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MONETARY ANALYSIS TOOLS FOR CENTRAL BANKING

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1. Motivation

Monetary developments have helped to guide the decisions of central bankers over the last decades. The relatively simple models based on the "monetarist" theories of Milton Friedman have become increasingly accepted as the main tool for monetary policy analysis since the 1970s. These models suggested that nominal GDP could be reasonably well forecasted on the basis of the previous rates of growth of monetary aggregates. In effect, money growth would drive inflation and inflationary expectations, while Friedman expected that real growth would quickly return to trend once shocked away from it.

Unfortunately, those accepting this "monetarist" logic, including those central banks that had adopted monetary targeting, were quickly disappointed. Obtaining the stable demand for money function, on which the whole monetarist framework was based, proved to be an elusive objective. Monetary targets subsequently became much less fashionable, though monetary indicators remained an important guide for policy at some central banks, the European Central Bank in particular. Moreover, following the financial crisis of 2008, the importance of previously overlooked aspects of monetary analysis has been recognized.

Nowadays, monetary analysis is used, first and foremost, to identify risks to price stability, especially at longer horizons. The relevance of such considerations for a central bank with the mandate to maintain price stability over the medium term is self-evident. An important direction of such research is an attempt to identify with greater precision the persistent (or lower-frequency) developments in money that have proved robustly related to the evolution of the price level. In this respect, enhancement of the monetary analysis over recent years embodies important elements of continuity with the long-established focus of such analysis on underlying trends in money and prices. Deepening this traditional approach by developing new tools to explore the relationship between monetary trends and underlying price level dynamics has proved central to recent research agenda (see Papademos and Stark (2010) for discussion).

The financial crisis has also predetermined another important avenue of monetary analysis. The dominant pre-crisis paradigms viewed finance largely as a sideshow to macroeconomic fluctuations. The crisis demonstrated that this presumption was dangerously wrong. In contrast to what much of the literature assumed, interest rates could not capture all the interactions between the financial and real sides of the economy. A rapidly growing literature is now seeking to remedy these shortcomings: by documenting empirically the behaviour of the relationship between money, credit, asset prices and real economic activity; by developing

leading indicators of financial distress; and by examining the forecasting properties for economic activity of various financial indicators beyond interest rates.

Finally, the knowledge of the mechanism of money creation is crucial for the understanding of monetary policy transmission in given institutional environment. The concept of endogenous money and the implications of the fact that money is a by-product of credit are crucial for correct interpretation of monetary developments.

The emergence of digital finance has recently become another focal object of research on monetary analysis. The implications of these developments for the banking system are yet to be fully comprehended.

2. Objectives

This dissertation develops the tools for different aspects of monetary analysis for the Russian economy. This is mostly a novel research that was not applied to Russia previously. In some cases we contribute to the literature not only by conducting Russia-specific analysis but also by developing the tools that are relevant for other central banks in emerging market economies.

We focus on several aspects of monetary analysis.

Firstly, we discuss the composition of drivers behind money creation in Russia and deposit dollarization. Identifying money supply shocks and their macroeconomic consequences is an important practical task for day-to-day monetary policy analysis. There are models developed to interpret monetary developments, but simply copying these tools would not be advisable as the economic and financial environment in Russia differs to some extent from the developed economies. Notably, sovereign wealth funds and active foreign reserves management by the Bank of Russia can significantly influence money creation and thereby, may be understood as exogenous factors which influence monetary developments beyond the usual loan demand and supply factors. Another peculiarity of monetary developments in Russia is that the high inflationary and hyperinflationary periods are closer in the collective memory than in developed economies and foreign currency has often served as a safe haven. Currency substitution, or, in its broader definition, “dollarization” has inertia and monetary aggregates that include foreign denominated components should behave differently to those that do not. The

analysis of dollarization of the system of international settlements has recently also acquired considerable practical relevance.

Secondly, we explore the interplay between monetary developments and measurement of several key unobserved variables: underlying inflation, natural interest rate and potential output.

There are several methodologies for calculating underlying inflation and some criteria (which are not mutually exclusive but are not necessarily interrelated) that can be used to make an implicit estimation of properties of the indicators obtained. We calculated 20 underlying inflation measures, using four alternative approaches. Most importantly, we use the monetary approach to underlying inflation measurement as another alternative model. Under this we attempt to evaluate the information content of money with regard to inflation developments by applying the dynamic factor model approach on a cross-section of variables comprising the broad monetary aggregates (as well as their components) and the collection of different price indices.

The estimation of potential output growth in emerging markets has recently been a challenging task. Estimates obtained by using conventional univariate statistical filters (e.g. the Hodrick–Prescott (HP) filter) generally failed to detect imbalances prior to the onset of the crisis in late 2008. Moreover, these filters were not always helpful in decomposing the post-crisis slowdown in output growth into its cyclical and trend components. In these circumstances, it seems to be appropriate to rely on additional macroeconomic indicators to diagnose the state of the business cycle. It is generally accepted that inflationary pressure builds when output is above potential and subsides when output falls below potential. As such, inflation in particular is viewed as a key symptom of unsustainability. The same applies to another conventional theory that links fluctuations in unemployment with the output gap (Okun's Law).

This consensus in macroeconomics was severely challenged by the global financial crisis. It is becoming increasingly clear that certain cyclical activities are not captured by this approach, such as unsustainable developments in the financial sector. For example, asset price bubbles can generate huge business cycles without creating any inflation as reflected by the average household consumer basket which is the common notion of inflation. Financial indicators are therefore essential for the balanced assessment of output growth, and the aim of our exercise is to incorporate the information contained in them into the estimation of sustainable output growth in emerging market economies.

