggests the presence of strong non-linearity in this case.

In conclusion, two measures of balance sheet strength ($CBFS_1$ and NNIBL) seem to behave according to Klüh and Stella (2008) in the pooled OLS estimates in the sense that only a strong balance sheet impairment causes an upward effect on inflation. At the same time, the expected significantly negative relationship is found only for countries with relatively high inflation rates and low central bank independence. Using the System GMM method, only rather weak financial indicators ROAA and ETA are associated with higher inflation.

Other robustness checks were carried out, too. In the first instance, all regressions were rerun using alternative dependent variables, i.e. the inflation rate itself and a logarithmic transformation of inflation $\ln(1+\pi)$. The latter served to check how the bounded nature of the d variable (and the departure from the normality assumption) would affect the results. Overall, all these additional model specifications led to estimation outcomes similar to those presented in Tables 4.1–4.4, and are thus not presented here. Although the values of the estimated coefficients changed somewhat with different model specifications, their significance levels remained broadly unaffected.

6. Conclusions

The issue of whether central banks' finances affect their policy performance has become very topical in recent years. Unlike in the past, it is directly relevant not just for the Czech National Bank and for a few other central banks in catching-up economies that have experienced negative equity in the last decade, but also now for major central banks in advanced economies that have accumulated large financial exposures due to their anti-crisis measures.

Unfortunately, the empirical evidence on this subject is very limited, with the papers by Klüh and Stella (2008) and Adler et al. (2012) being two notable exceptions. We contribute to bridging this gap in the literature. The value added of our analysis consists mainly in using a broader and more recent panel data sample, enriching the set of variables capturing the financial strength of central banks, using some alternative control variables and employing econometric techniques better suited to our panel data set-up. We also investigate if the relationship between central bank finances and inflation outcomes depends empirically on the degree of legal central bank independence.

To summarize our results, we indeed found a statistically significant negative relationship between some measures of central bank financial strength and inflation in a few regressions. Nevertheless, the results lack robustness with respect to the choice of alternative measures of financial strength and the econometric technique. In particular, no financial strength indicator maintains a significantly negative coefficient across all econometric methods. The two broader balance sheet measures of central bank financial strength, i.e. $CBFS_1$ and NNIBL, have the expected negative coefficients in the pooled OLS regression, but not when the other econometric techniques are used. At the same time, the recursive OLS estimations confirm the findings of Klüh and Stella (2008) concerning non-linearity of the relationship; this holds only in countries with relatively high inflation rates, substantial central bank financial weakness and/or very low central bank independence. Using the System GMM, but no other method, we find a significantly negative coefficient for ROAA, but only when the financially weakest observations are included in the sample. The negative relationship holds also for some sub-samples of countries with relatively weak ETA.

In general, the explanatory power of the central bank financial strength indicators is rather weak, with the other inflation determinants – including the adoption of an inflation targeting framework – playing a more important role. This is not to suggest that central bank financial weakness can never play a role for monetary policy outcomes; but the relationship is likely to be conditional on many aspects, including the size of central bank financial weakness, its underlying reasons, the long-term sustainability of the central bank's finances and the overall institutional arrangements of monetary policy.

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Appendix 1: Data Description, Summary Statistics and Correlations

Table A.1.1: Data Description

Variable	Source	
d	CPI inflation/(1+CPI inflation)	World Development Indicators (2011)
Price of oil	Average price of oil WTI	Energy Information Administration (EIA)
Real GDP per capita	PPP converted GDP per capita (Laspeyres), Derived from growth rates of c, g, i, at 2005 constant prices	Penn World Table, Center for International Comparisons of production, income and prices
Trade openness	Imports over GDP	World Development Indicators (2011)
CA openness	Chinn-Ito de jure measure of financial openness	Chinn and Ito (2008)
Fixed regime	Dummy variable, IMF classification	AREAER, several issues, IMF
Inflation targeting	Dummy variable	Mishkin and Schmidt-Hebbel (2007)
Central bank independence (CBI)	Index	Crowe and Meade (2003)
CBFS	Sum of central bank capital and other items net divided by average total central bank assets	IFS, IMF
NNIBL	(Equity+other non-interest bearing liabilities-non-earning assets-fixed assets)/total assets	BankScope
ETA	Equity/total assets	BankScope
ROAA	Net income/total assets	BankScope
ROAE	Net income/equity	BankScope

