

To SVAR or to SVEC? On the transmission of capital buffer shocks to the real economy

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Abstract

Shocks to banks' capital buffer can impact the real economy via a number of channels. We investigate the transmission of aggregate capital buffer shocks to loans, prices and economic activity in Poland over the period 2002–2015 using multivariate time series techniques. Impulse-response functions from both SVAR and SVEC models indicate an increase in GDP and loan levels in the aftermath of a positive capital buffer shock. Although previous literature predominantly focuses on SVAR analyses, only the SVEC-based simulation yields economically reliable long-run estimates of the impact. Our long-run relationships indicate that capital policy may have a lasting impact on the real variables, unlike monetary policy.

Keywords: bank capital buffers, shocks to capital ratio, impulse-response, SVAR, SVEC

JEL: C32, E44, E51, G21, G32

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1 Introduction and research motivation

The viability of banking institutions and the stability of their operations are essential for financial intermediation and efficient allocation of resources in the economy. For this reason, shocks to banks' asset values, which may trigger a risk of bank default, are of critical interest to many stakeholders, including depositors and creditors, but above all to public authorities. The key safeguard against this risk is the bank capital, which absorbs unexpected losses, provides protection for uninsured depositors and reduces the probability of bank insolvency. In order to assure an adequate level of protection, the Basel accords enforce setting the value of a bank's capital (equity and junior liabilities) in proportion to the value of its risk-weighted assets. This proportion is called the capital ratio.

The interactions between bank capital ratios, credit supply and output have been analysed in both the theoretical and empirical literature surrounding the debate on the international capital standards. It has long been recognised that, apart from security benefits, the attempts of banks to hold a particular level of capital ratio may entail some important economic costs. This is particularly visible in the case of lending policy – perhaps one of the most important tools used for aligning actual capital ratios to the desired level. Restricting the supply of credit or outright sale of assets might in some situations help to target a given capital ratio via its denominator. The most important policy implication of this fact is that exogenous (from the bank decision-making perspective) shocks to bank capital may act procyclically. The underperformance of a single class of assets (e.g. loans to a particular type of company) may induce banks to reduce the availability of credit for other sectors of the economy, thus propagating shocks and increasing the variation of total output.

This study complements this line of research – we contribute to the existing literature by exploring the dynamic link between bank capital buffers and GDP using aggregated Polish banking sector data. Whereas some of the existing international literature investigates these dynamic links in a SVAR framework, we also consider a SVEC version as more reliable for mid- to long-term policy simulations.

The remainder of the study is structured as follows. Section 2 presents related strands of theoretical and empirical research on the interdependencies between changes in bank capital ratios, bank lending policy and economic activity. In Section 3, we develop two dynamic models – SVAR and SVECM – to analyse the consequences of shocks to capital ratio of the Polish banking sector on bank lending and GDP.¹ Section 4 concludes.

2 Related literature

2.1 Bank's motives for holding capital buffers

Bank capital has largely been ignored in traditional monetary economics (cf. Van den Heuvel 2002). Indeed, under the Modigliani-Miller theorem (Modigliani, Miller 1958), the amount of equity a bank holds is relevant for neither the size and structure (lending and investment) of that bank's activity nor for the value of the bank. Given the departures from assumptions of the Modigliani-Miller theorem induced by systems of deposit insurance and capital regulation (requiring banks to hold a certain minimum amount of capital), some authors argue that banks' optimal behaviour could be to hold

¹ The calculations for the purposes of this paper were conducted in Eviews 8, JMulTi and GNU R.

exactly the required minimum capital (see Schaefer 1987, p. 101; Mishkin 2004, p. 215). In practice, however, banks – in Poland as well as in other countries – tend to hold substantial buffers of capital over the regulatory requirements (see for example Memmel, Raupach 2007). Throughout the remainder of the paper, the term ‘capital buffer’ will refer to the excess of bank capital over the regulatory requirement set by the market supervisory authority in accordance with international capital standards (Basel II capital framework).

A review of factors shaping bank target capital ratios can be found in Berger et al. (2008) and Wall and Peterson (1996). Below, we focus on the set of hypotheses which have been put forward to explain the fact that banks might target certain levels of capital ratios in excess of the regulatory capital requirement. The majority of these hypotheses can be grouped under the title of market discipline. They postulate that there exist (bank-specific) capital ratios which maximise the market value of each bank (by influencing the weighted cost of capital and stream of expected future revenues). Apart from market discipline factors, a number of authors mentioned below have pointed to agency problems between banks’ managers and owners which may lead to holding an excess of capital over regulatory requirements.

One of the commonly cited arguments behind banks’ capital buffers is the need to secure options for future investment. Indeed, following the work of Myers (1984) and Myers and Majluf (1984), Berger, Herring and Szego (1995) noted that raising a bank’s equity in a short time (via stock issuance) might be overly expensive. Consequently, a bank holding just enough capital to cover the regulatory requirement may be forced to pass up some investment opportunities (including acquisition opportunities) as they occur over time. To avoid this, banks might be willing to hold capital cushions.

A somewhat similar argument – also resting on the observation that the cost of capital ratio adjustment in the short-term might be too high to be accepted by banks in some situations – can be found in Furfine (2000) and Rime (2001). As the adjustment costs (e.g. costs of issuing new equity) would deter the bank from instantaneous reaction to unfavourable changes in capital ratio, the bank may be willing to hold a certain capital buffer in order to reduce the risk of falling subject to regulatory scrutiny and costly sanctions in the event that the regulatory requirement is breached for reasons beyond the bank’s control (e.g. unexpected loan losses leading to negative shocks to equity).

Symmetrically to the argument pointing to deposit insurance systems as the reason for banks not to hold sufficient capital ratios, Flannery and Rangan (2004) argue that a weaker safety net of the banking sector results in elevated bank capital holdings. If the public explicit or implicit commitment to bail out failing banks weakens, the perceived exposure of the debt securities holders and depositors to bank default risk is augmented. As a result, the required compensation to banks’ liabilities increases. Banks’ managers can counter this by decreasing the probability of default via reducing leverage (increasing capital ratio). It follows that small banks, which do not benefit from an implicit public guarantee for too-big-to-fail institutions, may need to hold higher capital ratios than larger banks with an equivalent portfolio risk profile (see Lindquist 2004). Findings of the Global Financial Stability Report published in April 2014 (IMF 2014) show that the too-big-to-fail institutions have kept benefitting from a substantial implicit public subsidy at least through 2013, providing evidence that the discussed argument holds despite the experiences of the post-Lehman crisis.

Also, increased requirements regarding information disclosure may encourage banks to hold higher capital ratios (Nier, Baumann 2006). Banks which are subject to more stringent information disclosure rules are more transparent about the portfolio risk from the depositors’ perspective. This in

turn strengthens incentives for depositors to require a higher capital ratio for a given level of portfolio risk (in order to protect against default risk). Additionally, a higher share of uninsured deposits in a bank's funding structure (larger exposure of depositors to bank default risk) increases market discipline and pushes the bank to hold a higher capital ratio.

Some authors (see Alfon, Argimon, Bascuñana-Ambrós 2004) also postulate that banks may decide to hold excess capital ratios in order to be assigned a certain credit rating, thus explicitly targeting a more favourable cost of issuing debt. A similar mechanism will be at work in the case of banks seeking to access certain segments of financial markets (e.g. OTC markets).

Demsetz, Saidenberg and Strahan (1996) and Hellmann, Murdock and Stiglitz (2000) show that the bank owners may have incentives to reduce the bank's default risk (by increasing capital ratio) if the institution benefits from high franchise value, i.e. value of expected future profits, for example due to profitable lending opportunities. Under this optic, banks which possess high franchise values will be willing to hold high capital ratios, possibly in excess of regulatory requirements. The creation of bank franchise value through lending relations and optimal capital decisions of banks have been analysed by Diamond and Rajan (2000).

Finally, the bank's target of capital holdings may be high due to agency problems between the bank's managers and owners. This is because the managers may be acting to protect the rents they are able to extract while working at the bank (firm-specific human capital) against the event of bankruptcy (Hughes, Mester 1997; Saunders, Strock, Travlos 1990). For this reason, the managers may be willing to substitute leverage risk for portfolio risk – increasing the capital ratio when portfolio risk increases. Similar reasoning and conclusions with regard to the portfolio risk and capital structure may be found in other studies belonging to the line of research analysing banks' capital decisions in the mean-variance portfolio optimisation framework (see e.g. Kim, Santomero 1988).

It is worth highlighting that some of the factors listed above tie the target amount of capital held by banks directly to the regulatory capital requirement (explicitly in the form of a capital cushion that banks add to the regulatory requirement – the capital buffer). If these factors were the only factors at play, then banks – targeting a specific buffer over the regulatory minimum – would react both to exogenous changes in the actual capital ratio and to changes in the level of capital requirement (both of which modify the actual buffer against the target capital buffer).

On the other hand, some of the enumerated hypotheses suggest that target capital ratios are shaped independently of the capital requirements. If this was the case, observable changes in capital buffers would have an impact on bank policies only insofar as they were driven by changes in actual capital ratios. The changes in the regulatory capital requirement (if not binding) would not influence bank behaviour.

In the subsequent sections, we do not verify which of the factors play a deciding role in shaping banks' target capital ratios. Numerous studies, however, including Ediz, Michael and Perraudin (1998) and Alfon, Argimon and Bascuñana-Ambrós (2005), have demonstrated that banks react to hikes in capital requirements by rebuilding their capital ratios over the requirement. Some studies (e.g. Bridges et al. 2014) found that banks' reactions to changes in capital requirements are complete, i.e. banks strive to keep stable capital buffers over the regulatory requirement, although the adjustments to changes in the requirements take considerable time. These findings lend support for the hypothesis that banks' behaviour must be at least partially driven by the first set of factors, which link the target capital ratio to regulatory capital requirement.