Global real interest rates have remained exceptionally low since the Great Financial Crisis, triggering a debate about the causes and consequences of the decline. The usual

presumption is that the evolution of real interest rates reflects structural changes in the underlying consumption and investment determinants. These are seen to govern variations in a notional 'equilibrium' or natural real rate, most commonly estimated using semi-structural filtering methods in the spirit of Laubach and Williams (2003). A large number of recent economic research papers endeavour to estimate the current level and trend in the equilibrium real interest rate, and a common finding of these studies is that the equilibrium real interest rate has declined in recent years to a level that has not been seen in decades.

The objective of our exercise is to show that the fluctuations of the estimated natural rates of interest do not necessarily indicate changes in macroeconomic fundamentals. Note that the standard filters assume a constant linear relationship between interest rate, inflation and output. Therefore, if this is not the case and the models are misspecified, the standard approach will give indication of the changes in the unobserved trend value of the interest rate even when there is no change in the true data generating process. Interestingly, there is ample evidence on the instability of the relationship between the main macroeconomic variables depending on the state of financial conditions. Such instability cannot be captured by a simple linear relationship between output, inflation and observed interest rate and will be accommodated by the fluctuations in the natural interest rate estimate.

Finally, we address the role of money and credit developments in assessing the threats to financial stability. We focus mainly on the issues that are crucial for application of these tools to emerging markets.

The debate about the reliability of credit gap estimates intensified after Basel III introduced it as a measure of the credit cycle phase and a guide for setting countercyclical capital buffers (CCB) (BCBS 2010). Although the useful properties of this indicator are confirmed generally for a broad array of countries and over a long time span, which includes the most recent crisis, criticism of this choice appears in the literature, focusing on several areas (see Drehmann and Tsatsaronis 2014 for a summary). We address several such criticisms: the problem of the credit gap's practical measurement and the end-point problems as well as applicability of early warning systems developed for economies to emerging markets. We also experiment with incorporating financial development indicators into early warning systems.

3. Brief literature review

3.1 Money creation

Money is created by bank lending. When a bank grants a loan, it books the loan as an asset and the newly created deposit as a liability. Therefore, when banks lend to borrowers, they thereby create deposits (initially held by the borrowers). Deposits may later be used as payment media and thus may be spread among customers of different banks. This mechanism, which is present in a number of comprehensive (if somewhat heterogeneous) theoretical economic models (Godley and Lavoie (2007), Jakab and Kumhof (2015), Brunnermeier and Sannikov (2016), Hanson et al. (2015)) and has found empirical support (Badarudin, Ariff, and Khalid (2013), Werner (2014), Werner (2015)), is widely accepted as state of the art in monetary analysis (ECB (2011a), McLeay, Radia, and Thomas (2014), Borio and Disyatat (2015)). The concept is crucial for understanding monetary policy transmission. Money being a by-product of credit, however, shifts the focus of monetary analysis from the liability side of the banking system to the asset side (see e.g. (Friedman 2012), Werner (2012), Turner (2013)), i.e. from money to credit. Accordingly, credit extension creates new purchasing power and is thus crucial for economic analysis. The creation of various combinations of instruments on the liability side of the banking system balance sheet becomes irrelevant in this context.

Nonetheless, there is a strand of literature that spotlights monetary aggregates and especially to the divergence between deposits and loans. One reason for this is the connection between such developments and movements in important financial stability indicators such as the loans-to-deposits and Net Stable Funding ratios. Hahm, Shin, and Shin (2013) find that disproportional growth of non-core bank liabilities has significant predictive power for currency and credit crises. Furthermore, Kim, Shin, and Yun (2013) and Chung et al. (2015) argue that certain components of monetary aggregates may represent a non-core (i.e. unstable) segment of bank liabilities. Specifically, Chung et al. (2015) point out that money stock may see rapid increases due to the cross-border operations of non-financial corporations, either via direct borrowing from abroad or via operating overseas subsidiaries. Kim, Shin, and Yun (2013) and Chung et al. (2015) argue that the much of the divergence between loans and deposits may occur during credit booms because the growth of retail deposits cannot exceed the growth of household-sector wealth. However, the mechanism through which this adjustment may take place is not described explicitly. For example, excess deposits may be used to repay debt (Lavoie 1999) or the prices of alternative assets may increase in response to deposit expansion

(Brunnermeier & Sannikov 2016). In such cases, the share of deposits in total wealth remains stable, but the loans-to-deposits ratio is also unaffected.

In a number of emerging market economies, the public sector in recent decades has accumulated sizeable cross-border financial assets, mainly in the form of central banks' foreign exchange reserves. The reserve accumulation has not necessarily been the by-product of fixed exchange rate monetary policy frameworks focused on resisting exchange rate appreciation. Some of this accumulation reflects efforts to bolster the buffer stocks of reserves as a precaution against the possibility of international capital flows suddenly stopping. Accordingly, the monetary authorities in these countries have not abandoned their independent interest rate policy (i.e. the central banks have continued to steer the short-term money market interest rates). To deal with the undesirable effects of foreign exchange interventions (FXIs) in the domestic monetary conditions, they have frequently resorted to sterilization operations, which can be defined in general as a set of policies designed to mitigate the impact of reserve accumulation on domestic interest rates. Even when successful in steering interest rates, such a strategy can potentially have macroeconomic effects, which are discussed in the related literature (International Relations Committee Task Force 2006, Mohanty and Turner 2006, Cook and Yetman 2012, Filardo and Grenville 2012, Filardo and Yetman 2012, Gadanecz et al. 2014 and Blanchard et al. 2016). We contribute to this strand of research and suggest a novel approach to forecasting the consequences of foreign exchange reserve accumulation by a central bank for the banking system's balance sheet.

Credit and broad money supply developments are only scarcely analysed in the standard literature on FXIs. Instead, the common approach is to examine the outcome of FXIs for reserve money and the central's bank net domestic assets (Aizenman and Glick 2009, Ouyang and Rajan 2011, and Cavoli and Rajan 2015). Presumably, the reason behind such an approach is the tacit existence of a stable relationship between bank reserves and broad money aggregates – the "money multiplier". The practical applicability of this concept, however, is questioned in the contemporary literature (Bindseil 2004, Borio and Disyatat 2010, Carpenter and Demiralp 2012, and Bundesbank 2017).