Table A.1.2: Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
d	840	0.055	0.053	-0.051	0.521
Price of oil	840	0.517	0.217	0.225	0.940
Real GDP per capita	840	16.531	17.364	0.368	159.145
Trade openness	840	0.504	0.293	0.105	2.130
CA openness	840	1.032	1.531	-1.844	2.478
Fixed regime	840	0.464	0.499	0	1
Inflation targeting	840	0.219	0.414	0	1
CBI	640	0.615	0.212	0.167	0.975
CBFS(t-1)	711	0.095	0.212	-1.806	0.593
NNIBL(t-1)	625	0.306	0.287	-0.956	0.958
ETA(t-1)	705	0.077	0.163	-1.132	0.670
ROAA(t-1)	684	0.008	0.039	-0.271	0.199
ROAE(t-1)	672	0.250	1.073	-9.996	8.437

Table A.1.3: Correlation Analysis

Standard correlation coefficients	d	Price of oil	Real GDP per capita	Trade openness	CA openness	Fixed regime	Inflation targeting	CBFS (t-1)	ROAA (t-1)	ROAE (t-1)	ETA (t-1)
Price of oil	0.25										
Real GDP per cap.	-0.54	0.06									
Trade openness	-0.04	0.06	0.09								
CA openness	-0.38	0.03	**0.55**	0.05							
Fixed regime	-0.22	0.03	**0.31**	**0.35**	0.14						
Inflation targeting	-0.15	0.03	0.18	-0.24	0.05	**-0.43**					
CBFS(t-1)	-0.26	-0.04	0.22	0.01	0.13	0.18	-0.08				
ROAA(t-1)	0.05	0.04	-0.06	0.08	-0.09	0.07	-0.15	**0.40**			
ROAE(t-1)	0.08	0.07	-0.11	0.01	-0.11	-0.05	-0.11	-0.06	**0.51**		
ETA(t-1)	-0.05	-0.07	0.06	0.09	-0.01	0.21	-0.17	**0.66**	**0.43**	-0.20	
NNIBL(t-1)	-0.24	-0.10	0.23	0.07	0.03	0.27	-0.23	**0.37**	0.26	0.02	**0.39**

Spearman correlation coefficients	d	Price of oil	Real GDP per capita	Trade openness	CA openness	Fixed regime	Inflation targeting	CBFS (t-1)	ROAA (t-1)	ROAE (t-1)	ETA (t-1)
Price of oil	0.24										
Real GDP per cap.	-0.41	0.06									
Trade openness	-0.05	0.05	0.14								
CA openness	-0.30	0.05	**0.49**	0.04							
Fixed regime	-0.27	0.05	**0.34**	**0.35**	0.17						
Inflation targeting	-0.15	0.02	0.07	-0.19	0.02	**-0.42**					
CBFS(t-1)	-0.25	-0.06	0.24	0.04	0.14	0.15	0.02				
ROAA(t-1)	0.04	0.06	-0.06	0.02	-0.02	-0.04	-0.05	0.29			
ROAE(t-1)	0.05	0.06	0.05	-0.04	-0.02	0.03	-0.07	0.01	0.30		
ETA(t-1)	-0.04	-0.07	0.01	0.18	0.07	0.15	-0.08	**0.55**	**0.39**	-0.05	
NNIBL(t-1)	-0.21	-0.10	0.25	0.04	0.02	0.22	-0.14	0.29	0.14	-0.01	**0.39**

Source: Authors' calculations.