2.2 The impact of changes in capital buffers on banks' behaviour

The regulatory capital requirement is a one-sided constraint (the bank capital ratio cannot be too high from the regulatory perspective). In contrast, the 'inadequacy' of the actual capital ratio in relation to internal and/or market-based capital targets is two-sided. In other words, deviating both to the upside and to the downside from the target capital ratio causes the bank to incur a loss or to forego a potential gain. Wall and Peterson (1996) note that banks' managers and owners will take appropriate actions in order to align actual capital ratios to the target as long as the static² costs of deviation from the target ratio surpass the costs of adjustment. In the event that the capital ratio deviates from the bank internal target, the institution can take several measures (Cohen 2013):

- increase capital by issuing new equity or retaining earnings (reducing dividend payments);
- reduce the rate of asset volume growth (possibly liquidate assets and redeem liabilities);
- change the asset structure towards lower average risk weights.

The literature analysing the effects of shocks to capital buffers on the bank behaviour in these dimensions is rich. Below we summarise the conclusions from studies focused on the credit supply reaction to these shocks. We are aware that the differences in methodologies used (not least the outcome variable) in the literature reviewed below, as well as differences in time periods and countries under investigation, make a direct comparison of the numerical results very difficult (cf. the work by Dagher et al. (2016) including a review of recent empirical results provides evidence on how diverse the approaches to the topic may be). However, we are rather interested in the acceptance or rejection of the general hypothesis that shocks to capital buffers entail banks' behavioural reactions.

Studies of the effects of shocks to bank capital on lending can be traced back at least to Bernanke (1983), Bernanke and Lown (1991) and Peek and Rosengren (1992), who argued that reductions in banks' equity due to large loan losses might force these banks to reduce lending.

Among more recent literature, a large group of studies analysing the effects of changes in capital buffers due to changes in capital requirements can be distinguished. Analysing bank-level data and using the dynamic panel model approach, Bridges et al. (2014) concluded that banks faced with a 1 percentage point increase in regulatory requirement reduced lending to different classes of borrowers by up to 8 percentage points over the first year after the negative shock to the capital buffer. A large impact of hikes in capital requirements on bank lending has also been found by Fraisse, Le and Thesmar (2015). Using a rich dataset including data on particular banks' lending to individual clients, the authors estimated that a 1 percentage point increase in the regulatory capital requirement may lead banks to reduce credit growth by 8 percentage points. Aiyar et al. (2012) estimated that a 1 percentage point increase in capital requirements reduced bank lending by 6.5–7.2 percentage points. A somewhat smaller impact of increases in the capital requirement on bank lending was found by Mésonnier and Monks (2015). The authors concluded that a 1 percentage point hike in the core capital requirement was associated with a reduction in annualized loan growth by 1.2 percentage point over three quarters following the hike. Other studies in this line of research also pointed to the negative results of increases in capital requirements for credit supply (Noss, Toffano 2014; Aiyar et al. 2014; Aiyar,

² These costs are 'static' in the sense that they arise from the current size of deviation from the target capital ratio and are borne by the bank as long as the deviation persists. They are different from the 'dynamic' costs of adjusting the actual capital ratio to the target. The bank will consider both the static and dynamic costs in deciding whether to adjust the capital ratio to the target. A model based explicitly on the trade-offs between these two types of costs has been developed by Estrella (2004).

Calomiris, Wieladek 2014). In a recent study, Maurin and Toivanen (2015) confirmed that banks use internal target capital ratios and that adjustments to higher optimum capital ratios affect the level of assets held by banks. In particular, while reducing the leverage towards the internally set equilibrium level, banks diminish security holdings and loan portfolios, although the effects for securities are larger than for loans.

Eber and Miniou (2016) analyse banks' reactions to the announcement of stricter capital requirements imposed by the single supervisory mechanism. The authors concluded that faced with the prospect of ECB comprehensive assessment, banks substantially reduced their leverage, which was mostly achieved by reducing assets.

Some authors have focused on the role of banks' capital (in the context of capital requirement regulation) as a means of shock propagation in the economy. For example, Gambacorta and Mistruli (2004) demonstrated that after a shock to banks' earnings and capital due to unexpected monetary policy tightening, better capitalised banks can better preserve their lending than banks holding less capital relative to the regulatory requirement.

Cosimano and Hakura (2011), who used the two-step GMM panel modelling approach on bank-level data, showed that the increase in lending rates (needed to cover the higher weighted average cost of capital related to the transition to Basel III capital requirements) could reduce bank lending in the long term.

Hancock, Laing and Wilcox (1995), in turn, developed a dynamic model of banks' reactions to exogenous changes in capital ratios. The authors concluded that adjustments in loan portfolios after shocks to capital holdings took banks up to three years, substantially longer than adjustments to securities holdings.

In a recent study of propagation of bank capital shocks to the economy using a mixed-cross-section global vector autoregressive (MCS-GVAR) model for 28 EU countries, Gross, Kok and Zochowski (2016) include both balance sheet data at the individual bank level and banking sector aggregates for the EU countries. The authors distinguish between different types of bank deleveraging (contractionary and expansionary) and find that their impacts on real activity differ.

Some authors, however, have found little or no impact of changes in capital ratios on banks' lending decisions. For example, Berrospide and Edge (2010) analysed a detailed bank-level dataset to capture the effects of changes in bank capital on loan activity and concluded that these effects are small. Nevertheless, these authors pointed out that loan growth in banks with larger capital buffers (against an estimated unobservable target) was faster than in other banks. Similarly, Francis and Osborne (2009) found that the effects of changes in capital ratios on lending, although negative, are modest. Kok and Schepens (2013), in turn, found that banks prefer to increase equity or change the risk composition of their portfolios instead of reducing lending, upon falling below their target Tier 1 capital ratios.

The literature on the reaction of Polish banks to changes in capital ratios is scarce, and in fact the existing studies focus on the long-term effects of introducing tougher capital standards from the perspective of macroprudential policy. Two analyses may be mentioned. In a structural multi-equation modelling framework, Wdowiński (2011) demonstrates that an increase in regulatory capital requirement by 2.5 percentage points could reduce bank lending by up to 2.95 percentage points in the long term (and up to 7 percentage points for certain groups of clients) and have a marginally negative impact on long-term GDP growth. Marcinkowska et al. (2014) used a panel data model and a macroeconomic model to analyse Polish banking sector data and found similar results – increases

in regulatory capital requirements could lead banks to increase interest rates on loans and induce a fall in demand for credit. The study agreed with the conclusions of the analysis by Wdowiński (2011) that the adjustment by Polish banks to higher capital standards could lead to a negligible reduction in economic growth. Although insightful, the conclusions of analyses by Wdowiński (2011) and Marcinkowska et al. (2014) are not directly relevant to our case, as they focus on the effects of an expected transition to a more stringent capital requirement regime instead of unexpected shocks to bank capital buffers.

Following the existing literature, we focus our empirical analysis on the changes in bank capital buffers (excess capital ratio over the regulatory minimum) as the most relevant measure of capital that shapes bank policy. In the next section, we look at the interplay between the buffers and economic activity in Poland, whereby our main point of interest is the links between shocks to bank capital and two time series: lending policy proxy (credit supply) and GDP growth. Given that we are interested in both the short-term and long-term consequences of variation in bank capital for lending and economic activity, we model the interactions between aggregate capital buffers, credit growth and GDP in a dynamic modelling framework using Polish banking sector and macroeconomic quarterly data.

To see the postulated relationships between our main variables of interest, i.e. GDP, credit and the capital requirement (the excess over which constitutes the capital buffer), see Figure 1. The horizontal axis represents the level of capital requirement, while the vertical axis represents the credit supply. Given a certain level of bank equity, banks' credit supply negatively depends on the requirements with the equilibrium point located at the leverage-maximizing intersection of the vertical line (representing the current level of capital requirement) with the downward-sloping curve (point A).

Consider a specific type of capital buffer shock related to an unexpected increase in the regulatory capital requirement (the vertical line moves to the right). In order to comply with the regulation (or to re-optimize the capital buffer), banks could shrink their credit supply if equity was to remain unchanged (moving along the curve from point A to B1). While this could be seen as likely short-run behaviour, there is in principle another possibility that equity is increased (or grows organically, as a result of growing GDP), which could motivate moving from A to B2 (rather than B1). Hence, our empirical analysis is aimed at determining what combination of B1 and B2 prevails empirically, and in what time horizon (short- versus long-run). Note that a number of factors can affect the level of equity, not least the level of GDP.

3 The impact of shocks to banks' capital buffers on the Polish economy

We analyse the impact of capital shocks on the Polish economy using two distinct empirical strategies with a similar theoretical background. The first (benchmark) approach that we adopt is a SVAR model based on the specifications proposed by Lown and Morgan (2006) and Berrospide and Edge (2010), which combine standard new Keynesian VAR models (explaining output, inflation and interest rates and sometimes commodity prices) with simplified representations of the banking sector. It allows us to capture the short-term dynamic relationships within a set of variables – in particular following unexpected changes in banks' capital buffer. We use impulse response functions (in quarterly year over year, or y/y terms) from the SVAR model to simulate the paths of key variables after the shock (making some tentative conclusions in terms of levels). The second approach that we adopt is a SVEC model which enables us to address some caveats at SVAR analysis, such as the missing long-term relationships

(and hence the inability to produce more reliable mid- to long-term simulations). We conclude this section with a short discussion of the differences between the results of these two approaches.

3.1 The SVAR model

Our benchmark VAR model has the following reduced form representation:

$$\mathbf{A}(L)\mathbf{y}_t = \mathbf{A}_0\mathbf{d}_t + \boldsymbol{\varepsilon}_t \quad (1)$$

where:

- \mathbf{y}_t – vector of endogenous variables describing the economy of Poland,
- $\mathbf{A}(L)$ – lag polynomial,
- \mathbf{d}_t – vector of deterministic regressors including the intercepts,
- $\boldsymbol{\varepsilon}_t$ – vector of reduced form shocks.