The conventional view of banks' interest rate-setting strategy implies that decisions about deposit and loan rates may be made independently. This is reflected in the standard theoretical models (usually based on the Klein-Monti approach) as well as in the applied structural macroeconomic models (e.g., Gerali et al., 2010). The separation approach to interest rate determination is also considered state-of-the-art in actual banking practices (Grant, 2011). There

are seemingly good reasons for such an approach, as the volume of collected deposits is not directly affected by the volume of extended loans.

Nevertheless, many authors have tried to show that under some changed assumptions, loan and deposit decisions can be interdependent. Most notably, Dermine (2013) outlines the approach to joint loan and deposit interest rate setting in order to account for the need to build up a Basel III contingency liquidity buffer, the need to adjust to the credit riskiness of specific assets of the bank, the liquidity premium on the term structure of interest rates in the case of long-term funding, and the need to take into account the bank's credit spread when its default risk is not trivial. Further, Dermine (1986) and Cooper and Davydenko (2007) show that loan and deposit decisions are interdependent if the bank faces a positive probability of default (the link between the two decisions is facilitated through the limited liability of the bank). Another case of interdependence is discussed by Pringle (1973), who relaxes the assumption of a single decision period; Prisman et al. (1986) introduce liquidity risk in a two-stage setting; Van Loo (1980) builds a model with liquidity and solvency constraints and Broll et al. (2002) achieve interdependence through hedging with basis risk. Finally, Chiappori et al. (1995) use a spatial competition model to show that interdependence arises through tied sales, which becomes the bank's optimal strategy after the deposit rate regulation is imposed.

Notably, all the reviewed models with interdependence between loans and deposits are more complex when compared to the original Monti-Klein model. Their setups depart far from the original model and, thus, significantly reduce the generality of their implications. On the other hand, a simple alternative assumption of a predetermined liabilities structure (in the spirit of Berlin and Mester, 1999) would justify a causal link between deposit and loan interest rates. However, this assumption may seem implausible, as it implies that the availability of deposits automatically increases (decreases) when more (fewer) loans are granted. In this paper, we argue that in certain circumstances, such a claim may (at least partially) be reasonable, considering that money is created via lending. This may result in a loss of independence in deposit and loan rate determination.

3.2 Financial dollarization

Deposit dollarization has always been an important feature of the Russian economy as well as many other emerging markets. The hyperinflation that occurred in the early 1990s and the currency crisis of 1998 increased the demand for foreign currency-linked deposits for holding savings. In subsequent years, periods of extensive de-dollarization in times of ruble appreciation have alternated with renewed shifts to foreign currency-linked deposits in times of ruble

depreciation (e.g. during the financial crisis of 2008) presumably providing the indications of the speculative behavior of households. Among the drivers of domestic financial dollarization the yield and borrowing cost differentials are usually regarded as the key factors (see e.g. Ize and Levy-Yeyati (2005) and Levy-Yeyati (2006) for a review of the relevant theories). Although in some instances it may be a rational response of economic agents to political or economic uncertainties, its adverse effects (e.g. a reduction or loss of control of monetary and exchange rate policy and increased foreign exchange risk in the financial system and other sectors) often motivate countries to reduce its level. Dollarization is usually associated with macroeconomic instability and depreciation of the national currency, but unfortunately the ensuing stabilization does not always lead to rapid dedollarization. Once dollarization takes hold, economic agents are reluctant to switch back to using the local currency, because they lack confidence and the cost of redenominating transactions is high until consensus is reached among market participants on the use of the local currency.

This persistence is called hysteresis or the ratchet effect (Calvo and Vegh, 1992) and may substantially impede the efficiency of policies aimed at achieving dedollarization. Analysis of the hysteresis effect is commonly applied to situations of currency substitution. Numerous theoretical models have been developed for this purpose (Oomes, 2003; Guidotti and Rodriguez, 1992; Uribe, 1997) for which related empirical results are available (Kamin and Ericsson, 1993; Menon, 2008; Samreth, 2011; Valev, 2010). There are also theories explaining the hysteresis effect in the dollarization of bank balance sheets (Ize and Levy-Yeyati, 2003; Duffy et al., 2006), as well as some empirical estimations of the hysteresis effect on financial dollarization: Mueller (1994), De Freitas (2003), Fernández Tellería (2006) analyse deposit dollarization; Peiers and Wrase (1997) examine loan dollarization.

Interestingly (and somewhat surprisingly), the increase in volatility of exchange rate fluctuations in Russia in 2015-2016 did not translate into dramatic changes in households' deposits dollarization. In fact, in this environment the changes in household's deposits dollarization were insubstantial and seem to have detached from the observed exchange rate development, implying an evidently time-varying link between the variables. This observation gives us the insight that we cannot rely on the assumption of linear adaptive expectations to model dollarization.

The idea that the linkage between exchange rate and dollarization developments is nonlinear is not new. However, previous studies mostly focused on implementing the hysteresis effect (Kamin and Ericsson 2003, Feige 2003, Valev 2010, Samreth 2011). Barajas and Morales (2003) and Kokenyne et al. (2010) report that a pegged exchange rate regime encourages

dollarization but do not offer the underlying model. Meanwhile, the aim of this paper is to provide a model that is able to capture the endogenous change in the sensitivity of dollarization to exchange rate developments during the transition to a different exchange rate regime.