Appendix 2: Additional Estimation Results

Table A.2.1: Estimation Results for Control Variables

	OLS		Fixed	Random
	Robust	Cluster	effects	effects
Price of oil	0.0427***	0.0427***	0.0293**	0.0405***
	(0.0084)	(0.0101)	(0.0146)	(0.0107)
Real GDP per capita	-0.0005***	-0.0005*	-0.0006***	-0.0006**
	(0.0001)	(0.0003)	(0.0002)	(0.0003)
Trade openness	-0.0085	-0.0085	0.1386***	0.018
	(0.0057)	(0.0098)	(0.0494)	(0.0165)
Cap account openness	-0.0069***	-0.0069***	-0.0079*	-0.0076***
	(0.0014)	(0.0026)	(0.0047)	(0.0022)
Fixed regime	-0.0175***	-0.0175**	0.0075	-0.0093
	(0.0044)	(0.0081)	(0.0084)	(0.006)
Inflation targeting	-0.0295***	-0.0295***	-0.0382***	-0.0275***
	(0.004)	(0.0071)	(0.0137)	(0.0069)
Constant	0.0676***	0.0676***	-0.0074	0.0531***
	(0.0068)	(0.0106)	(0.0221)	(0.0091)
Observations	840	840	840	840
R2 (adjusted/within)	0,207	0,207	0,122	
F	42,95	21,14	12,85	
Chi2				109,73

Note: Dependent variable is *d*. Standard errors in parentheses, R-sq is adjusted for OLS estimation, within for estimate with fixed effects. The statistical significance is *** at 1%, ** at 5% and * at 10%.

Table A.2.2: Estimation Results for Central Bank Independence

	OLS cluster	**Fixed effects**	**OLS cluster**	**Fixed effects**	**OLS cluster**	**Fixed effects**	**OLS cluster**	**Fixed effects**
Price of oil	0.056***	0.044***	0.05***	0.044***	0.048***	0.038***	0.056***	0.048***
	(0.009)	(0.0102)	(0.0079)	(0.0094)	(0.0092)	(0.0117)	(0.0082)	(0.009)
Real GDP per capita	-0.0007***	-0.0002	-0.0004	-0.001***	-0.0005*	-0.001	-0.0005*	0***
	(0.0003)	(0.0008)	(0.0003)	(0.0001)	(0.0003)	(0.0008)	(0.0003)	(0.0002)
Trade openness	-0.0136	0.0704**	-0.0123	0.0849***	-0.0034	0.0943***	-0.0161	0.0751***
	(0.0097)	(0.0268)	(0.0119)	(0.0299)	(0.0104)	(0.0326)	(0.0116)	(0.0263)
Cap account openness	-0.003	-0.011*	-0.005	-0.01*	-0.0062**	-0.0108*	-0.0045	-0.0102*
	(0.0027)	(0.006)	(0.0031)	(0.0057)	(0.003)	(0.0064)	(0.003)	(0.0056)
Fixed regime	-0.0103	0.0026	-0.0093	0.0031	-0.0127	0.0074	-0.009	0.0026
	(0.0086)	(0.0072)	(0.0097)	(0.0073)	(0.0089)	(0.0079)	(0.0095)	(0.0072)
Inflation targeting	-0.022***	-0.026***	-0.024***	-0.026***	-0.026***	-0.035***	-0.023***	-0.025***
	(0.0078)	(0.0094)	(0.0081)	(0.0084)	(0.0078)	(0.0073)	(0.008)	(0.0076)
ROAA/CBI (t-1)	-0.012	0.03						
	(0.0379)	(0.0219)						
CBFS1/CBI (t-1)			-0.004	0.009				
			(0.0046)	(0.0058)				
NNIBL/CBI (t-1)					**-0.013****	-0.003		
					(0.0055)	(0.0051)		
ETA/CBI (t-1)							0.012	0.02
							(0.0163)	(0.0171)
Constant	0.052***	0.012	0.055***	0.014	0.063***	0.016	0.05***	0.012
	(0.0093)	(0.0217)	(0.0104)	(0.0157)	(0.01)	(0.0206)	(0.011)	(0.0154)
Observations	519	519	544	544	465	465	539	539
R2 (adj/within)	0,26	0,22	0,21	0,19	0,29	0,20	0,22	0,21
F	9.23	11.02	10.98	10.18	9.26	12.56	11.17	9.76

Note: Dependent variable is *d*. CBI stands for central bank independence. Standard errors in parentheses; R-sq is adjusted for OLS estimation, within for estimate with fixed effects. The statistical significance is *** at 1%, ** at 5% and * at 10%.