Throughout the (S)VAR analysis (Subsection 3.1), the vector \mathbf{y}_t consists of the following endogenous variables (see Table 10 for specific data sources):

$$\mathbf{y}_t = \begin{bmatrix} \Delta_4 l_GDP_t \\ \Delta_4 l_CPI_t \\ WIBOR_t \\ \Delta_4 l_Loans_t \\ \Delta_4 l_NEER_t \\ Capital_buffer_t \end{bmatrix} \quad (2)$$

where:

- $\Delta_4 l_GDP_t$ – real y/y output growth (ordinary, not logarithmic),
- $\Delta_4 l_CPI_t$ – y/y rate of change in consumer prices,
- $WIBOR_t$ – value of the 3-month Warsaw Interbank Offered Rate,
- $\Delta_4 l_Loans_t$ – y/y rate of change in loan portfolio value (adjusted for the changes in the exchange rates) in the Polish banking sector,
- $\Delta_4 l_NEER_t$ – y/y rate of change of nominal effective exchange rate (weighted average against 42 main trading partners of Poland),
- $Capital_buffer_t$ – surplus of capital over the minimum capital adequacy ratio required by the Polish Financial Supervision Authority (Komisja Nadzoru Finansowego, KNF).

We refer to the difference between actual and required capital ratio as capital buffer, a word that might suggest positive values, since bank capital shortages at the aggregate level are in fact extremely rare. In the contexts other than the annual rates of change, the prefix $l_$ indicates the use of the logarithm.

The core of the economy described by our VAR model consists of three variables, namely $\Delta_4 l_GDP_t$, $\Delta_4 l_CPI_t$ and $WIBOR_t$ that together form a system close to the new Keynesian trinity framework. In addition, the $Capital_buffer_t$ and $\Delta_4 l_Loans_t$ are used to include the banking sector in the model

(following the approach of Lown, Morgan 2006 and Berrospide, Edge 2010), whereas the exchange rate ($\Delta_4 l_{NEER_t}$) is used to take into account the external factors affecting the economy (following the reasoning of Smets 1997). We discuss the economic justification for the inclusion of particular variables in our model later on as we describe our identification strategy.

The results of the ADF unit root tests for the respective variables (in levels/logs, first differences and seasonal differences as appropriate) are outlined in Table 1. Only in the case of 2 out of 6 variables used in the SVAR model, we reject the null of non-stationarity under 0.05 significance level ($\Delta_4 l_{GDP_t}$ and $\Delta_4 l_{NEER_t}$), which is related both to partial inclusion of the disinflation period and, possibly, the problem of short sample. We proceed, however, with the estimation of the SVAR model with non-stationary variables, taking into account that otherwise we could (i) overdifference the loan variable ($\Delta_4 l_{Loans_t}$) as the p-value remains relatively close to the 0.05 significance level, (ii) risk a doubtful application of additionally differenced $\Delta_4 l_{CPI_t}$ after the end of the disinflation period, as well as (iii) lack viable economic interpretation of first-differenced $WIBOR_t$ and $Capital_buffer_t$ variables. In particular, while one could consider differencing the capital buffer variable, it would no longer be related to the minimum levels of capital adequacy (or deviations thereof) required by KNF which is crucial from the point of view of our study. For that reason, we use the level of $Capital_buffer_t$ in the SVAR model, while most of the remaining variables (except $WIBOR_t$) are expressed as annual rates of change. Although we regard the above decisions as the optimum choices in the SVAR model, we address the possible controversy related to these choices by using the SVEC model later on.

We estimated the VAR model using quarterly data from the 2002 Q2 to 2015 Q3. The sample might seem shorter than feasible, but we chose this data range as a relatively homogenous period excluding the impact of disinflation in Poland (before 2002) on the data. Going back well beyond 2002 would result in taking into account a different monetary policy regime. Before 2002, monetary policy in Poland was focused on reducing inflation and stabilising it at a low level while the inflation target was set annually in the Monetary Policy Guidelines (published by Narodowy Bank Polski) in the form of an interval for the desired inflation rate. In 2002, the inflation target in Poland took a specific value equal to 5%, in 2003 it was lowered to 3% and since 2004 it remains at the level of 2.5%.

Using standard tests for autocorrelation and information criteria, and bearing in mind the sample length considerations, we determine that the optimal lag length of the model equals 2. This is a compromise between the parsimonious indication of Schwartz (see Table 2) and eradication of autocorrelation of the errors (see Table 3).

Based on the indications of the Jarque-Bera and Lütkepohl test, we supplement the VAR model with binary exogenous variables for 2008 Q4–2009 Q1 and 2012 Q1 (that take into account the beginning of the financial crisis related to the Lehman Brothers bankruptcy and the period after several NBP interventions in the foreign exchange market). Thereby we determine the vector of deterministic regressors as $\mathbf{d}_t = [1 \quad d_{08q4_09q1} \quad d_{12q1}]$. Under such a specification, the residuals are normally distributed (see Table 4), which in turn indicates that the conditions for the correct statistical inference are fulfilled.

Furthermore, as demonstrated in Figure 1, all inverse roots of the characteristic polynomial are located within the unit root circle, which implies that all the impulse response functions converge to the steady state.

Following the approach of Lown and Morgan (2006) and Berrospide and Edge (2010), we propose the recursive identification strategy (Cholesky decomposition). Following equation (1), the residuals from the reduced form estimation are denoted as $\boldsymbol{\epsilon}_t$, and they can be transformed into structural shocks \mathbf{u}_t by the following general structural equation:

$$\mathbf{A}\boldsymbol{\varepsilon}_t = \mathbf{B}\mathbf{u}_t \quad (3)$$

We assume that \mathbf{A} is an identity matrix and \mathbf{B} is a lower triangular matrix of the following form:

$$\begin{pmatrix} \varepsilon_t^{GDP} \\ \varepsilon_t^{CPI} \\ \varepsilon_t^{WIBOR} \\ \varepsilon_t^{Loans} \\ \varepsilon_t^{NEER} \\ \varepsilon_t^{Capital_buffer} \end{pmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ b_{21} & 1 & 0 & 0 & 0 & 0 \\ b_{31} & b_{32} & 1 & 0 & 0 & 0 \\ b_{41} & b_{42} & b_{43} & 1 & 0 & 0 \\ b_{51} & b_{52} & b_{53} & b_{54} & 1 & 0 \\ b_{61} & b_{62} & b_{63} & b_{64} & b_{65} & 1 \end{bmatrix} \begin{pmatrix} u_t^{GDP} \\ u_t^{CPI} \\ u_t^{WIBOR} \\ u_t^{Loans} \\ u_t^{NEER} \\ u_t^{Capital_buffer} \end{pmatrix} \quad (4)$$

By ordering GDP and CPI shocks in front, we assume no instantaneous reaction of the real sector (output) and prices in the whole economy to shocks in the monetary sector ($WIBOR$, Δ_4Loans , Δ_4NEER and $Capital_buffer$ shocks). The third equation in (4) can be viewed as the mechanism of monetary policy response to contemporary shocks in the real output and prices, following the standard Taylor rule (as the $WIBOR$ rate is to the largest extent related to the NBP reference rate).

Likewise, loans respond contemporaneously to the innovations in the real economy (GDP) and to the changes in the financial sector that affect the overall debt burden and cost of debt, both through the inflation rate (affecting the real value of debt burden) and $WIBOR$ (affecting the interest payments). In line with the reasoning of Smets (1997), we decided to include the nominal effective exchange rate as it plays an important role in Poland (as an open economy with a flexible exchange rate regime). The exchange rate included in our model is allowed to respond instantly to the changes in the real economy and in the financial markets. Finally, the capital in excess of the minimum capital adequacy ratio required by the KNF reacts immediately to all the changes in the remaining variables. This is because the innovations in all the remaining variables might affect the capital adequacy ratio both through the numerator (for instance, through bank quarterly profit) and denominator (e.g. risk weighted assets might be affected by changes in the exchange rate as the value of assets denominated in foreign currencies, e.g. CHF denominated mortgage loans, expressed in PLN, will adjust accordingly).

Treating the SVAR model as a semi-structural model (in the sense of Kilian 2013), we focus on the interpretation and consequences of the crucial innovation $u_t^{Capital_buffer}$ – the capital adequacy shock. It might be related to changes in (i) regulations affecting risk weights applied to particular classes of assets, (ii) valuations of particular assets, (iii) equity as well as (iv) the KNF requirements with respect to the minimum capital adequacy ratio.

Our model demonstrates satisfying properties in reflecting the monetary transmission mechanism (see Figure 5 for the average impact of one standard deviation structural shock on a given variable together with a confidence band of two standard errors). We can observe that an increase in the $WIBOR$ rate has a negative effect on the GDP dynamics, but only in the short-run. Furthermore, a higher $WIBOR$ leads to a decline in the inflation rate and appreciation of the Polish zloty – a result in line with, among others, Cushman and Zha (1997).

Moreover, an increase in the inflation rate leads to the monetary policy response via a higher WIBOR rate, which in turn leads to some appreciation of the currency and a temporary decrease in GDP dynamics. Further, a shock causing the currency to appreciate leads to a decrease in CPI inflation (see for example Bussière, Chiaie, Peltonen 2014). As a result, the WIBOR rate decreases, which in turn leads to an increase in the value of the loan portfolio.

A positive capital shock leads to an acceleration of bank lending and hence to higher GDP growth accompanied with a peak in the inflation rate (all statistically significant). On the other hand, a shock leading to an increase only in the loan portfolio value itself has little (and statistically insignificant) effect on GDP, as it is associated with a decrease in the level of the capital ratio available to back credit expansion.

It is worth noting, however, that the IRF show significant inertia in the reactions of the capital buffer (see the “Response of *Capital_buffer* to *Capital_buffer*” subpanel of Figure 5). However, such a result has an appropriate economic interpretation as it usually requires time for banks to rebuild their capital after assuming losses or to adjust to the new capital requirements set by the financial supervisor.

The statistical significance of the impact of the capital adequacy shock on Δ_4GDP and Δ_4Loans provides us with justification to carry out the simulation analysis of the impact of capital adequacy shock on the levels of *GDP* and *Loans*, respectively, as summarised in the following subsection.

A possible shortcoming of the SVAR approach is that it treats the level of the optimal capital buffer as time-invariant and independent from innovations in the actual capital buffer. In fact, however, unexpected exogenous shocks to bank capital may impact the level of the capital buffer that banks consider optimal. For example, the materialization of an uncertain negative event, against which a bank holds a capital cushion, might reduce both the observed capital buffer and the unobserved optimal capital buffer. After the shock, the bank may decide that an additional capital buffer is no longer needed. In that case, the shock – although changing the level of the observable capital buffer – may be neutral from the bank lending policy perspective. This problem with dynamic modelling of interactions between bank capital and loan growth has been recognized by Berrospide and Edge (2010). The authors use two different methods to manage this problem: (1) explicitly estimate the target capital ratios in a partial adjustment modelling framework, following the Hancock, Laing and Wilcox (1995) approach, and (2) HP-filter the actual bank capital ratios to obtain a dynamic estimate of the target ratio. We take a different approach as we turn to the SVEC framework to deal with this possible identification problem.