3.3 Exploring the link between monetary developments and key macroeconomic variables

3.3.1 Money and underlying inflation rate

The lead-lag pattern in the long-run relationship between monetary growth and consumer price inflation is a well-documented empirical fact. A large amount of empirical evidence across various economies and monetary regimes demonstrates this link. Regular consideration of this relationship supports a medium-term orientation of monetary policy by pointing the attention of central banks towards longer-term developments in nominal variables – ultimately, the price level – over which they can exert control and for which, given the mandate to maintain price stability, they should be held accountable. In particular, the assessment of risks to price stability in the euro area stemming from monetary analysis is an essential ingredient of the ECB's two-pillar strategy (see, e.g., Papademos and Stark 2010 for a comprehensive review). The leading properties of money for inflation have been widely discussed in several empirical contributions, including Masuch et al. (2001), Nicoletti-Altimari (2001), Trecroci and Vega (2002), Hofmann (2006, 2008) and Fischer et al. (2008). Admittedly, the prominent role assigned to money has been the subject of an intense debate in light of the deteriorating ability of money-based models to predict future inflation during the last several decades. Notably, some authors point out that the diminishing predictability of inflation is a natural feature − common to several forecasting models and not confined to money-based forecasts – that mainly reflects the structural break in the inflation rate process observed in economies moving to inflation-targeting regimes (Stock and Watson 2007, D'Agostino et al. 2006, D'Agostino and Giannone 2006, Hofmann 2008). However, general evidence of the ability of money growth to forecast inflation is well acknowledged.

Admittedly, monetary analysis of inflation is far from being immune from problems. For example, models of inflation that are required to identify a stable money demand relationship (as in the VECM framework; see e.g. Korhonen and Mehrotra 2010) or in order to estimate excess liquidity measures (see e.g. Oomes and Ohnsorge 2005) may fail to do so in a rapidly developing financial environment. Furthermore, a significant part of the consumer price index (CPI) measure in Russia is composed of food and administered prices predetermining the indicator's high volatility. Therefore attempts to link all CPI fluctuations with (especially monetary) fundamentals may potentially be misleading. In theory, one may try to overcome this problem by

smoothing the inflation rate over longer horizons (e.g. as outlined in Chapter 4 of Papademos and Stark 2010, and employed in Ponomarenko et al. 2014), although this approach might also require a longer time sample than is currently available for Russia. Another option is to identify relevant monetary shocks using theoretically founded assumptions.

Against this background, we evaluate the information content of money with regard to inflation developments in the spirit of Nobili (2009), i.e. by applying the dynamic factor model approach on a cross-section of variables comprising the broad monetary aggregates (as well as their components) and the collection of different price indices. Arguably, the resulting process may be regarded as money supply developments as opposed to movements in demand for money that do not have implications for inflation (King 2007). This parsimonious approach is similar to Bruggeman et al. (2005) who identify underlying money growth as a component of money that feeds into inflation movements with certain periodicity. Simultaneously, given that we rely on a range of price indicators to reflect inflation developments, we expect to filter out the volatile component of CPI growth that might otherwise distort the relationship with money growth.

Headline inflation measures can be volatile and 'noisy'. The fluctuations associated with measurement errors and changes in relative prices can make it difficult for policymakers to accurately judge the underlying state of and prospects for aggregate price level dynamics. Therefore, estimates of 'underlying' ('core') inflation are widely used by academics and central banks not only as a statistical measure but also as an analytical tool.

Despite its prevalence, there is neither a commonly accepted theoretical definition nor an agreed method of measuring underlying inflation. Different approaches are described in the literature for constructing indicators of underlying inflation, and different criteria for measuring their performance in terms of the desirable empirical properties of underlying inflation are proposed. These criteria are given in, e.g., Amstad et al. (2014), Mankikar and Paisley (2004), Silver (2006) and Wynne (1999) and may be broadly categorized into two alternative approaches. The most common view is that underlying inflation measures should only reflect long-term price fluctuations that are useful for forecasting actual headline inflation at a certain horizon (as opposed to the effects of one-off events that disappear without affecting future price developments). Another view suggests that underlying inflation relates to some observable macroeconomic indicator such as the growth rate of the money supply or output. In practice, these alternative concepts are not necessarily either competing or complementary. That is why, for practical purposes, the above studies recommend the use of a set of underlying inflation indicators.

3.3.2 **Credit cycle and potential output**

The estimation of potential output growth in emerging markets has recently been a challenging task. Estimates obtained by using conventional univariate statistical filters (e.g. the Hodrick–Prescott (HP) filter) generally failed to detect imbalances prior to the onset of the crisis in late 2008. Moreover, these filters were not always helpful in decomposing the post-crisis slowdown in output growth into its cyclical and trend components. For example, Borio et al. (2013, 2014) analyse the real-time performance of the HP filter and show that in the US, the UK and Spain univariate filter estimates had large upward bias before the recent crisis, which was revealed only after the crisis. Traditional approaches also overestimated potential output growth in the euro area before the crisis (ECB (2011b); Marcellino and Musso (2011)). This effect is even more pronounced in Central and Eastern European countries (Bernhofer et al. (2014)).

In these circumstances, it seems to be appropriate to rely on additional macroeconomic indicators to diagnose the state of the business cycle. It is generally accepted that inflationary pressure builds when output is above potential and subsides when output falls below potential. As such, inflation in particular is viewed as a key symptom of unsustainability. The same applies to another conventional theory that links fluctuations in unemployment with the output gap (Okun's Law).

As discussed in Bernhofer et al. (2014), this consensus in macroeconomics was severely challenged by the global financial crisis. It is becoming increasingly clear that certain cyclical activities are not captured by this approach, such as unsustainable developments in the financial sector. For example, asset price bubbles can generate huge business cycles without creating any inflation as reflected by the average household consumer basket which is the common notion of inflation. The global financial crisis is a case in point. Hume and Sentance (2009) propose two explanations for the decoupling of asset and output inflation. First, the financial upturn of the 2000s had a relatively limited impact on effective demand. Second, in cases where the demand effect was larger, inflation pressure was dampened by a deterioration of external balances instead of reaching domestic capacity constraints. Borio et al. (2013) discuss four additional reasons why output inflation could remain low and stable against the backdrop of soaring asset price inflation, namely (i) financial booms that coincide with positive supply shocks, (ii) increases in potential output in prolonged economic upturns (as measured by conventional approaches), (iii) capital inflows leading to currency appreciation and (iv) the existence of sectoral misallocation rather than "aggregate" capacity constraints. Financial indicators are therefore essential for the balanced assessment of output growth, and the aim of this paper is to incorporate the information

contained in them into the estimation of sustainable output growth in emerging market economies.