Source: Authors' calculations.

Appendix 3: Recursive Regression Outcomes

Figure A.3.1: Recursive Regressions according to Inflation – Pooled OLS

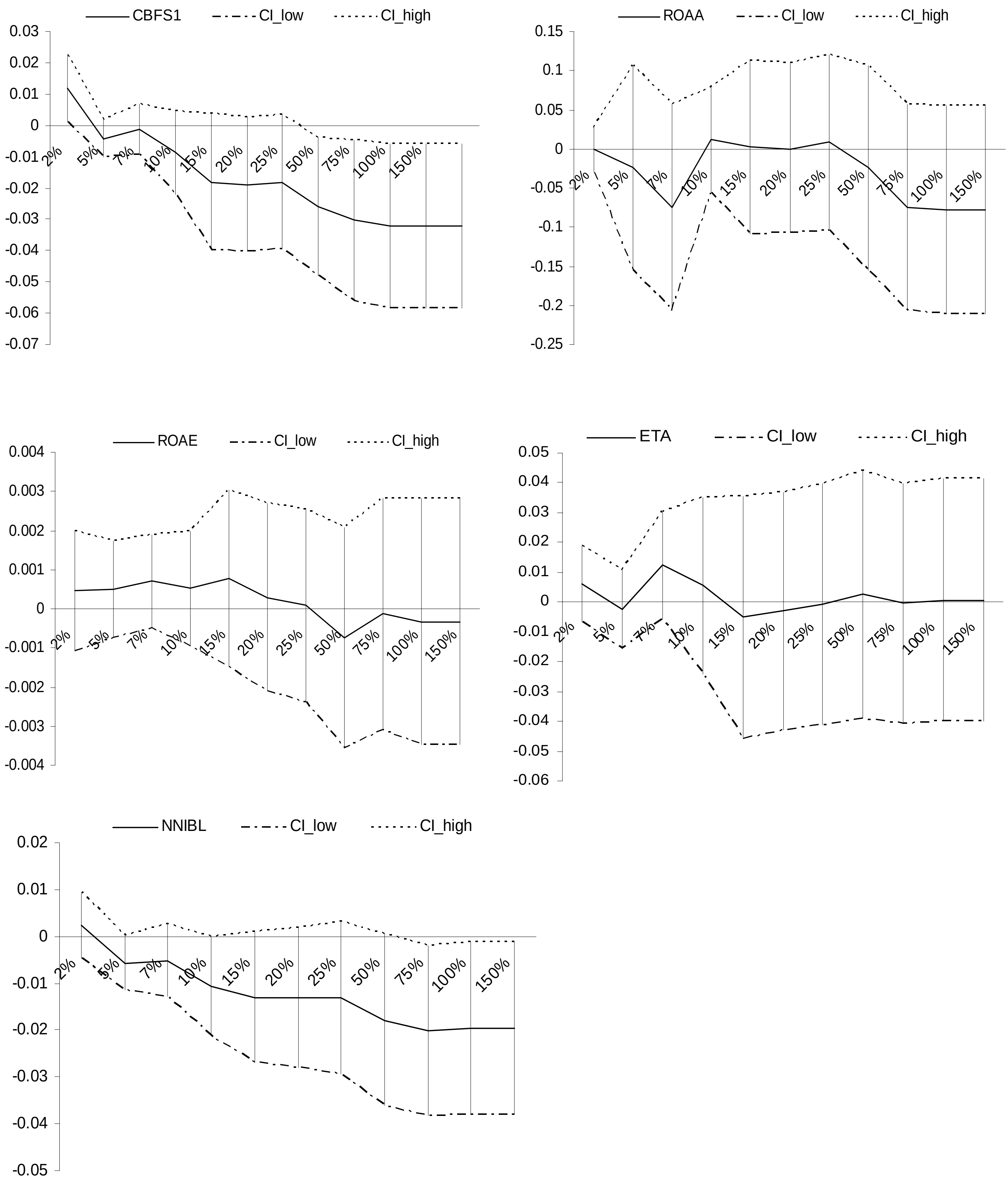