3.2 The SVEC model

While present in the literature, the SVAR approach has drawbacks that have motivated us to switch to SVEC analysis.

Firstly, a SVEC model allows to account for the aforementioned possible time variability of the optimal level of capital buffer. Indeed, as evidenced below, the capital buffer is cointegrated with other variables and aligns accordingly.

Secondly, the variables we use are mostly I(1) and seasonal (annual) differencing eradicates the long-term relationships that may be of interest. For example, under a low credit-to-GDP ratio, the loan dynamics might be persistently supported by a low base effect, even under limited y/y GDP growth.

Finally, our ultimate research goal is to determine the impact of the capital adequacy ratio on the level of GDP, in the form of a point and interval forecast. The use of the VEC model provides a natural framework for the assessment of the impulse-response function in levels, including the assessment of statistical uncertainty. While the y/y SVAR model discussed above also allows for an assessment of the impact of capital shocks on levels of particular variables after some additional transformation of the respective IRFs (discussed later on), the calculation of confidence intervals for the result of such a transformation is not straightforward and is not the subject of this paper.

The VEC models includes the following variables in levels (see, again, Table 10 for specific data sources):

- GDP, real, seasonally adjusted, as logs (l_GDP),
- adjusted loans (defined as in Section 2), real (CPI-deflated), as logs (l_Loans),
- capital buffer (defined as in Section 2), in percentage points/100 ($Capital_buffer$),
- nominal effective exchange rate, as logs (l_NEER),
- WIBOR 3M, in percentage points/100 ($WIBOR$).

We define the vector y_t as follows:

$$y_t = \begin{bmatrix} l_GDP_t \\ l_Loans_t \\ Capital_buffer_t \\ l_NEER_t \\ WIBOR_t \end{bmatrix} \quad (5)$$

Following the notation by Juselius (2006), we estimate the VEC model as:

$$\Delta y_t = \alpha^T \beta y_{t-1} + \sum_{i=1}^{n-1} \Gamma_i \Delta y_{t-i} + \Gamma_0 d_t + \varepsilon_t \quad (6)$$

Noticeably, the above model is not a simple isomorphic transformation of the SVAR model from Subsection 3.1. Firstly, integration from differences to levels would lead to the inclusion of price level in the variable space (and hence cointegrating relation(s) with the rest of the variables). The missing economic rationale for such a specification, confirmed by the unintuitive performance of the SVEC model with 6 variables, led us to skip the CPI variable. At the same time, omission of the CPI variable allows us to use a longer sample period than in the case of the SVAR model, while controlling for the negative trend in WIBOR (related to disinflation) with a linear trend variable.

Secondly, the isomorphic relation between SVAR and SVEC is broken by the fact that SVAR operates on seasonal differences (y/y transformation of l_GDP , l_Loans and l_NEER) that render the data less noisy than regular, quarterly differences. As a result, a seasonally adjusted version of l_GDP series was chosen as an alternative to ensure compliance with the standard VEC specification (6). Thirdly, given the abovementioned changes in model structure, the lag length was determined separately for both models so as to take into account the removal of residual autocorrelation and different sample size context.

The number of lags was set on the basis of standard diagnostics criteria for a separate VAR model corresponding (in terms of the variables included in the system) to the SVEC model (see Tables 5 and 6).

The information criteria indicate from 1 (Schwarz) to even 8 lags (Akaike). Yet the minimum forecast prediction error can be achieved with 6 lags, the likelihood ratio test indicates 5 lags, and for lags 4 and higher, the null hypothesis of no serial correlation in multivariate LM test is not rejected. Therefore we decided to include $n = 5$ lags in the preliminary VAR model and we opted for the corresponding lag length of $n - 1 = 4$ in the VEC model. Under VEC specification, the joint lag exclusion test definitely rejects the null of exclusion restriction on the fourth lag.

Note that for the purposes of the VEC model, we choose a higher maximum lag order than in the case for the VAR model described in previous subsections (4 against 2). There are at least two reasons for this discrepancy. Firstly, the VAR model is specified in terms of y/y rates of change, so it already includes the information for the 4 preceding quarters. Secondly, the VEC model includes one equation short of SVAR described in previous subsections, meaning that adding each lag consumes less degrees of freedom.

Based on the indications of the Jarque-Bera test, we supplement the VEC model with binary exogenous variables for 2012 Q1, as well as 2008 Q4–2009 Q1. Thereby we determine the vector of deterministic regressors as $\mathbf{d}_t = [1 \quad d_{12q1} \quad d_{08q4_09q1}]$. The constant also appears in the cointegrating relation, additionally supplemented by a trend (due to the linear downward trend in WIBOR). Under such specifications, the residuals are normally distributed (see Table 7).

Both the trace test and the maximum eigenvalue test indicate that the rank of the cointegrating space is equal to 2, at the significance level of 0.05 (see Table 8).

Nine additional restrictions are imposed on matrices α and β , which makes these matrices over-identified:

1. Normalisation of the first cointegrating relation (CR) to l_GDP and the second CR to $WIBOR$. As a result, the first equation can be viewed as determining the output trajectory in the long run, while the latter – as a monetary policy rule.

2. Restriction on $WIBOR$ parameter in the first CR equal to 0 (l_GDP should not depend on its level in the long run). This is in line with the common assumption that monetary variables (such as nominal GDP) should not affect real, low-frequency trends.

3. Restrictions on l_GDP and $Capital_buffer$ parameters in the second CR equal to 0 ($WIBOR$ should not depend on them in the long run, i.e. monetary policy is neutral to long-term real growth and independent from capital buffer policy).

4. Restrictions on correction coefficients to both CR in the l_NEER equation equal to 0 (weak exogeneity of l_NEER – the nominal exchange rate does not adjust to misalignments from any cointegrating equation, i.e., it is determined outside the model or by short-run developments).

5. Additional restrictions on the correction coefficients of $WIBOR$ and l_Loans to first CR (based on exogeneity testing; this relationship is not related to monetary policy represented by $WIBOR$) and of l_Loans and l_GDP to the second one equal to 0 (these correction terms are insignificant in an unconstrained model).

The likelihood ratio test does not reject the following identifying structure at the significance level 0.05, with p-value equal to 0.0885 (see Table 9).

The first CR can be interpreted as capturing the long-run equilibrium of all the variables against GDP. The autonomous, trend-related growth amounts to 0.6% per quarter. l_GDP is also increased in the long term by 0.21% in response to 1% growth of loans, by 1.24% in response to a 1-percentage point increase in the capital buffer and by 0.31% in response to NEER depreciation by 1%. Note that,

under re-normalisation, this equation could also be interpreted as the equilibrium capital buffer, given the levels of other variables; inspection of the adjustment matrix confirms this finding. One may also see it as the inverted form of the relationship illustrated in Figure 1.

The second CR can be regarded as a policy rule, guiding the *WIBOR* rate setting. There is an autonomous decrease of *WIBOR* at the pace of 0.6 percentage point per quarter, as the sample period covers a significant part of the disinflation process. On top of that, *WIBOR* is increased by 0.20 percentage point when loans grow by 1% and increased by 0.58 percentage point when *NEER* depreciates by 1%.

All the unrestricted correction coefficients take correct signs (i.e. opposite to the sign of the explained variable in a given short-run equation, taken by this variable in the respective CR), whereby the strongest correction takes place for the level of GDP with respect to the first CR.

The question of how the decrease (or increase) of capital buffer affects other variables is addressed in a similar fashion as with the SVAR model, i.e. via impulse-response analysis with Cholesky structuralisation and the same ordering of variables as in Subsection 3.1 (with the only exception being CPI inflation, which is omitted in the VEC analysis). As suggested by Figure 3, a non-explosive behaviour of the responses is expected. We use Hall's (1992) 95% confidence intervals for statistical inference (generated with 1000 bootstrap iterations – see Figure 6 for all the related impulse-response functions).

A shock to the capital buffer should be interpreted, like in the SVAR analysis in Subsection 4.1, as a change in (i) regulations affecting risk weights applied to particular classes of assets, (ii) valuations of particular assets, (iii) banking sector equity or (iv) the KNF requirements with respect to the minimum capital adequacy ratio. Either way, expansion of the capital buffer is supportive of both the volume of loans (after some time) and of GDP (immediately). Both GDP and loans grow significantly in the long term following a positive shock to the bank capital ratio. Inversely, a widespread, significant, systemic factor leading to banks' losses would in turn lead to a decrease in GDP and contraction in credit. Looser credit policy also leads to a lower level of the *WIBOR* rate in the long run, and some *NEER* appreciation.

It is noteworthy that the findings from the SVEC analysis confirm the long-term impact of the regulatory policy as regards the capital-to-assets ratio on GDP and loans, but do not confirm any respective long-term impact of the *WIBOR* rate shocks. This is in line with the long-term neutrality of monetary policy and implies that macroprudential policy might exert a long-term impact, as opposed to complementary monetary policy tools, responsible for the fine-tuning on the demand side of the economy.

3.3 Simulated impact of capital buffer shock on GDP: SVAR and SVEC versions

The SVAR model is predominantly based on *y/y* growth rates of I(1) time series. In order to find out how an impulse in the capital buffer translates into changes in the overall loan value or GDP level, one needs to carry out some additional transformations of particular IRFs describing the impact of capital shocks on $\Delta_4 l_{GDP}$ and $\Delta_4 l_{Loans}$. The purpose of this subsection is to present our approach to these transformations.

A VAR model with stationary variables can be solved in terms of VMA(∞):

$$y_t = \bar{y} + \sum_{k=0}^{\infty} \Phi_k \varepsilon_{t-k} \quad (7)$$

in which \bar{y} is the vector of the steady states of all variables in the system and Φ_k is the matrix of coefficients of the VMA.

