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Capital Adequacy Regulations in Hungary: Did It Really Matter?

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Abstract- The main purpose of this paper is twofold. First, it aims to estimate the effect of the tightening of regulatory capital requirements on the real economy during credit upswing. Second, it intends to show whether applying a countercyclical capital buffer measure, as per the Basel III rules,could have helped decelerate FX lending growth in Hungary, mitigating the build-up of vulnerabilities in the run-up to the global financial crisis. To answer these questions, we use a Vector Autoregression-based approach to understand how shocks affected to capital adequacy in the pre-crisis period.Our results suggest that regulatory authorities could have slowed the increase in lending temporarily.They would not, however, have been able to avoid the upswing in FX lending by requiring countercyclical capital buffers even if such a tool had been available and they had reacted quickly to accelerating credit growth. Our results also suggest that a more pronounced tightening might have reduced FX lending substantially, but at the expense of real GDP growth. The reason is that an unsustainable fiscal policy led to a trade-off between economic growth and the build-up of new vulnerabilities in the form of FX lending.

Keywords: FX lending, capital adequacy, bank regulation, counterfactual analysis.
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I. Introduction

The global financial crisis (GFC) shed light on the importance of the so-called macro-financial linkages through which financial sector activity could have a meaningful impact on economic activity. At the same time, it was also made clear that neither pre-crisis financial supervisory practices nor monetary policy succeeded in ensuring financial stability. As part of a general reassessment of economic policies, macroprudential policies gained traction and have become a part of the overall policy response to the challenges the crisis posed.

Several factors have complicated the adoption of these policies.[1] First, macroprudential policies should be motivated by externalities and market failures. However, there is no clear guidance on the design of these policies. Second, given that most countries resorted to macroprudential policies only recently, there is limited experience and empirical analysis to judge their efficiency.

Hungary, like other countries, also had to realize the importance of macro-financial linkages. In contrast to several other countries that experienced an asset price boom and/or excessive credit growth in the pre-crisis period, however, the main source of vulnerability was the currency mismatch stemming from the foreign currency, mostly Swiss franc, borrowing by households and corporations as well as the maturity mismatch of banks. Specifically, the banking sector financed its long-term foreign currency lending with short-term off-balance sheet transactions (mostly FX, but also currency interest rateswaps). The GFC impacted the banking sector in at least three key ways. First, increased risk aversion in global financial markets prompted a flight to safe assets, including the Swiss franc. The rising debt service of households and corporations stemming from the appreciation of the Swiss franc then led to an increase in bank losses on their loan portfolio. Second, banks had to meet margin calls on their FX swaps due to the depreciation of the Hungarian forint. Third, a few banks had difficulties in rolling over their short-term FX swaps during the crisis.

In this paper, we apply a counterfactual analysis to assess whether excessive credit growth and the build-up of FX loans could have been prevented by the use of macroprudential policies.[2] Specifically, by estimating the historical relationship between aggregate capital adequacy, lending and a set of macroeconomic variables, we calculate an alternative scenario of pre-crisis lending based on a hypothetical capital adequacy regulation.

The structure of the paper is as follows. Section 2 reviews the literature. Section 3 gives an overview on the motivation of the analysis. Sections4 and 5 describe the data and the estimation technique, respectively. Section 6 summarizes the estimation results and section 7 concludes.

II. Related Literature

Given the brief history of the application of macroprudential policies, there is only a small number of empirical papers analyzing the efficiency of these tools. Estimating the effect of macroprudential rules is complicated for at least two reasons: (i) they rarely existedbefore the GFC; and (ii) those already in place (especially the capital adequacy ratio) were broadly stable in the pre-crisis period.

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[1] SeeClaessens (2014).

[2] Based on IMF (2000), aggregate capital adequacy ratio is considered to be a macroprudential indicator.

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Based on the applied method, we can group the existing literature into two categories:

1. Bottom-up approach, i.e. estimations using micro-level data

   Bridges et al. (2014) analyzed the effect of changes in the regulatory capital requirements on lending, based on bank-level data. They used estimation results from panel regressions of lending to different sectors on regulatory capital requirements and observed capital ratios to build impulse responses with the aim of understanding the effects of a permanent 1 percentage point increase in capital requirements. Although the results vary across sectors, they found that an increase in capital requirements reduces loan growth with a lag of one year and a recovery within three years. The cumulative effect of a 1 percentage point increase in the regulatory capital on loan volumes is -3.5 percent after 12 quarters.Brun et al. (2014) used loan-level data in France with the aim of estimating the effect of an easing of the capital requirement on corporate lending. Theirtime span covered the transition from Basel I to Basel II in order to estimate the elasticity of corporate lending to capital requirement. They found a relatively large effect of capital requirements on lending, i.e. a 1 percentage point decrease in capital requirements led to a 0.75 percent growth in outstanding corporate loans.Berrospide et al. (2010) examined the effect of capital injection programs in the U.S., such as that ofthe Capital Purchase Program (CPP). They carried out both panel regression and VAR-based analysis, and found only a modest effect of capital on lending. According to their results, a 1 percentage point increase in the capital-to-assets ratio triggered an increaseof 0.7-1.2 percentage point in lending growth.

2. Top-down approach, i.e. estimations using aggregated data

   As a part of their impact studies for Basel III, BIS (2010) implemented two different one-step top-down approaches for estimating the effect of increasing capital requirements.First, they used DSGE models that explicitly incorporated the banking sector. The results are modest, with a 1 percentage point increase in the target capital adequacy ratio leading to a decrease of 0.14 percentin output after 18 quarters. Second, they estimated VAR models that included standard macroeconomic variablessuch as real GDP growth, GDP deflator and interest rates as well asbanking sector variables such as aggregate bank loans and capital/asset ratios. The results from these estimations were more pronounced, with a 1 percentage point increase in the target capital ratio leading to a 0.4 percentdecrease in output. Noss and Toffano (2014) assessed the impact of changes in capital requirements on lending in the United Kingdom, by estimating a SVAR model. They assumed that an increase in banks' capital requirements would have a negative effect on lending at least in the short run. This assumption is necessary to understand to what extent the change in bank lending behavior was a result of the increasing capital requirement, rather than broader macroeconomic developments. They found that a 15 basis point increase in capital requirements during an economic upswing is associated with a 1.4 percentage point decrease in lending after 16 quarters. At the same time, its effect on GDP was found to be insignificant.

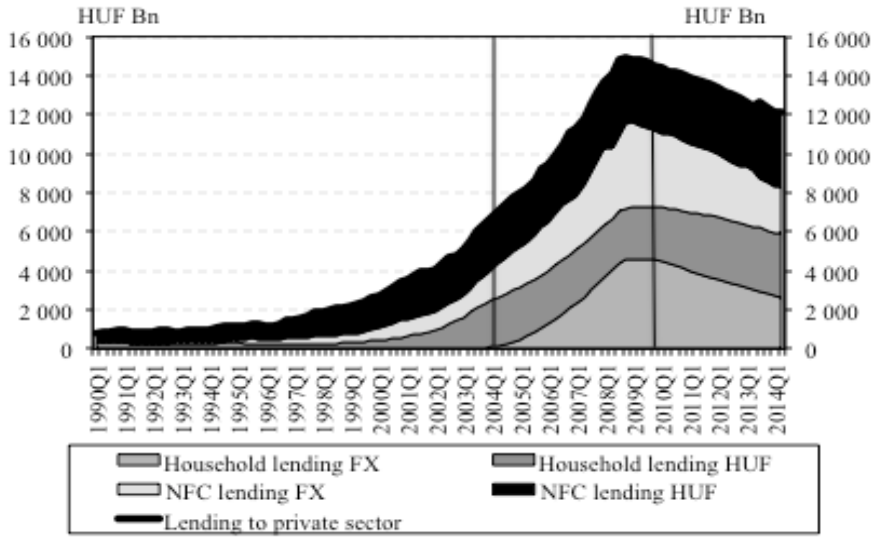
A few studies aimed to estimate the effect of changes in regulatory capital in Hungary. Following the introduction of regulations based on Basel II, Zsámboki (2007) investigated their potential consequences, in particular on financial stability. He pointed out that given the procyclical nature of the regulation, banks should build up capital reserves above the regulatory minimum requirements during an economic upswing in order to be able to cover any future losses. Although the analysis drew attention to the procyclical nature of the Basel II regulation, it did not examine its potential effect on the real economy. Szombati (2010) analyzedthe macroeconomic effect of Basel III rules. She found that a 1 percent(equivalent to around 13 basis points) increase in the capital requirement is associated with a decrease of 0.63-1.05 percent in real GDP after 32 quarters. These results assumed that (i) the banking sector adapts to the new regulationin equal measure with capital increases and asset reductions; (ii) the adjustment would be faster in corporate lending than in household lending; and (iii) banks with larger capital buffers could take over loans from other banks with lower capital buffers.