Our work is related to the recent literature on the link between business cycles and financial cycles (Alessi and Detken (2011); Claessens et al. (2012); Schularick and Taylor (2012)). We concentrate here on developments in emerging markets, which means that data limitations will effectively restrict our analysis to the latest boom/bust episode. This closely links our work with the literature on the main factors explaining output fluctuations during the crisis of 2008 (Frankel and Saravelos (2010); Lane and Milesi-Ferretti (2011); Cecchetti et al. (2011); Feldkircher (2014)). Our main contribution to these strands of research is that we follow Alberola et al. (2013), Borio et al. (2013, 2014) and Bernhofer et al. (2014) in employing an empirical model that enables us to decompose output fluctuations into cycle and trend components based on the empirical relationships with various measures of imbalances. The resulting indicators may be interpreted, in an economic sense, as metrics of sustainable (i.e. not associated with the build-up of imbalances) output and the output gap.

3.3.3 **Credit cycle and natural rate of interest**

Global real interest rates have remained exceptionally low since the Great Financial Crisis, triggering a debate about the causes and consequences of the decline. The usual presumption is that the evolution of real interest rates reflects structural changes in the underlying consumption and investment determinants. These are seen to govern variations in a notional 'equilibrium' or natural real rate, most commonly estimated using semi-structural filtering methods in the spirit of Laubach and Williams (2003). A large number of recent economic research papers (see e.g. Justiniano and Primiceri (2010), Laubach and Williams (2016) and Holston et al. (2017)) endeavour to estimate the current level and trend in the equilibrium real interest rate, and a common finding of these studies is that the equilibrium real interest rate has declined in recent years to a level that has not been seen in decades.

In these models, the natural rate measure is anchored to theory-prescribed relationships, such as the Phillips curve and aggregate demand (IS), that govern the joint dynamics of the interest rate, output and inflation (in general, rising inflation indicates that the output is above the potential and, correspondingly, that the actual interest rate is below the natural rate; falling inflation and lower output indicate the reverse). The changes in the observed relationships are accommodated by the changes in the implicitly estimated natural rate of interest. The variability of the natural rate is usually interpreted as an indication of undergoing structural developments. The potential explanations include a persistently weak demand for capital and a rising propensity

to save (Summers 2014, 2015), investors' growing preference for safe assets (Bernanke 2005; Caballero et al. 2008; Broadbent 2014) and demographic changes (Carvalho et al. 2016; Gagnon et al. 2016; Rachel and Smith 2017). See also Borio et al. (2017, 2018, 2019) for a critical assessment of these hypotheses.

Note that the standard filters assume a constant linear relationship between interest rate, inflation and output. Therefore, if this is not the case and the models are misspecified, the standard approach will give indication of the changes in the unobserved trend value of the interest rate even when there is no change in the true data generating process. Interestingly, there is ample evidence on the instability of the relationship between the main macroeconomic variables depending on the state of financial conditions (see e.g. Silvestrini and Zaghini (2015), Metiu et al. (2015), Gross et al. (2017), Carriero et al. (2018), Asanović (2020), Peña (2020), Nain and Kamaiah (2020)). Such instability cannot be captured by a simple linear relationship between output, inflation and observed interest rate and will be accommodated by the fluctuations in the natural interest rate estimate. These concerns are not unprecedented. In a related strand of research, Juselius et al. (2017), Krustev (2018) and Belke and Klose (2019) also claim that conventional models for natural interest rate estimation may be misspecified and augment them with financial variables.

3.4 Credit cycle models

There are good reasons to believe that correctly determining the current phase of the credit cycle is essential for efficient policymaking. Borio and Lowe (2002, 2004) document the property of the credit gap (the gap between the credit-to-GDP ratio and its long-term trend) as a very useful early warning indicator for banking crises. The association of general macroeconomic and financial developments with credit boom/bust cycles is also examined closely in a number of studies (see e.g. Mendoza and Terrones (2012)). Importantly, the close link between credit cycle indicators and credit losses is well documented (Dell'Ariccia et al. 2012; Geršl and Seidler 2015; Jokivuolle et al. 2015).

The debate about the appropriate measure of the credit cycle intensified after Basel III introduced the credit gap as a measure of the credit cycle phase and a guide for setting countercyclical capital buffers (CCB) (BCBS 2010). Although the useful properties of this indicator are confirmed generally for a broad array of countries and a long time span that includes the most recent crisis, criticism of this choice appears in the literature, focusing on several areas (see Drehmann and Tsatsaronis (2014) for a summary). The first strand of arguments is related to the ultimate relevance of the credit gap indicator as a measure of

disequilibrium. In this paper, however, we will not address this issue and concentrate on the problem of the credit gap's practical measurement and the end-point problems (reported by e.g. Edge and Meisenzahl (2011)).

This assessment is not, however, without its caveats. The underlying analysis is usually conducted by means of an examination of the early warning properties of credit gaps estimated recursively of the expanding time sample (i.e. 'real-time' credit gap estimates). Accordingly, the performance of these estimates is the average usefulness of the gap measures calculated over the range of time samples of different lengths (starting from the shortest possible one to the longest currently available). The result of this exercise is obviously different from the expected usefulness of the indicator in the coming years if it is used as an early warning indicator from now on. Similarly, if the credit gap estimates were not found useful during the period of rapid changes in the pace of financial deepening it does not mean that they may not eventually become useful once this process stabilizes. Therefore, there are good reasons to try to separately evaluate the reliability of credit gap measures estimated over different length time samples and to examine the evolution of credit gap measures' reliability during and after the changes in the financial deepening process. Incidentally, the evaluation of the predictive ability of forecasting models over a wide range of window sizes is a common issue in time series econometrics literature (Pesaran and Timmerman 2007, Inoue and Rossi 2012, Inoue et al. 2017).