Given the recursive identification strategy as discussed in the previous subsection ($\varepsilon_t = Bu_t$), we can transform the equation (4) and (7) to become a function of structural shocks in the following way:

$$y_t - \bar{y} = \sum_{k=0}^{\infty} \Phi_k Bu_{t-k} = \sum_{k=0}^{\infty} \Psi_k u_{t-k} \quad (8)$$

We can think of IRF as a function describing the deviation of variable i from its steady state levels in response to shocks to variable j in k -th period after the shock occurred:

$$\{\Psi_k\}_{i,j} = \frac{\partial y_{it+k}}{\partial u_{jt}} = \frac{\partial (y_{it+k} - \bar{y}_i)}{\partial u_{jt}} \quad (9)$$

In order to compute the actual dynamics of a given variable under different policy scenarios, we need to make additional assumptions with respect to \bar{y} . For the purpose of simulation analysis, we use the sample averages of $\Delta_4 l_GDP$ (equal to 3.7%) and $\Delta_4 l_Loans$ (equal to 11.4%) as our steady states. The steady states taken directly from the estimated VAR model resulted from historical, stronger dynamics, inadequate for simulating future possible GDP and loans developments under various policy scenarios.

As a further step, we translate the dynamics of $\Delta_4 l_GDP$ and $\Delta_4 l_Loans$ into cumulative changes in levels by applying y/y growth rates under two scenarios:

- the baseline scenario, in which the growth rate is constant at the steady state level (constant over the course of the simulation);
- the alternative scenario, in which particular variables grow at rates equal to their steady state growth rates plus appropriate IRF values (leading to increased or decreased dynamics, depending on the direction of impact of shocks on particular variables). The total growth rates vary over the course of the simulation, but for stationary SVAR, they eventually converge to their steady state levels.

In this way, we obtain the path of *GDP* and *Loans* indices under the baseline and alternative scenarios. The computation of y/y dynamics in the model leaves the q/q dynamics in the first 4 quarters of simulation period unidentified. We tackle this issue by starting with 4 base periods each equal to 100 and then by calculating the moving averages to avoid an annual pattern of level shifts.

As the final step in our SVAR simulation analysis, we calculate the percent deviations of *GDP* and *Loans* levels from the baseline scenario, resulting from the capital adequacy shock.

The computation of SVEC impulse-response in levels is straightforward (we transform logarithmic rates of change into ordinary rates of change).

We compare the impact of a single standard deviation capital adequacy shock on the *GDP* and *Loans* level according to the SVAR simulation and SVEC impulse response functions in Figure 4.

As the value of shock is different for SVAR and SVEC models (due to, among others, different sample sizes), we use the same value of shock derived from the SVEC model to assure comparability of the corresponding results.

The results with respect to the GDP level seem to be largely similar in terms of magnitude up to the 16th quarter of the simulation and after that period, the SVAR and SVEC results diverge. This is because the SVAR model has no equilibrium reversion mechanism embedded, and hence what we see is only the extrapolation of short-run dynamics into the long-run, which is not a likely scenario. This demonstrates that the SVAR model is an appropriate tool for short-run policy analysis, but in the long run, the SVEC model seems to be more adequate. The differences seem to be even larger in terms of the impact of the capital buffer shock on the level of loans. What is more, the impact for SVEC is slightly negative up to the 4th quarter and only after that period does it become positive, whereas SVAR models points at continuous growth. Such a divergence might also be a result of our assumptions with respect to steady-state dynamics in the SVAR simulation.

4 Conclusions

Shocks to bank capital buffers do translate into the real economy, i.e. an increase in the capital buffer boosts GDP and loans in the short and long run. The capital buffer shock has been identified, in line with the existing literature, within a Cholesky ordering scheme, as the “most endogenous” shock in terms of contemporaneous linkages, in a SVAR and SVEC model constructed on a set of traditional new Keynesian trinity of variables (GDP, inflation, short interest rate), an open economy extension (nominal effective exchange rate), and financial sector extensions (loans, capital buffer). Our study is based on aggregate macroeconomic quarterly time series for Poland ranging from 2002 to 2015.

The aggregate capital buffer in the banking sector, as a measure of the sector’s capital ratio versus the threshold set in supervisory requirements, is naturally different from an individual bank’s capital buffer in the sense that the distribution of a possible shock between banks might significantly affect the results. Our simulations can by no means be associated with a shock to an individual bank’s capital buffer, but should be interpreted as a shock to the sector with distribution between banks close to historical standards. The systemic implications of the former are not the subject of this analysis.

The construction of the SVAR model, in line with some preceding literature, may leave some ambiguity as regards the time perspective of the results. While the short-run impact can be computed from seasonally-log-differenced GDP in a straightforward way (as this variable is included in the model), the mid- to long-term perspective can only be simulated with some additional assumption regarding the steady-state growth. Still, a better solution to discuss the short- to long-run impact in terms of levels is to use a SVEC model. In our case, two cointegrating relations were found, one of which defines the equilibrium between GDP and, among others, the capital buffer. On top of that, the SVEC model suggests that capital buffer policy dominates over interest rate policy in the long run. This conclusion is additionally reinforced by the good statistical properties of the model.

Some policy implications might be formulated based on the presented results. Since the impact of shocks to capital buffers on loan growth and economic activity is positive, a gradual and predictable strengthening of prudential regulation requiring higher bank capital ratios may provide better conditions for economic agents to accommodate these changes than more rapid, high-magnitude

policy actions concentrated over a short period of time. Also, our results might be interpreted as providing support for using the variable representing regulatory buffers in bank capital (as allowed by the Basel III accord) as one of the instruments in the countercyclical policy toolbox. Finally, the presented results may provide an argument for introducing regulatory incentives or facilitations for banks to raise equity capital instead of decreasing asset growth in attempts to reduce leverage.

Further work on the topic may include a number of possible extensions: of time scope, spatial scope (more countries to construct a cointegrated panel), moving to the micro level data, including additional variables or more sophisticated identification schemes. An explicit estimation of bank target capital ratios could also be an interesting extension of the study. Furthermore, in our opinion, future research could and should lay the ground – or at least provide a purely empirical benchmark – for a micro-founded model such as a DSGE model with the financial sector. We find our semi-structural analysis a useful source of empirical ‘stylized facts’ in the construction of such theoretical models.

References

- Aiyar S., Calomiris Ch.W., Hooley J., Korniyenko Y., Wieladek T. (2014), *The international transmission of bank capital requirements: evidence from the United Kingdom*, Bank of England Working Paper, 497.
- Aiyar S., Calomiris C.W., Wieladek T. (2012), *Does macro-pru leak? Evidence from a UK policy experiment*, NBER Working Paper, 17822.
- Aiyar S., Calomiris Ch.W., Wieladek T. (2014), *How does credit supply respond to monetary policy and bank minimum capital requirements?*, Bank of England Working Paper, 508.
- Alfon I., Argimon I., Bascuñana-Ambrós P. (2004), *What determines how much capital is held by UK banks and building societies?*, Occasional Papers Series, 22, Financial Services Authority.
- Alfon I., Argimon I., Bascuñana-Ambrós P. (2005), *How individual capital requirements affect capital ratios in UK banks and building societies?*, Banco de España Working Paper, 0515.
- Berger A.N., DeYoung R., Flannery M., Lee D., Oztekin O. (2008), *How do large banking organizations manage their capital ratios?*, *Journal of Financial Services Research*, 34(2–3).
- Berger A.N., Herring R.J., Szego G.P. (1995), *The role of capital in financial institutions*, University of Pennsylvania Center for Financial Institutions Working Papers, 95-01.
- Bernanke B.S. (1983), *Non-monetary effects of the financial crisis in the propagation of the Great Depression*, NBER Working Paper, 1054.
- Bernanke B.S., Lown C.S. (1991), *The credit crunch*, *Brookings Papers on Economic Activity*, 22(2), 205–248.
- Berrospide J.M., Edge R.M. (2010), *The effects of bank capital on lending: What do we know, and what does it mean?*, *International Journal of Central Banking*, 6(34), 1–50.
- Bridges J., Gregory D., Nielsen M., Pezzini S., Radia A., Spaltro M. (2014), *The impact of capital requirements on bank lending*, Bank of England Working Paper, 486.
- Bussière M., Chiaie S.D., Peltonen T.A. (2014), *Exchange rate pass-through in the global economy: the role of emerging market economies*, *IMF Economic Review*, 62(1), 146–178.
- Cohen B.H. (2013), *How have banks adjusted to higher capital requirements?*, *BIS Quarterly Review*, September, 25–41.