Tamási and Világi (2011) andHosszú et al. (2013) estimated a Bayesian VAR model for the Hungarian economy and applied sign restrictions to identify macroeconomic and credit supply shocks. Assuming that different types of credit supply shocks might require different policy responses, they analyzed the effect of changing risk assessments of financial institutions as well as that of changing regulatory requirements (credit spread shock). They found that the impact of the two shocks differs substantially. For changing risk assessment, the response of credit portfolio and real GDP are much more pronounced and permanent than foracredit spread shock. Their results show that changing risk assessment indicates a 1 percent decrease in lending and 0.21 percent decrease in real GDP, while changing regulatory requirements has a negative effect of 0.18 percent on real GDP. The order of magnitude and the permanence of the response ofreal variables could be explained by the fact that the underlying VAR model contained only corporate loans whose duration is typically lower than that of households.

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III. Motivation: Excessive Borrowing in Foreign Currency?

Private sector borrowing increased substantially between 2004 and 2009 mostly driven by foreign currency (Swiss franc) denominated loans (Figure 1). Both non-financial corporations and households increased their foreign currency borrowing;however, the borrowing was more pronounced in the household sector.



Note: Household FX lending has been corrected for the effect of the early repayment scheme (starting in 2011 Q4). Data are adjusted for changes in the exchange rate.

Source: Central Bank of Hungary

Figure 1: Lending to private sector

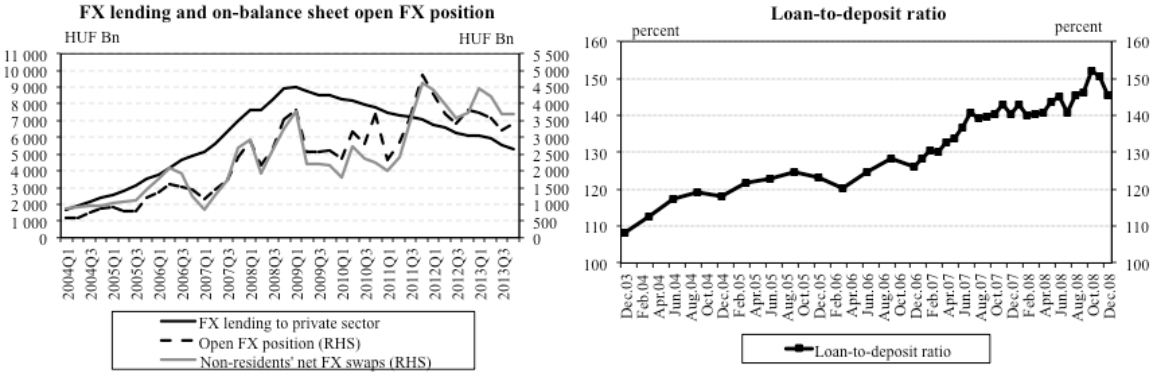
Using four different trend-filtering methods, Hosszú et al. (2015) showed that in the early 2000s, the initially negative credit gap turned into a significant positive credit gap both in the household and corporate sectors. Their results are mostly in line with that of Holló (2012). He found that the imbalances in the Hungarian banking system, namely the excessive credit growth and the sharp increase in the ratio of total liabilities to stable funds, started to emerge in the last quarter of 2005 and lasted until the onset of the financial crisis. Kiss et al. (2006) concluded that although credit growth between 2004 and 2005 was somewhat faster than its equilibrium rate,[3] this can be justified by convergence. It implies that it was not the speed of lending growth per se that should have given rise to concerns but rather its currency composition; i.e. the excessive lending in foreign currency.

There are several possible explanations why foreign currency lending gained momentum in Hungary. To find explanations, we first try to identify whether the motivation originated from the demand or the supply side.

Bethlendi et al. (2005) found that the increase in FX lending, which started in 2004,was mostly due to rising demand, possibly reflected bythe opening of Hungarian banks' on-balance sheet FX position and their increasing loan-to-deposit ratio (Figure 2).

[3] The equilibrium level is identified by some fundamental macroeceonomic variables for developed countries based on a longer time frame.

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Source: Central Bank of Hungary

Figure 2: FX lending, on-balance sheet open FX position and loan-to-deposit ratio of Hungarian banks

Bethlendi et al. (2005),Rosenberg and Tirpák (2008) and Csajbók et al. (2010)identified the following factors on the demand side that presumably contributed to the increase in FX lending. The first three are more relevant for households, while the fourth concerns mostly non-financial corporations.

- Interest rate differentials: The increasing share of FX lending in the private sector stems from a portfolio allocation decision based on the uncovered interest rate parity. Specifically, the domestic interest rate is equal to the sum of the foreign interest rate, the expected depreciation of the exchange rate and the exchange rate risk premium. As long as the risk awareness of borrowers is the same as the sum of expected exchange rate movements and exchange rate risk premium, changes in interest rate differential do not induce substitution between domestic and foreign currency loans. Substitution only happens if exchange rate expectations are not homogenous. Since households had relatively good experiences with consumer FX loans, their risk sensitivity against exchange rate and interest rate was probably quite low. The substantial interest rate differential thus led households to borrow in foreign currency.The latterwas also an important factor for non-financial corporations operating in the non-tradable sector (Bodnár, 2006), therefore they became exposed to exchange rate risks to a similar extent as households.
- 'Fear-of-floating' factor: Given lack of fixed-rate domestic currency loans, borrowers might weigh the risks associated with floating-rate domestic currency loans against foreign currency loans. Specifically, to the extent domestic currency interest rate volatility exceeds exchange rate volatility, borrowers might find foreign currency borrowing more attractive. This can be reinforced by the monetary authority, if it uses interest rate policy to smooth exchange rate movements.
- Liquidity constraint: Ifa household is only able to pay more than a certain proportion of its income to service its debt,the size of the monthly debt service and its variance arecrucial factors. Most households could not afford the high monthly repayment of HUF loans. Households with stronger liquidity constraints typically generated demand for cheaper FX loans. Moreover, the longer the maturity of the loan, the larger the effect of the interest rate differential on the monthly repayments.
- Regulatory changes: The tightening of the eligibility criteria of subsidized mortgage loans in 2004 could also have prompted households to switch to cheaper FX loans.
- Hedging FX deposits: Non-financial corporations that have FX revenues borrowed in foreign currency in order to hedge their FX income.

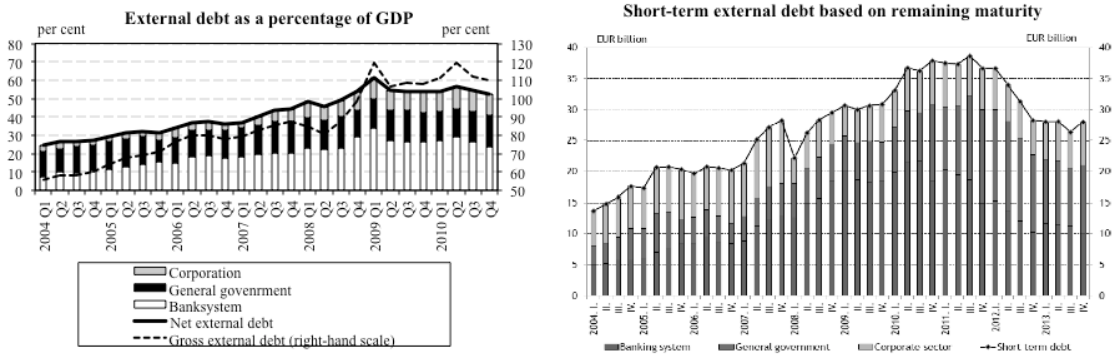
On the supply side, the authors mention that the availability of foreign funds stemming fromstrong financial ties between domestic commercial banks and their parent banks residing in the EU might also have influenced the currency composition of loans.

The private sector's increasing demand for FX loans increased the banking sector's need for FX funds. Hungarian banks collecting mostly HUF deposits had two possibilities to fulfil this need:

1. On-balance sheet foreign currency financing, typically from parent banks,
2. Off-balance sheet swap transactions.

Both forms of FX funding contributed to the build-up of macroeconomic vulnerabilities. First, risks related to on-balance sheet FX fundingstem from a country's increasing external debt (Figure 3). Moreover, banks typically financed long-term mortgage FX loans with short-term foreign funds, leading to a maturity mismatch and thus substantial roll-over risks as well as potential reliance on emergency FX liquidity facilities.