It is argued that the reliability of the credit gap indicator may be improved when used in combination with alternative indicators in an early warning indicator system (EWI) set-up. The interest in such supplementary indicators is also driven by the demand for a system that could provide a signal that is early enough to account for the 12-month implementation period for raising the capital buffers specified in the Capital Requirements Directive IV regulation. The literature on such EWIs developed for advanced countries is ample (see e.g. Detken et al. (2014) and Kalatie et al. (2015) for a comprehensive review) but noticeably scarcer for emerging markets (see Guarín et al. (2014) and Valinskytė and Rupeika (2015) for such examples, Drehmann and Tsatsaronis (2014) also touch on the performance of the credit gap indicator in emerging markets).

A large and increasing body of literature aimed to analyze the role of financial development in the occurrence of banking crises. Demirguc-Kunt and Detragiache (1998) notably find that the level of banks' credit-to-GDP ratio and the growth of banks' credit significantly increase the occurrence of banking crises only sometimes. Subsequent studies confirm the existence of such conflicting effects (see Kauko, 2014, for a survey). For example, when extending their database to include 77 crises for 94 countries, Demirguc-Kunt and

Detragiache (2005) reveal a positive effect of the level of the credit-to-GDP ratio and of the growth of credit on the occurrence of banking crises, irrespective of the considered specification (see also Eichengreen and Arteta 2000, Bekaert et al. 2011). In contrast, when revisiting Demirguc-Kunt and Detragiache (2005), Davis & Karim (2008) fail to find a robust effect of either the credit-to-GDP ratio or the growth of credit in a sample of 105 countries. A number of studies also report the relevance of financial development for more general credit cycle analysis exercises (Cottarelli et al. 2005, Égert et al. 2006, Buncic and Melecky 2014, Bahadir and Valev 2015, Naceur et al. 2019).

On the other hand, the existing EWSs rarely (successfully) make use of these variables in the forecasting exercises. Davis and Karim (2008), von Hagen and Ho (2007) find that the level of credit-to-GDP ratio is not a good predictor of banking crises. Hahm et al. (2013) and Rose and Spiegel (2011) also find that the ratio of credit relative to GDP was not a strong predictor of the 2007-08 Global Financial Crisis. Mathonnat and Minea (2018) find that the level of the credit-to-GDP ratio does not affect significantly the occurrence of banking crises when jointly introduced with its growth and volatility.

4. Methodology

4.1 Money creation

Loans create deposits, but the two are not necessarily equal. That the deviation between them may be significant and have economic implications is evident from the ample amount of analysis that has been done on fluctuations in the loans-to-deposits ratio and has been centered on several areas. Mainly, these are studies related to macroprudential policy issues (see Van den End (2016) for a review) but occasionally touch upon more general problems in macroeconomics and finance (Ritz and Walther (2015)). Obviously, the loans-to-deposits ratio is used extensively in banks' behavior analysis (DeYong and Jang (2016)). However, the description of the exact causes of loans-to-deposits ratio fluctuations are rarely discussed in detail.

Kim et al. (2013) and Chyung et al. (2015) argue that the much of the divergence between loans and deposits may occur during credit booms because the growth of retail deposits cannot exceed the growth of household-sector wealth. However, the mechanism through which this adjustment may take place is not described explicitly. For example, excess deposits may be used to repay debt (Lavoie (1999)) or the prices of alternative assets may increase in response to

deposit expansion (Brunnermeier and Sannikov (2016)). In such cases, the share of deposits in total wealth remains stable, but the loans-to-deposits ratio is also unaffected.

Choi and Choi (2016), on the other hand, argue that monetary tightening reduces deposit supply and leads to banks' greater reliance on wholesale funding. They reasonably point out that deposits will contract due to less money creation by banks (i.e. lending). Interestingly, under this assumption, it is not clear why there should be an increase in either the amount of banks' wholesale funding or in the loans-to-deposit ratio. The alternative explanation for deposit contraction simply assumes that depositors replace them by other less liquid claims on banks[1] because the interest rates on these instruments are more responsive to hikes in policy rates. Borio and Lowe (2004) also mention portfolio shifts as the main source of the wedge between private credit and money growth rates.

It is may thus be useful to discuss the sources of deviations between loans and deposits in more detail. Economists have long known about these sources, which are transactions of the non-banking sector with other sectors and are sometimes referred to as 'leakages'.[2] The outside sectors are the government, the banking sector and the foreign sector. The role of the government (if it is not accumulating sovereign funds) is usually quite straightforward. It may borrow from the banking[3] sector and transfer funds to the private non-banking sector, which lowers its loans-to-deposits ratio. As regards transactions with banking sector, any investments by the non-banking sector in financial instruments other than bank deposits will result in a decrease in deposits. Non-financial transactions that create undistributed profits and accumulation of capital in the banking sector is another type of leakage.

In this paper we, however, focus on transactions with the foreign sector. The non-banking sector may conduct financial and non-financial external transactions. The sum of these transactions constitutes the change in funds owned by the non-banking sector. In the balance of payments, this sum also equals the sum of the banking sector's external transactions. For simplicity we ignore the non-financial external transactions of the banking sector and assume that the change in net foreign assets summarizes all transactions (see Bê Duc et al. (2008) for a detailed discussion of the monetary approach to the balance of payments). From the banks' balance sheet perspective, it is equally correct to regard increasing claims on the foreign sector as the counterpart of accepting liabilities into domestic non-banking sector.