- Cosimano T.F., Hakura D.S. (2011), *Bank behavior in response to Basel III: a cross-country analysis*, IMF Working Paper, 119.
- Cushman D.O., Zha T. (1997), Identifying monetary policy in a small open economy under flexible exchange rates, *Journal of Monetary Economics*, 39(3), 433–448.
- Dagher J., Dell’Ariccia G., Laeven L., Ratnovski L., Tong H. (2016), *Benefits and costs of bank capital*, IMF Staff Discussion Notes, 16/04, International Monetary Fund.
- Demsetz R.S., Salden M.R., Strahan P.E. (1996), Banks with something to lose: the disciplinary role of franchise value, *Economic Policy Review*, 2(2), 1–12.
- Diamond D.W., Rajan R.G. (2000), A theory of bank capital, *The Journal of Finance*, 55(6), 2431–2465.
- Eber M., Miniou C. (2016), *How do banks adjust to stricter supervision?*, mimeo.
- Ediz T., Michael I., Perraudin W. (1998), The impact of capital requirements on U.K. bank behaviour, *Economic Policy Review*, 4(3), 15–22.
- Estrella A. (2004), The cyclical behavior of optimal bank capital, *Journal of Banking and Finance*, 28, 1469–1498.
- Flannery M.J., Rangan K.P. (2004), *What Caused the Bank Capital Build-up of the 1990s?*, FDIC Center of Financial Research.
- Fraisse H., Lé M., Thesmar D. (2015), The real effect of bank capital requirements, *Débats économiques et financiers*, 8, 3–26.
- Francis W., Osborne M. (2009), *Bank regulation, capital and credit supply: measuring the impact of prudential standards*, FSA Occasional Papers Series in Financial Regulations, 36, Financial Services Authority.
- Furfine C. (2000), *Evidence on the response of US banks to changes in capital requirements*, BIS Working Papers, 88, Bank for International Settlements.
- Gambacorta L., Mistrulli P.E. (2004), Does bank capital affect lending behavior?, *Journal of Financial Intermediation*, 13, 436–457.
- Gross M., Kok Ch., Zochowski D. (2016), *The impact of bank capital on economic activity – evidence from a mixed-cross-section GVAR model*, ECB Working Papers Series, 1888, March, European Central Bank.
- Hall P. (1992), *The Bootstrap and Edgeworth Expansion*, Springer.
- Hancock D., Laing A.J., Wilcox J.A. (1995), Bank capital shocks: dynamic effects on securities, loans, and capital, *Journal of Banking and Finance*, 19, 661–677.
- Hellmann T.F., Murdock K.C., Stiglitz J.E. (2000), Liberalization, moral hazard in banking, and prudential regulation: are capital requirements enough?, *American Economic Review*, 90(1), 147–165.
- Hughes J.P., Mester L.J. (1997), *Bank capitalization and cost: evidence of scale economies in risk management and signaling*, Federal Reserve Bank of Philadelphia Working Paper, 96-2/R.
- IMF (2014), How big is the implicit subsidy for banks considered too important to fail?, in: *Global Financial Stability Report, April 2014. Moving from liquidity to growth-driven markets*, International Monetary Fund.
- Juselius K. (2006), *The Cointegrated VAR Model*, Oxford University Press.
- Kilian L. (2013), Structural vector autoregressions, in: N. Hashimzade, M.A. Thornton (eds.), *Handbook of Research Methods and Applications in Empirical Macroeconomics*, Edward Elgar.

- Kim D., Santomero A.M. (1988), Risk in banking and capital regulation, *The Journal of Finance*, 43(5), 1219–1233.
- Kok Ch., Schepens G. (2013), *Bank reactions after capital shocks*, ECB Working Paper, 1611, European Central Bank.
- Lindquist K.-G. (2004), Banks' buffer capital: How important is risk, *Journal of International Money and Finance*, 23(3), 493–513.
- Lown C., Morgan D.P. (2006), The credit cycle and the business cycle: new findings using the loan officer opinion survey, *Journal of Money, Credit and Banking*, 38(6), 1575–1597.
- Marcinkowska M., Wdowiński P., Flejterski S., Bukowski S., Zygierewicz M. (2014), *Wpływ regulacji sektora bankowego na wzrost gospodarczy – wnioski dla Polski*, Materiały i Studia, 305, Narodowy Bank Polski.
- Maurin L., Toivanen M. (2015), Risk, capital buffers and bank lending: the adjustment of euro area banks, *Journal of Banking and Financial Economics*, 1(3), 113–129.
- Memmel Ch., Raupach P. (2007), *How do banks adjust their capital ratios? Evidence from Germany*, Discussion Paper Series 2: Banking and Financial Studies, 06, Deutsche Bundesbank.
- Mésonnier J.-S., Monks A. (2015), Did the EBA capital exercise cause a credit crunch in the euro area?, *International Journal of Central Banking*, 11(3), 75–117.
- Mishkin F.S. (2004), *The Economics of Money, Banking and Financial Markets*, Pearson Addison Wesley.
- Modigliani F., Miller M.H. (1958), The cost of capital, corporation finance and the theory of investment, *American Economic Review*, 48(3), 261–297.
- Myers S.C. (1984), The capital structure puzzle, *Journal of Finance*, 39(3), 575–592.
- Myers S.C., Majluf N.S. (1984), Corporate financing and investment decisions when firms have information the investors do not have, *Journal of Financial Economics*, 13, 187–221.
- Nier E., Baumann U. (2006), Market discipline, disclosure and moral hazard in banking, *Journal of Financial Intermediation*, 15(3), 332–361.
- Noss J., Toffano P. (2014), *Estimating the impact of changes in aggregate bank capital requirements during an upswing*, Bank of England Working Paper, 494.
- Peek J., Rosengren E.S. (1992), Crunching the recovery: bank capital and the role of bank credit, in: L.E. Browne, E.S. Rosengren (eds.), *Real Estate and the Credit Crunch*, Federal Reserve Bank of Boston.
- Schaefer M.S. (1987), The design of bank regulation and supervision, in: R. Portes, A. Swoboda (eds.), *Threats to International Financial Stability*, Centre for Economic Policy Research.
- Rime B. (2001), Capital requirements and bank behaviour: empirical evidence for Switzerland, *Journal of Banking and Finance*, 25, 789–805.
- Saunders A., Strock E., Travlos N.G. (1990), Ownership structure, deregulation, and bank risk taking, *Journal of Finance*, 45(2), 643–654.
- Smets F. (1997), Measuring monetary policy shocks in France, Germany and Italy: the role of the exchange rate, *Swiss Journal of Economics and Statistics*, 133(3), 597–616.
- Van den Heuvel S.J. (2002), Does bank capital matter for monetary transmission?, *Economic Policy Review*, May, 259–265.
- Wall L.D., Peterson P.P. (1996), Banks' responses to binding regulatory capital requirements, *Federal Reserve Bank of Atlanta Economic Review*, 81(2), 1–17.

Wdowiński P. (2011), *Makroekonomiczne skutki wyższych standardów kapitałowych: analiza symulacyjna dla Polski*, Urząd Komisji Nadzoru Finansowego.

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Appendix

Table 1

The results of the ADF (p-values) and KPSS tests for a sample spanning from Q2 2002 to Q3 2015 (54 observations)

Variable	Levels	Δ	Δ_4	KPSS conclusion (significance 0.05)
<i>l_GDP</i>	0.7479	0.0093	<u>0.0072</u>	> I(1)
<i>l_CPI</i>	0.8159	0.1787	<u>0.1686</u>	I(1)
<i>WIBOR</i>	<u>0.2616</u>	0.0000	–	I(1)
<i>l_Loans</i>	0.5068	0.1505	<u>0.0807</u>	I(1)
<i>l_NEER</i>	0.0246	0.0001	<u>0.0003</u>	I(0)
<i>Capital_buffer</i>	<u>0.3969</u>	0.0000	–	I(1)

Notes:

The test results for variables used in the SVAR model are underlined. ADF test regressions with constant (without trend), number of lags selected automatically by Schwarz info criterion (max. number of lags = 10). KPSS test regressions with constant (without trend) using Bartlett kernel with bandwidth selected automatically by the Newey-West criterion. The variables are not seasonally adjusted.

Table 2

Lag length criteria in the VAR model

Lag	Log-likelihood	Likelihood ratio	FPE	AIC	SC	HQ
0	-750.920	NA	94083.49	28.47851	29.14151	28.73420
1	-375.546	625.6232	0.333097	15.90911	17.89809*	16.67618
2	-325.778	71.88651	0.214783	15.39920	18.71417	16.67765
3	-293.112	39.92603	0.287827	15.52265	20.16361	17.31249
4	-262.881	30.23030	0.496960	15.73634	21.70330	18.03756
5	-216.976	35.70414	0.629517	15.36948	22.66242	18.18208
6	-151.435	36.41139	0.624224	14.27539	22.89432	17.59937
7	47.875	66.43681*	0.012118*	8.226853*	18.17177	12.06222*

* indicates lag order selected by the criterion.

Table 3

Serial correlation diagnostics for the VAR(2) model

Lags	Lagrange multiplier statistic	p-value
1	34.28104	0.5505
2	33.98891	0.5646
3	31.46559	0.6841
4	27.52871	0.8436
5	35.79710	0.4782
6	33.97873	0.5650
7	42.37750	0.2151
8	35.99809	0.4687

Table 4

Tests of normality of the distribution of the error terms

Component	Jarque-Bera	Probability
$\Delta_4 I_GDP$	1.154950	0.5613
$\Delta_4 I_CPI$	1.923828	0.3822
<i>WIBOR</i>	0.372008	0.8303
$\Delta_4 I_Loans$	0.604252	0.7392
$\Delta_4 I_NEER$	0.311598	0.8557
<i>Capital_buffer</i>	1.184806	0.5530
Joint (Lütkepohl)	5.551442	0.9370

Table 5

Lag length selection criteria in the VAR model, corresponding to the VECM model

Lag	Log-likelihood	Likelihood ratio	FPE	AIC	SC	HQ
1	1027.390	NA	$1.08 \cdot 10^{-19}$	-29.48205	-28.66606*	-29.15873*
2	1061.886	58.84654	$8.26 \cdot 10^{-20}$	-29.76136	-28.12936	-29.11471
3	1085.236	36.39874	$8.90 \cdot 10^{-20}$	-29.71283	-27.26484	-28.74286
4	1110.299	35.38205	$9.37 \cdot 10^{-20}$	-29.71466	-26.45068	-28.42137
5	1147.552	47.11524*	$7.15 \cdot 10^{-20}$	-30.07507	-25.99509	-28.45846
6	1179.206	35.37746	$6.80 \cdot 10^{-20}$ *	-30.27076	-25.37479	-28.33083
7	1202.680	22.78388	$8.85 \cdot 10^{-20}$	-30.22589	-24.51392	-27.96263
8	1237.342	28.54466	$9.20 \cdot 10^{-20}$	-30.51005*	-23.98208	-27.92347

*indicates lag order selected by the criterion.