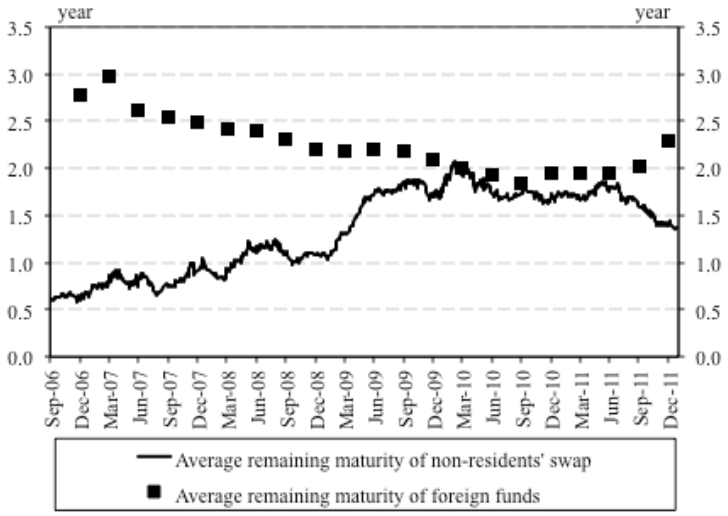
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Source: Central Bank of Hungary, Central Bank of Hungary (2014)

Figure 3: External debt as a percentage of GDP and short-term gross external debt based on remaining maturity and by sector

Second, synthetically creating FX exposure through swaps is even riskier. In addition toincreasing the country's external debt, it has further drawbacks: (i)while foreign funds enhance liquidity, bolstering the balance sheet of the banking sector, FX swaps only change the denomination of existing liquidity without any change in total liquidity and balance sheet; (ii) the maturity of FX swaps has been generally shorter than that of foreign funds (Figure 4). As a result, the rollover risk is even higher than in the case of foreign funds.

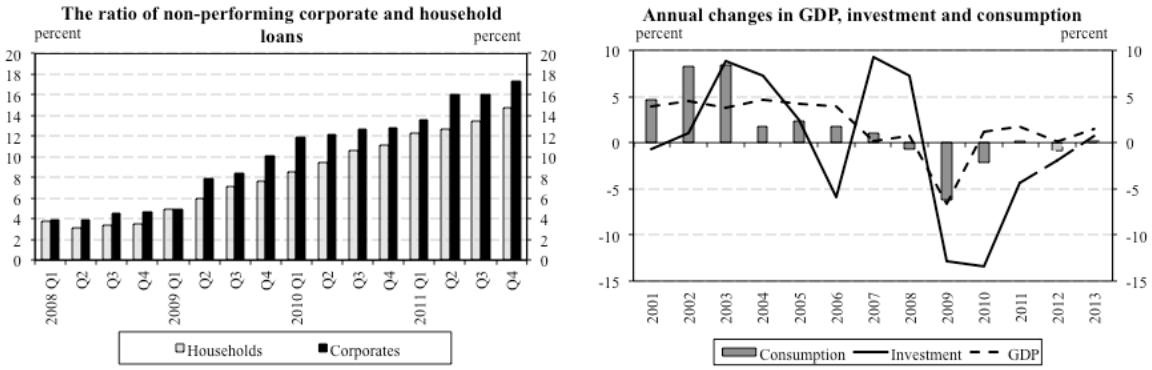


Note: Data for the remaining maturity of the banking sector's foreign funds are available from 2006.
Source: Central Bank of Hungary

Figure 4: Average remaining maturity of foreign funds and gross foreign swaps

These vulnerabilities had serious consequences for Hungary during the crisiswhen risk aversion intensified and investorsflew to safe-haven currencies, such as the Swiss franc. First,the weakening of the Hungarian forint against the Swiss franc substantially increased the monthly repaymentsfor households. Eventually, this resulted in increasing non-performing loan (NPL) ratios as well as decreasing consumption and investments(Figure 5).

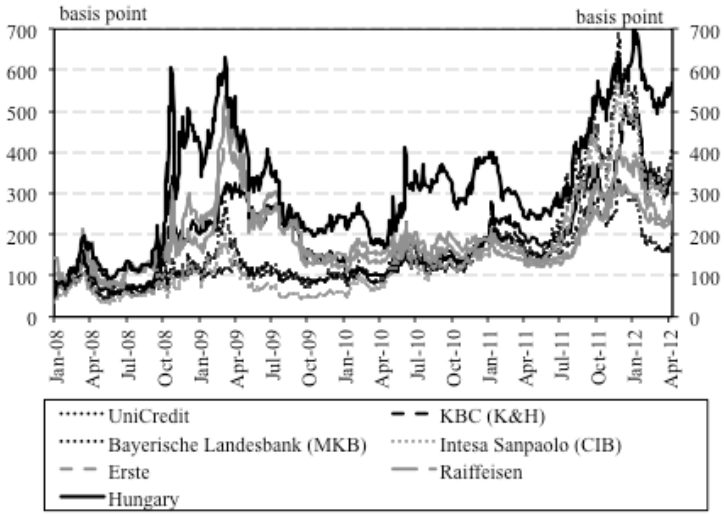
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Source: Central Bank of Hungary

Figure 5: Ratio of non-performing corporate and household loans within total loan portfolio and annual changes in GDP, investment and consumption

Second, the renewal of foreign fundsand swaps became more expensive as the country's and the parent banks' CDS spreads, the most important pricing component, increased substantially (Pálesand Homolya, 2011) (Figure 6).

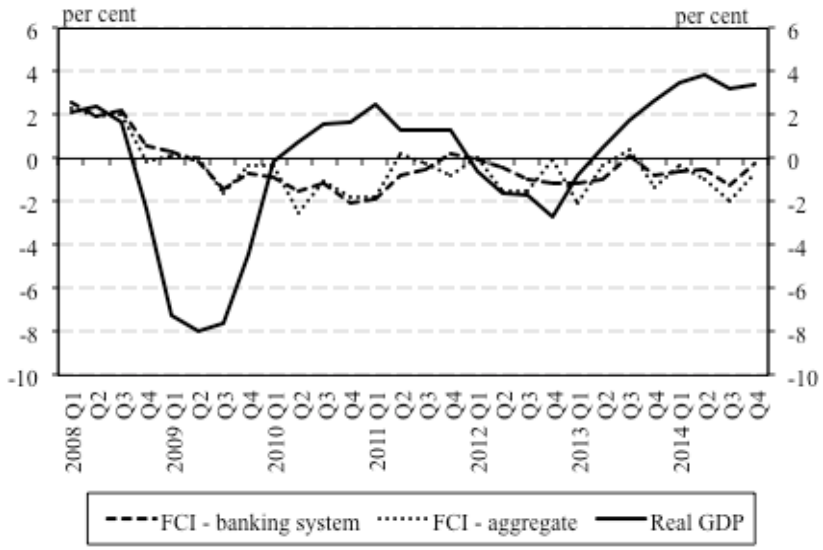


Source: Central Bank of Hungary, Bloomberg

Figure 6: 5-year CDS spreads of Hungary and parent banks

The prevalence of FX loans played an important role in the deepening of the crisis. Increasing funding costs and NPL ratios put pressure on the banking sector's income-generating capabilities,limiting its ability to contribute to real GDP growth (Figure **7**). As such, it is of great importance to examine whether the excessive FX lending could have been avoided by requiring a countercyclical capital buffer as per Basel III rules and if so, at what macroeconomic costs.

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Note: The annual growth rate of FCI shows the contribution of the financial intermediary system (banking sector) to the annual growth rate of real GDP. While the banking sector sub-index only contains the variables related to lending, the 'overall' index also contains the monetary conditions, i.e. the interbank rate and the exchange rate. A revision was made on the time series because of the transition of the model to a transactional basis.
Source: Central Bank of Hungary

Figure 7: Financial Conditions Index (FCI) and annual real GDP growth

In this paper, using a Vector Autoregression Model (VAR), we estimate the effect of changes in regulatory capital requirements based on the pre-crisis relationship between aggregate capital adequacy ratio and other macroeconomic variables. The results could provide policy makers with a sense of themacroeconomic effect of changes in macroprudential capital requirements.