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[1] Note that non-banking agents' investments in other non-banking agents' financial liabilities do not lead to deposit outflows.

[2] See e.g. Tobin (1982) for theoretical discussion as well as Berg (2012), Kuzin and Schobert (2015) and Kauko (2015) for recent applications.

[3] For simplicity, we will not specifically discuss the case of government borrowing from the foreign sector.

An increase in banks' net foreign assets is therefore crucial for deposits growth. Arguably, the fact that the banking system wishes to increase its net foreign assets predetermines deposits expansion via external transactions of the non-banking sector (irrespective of whether funds flow in via the financial or current account).[4]

Obviously, this also means that an increase in banks' net foreign liabilities is mechanically linked with a corresponding decrease in deposits. Therefore, the notion of banks supplementing insufficient deposits on their balance sheet by borrowing from abroad in order to grant a loan may be misleading. An alternative interpretation could be that banks facing a leakage of deposits to the foreign sector (which may or may not be correlated with increased lending) respond by accumulating net foreign liabilities. It is also equally plausible to claim that banks cause a decline in deposits by increasing their foreign liabilities.

Surely, through several transactions banks may end up with more loans and more foreign liabilities on their balance sheet. We may consider loan extension (which also implies creation of new deposits) as the first independent step. Next, banks increase their net foreign liabilities (by borrowing abroad and selling the obtained foreign assets). At this stage we will see the following adjustment in the balance of payments: financial inflows generated by the banking sector will be balanced by either financial outflows from the non-banking sector or by current account deterioration (probably together with exchange rate appreciation). In both cases there will be an outflow of funds from the non-banking sector[5]. It is possible that replacing domestic liabilities by foreign ones leads to lower funding costs and therefore may fuel a credit boom. Typically (see e.g. Hahm et al. (2013)) we thus see a pattern of rapid credit and foreign liabilities growth accompanied by slower growth of deposits.

The definite link between changes in the banking sector's net foreign assets and external transactions of the non-banking sector can thus also be considered to seriously restrict money creation. The accumulation of net foreign assets/liabilities is usually associated with a widening of currency mismatches, which are undesirable (and in many cases forbidden by the banking regulation). This may not be a problem for countries in a monetary union, but for other emerging markets the most likely driver of changes in the banking sector's net foreign assets are actions of the respective central banks. Accordingly, once the monetary policy set-up no longer implies

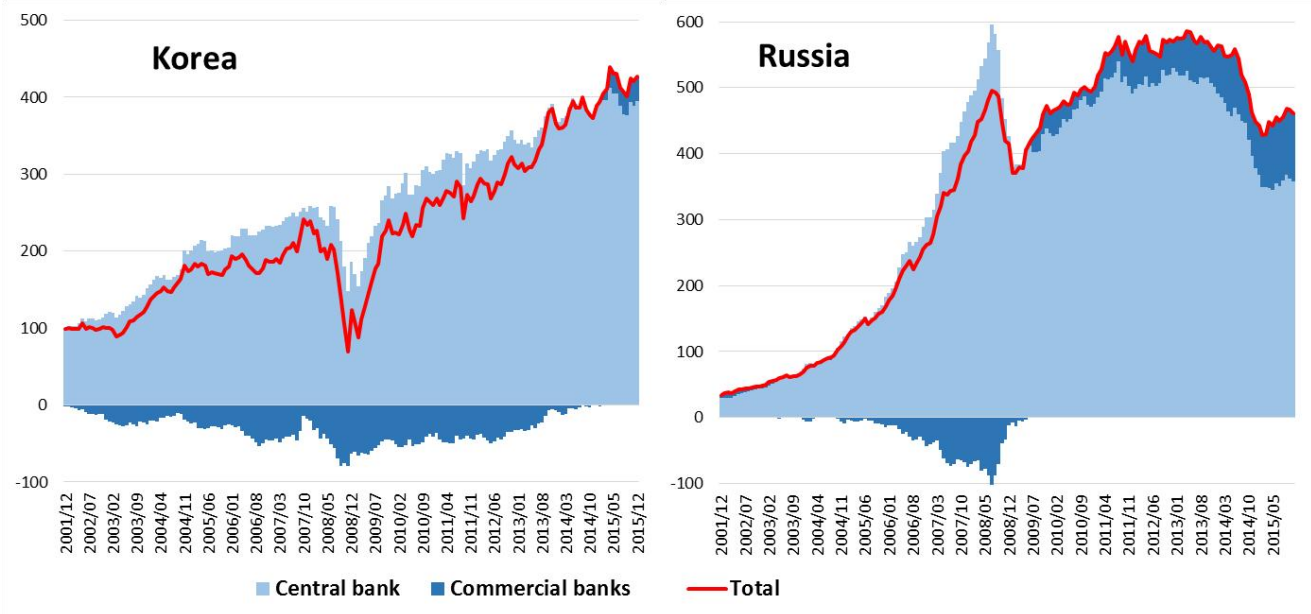
[4] For example, non-financial external transactions typically contributed to deposit creation in Germany prior to the crisis of 2008 (Kuzin and Schobert (2015)) whereas for the euro area as a whole money creation in 2013 -2014 was driven by both sizable capital inflows and a surplus in the current account. Chyung et al. (2015) note that borrowing by an overseas subsidiary that is used to cover costs of the domestic corporation will not be reflected in capital flow statistics. Such transaction will increase the current account.

[5] Alternatively, commercial banks may sell foreign reserves to the central bank. This will not change banking sector's net foreign assets or loans-to-deposits ratio. However, commercial banks' non-core liabilities ratio (as defined in e.g. Hahm et al. (2013)) will increase.

significant foreign exchange operations the role of external transactions in money creation diminishes.