Table 6

Serial correlation diagnostics for the VAR model, corresponding to the VECM model

Lags	Lagrange multiplier statistic	p-value
1	42.44900	0.0161
2	30.07299	0.2216
3	35.36274	0.0818
4	33.17213	0.1268
5	21.31523	0.6749
6	31.51414	0.1726
7	28.16025	0.3005
8	31.26480	0.1804
9	20.88929	0.6988
10	17.27942	0.8714
11	26.35399	0.3889
12	14.09518	0.9600

Table 7

Multivariate normality diagnostics of VEC residuals

Orthogonalization method	Skewness	Kurtosis	Jarque-Bera
Doornik-Hansen	0.6809	0.0513	0.1672
Urzua	0.7077	0.3680	0.3696

Table 8

Testing the cointegration rank – trace and maximum eigenvalue tests

Null hypothesis – number of CR	Eigenvalue	Trace statistic	p-value	Maximum eigenvalue statistic	p-value
0	0.510660	124.924600	0.0000	50.743480	0.0012
1	0.436862	74.181080	0.0053	40.770400	0.0034
2	0.246559	33.410690	0.3162	20.100430	0.2374
3	0.135514	13.310260	0.7137	10.339000	0.5826
4	0.040985	2.971260	0.8800	2.971260	0.8800

Table 9

Long-run and correction coefficients in the VEC model (sample: Q1 1998–Q3 2015)

		β		α	
		CR1	CR2	CR1	CR2
<i>l_GDP</i>	coefficient	-1	0	0.376	0
	standard error			0.067	
	t-stat			5.61	
<i>l_Loans</i>	coefficient	0.205	0.195	0	0
	standard error	0.018	0.047		
	t-stat	11.3	4.17		
<i>Capital_buffer</i>	coefficient	1.244	0	-0.191	0.082
	standard error	0.203		0.091	0.032
	t-stat	6.12		-2.08	2.60
<i>l_NEER</i>	coefficient	-0.311	-0.583	0	0
	standard error	0.050	0.108		
	t-stat	-6.18	-5.38		
<i>WIBOR</i>	coefficient	0	-1	0	0.142
	standard error				0.027
	t-stat				5.29
Trend	coefficient	0.006	-0.006		
	standard error	0.0004	0.0011		
	t-stat	14.8	-5.18		
Constant	coefficient	12.51	1.49		

Likelihood ratio test for binding restrictions (p-value) 0.088506

Table 10
Data sources

Variables	Name	Source
$l_GDP, \Delta_4 l_GDP$	GDP log-level and y/y ordinary growth rate	Eurostat
$\Delta_4 l_CPI$	Inflation rate, y/y	Central Statistical Office of Poland
<i>WIBOR</i>	3-month Warsaw Interbank Offered Rate	Eurostat
$l_Loans, \Delta_4 l_Loans$	Value and y/y rate of change of loan portfolio in Polish banks	Elaboration based on data from Narodowy Bank Polski. Adjusted for the effects of the exchange rate on the value of loans denominated in foreign currencies
$l_NEER, \Delta_4 l_NEER$	Level and y/y rate of change of nominal effective exchange rate	Eurostat
<i>Capital_buffer</i>	Ration of regulatory capital to risk-weighted assets in excess of the capital adequacy ratio required by KNF	Elaboration based on data from Narodowy Bank Polski and the Polish Financial Supervision Authority (KNF)

Notes:

In order to obtain a quarterly capital adequacy ratio for the entire sample period, capital adequacy ratios from quarterly KNF data from Q1 2014 to Q3 2015, monthly KNF data from Q1 2010 to Q4 2013, quarterly KNF data from Q1 2006 to Q4 2009 and annual KNF data from Q4 1996 to Q4 2005 period are used. 1996–2005 data is interpolated from annual to quarterly frequency by linear interpolation and adjustment for short-term variability based on NBP data on the values of assets and equity in the Polish banking sector over the Q4 1996–Q4 2005 period. Specifically, the value of basic own funds is divided by the value of domestic loans according to NBP to obtain a proxy of short-term capital adequacy variability over that period.

Figure 1
Capital requirements and the real economy

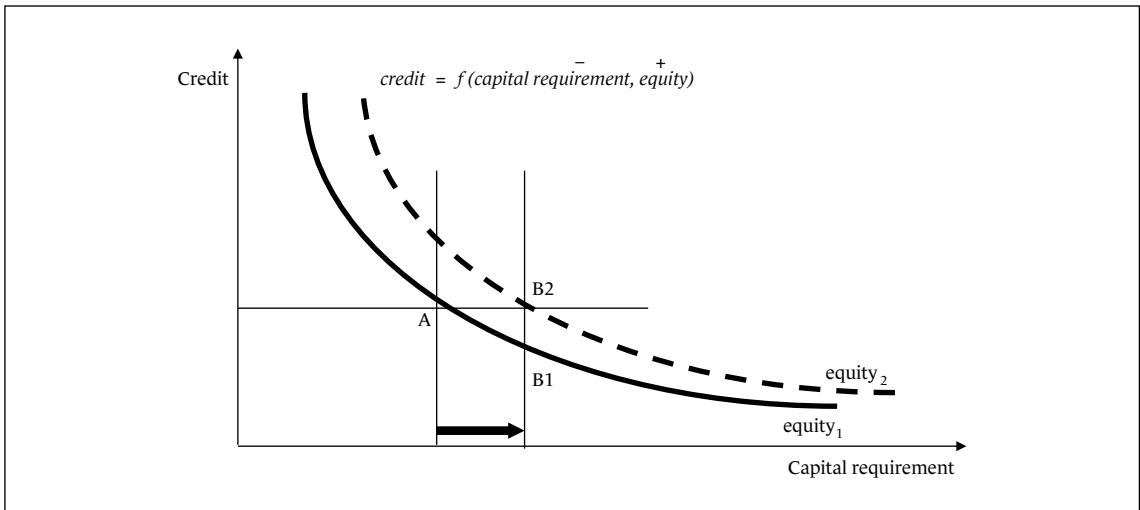


Figure 2
Inverse roots of characteristic polynomial in the VAR model

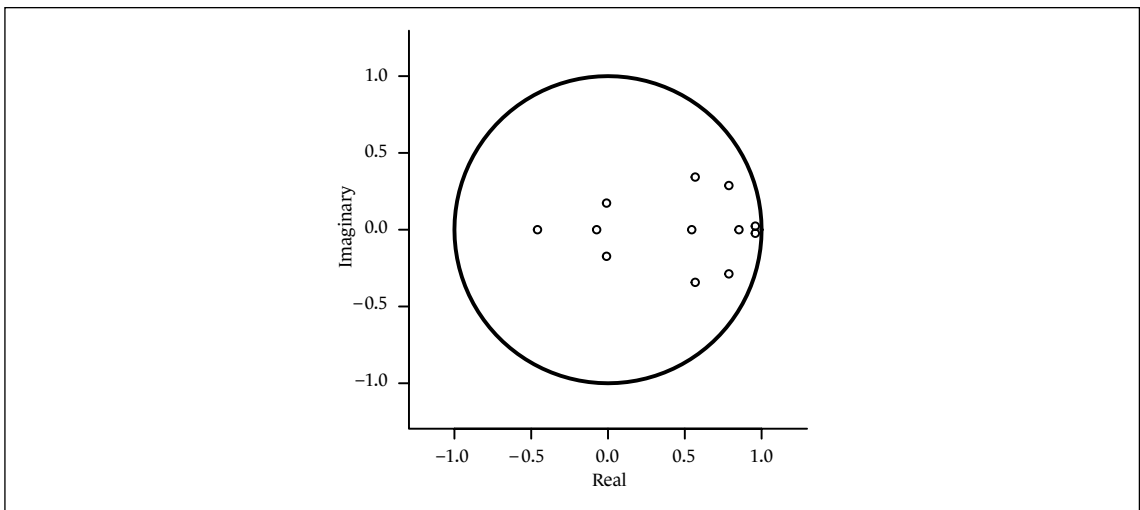


Figure 3
Inverse roots of characteristic polynomial in the VEC model

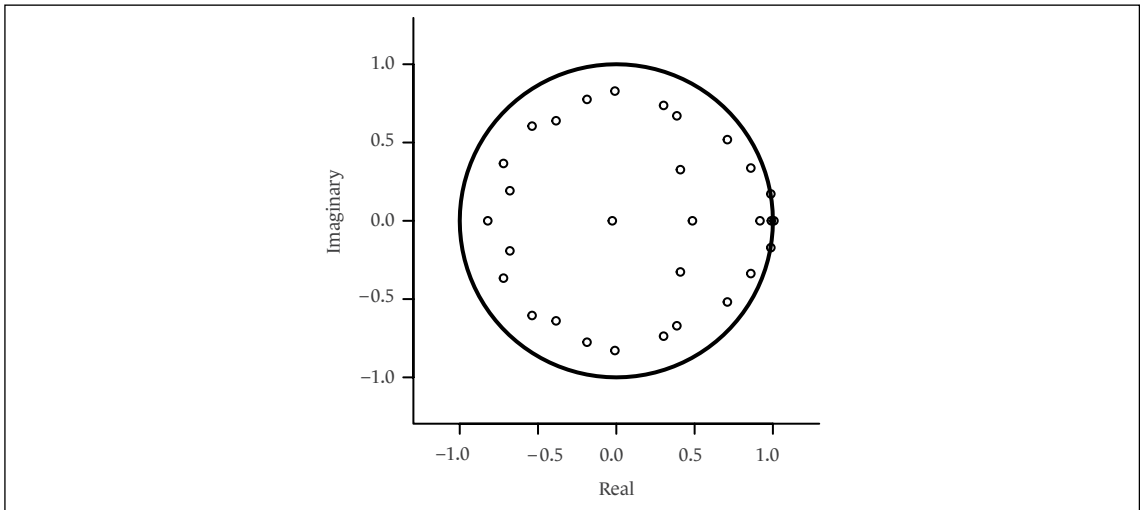


Figure 4
The impact of a one-standard-deviation capital adequacy shock on the level of GDP and loans