Figure A.3.2: Recursive Regressions according to Inflation – System GMM

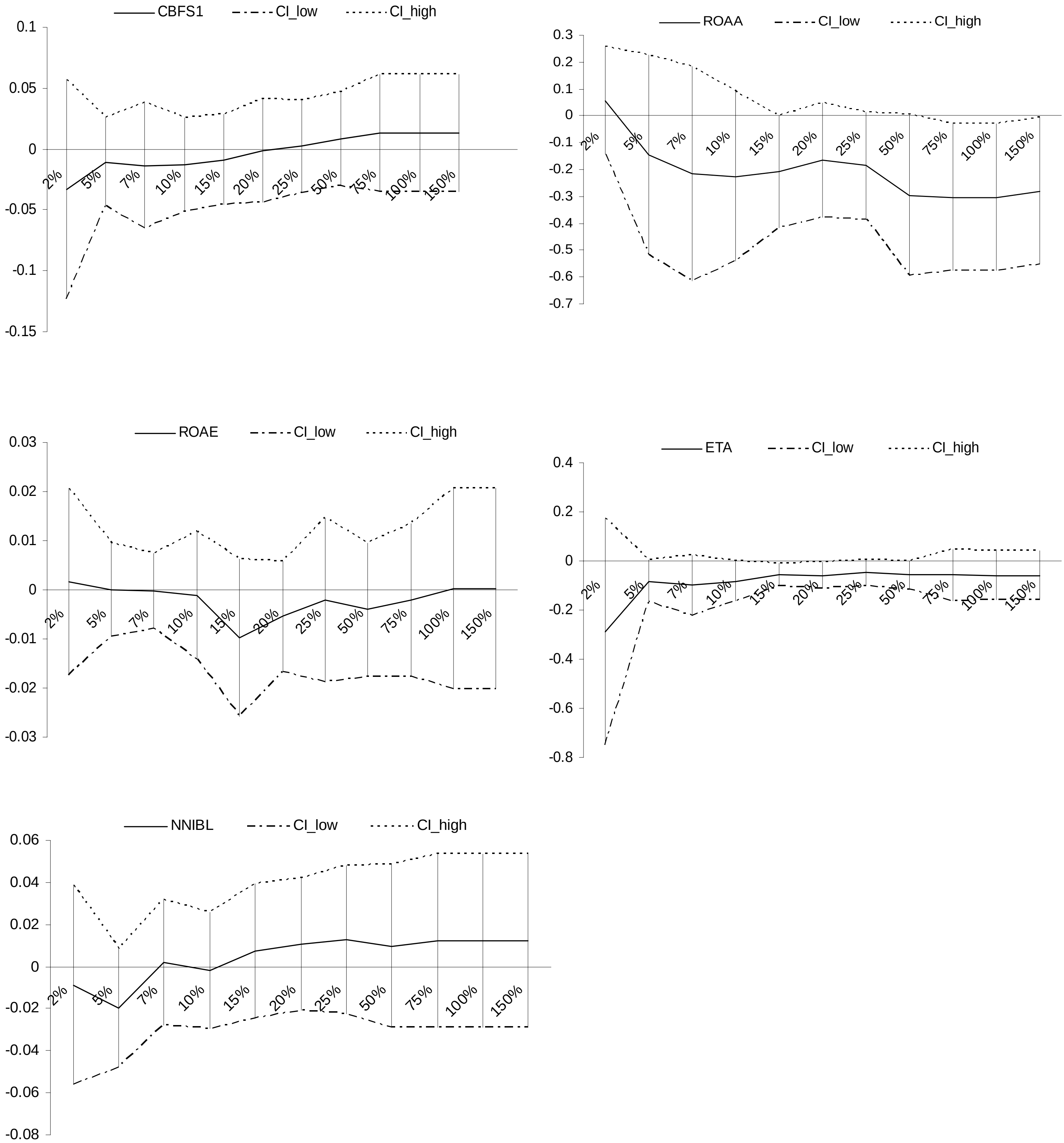


Figure A.3.3: Recursive Regressions according to Individual Indicators of CB Financial Strength – Pooled OLS