IV. Data

In the previous chapter, we identified 2004-2009 as a period of credit upswing in Hungary. The year 2004 was chosen as the start because households had hardly done any FX lending before that year. Lending to the private sector increased on a year-to-year basis even after the onset of the GFC until the end of 2009, therefore we consider it the turning point. In the estimation the following quarterly variableswere used:

1. Real GDP growth: The source of the data is the Hungarian Central Statistical Office.Seasonally adjusted growth rates were used for the estimation.
2. Growth rate of real lending to private sector: Data published by the Central Bank of Hungary. We adjusted growth rates seasonally and for exchange rate changes.
3. Alternative funding sources (growth rate): Theserefer to non-financial corporations (NFCs) and include loans from non-financial entities, other financial corporates, public institutions, households and foreign entities as well as bonds issued by non-financial corporates. The data, published by the Central Bank of Hungary, were seasonally and exchange rate adjusted.Since bank financing is by far the most dominant form of funding for corporates in Hungary, the explanatory power of this variable might be limited. However, given its importance in some segments of the economy, we decided to include it in the baseline model. More importantly, the inclusion of alternative funding is necessary to simulate a credit supply shock.
4. Hungarian sovereignCDS spread represents the FX funding costs of the Hungarian banking sector. Páles et al. (2011) showed that before the onset of the crisis, Hungarian banks were able to obtain foreign funds at levels corresponding to those of their parent banks and Hungarian sovereign CDS spreads. Between the onset of the crisis and 2009, both the funding costs of parent banks and Hungarian sovereign CDS spreads increased substantially. Although the funding costs of Hungarian banks remained at the level of those of theirparent companies during this period, they started to decouple significantly at the beginning of 2010. As a result, the Hungarian sovereign CDS spread seems a good proxy for the funding costs of banksbetween 2004 and 2009. CDS spreads were downloaded from Bloomberg.
5. Hungarian 3-month money market rate (BUBOR):Similarly to CDS spreads, this variable is used to capture Hungarian banks' HUF funding costs.BUBOR is expected to have an impact through the substitution channel, i.e. the higher HUFborrowing costs, the more households move

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toward borrowing in FX. The Central Bank of Hungary publishes data on a monthly basis.

6. Real Effective Exchange Rate (CPI based REER):This variable measures the country's competitiveness compared to its main international trade partners. Time series are published by the Central Bank of Hungary.
7. Capital Adequacy Ratio (CAD ratio):Data are coming from regulatory reports submitted to the Central Bank of Hungary. The denominator of the ratio is the risk weighted assets of the banks and is calculated according to Basel II rules.[4]Although there are arguments for using total assets instead of risk weighted assets in order to filter out the effect of any potential attempts made by banks trying to alter their balance sheet, the official CAD ratio still seems a better alternative given that the main purpose is to quantify the effect of changes in the CAD ratio. The capital adequacy ratio required under Pillar II by the authoritiesdiffers from bank to bank, but we assume that there is no bank with a higher required capital adequacy ratio than the sector average. This assumption ensures that an increase in the required capital ratio would lead to a decrease in banks' capital buffer.

The first three variables are expressed as growth rates, in the case of BUBOR and REER, their levels are used, while CDS spreadsand the aggregate capital adequacy ratio are in first difference in order to ensuretheir stationarity. As a preliminary attempt, the levels of these variables were used, but the estimated VAR did not satisfy the stability criteria.

Table 1shows descriptive statistics of the variables, while Table **2** contains their correlation matrix. The correlation matrix reveals thatreal GDP is positively correlated with real lending, alternative funding and the aggregate CAD ratio (albeit only weakly in the latter case), while it is negatively correlated with the Hungarian sovereign CDS spreads. Real lending is negatively correlated with alternative funding, CDS spreads, BUBORand the CAD ratio. Notwithstanding the intuitive relations between the variables, the contemporaneous correlationsdo not differ significantly from zero in most cases suggesting that lagged values might have better explanatory power.

Table 1 : Descriptive statistics, quarterly data, 2004Q1 – 2009Q4

	CAD ratio	Real lending	Real lending growth	Real GDP growth	Alternative funding sources*	Alternative funding sources growth rate	CDS spread	CDS spread change	BUBOR 3M (real)	REER
Mean	11.80	11 110.5	3.61	0.57	11 460.5	4.77	106.4	0.18	2.85	75.87
Std Dev	0.80	2 865.8	4.66	1.51	3 526.9	3.17	141.0	0.60	2.59	4.43
Min	10.06	6 748.3	-5.32	-3.54	6 379.8	-1.02	14.6	-0.33	-3.58	66.30
Max	13.35	15 355.0	10.26	3.62	18 412.2	13.75	490.1	2.03	6.99	84.24

Note: It contains bond issuance, other non-FI loans and loans from abroad of NFC.

Source: Central Bank of Hungary, author's calculations

Table 2 : Contemporaneous pairwise correlation, quarterly data, 2004Q1 – 2009Q4

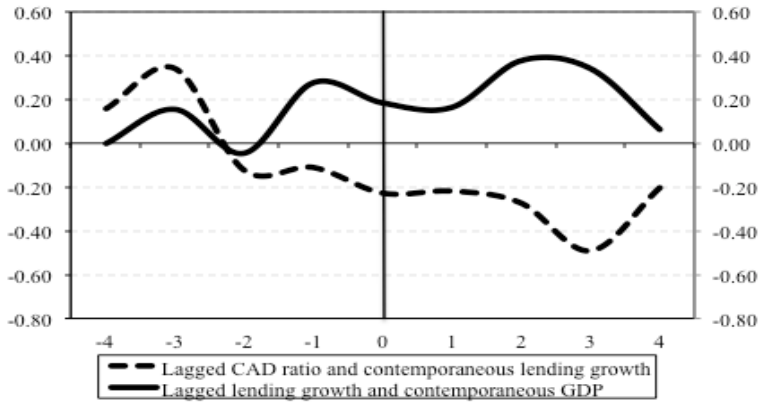
	Real GDP	Real lending	Alternative funding	CDS spread	CAD ratio	BUBOR 3M	REER
Real GDP	1.00000						
Real lending	0.18400	1.00000					
Alternative funding	0.15910	-0.04400	1.00000				
CDS spread	-0.29210	-0.31430	-0.21450	1.00000			
CAD ratio	0.01000	-0.22110	-0.60240	-0.05410	1.00000		
BUBOR 3M	-0.23430	-0.24310	-0.31190	0.04870	0.23010	1.00000	
REER	0.19400	0.23510	-0.00330	-0.13250	-0.06570	0.15570	1.00000

Source: Central Bank of Hungary, author's calculations

Figure 8 shows the correlation of lagged lending and contemporaneous GDP,i.e. the correlation between lending growth in period t + lag and GDP growth in period t, as well as between lagged CAD ratio and lending growth. Lending growth in any period has the highest correlation with GDP growth two quarters

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earlier, suggesting that corporations and households tend to arrange credit facilities during economic upswings, so that they have liquidity buffers during downturns. The relationship between the lagged CAD ratio and lending growth seems to confirm the pro-cyclical behavior of the banking sector:banks increase their leverage during upturns by increasing lending.

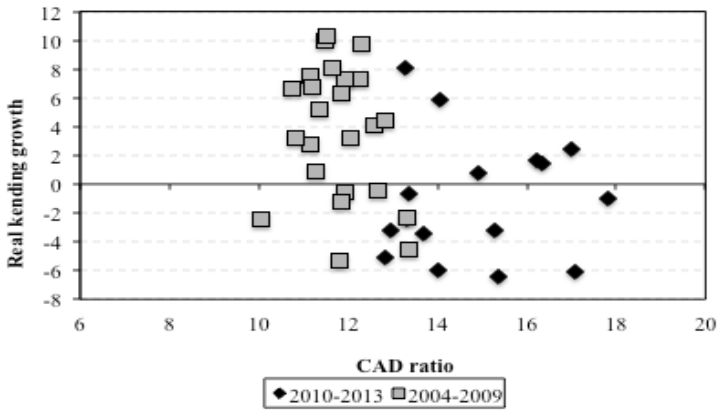


Note: Calculated using the level of CAD ratio.

Source: Central Bank of Hungary, author's calculations

Figure 8: Correlation between lagged and contemporaneous lending growth, GDP growth and CAD ratio, quarterly data, 2004Q1-2009Q4

The intuitive relationship between banks' capital adequacy ratio and real lending is also supported by post-crisis data. Between 2004 and 2009 capital ratios decreased as lending expanded, while in recent years the situation reversed (Figure 9).



Source: Central Bank of Hungary

Figure 9: Real quarterly lending growth versus aggregate capital adequacy ratio

V. Model

Our first goal is to understand the impact of changes in capital requirements on banks' funding costs. Based on the Modigliani-Miller (M&M) theorem (Modigliani and Miller, 1958), an increase in the regulatory capital requirement does not change banks'overall funding cost. However, this statement is conditional on a number of underlying assumptions, including the absence of frictions and taxes. In reality,the M&M theory does not hold for the following reasons:

1. Taxes: Since interest payments on debt are tax-deductible, banks have an incentive to operate with higher leverage.

Admati and Hellwig (2013) highlight two additional factors that create incentives for banks to increase leverage:

2. Explicit state guarantee: Deposit insurance schemes reimburse losses not covered by banks' assets, thereby lowering banks' funding costs. Moreover, during the recent financial crisis, governments extended guaranteeseven for non-deposit liabilities of banks.
3. Implicit state guarantee: By reducing the funding costs of too-big-to-fail institutions, itprovides these banks with an advantage over other banks.

As a result of these factors, banks' funding costs are lower than they would otherwise be.