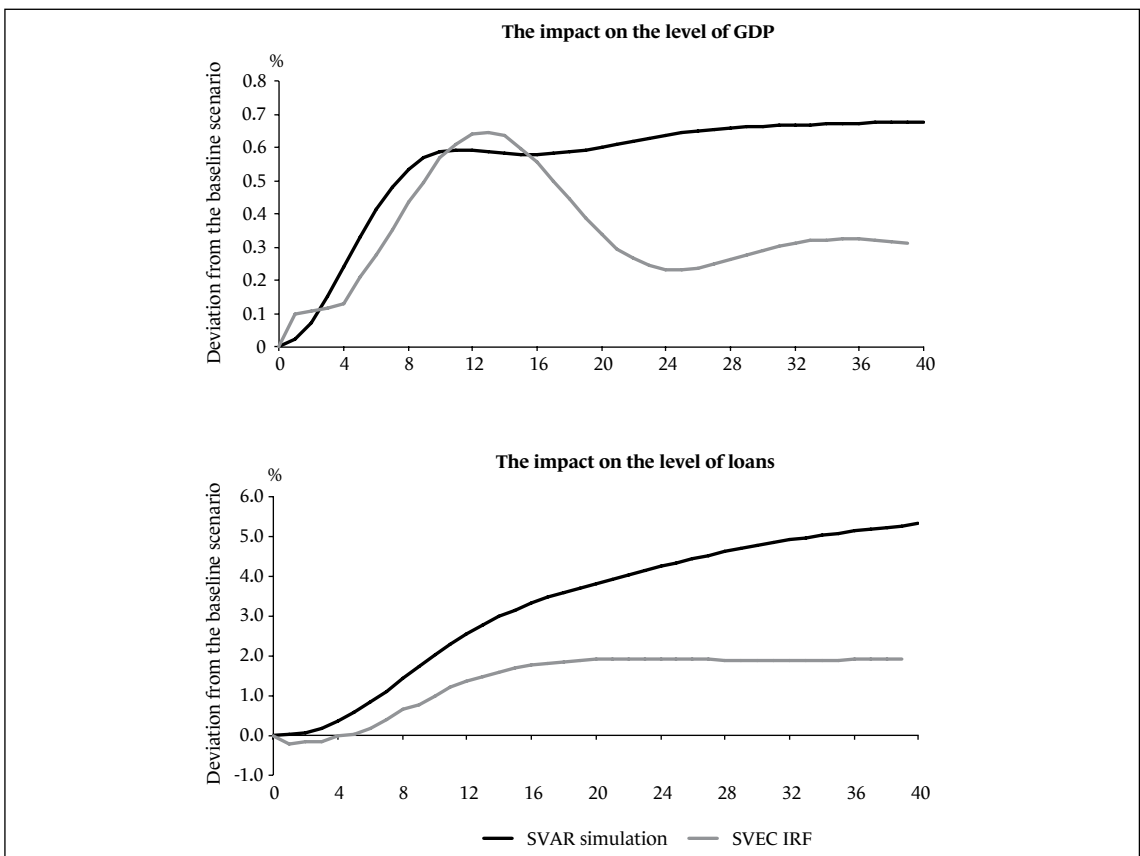
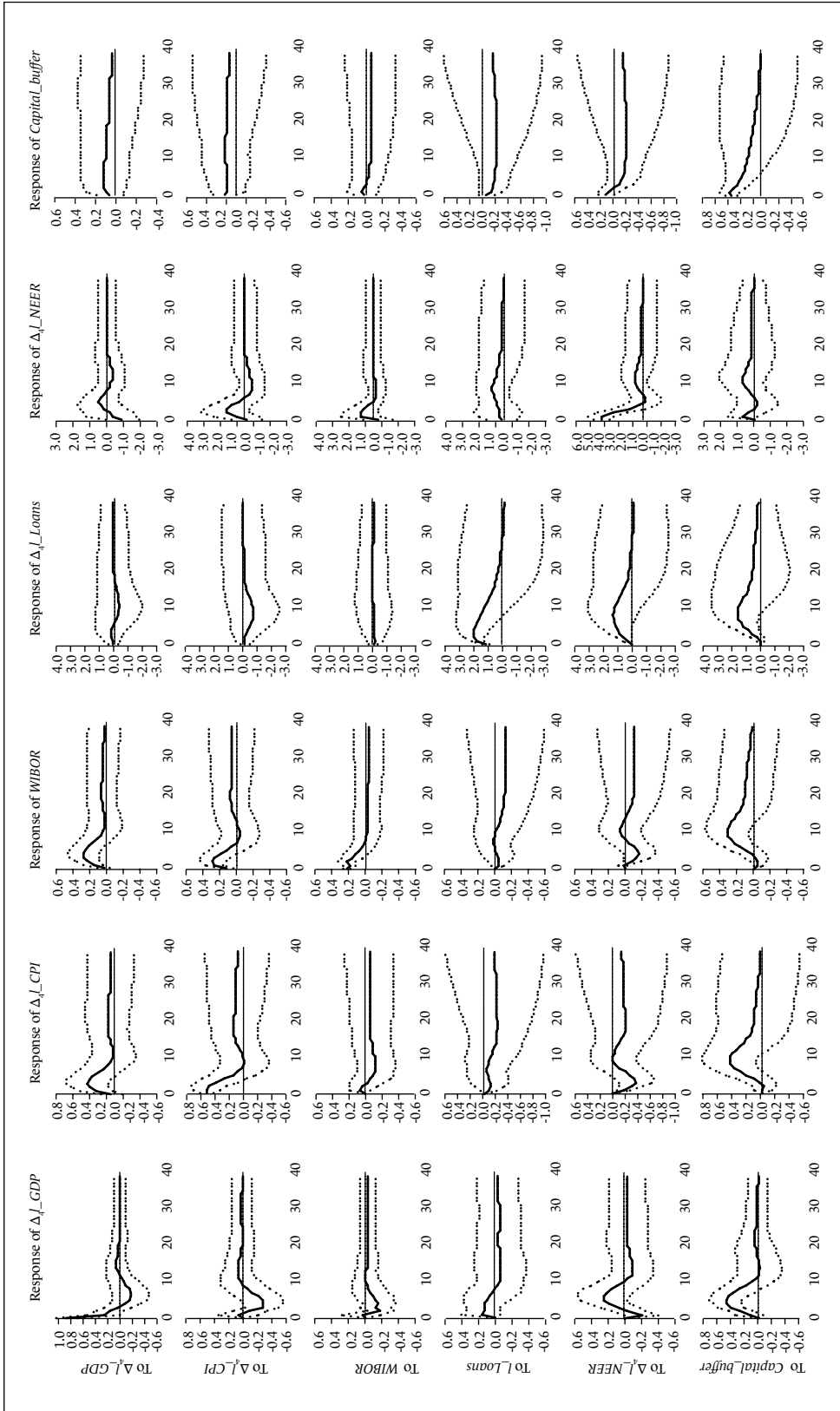
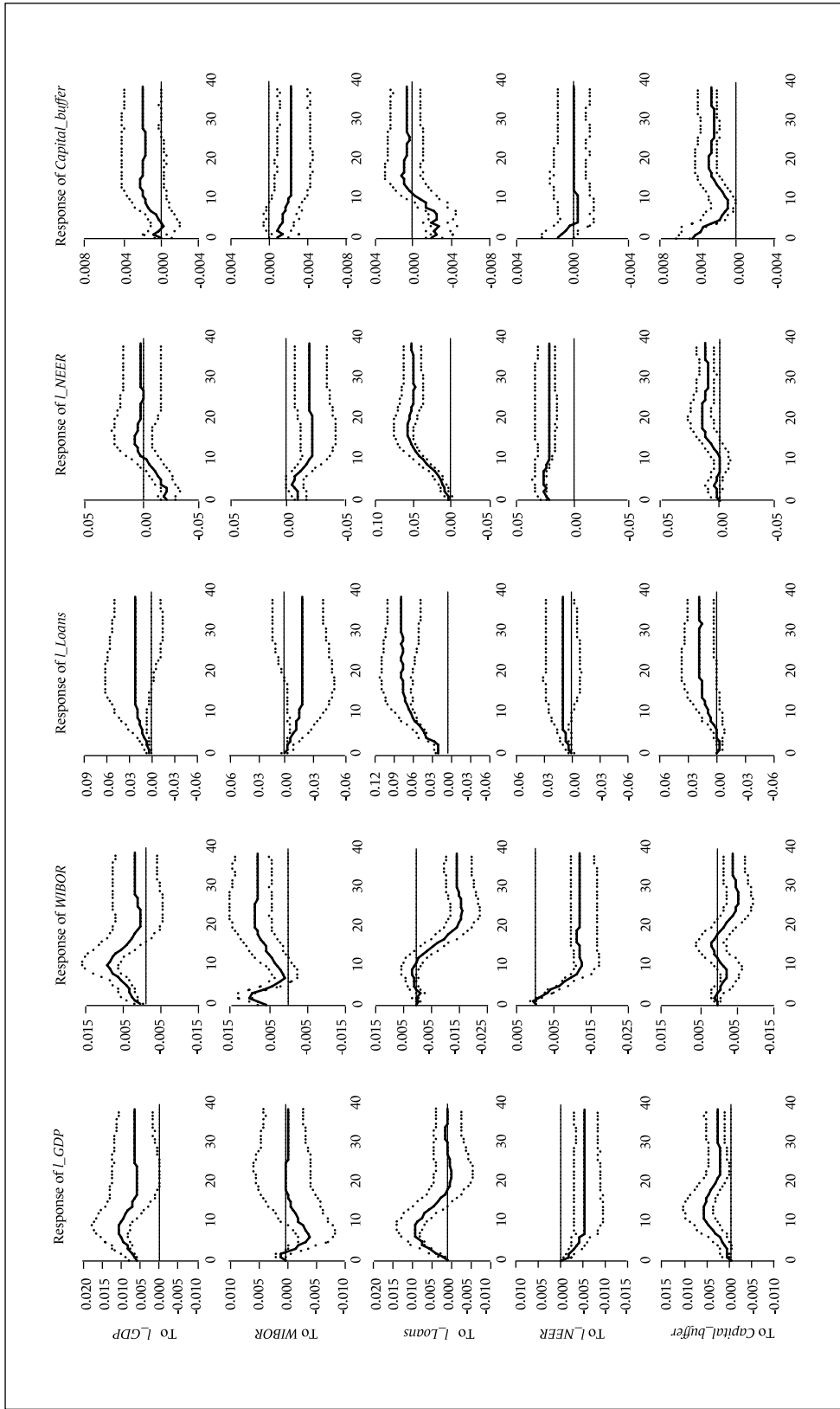


Figure 5
Impulse-response functions to one-standard-deviation shocks in the SVAR model



Notes: confidence intervals are ± 2 standard error CI; quarters after the shock on the horizontal axes.

Figure 6
Impulse-response functions to one-standard-deviation shocks in the SVECM model



Notes: confidence intervals are 95% (Hall) CI; quarters after the shock on the horizontal axes.