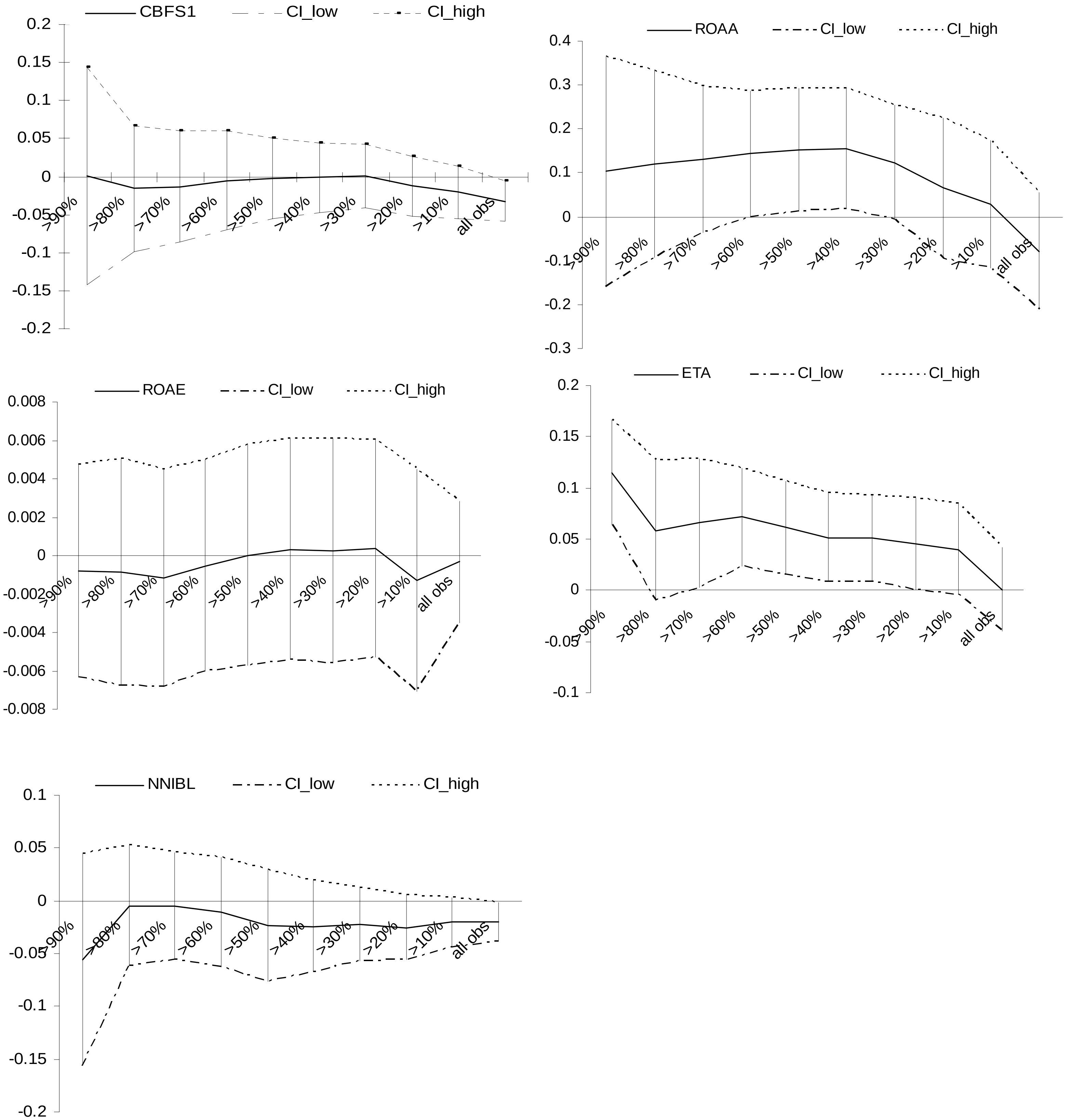


Figure A.3.4: Recursive Regressions according to Individual Indicators of CB Financial Strength – System GMM