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During the pre-crisis period, investors' risk perception related to the financial sector was very small. As a result, banks were able to borrow at low rates. In this environment, an increase in capital requirements was considered to be a credit supply shock, i.e. itwould have caused banks' funding costs to increase. Possible responses could have included the following: (i) decrease lending;(ii) increaseretained earnings;or(iii) raise capital. However, the first option seems the most likely outcome given some constraints associated with the second and third responses. Specifically,an increase in retained earnings is constrained by sticky dividend payments and banks' reluctance to reduce spending during economic upswing. Similarly, banks tend not to raise capital during those periods when they usually accumulated liquidity buffers. The reason is that investors are aware of the fact that a bank does not need to issue new equity, but if it does so, it would be a sign of the firm being overvalued (Myers and Majluf, 1984).

The above relationship between banks' funding costs and the level of the regulatory capital ratio, however, changed after the crisis. Specifically, it changed from positive to negative, i.e. higher capital requirements are associated with lower funding costs. The GFC revealed significant imbalances in the financial sector that were overlooked by investors in the pre-crisis period. In such an environment, an increase in the regulatory capital level could increase investors' confidence in the banking sector, by supporting banks'resilience as well as their ability to increase lending (Noss and Toffano, 2014).

Due to the above-mentioned ambiguous effect of an increase in the regulatory capital on lending, following Noss and Toffano (2014) we estimated two different models:(i) an unconstrained VAR model in which there are no assumptions regarding the impact of a capital adequacy shock; and (ii) a Structural VAR (SVAR) where we introduced a sign restriction on lending and on alternative funding growth, i.e. an increase in capital requirements is associated with a reduction in lendingand an increase in alternative funding. The latter reflects the assumption that the relationship between capital requirements and lending was negative before the crisis. This way, the results stemming from the two models could serve as a reasonable range for policy makers to estimate the effect of macroprudential regulation on the real economy regardless of the economic cycle.

The approach has strengths, specifically in identifying capital adequacy tightening-like situations in the past to gauge the impact of future changes when such policy action is not present in the historical data. Butit also has several caveats. Change in the regulatory minimum, for example, does not necessarily require banks to increase their capital adequacy ratios since they typically hold buffers above that minimum. As a result, the shock that we apply in the model could be interpreted in the following ways:

- Provided banks intend to keep their buffers constant in longer terms, an increase in the regulatory capital requirement has a one-to-one effect on the capital adequacy ratios. Bridges et al. (2014) showed that regulatory capital requirements impact bank capital ratios, i.e. banks typically rebuild their buffers following a tightening of capital regulations.
- The change can reflect a rise in the applicable risk weights for FX loans that leads to an increase in the capital requirement and a decrease in capital buffers.
- The tightening can also be considered as implementation of a countercyclical capital buffer as per the Basel III rules.

The primitive form of the Vector Auto Regression (VAR) model can be defined as follows (Enders, 2010):

$$\boldsymbol{B x_t = \Gamma_0 + \sum_{i=1}^{p} \Gamma_i x_{t-i} + \varepsilon_t}$$

where

p is the number of lags

x_t is a vector of the endogenous variables

$$x_t = \begin{pmatrix} realgdp_t \\ reallending_t \\ cdsspread_t \\ alternativefundingsources_t \\ CADratio_t \end{pmatrix}$$

B contains the contemporaneous effect of a unit change of an endogenous variable on another endogenous variable.

$$B = \begin{pmatrix} 1 & \cdots & b_{1p} \\ \vdots & \ddots & \vdots \\ b_{p1} & \cdots & b_{pp} \end{pmatrix}$$

Γ_0 is the constant

$$\Gamma_0 = \begin{pmatrix} b_{10} \\ b_{20} \\ b_{30} \\ b_{40} \\ b_{50} \end{pmatrix}$$

Γ_1 is a p x p matrix that contains the coefficients of the lagged endogenous variables

$$\Gamma_1 = \begin{pmatrix} \gamma_{11} & \cdots & \gamma_{1p} \\ \vdots & \ddots & \vdots \\ \gamma_{p1} & \cdots & \gamma_{pp} \end{pmatrix}$$

ε_t is the error term

$$\varepsilon_t = \begin{pmatrix} \varepsilon_{realgdp\ t} \\ \varepsilon_{reallending\ t} \\ \varepsilon_{CDSspread\ t} \\ \varepsilon_{alternativefundingsources\ t} \\ \varepsilon_{CADratio\ t} \end{pmatrix}$$

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Multiplying equation (1) by B^{-1}allows us to obtain a VAR model in standard form:

$$\boldsymbol{x_t = A_0 + \sum_{i=1}^{p} A_i x_{t-i} + e_t}$$

where

$$A_0 = B^{-1}\Gamma_0,\ A_1 = B^{-1}\Gamma_1, \text{ and } e_t = B^{-1}\varepsilon_t.$$

In this paper two lags were used in the estimation of the VAR. According to the standard information criteria, three lags should have been included in the model, but the resulting VAR did not satisfy the stability criteria. Moreover, the selection of two lags reflects the low degrees of freedom arising from having relatively few observations, relative to the number of variables in the model.

Sign restrictions were introduced in the following way based on Fry and Pagan (2007).

The relationship between residuals from the standard form and those from the primitive form of the VAR is as follows:$e_t = B^{-1}\varepsilon_t$. If there is an S matrix with the estimated standard deviations of the ε_t on the diagonal and zeros elsewhere, we could express residuals as $\mathrm{e_t = B^{-1}SS^{-1}\varepsilon_t = T\eta_t}$, where $\mathrm{\eta_t = S^{-1}\varepsilon_t}$ has unit variances.

Assuming that there is a Q matrix such that $\mathrm{Q'Q = QQ' = I}$, we can rewrite residuals as follows:

$$\mathrm{e_t = TQ'Q\eta_t = T^*\eta_t^*}$$

This results in a new set of estimated shocks $\mathrm{\eta_t^*}$with a covariance matrix I since $\mathrm{E(\eta_t^*;\eta_t^*) = QE(\eta_t;\eta_t')Q' = I}$.As a result we have a combination of the shocks $\mathrm{\eta_t^*}$ that have the same covariance matrix as $\mathrm{\eta_t}$, but a different impact on $\mathrm{e_t}$, hence the $\mathrm{x_t}$.

To create the above impulse responses and Q matrices, we take the following steps:

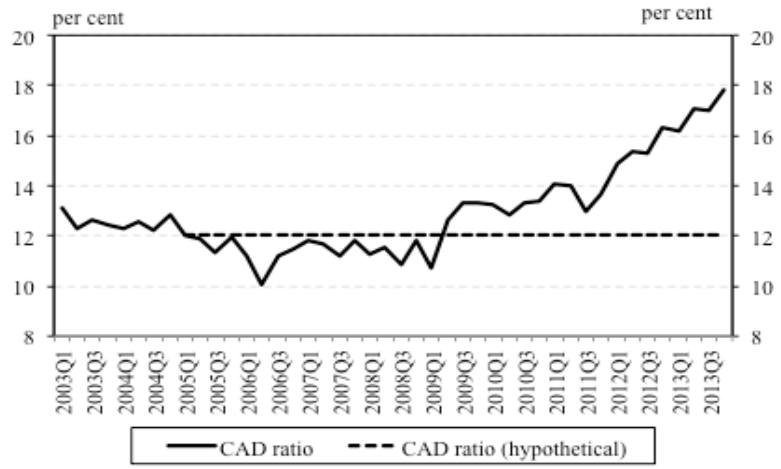
1. We compute $\mathrm{E(e_t;e_t') = \Sigma}$ and assume that $\mathrm{B^{-1} = chol(\Sigma)}$,[5] such that $\mathrm{e_t = B^{-1}\varepsilon_t}$;
5. We then repeat these steps 1,000 times and keep the results that satisfy the sign restrictions.

Interpreting the impulse responses that satisfy the scheme of imposed restrictions is not straightforward, since the model that produced the median response for one variable might not be the same for the other variables. Fry and Pagan (2007, 2011) suggest a solution to this problem that chooses those impulses that are the closest to the median responses (Median Target Method). To implement it, we first need to standardize our results by subtracting the median from each impulse response value and dividing it by its standard deviation over all models that satisfy the sign restrictions. These standardized impulses are placed in a vector $\phi^{(l)}$ for each impulse response value $\Theta^{(l)}$. Subsequently we choose the l that minimizes $\mathrm{MT} = \phi^{(l)\prime}\phi^{(l)}$ and then use $\Theta^{(l)}$to calculate impulse responses. This process does not necessarily provide a unique l, but in our case, the closest impulse response to the median came from the same model for all variables.

VI. Estimation Results

The VAR(2) model described in the previous section was estimated for a seven-equation system. The coefficients were jointly significant in each equation.

The magnitude of the shock was chosen such that policymakers would have intervened to maintain capital adequacy ratios at their 2005Q1 level (12.04 percent) (Figure 10). This choice seems plausibleas (i) it is greater than levels observedin the pre-crisis period but lower than levels seen in the aftermath of the crisis; and (ii) it is reasonable toassume that if a countercyclical capital buffer measure had been available, the authorities would have had enough time (four quarters after the start of the credit upswing) to react to increasing lending by requiring additional capital.



Source: Central Bank of Hungary

Figure 10: Aggregate CAD ratio

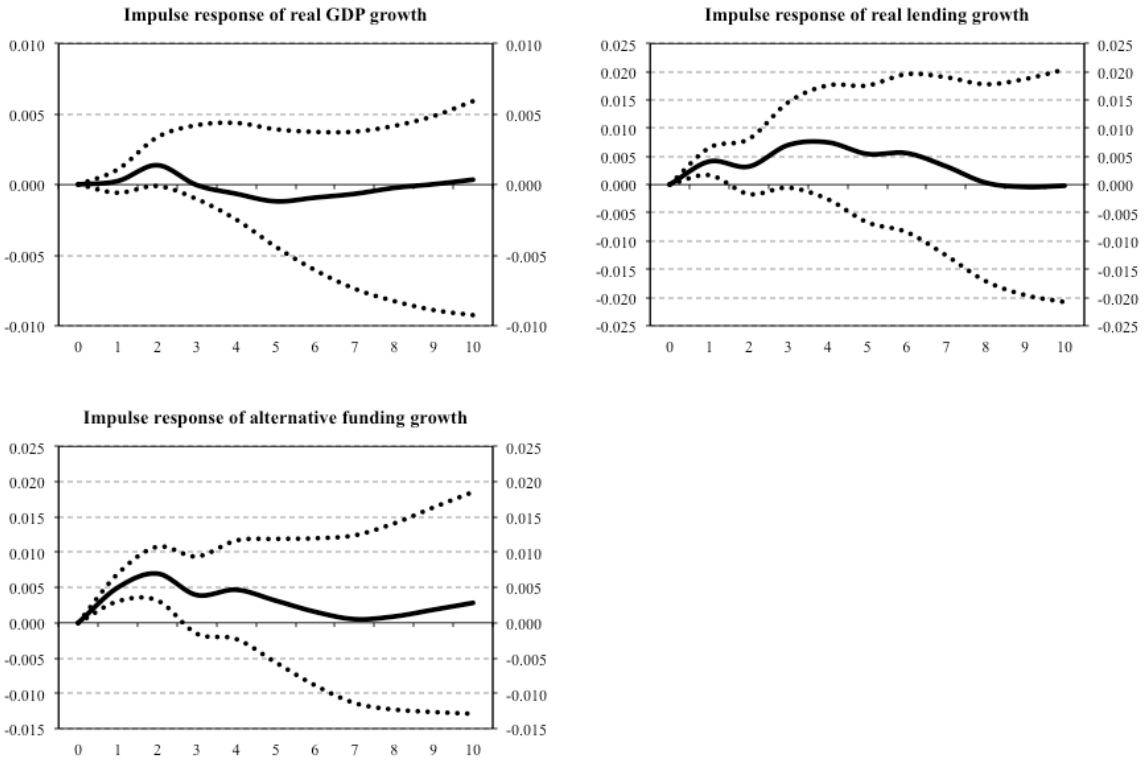
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In the remainder of this section, we describe the impact of changes in capital requirements based on the results of both the unconstrained and the constrained models.

Figure 11 shows the unconstrained effects of a macroprudential tightening on real GDP growth, real lending and alternative funding growth. As we mentioned earlier, the unconstrained model intends to simulate the post-crisis behavior of the banking sector and investors, i.e.a tightening of capital requirements does not necessarily induce a credit supply shock. The response of real GDP growth to an increase in the capital adequacy ratio is moderate; following a temporary increase, it returns to its pre-shock levelafter 10 quarters. The overall effect on real lending growth is similar to that on real GDP, i.e. it returns to its initial level after 10 quarters,albeit the initial increase proves to be more persistent.

The reason for the increase in real GDP and lending as a response to increasing capital requirements is at least twofold. First, as we argued in section 3, demand-side factors appear to be the main drivers of lending growth, in particular FX lending growth. Our estimation results seem to confirm this. Specifically, the positive impact of higher capital adequacy on lending suggests that strong demand could actually have resulted in an even higher lending growth rate. In other words, the latter was prevented by credit supply. As a result, an increase in capital adequacy could have allowed banks to better satisfy loan demand and thus could have led to higher lending growth. Second, as indicated in section 5, the relationship between capital adequacy and lending is ambiguous. Specifically, if higher capital adequacy improves investor confidence in the banking sector, it leads to lower funding costs, i.e. it could make it easier for banks to finance a further expansion in their loan portfolio.

Noss and Toffano (2014) found similarly weak positive responses for lending when they excluded the sign restriction. They explained it as lending being the only potential transmission channel for macroprudential capital requirements. It seems plausible in periods of credit upswing, when banks' cost of debt is insensitive to their capital level.



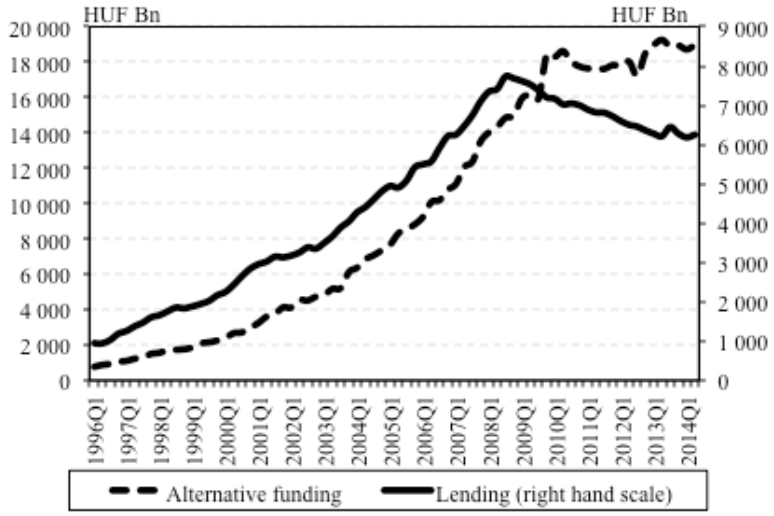
Source: author's calculations

Figure 11: Impulse responses of a 13 basis point shock to the change in the aggregate CAD ratio

[5] B^{-1} is usually indicated with A in econometric software.

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The reaction of alternative funding growth to an increase in the capital requirement seems puzzling at first glance as an increase in the supply of bank lending is associated with a increase in alternative funding, i.e. companies do not substitute bank funding with alternative sources. However, taking a closer look at the historical relationship of real lending growth and alternative funding growth could explain this. As it is shown in Figure 12, lending to corporations and funding from alternative sources moved together until the onset of the GFC. Two factors could be behind this: either (i) corporations faced a scarcity of bank funding, i.e. bank and alternative funding complemented each other; or (ii) they used other funding channels for specific reasons (e.g., the signaling effect of bond issuance in the case of listed companies).Given that the model was estimated for the pre-crisis period, it captures this positive relationship between bank and alternative funding. As a result, a change in capital adequacy affects these funding sources in the same directions. However, the GFC revealed that this relationship can change during periods of distress. As the figure shows, bank funding decreased during the crisis, while alternative funding increased slightly, suggesting that companies that have access to alternative sources of funding substituted for bank lending to some extent.



Note: Alternative funding contains bond issuance and loans from non-bank entities, such as households, public institutions, other-financial institutions, other corporations and foreign entities.