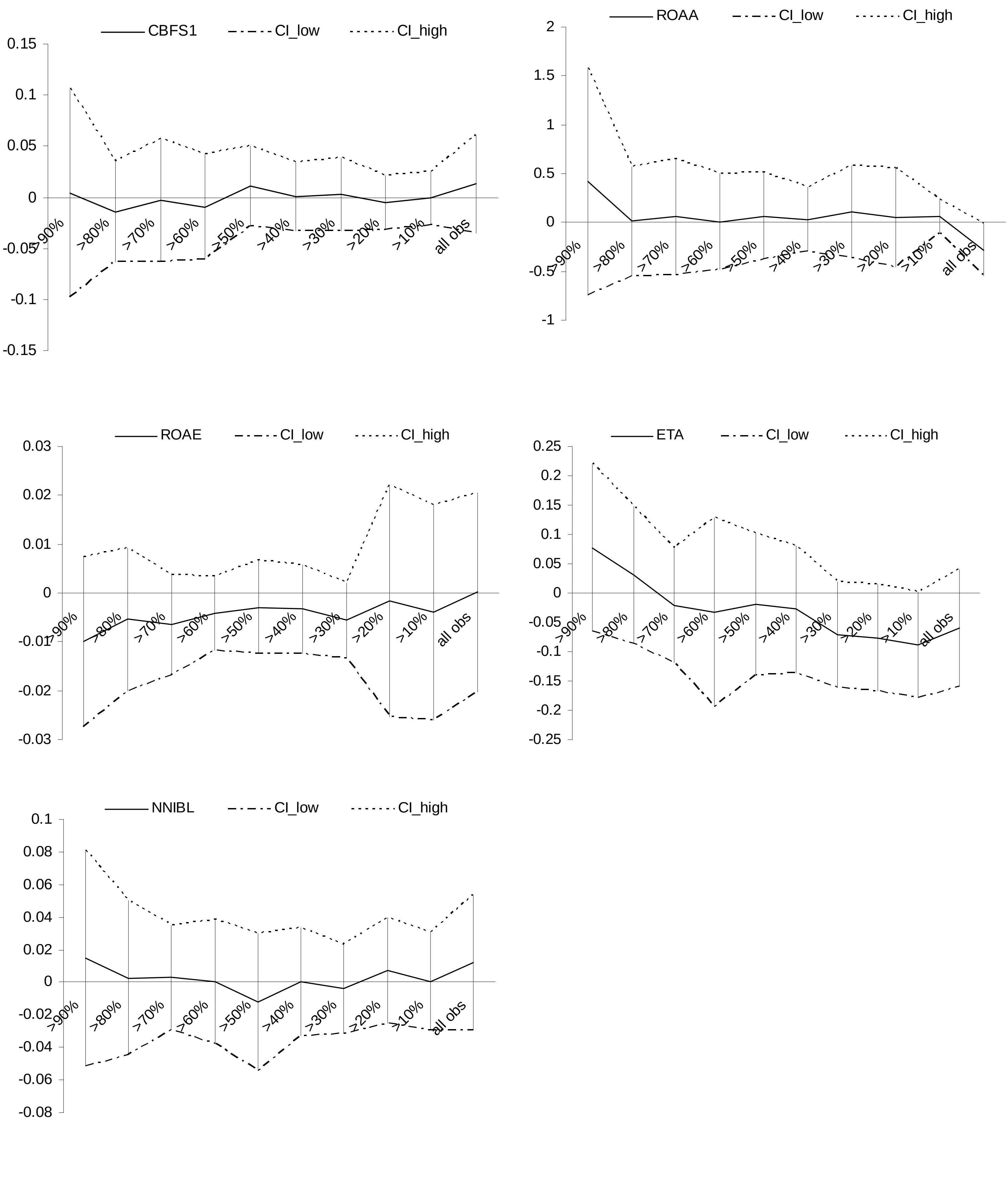
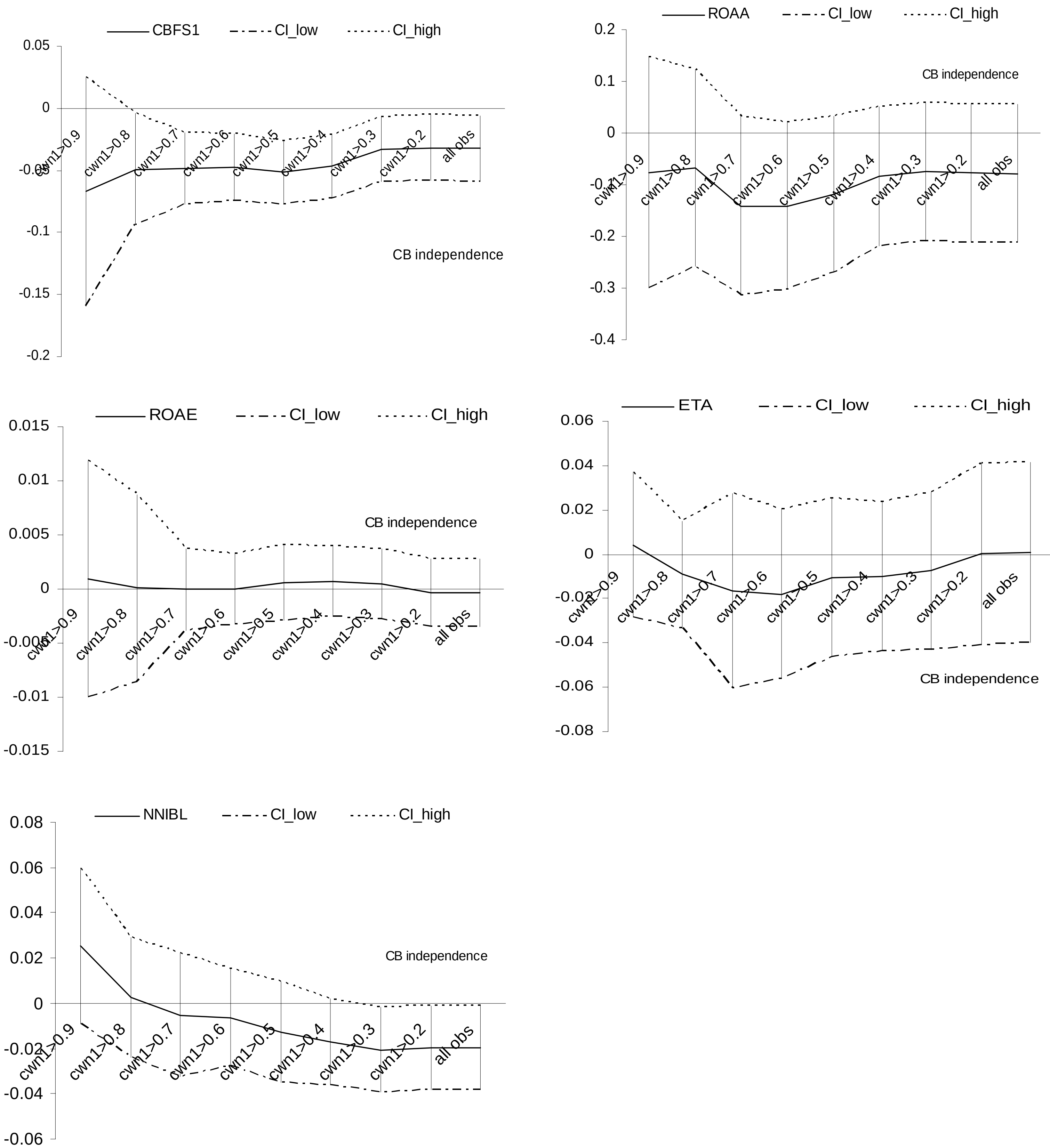


Figure A.3.5: Recursive Regressions according to CB Independence – Pooled OLS



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Czech National Bank
Economic Research Department
Na Příkopě 28, 115 03 Praha 1
Czech Republic
phone: +420 2 244 12 321
fax: +420 2 244 14 278
http://www.cnb.cz
e-mail: research@cnb.cz
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