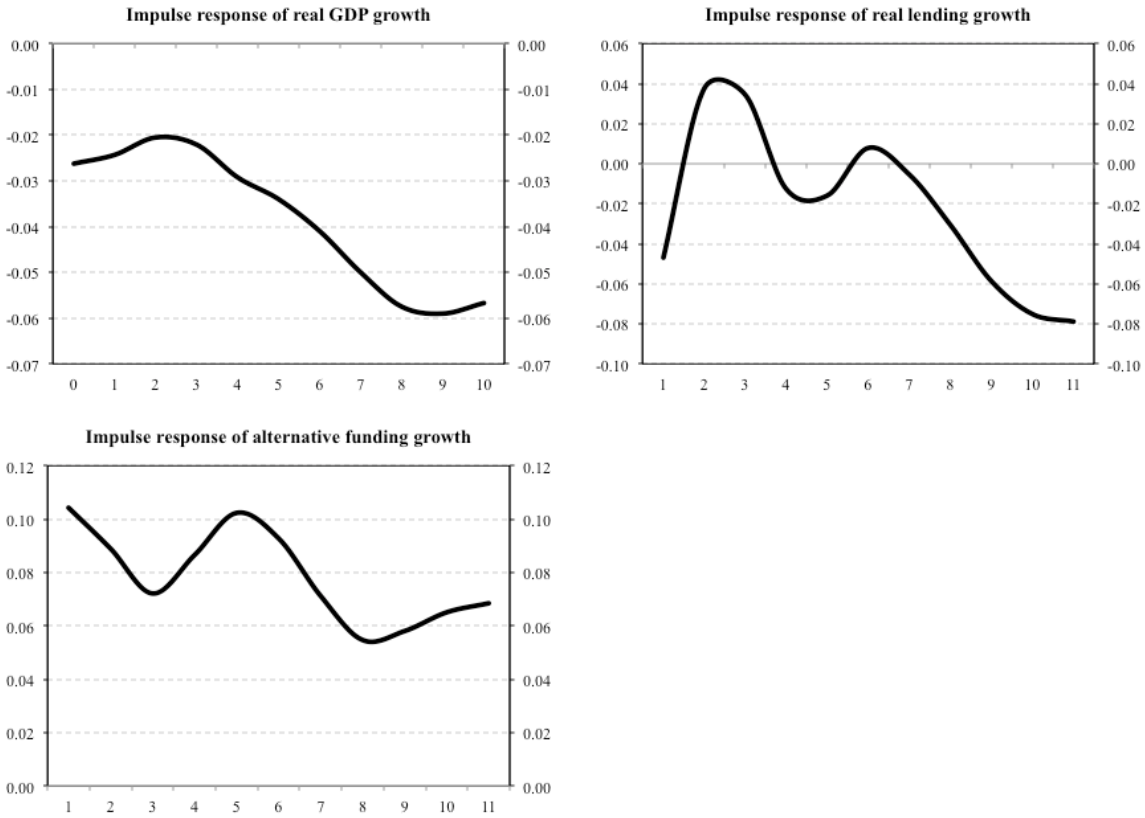
Source: Central Bank of Hungary

Figure 12 : Lending to corporations and alternative funding sources

Figure 13 shows the results from the SVAR model, i.e. where sign restrictions were introduced in order to simulate a credit supply shock. Specifically, an increase in the regulatory capital requirement is expected to lead to a decrease in lending and an increase in alternative funding growth. In line with our prior expectations, such a policy change has a stronger impact on real variables than the unconstrained VAR; however, its overall effect remains modest.

Real GDP growth has a relatively modest immediate response; however, it strengthens after 10 quarters. This pace of reaction could be due to a number of factors. An increase in capital requirements immediately restricts banks' risk-taking ability and thus reduces the availability of bank lending for companies. The resulting cancelation or postponement of leveraged investment projects might have a more pronounced impact on GDP as investments are partly financed with own resources. Moreover, the cancelation of investment has a multiplier effect on GDP.According to our results, lending growth also falls sharply in the third quarter and, after a temporary recovery, it continues to decrease afterwards. Alternative funding shows an opposite moving pattern, suggesting that companies seek for other funding sources as access to bank lending decreases. However, the demand for alternative funding fades after 10 quarters as real GDP growth declines.

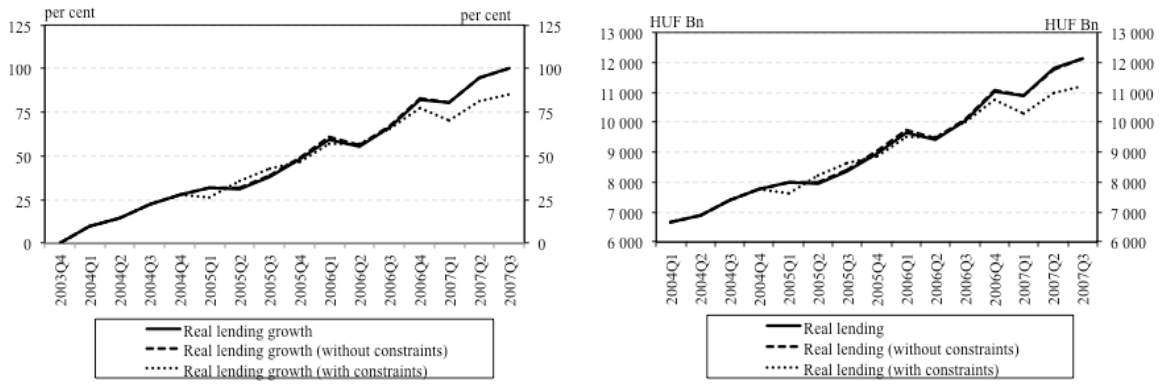
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Source: author's calculations

Figure 13: Impulse responses of a 13 basis point structural shock to the change in the aggregate CAD ratio

Using our estimation results, we conducted a counterfactual exercise. Specifically, we calculated the hypothetical evolution of real GDP and lending in the presence of a shock to capital adequacy at the beginning of 2005. The alternative paths of real lending can be seen in Figure 14. An increase in capital requirements would have had a modest effect on lending:the difference between actual and counterfactualoutstanding loans would have been in the range of aroundHUF -900 billion (constrained model) and HUF 5 billion (unconstrained model) at the end of the period. While actuallending to the private sector doubled in real terms during this period,it would have increased by 86 percent in the constrained counterfactual scenario, i.e. increasing capital requirements would have had only a moderate impact on lending.

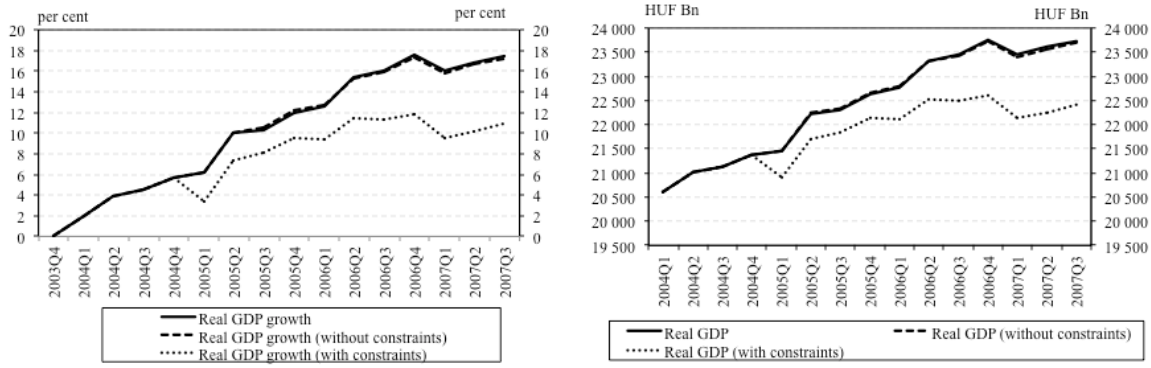


Source: Central Bank of Hungary, author's calculations

Figure 14: Growth and level of real lending in the alternative scenarios

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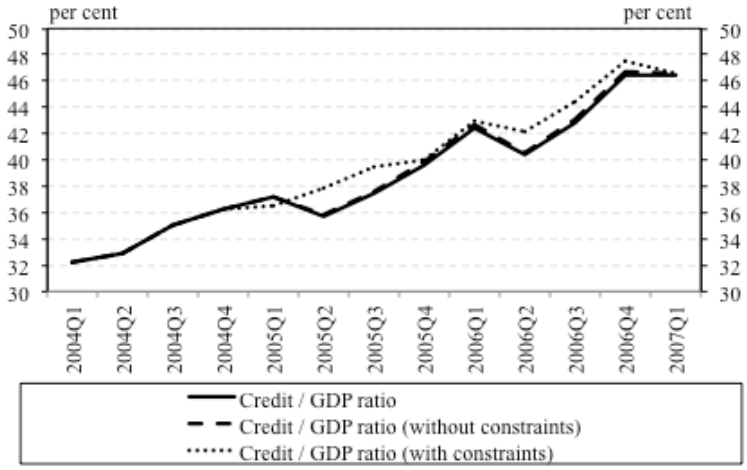
Given that real lending would not have changed notably, tightening the regulatory capital requirements would also have had a minor impact on real GDP growth. Specifically, the difference between the actual and counterfactual cumulative real GDP growth isin the range of+0.2 to -6.5 percentage points after 10 quarters(Figure 15).



Source: Central Bank of Hungary, author's calculations

Figure 15: Growth and level of real GDP in the alternative scenarios

The overall effect of an increased regulatory capital level could not have slowed the increase of the credit-to-GDP ratio. Although it could have held back lending growth, but it would have inferred an equal drop in real GDP growth (Figure 16). As a result, the difference in the ratio would have beenonly +0.1 percentage points after 10 quarters.



Note: Credit-to-GDP ratio is calculated by using level of real lending and real GDP.

Source: Central Bank of Hungary, author's calculations

Figure 16: Credit / GDP ratio

The total impact of our hypothetical regulatory tightening would have been modest in preventing the build-up of vulnerabilities in the banking sector. Even if regulatory authorities had reacted quickly, the use of countercyclical capital buffer would not have been able to significantly lower either the level of lending or its growth rate.

Although the overall impact of an increasing regulatory capital requirement is found to be modest, it is also interesting to see how this measure would have affected lending to different sectors. Since sectoral lending was not included in the VAR models due to identification difficulties (i.e. the number of variables in VAR would have been too large relative to the number of observations), we ran a "satellite model", in which we regressed the structural shocks of the capital adequacy ratioon changes in lending to different sectors:[6]

$$\textbf{sectoral lending growth}_t = \alpha * \textbf{sectoral lending growth}_{t-1} + \beta * \textbf{structural shock}_t + \varepsilon_t$$

where,

[6] See also *Noss and Toffano (2014)*.

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sectoral lending growth$_t$ includes lending to households and corporations in local and foreign currency.

The results of these regressions can be seen in Table 3. The second column shows that the regression coefficients on the structural shock are negative and significant at 10 percent level for each category except for household lending in HUF, i.e. an increase in capital requirement is associated with a reduction in growth in lending in the specific sectors. The lagged variables were used to simulate whether the impact of the shock fades over time. Although the signs are all positive in line with our prior expectations, they are not significant in the case of lending in HUF either in the household or in the corporate sector.

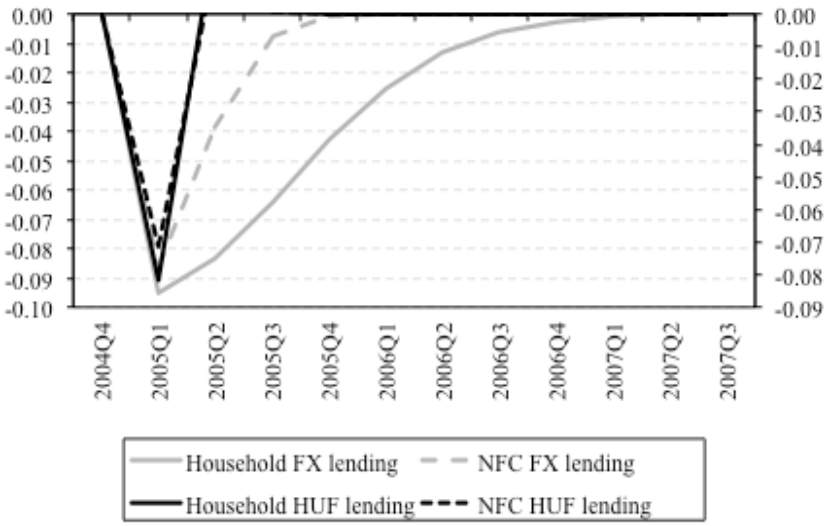
Table 3: Estimation results from the regression of sectoral lending growth on the series of structural shocks

	Lagged sectoral lending growth (α)	Contemporaneous structural shock (β)
Household FX lending	0 .8754***	-0.0951*
	(0.0000)	(0.0970)
NFC FX lending	0.4427**	-0.0778**
	(0.0260)	(0.0390)
Household HUF lending	-0.2893	-0.0817
	(0.1930)	(0.1500)
NFC HUF lending	-0.2182	-0.0715*
	(0.2720)	(0.0770)

*Note: *, ** and *** indicate significance at the 10, 5 and 1 percent level, respectively.*

Source: author's calculations

Using these estimation results, our calculations suggest that 53 percent of the total decrease in lending would have materialized in foreign currency lending (both in households and the corporate sector) and 47 percent in HUF lending (Figure 17). In the foreign currency segment, lending to households would have decreased roughly equally in lending to households and corporates. In contrast withthe intuitive assumption that adjustment is faster in the corporate segment, our results thus suggest that the banking sector would have reacted more intensely in the household segment.



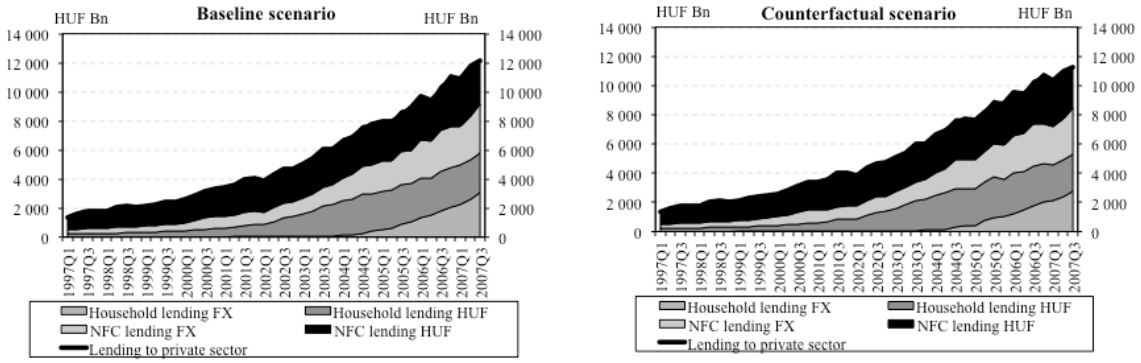
Source: author's calculations

Figure 17: Impulse responses of a 13 basis point shock to the change in the aggregate CAD ratio on growth of lending to different sectors

Based on the results of the SVAR model and the above regression, Figure 18demonstrates the alternative evolution of lending to the private sectorin the most pessimistic case, i.e. where the increase in the capital

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requirement was considered to be a credit supply shock. It shows that even if regulatory authorities hadreacted to the increasing (FX) lending by requiring a countercyclical capital buffer, they would have been able to only temporarily slow the build-up of FX loans. The outstanding amount of household loans denominated in HUF and FX would have been lower by around8 percent in both cases, while the reduction in corporate loans denominated in HUF and FX would have been 6 percent for both categories, at the end of the period.



Source: Central Bank of Hungary, author's calculations

Figure 18: Lending to private sector under different scenarios

VII. Conclusions

The main purpose of this paper was twofold. First, it aimed to estimatethe effect of the tightening of the regulatory capital requirements on the real economyduring credit upswing. Second, it intended to show whether applying a countercyclical capital buffer measure as per the Basel III rules could have helped decelerateFX lending growth in Hungary,reducing the build-up of vulnerabilities in the run-up to the GFC. To answer these questions, we used a VAR based approachto understand how shocks affected capital adequacy in the pre-crisis period. An increase in the regulatory capital requirement is typically considered to be a credit supply shock since it increasesbanks' funding costs. However, this relationship could have changed during the recent GFC.Specifically,stricter regulations could lower funding costs,by improving investor confidence.

Since the relationship between regulatory capital and lending growth is ambiguous, we estimated two VAR models. The unconstrained version aimed to provide the upper bound for the effect of macroprudential tightening on the real economy,as the shock need not be a supply shock. It allows, therefore, for the post-crisis assumption of the changed relationship between lending and capital. In contrast with this, in the SVAR model we introduced sign restrictions on lending and alternative funding growth (negative sign for the former and positive for the latter) in line with our assumption about their pre-crisis behavior. The results of this estimation serve as the lower bound for the possible effects on the real economy.The analysis concludes that an increase of 13 basis points in aggregate capital adequacy ratio, i.e. keeping the ratio at its 2005 Q1 level, is associated with a decline of 0-14 percentage points in cumulative real lending growth compared to actual growth after 10 quarters. Given that actual cumulative growth was 100 percent between 2004Q1 and 2007Q3, our estimation results thusindicate only a modest slowdownto 86 percent.Our results have three important implications.

First, regulatory authorities could not have avoided the upswing in FX lending by requiring countercyclical capital buffers even if such a tool had been available and they had reacted quickly to accelerating credit growth. By using this tool, they could have slowed the increase in lending only temporarily;however, after 4 quarters it would have regained its momentum.

Second, a more pronounced tightening might have eliminated FX lending, but at the expense of real GDP growth. Macroeconomic fundamentals were fragile when FX lending started,with the significant fiscal vulnerabilities requiring the central bank to keep the policy rate at elevated levels. Due to the highdifferential between HUF and FXinterest rates and households' low risk awareness regarding exchange-rate volatility, FX lending became very popular and contributed significantly to real GDP growth in the pre-crisis period. The bottom line is that an unsustainable fiscal policy led to a trade-off between economic growth and the build-up of new vulnerabilities in the form of FX lending.

Third, the results support the post-crisis conventional wisdom about the inadequacy of pre-crisis regulatory frameworks. Therefore, it points toward providing the authorities responsible for financial stability with more power and flexibility so that they can identify systemic risks and respond to them quickly and efficiently.

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