We will further pursue this point by looking at two countries: Korea and Russia. These countries are illustrative because the net foreign assets in their banking systems changed significantly during the last several decades, albeit for different reasons. The Bank of Russia was managing its exchange rate prior to 2009 and accumulated a large amount of foreign reserves while preventing ruble appreciation in 2006-2008. The Bank of Korea, which had no explicit exchange rate target, used interest rate steering as its main monetary policy tool. Nevertheless, it also accumulated foreign reserves as a means of preventing future financial crises, carried out via sterilization interventions in the foreign exchange market. In both cases, the contribution of commercial banks to foreign reserves accumulation was limited, although they transitioned to positive net foreign reserves holdings in 2008-2010 in Russia and in 2013-2015 in Korea (Figure 1).

Figure 1. Net foreign assets of the banking system (bln. USD)



We proceed to a more detailed analysis of flow of funds for these two economies. For this purpose, we express deposit growth in terms of its counterparts on the banking sector balance sheet:[6]

$$\Delta D = \Delta C^{P} + \Delta NC^{G} + \Delta NFA + \Delta OTHER \quad (1)$$

[6] This approach, which is in line with money counterparts analysis, has been regularly presented in the ECB's Monthly Bulletins.

where D is bank deposits, C^P is credit to the private non-banking sector, NC^G is net claims on general government, NFA is net foreign assets of the banking sector and OTHER is the balancing item (notably including cash, equities and other instruments).

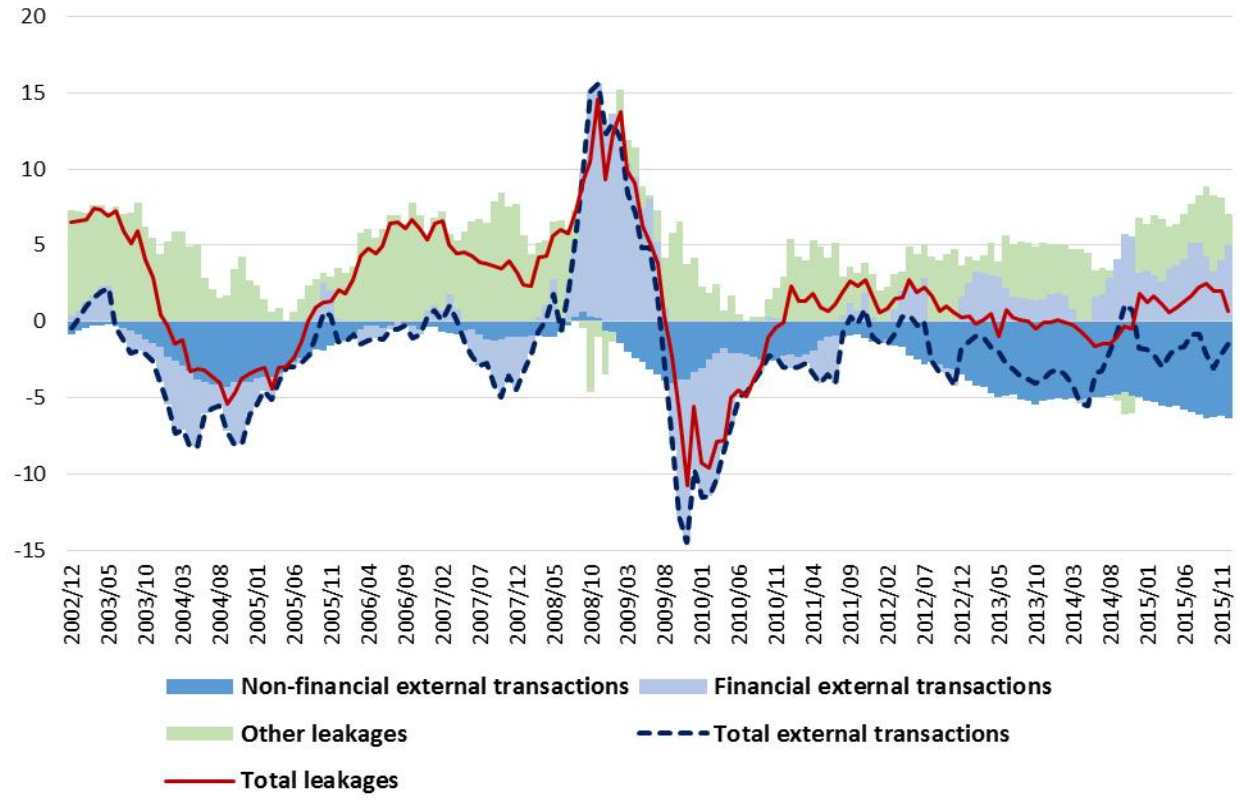
For convenience, we rewrite relationship (1). We replace ΔNFA by its counterpart: non-financial external transactions (NFET, proxied by current account surplus) and financial external transaction (FET, calculated as NFET-ΔNFA). For Russia, we also decompose ΔNC^G into net credit of commercial banks to the government (ΔC^G) and changes in liabilities of the Bank of Russia to the government that represent sovereign fund accumulation (ΔSF). Finally, we rearrange the balance sheet items to express the deposit leakages (difference between increases in credit and deposits).[7]

$$\underbrace{\Delta C^P + \Delta C^G - \Delta D}_{\text{Total leakages}} = \underbrace{FET - NFET}_{\text{Total external transactions}} + \Delta SF + \Delta OTHER \qquad (2)$$

We begin by examining the developments in these flows in Korea (Figure 2). In this economy, external transaction contributed significantly to money stock growth in 2004-2005 when both trade and financial channels generated an inflow of funds to the non-banking sector. In 2008-2009 drastic financial flows from/to the banking sector were also accommodated by the banking system. Starting from 2011 the deposit leakages produced by external transactions were limited, although the capital outflow from the commercial banking sector in 2013-2014 was offset by a larger current account surplus, which resulted in money creation.

[7] In this section we use data reported by the Bank of Korea and the Bank of Russia. We use changes in stocks to represent flows and adjust changes in net foreign assets for currency reevaluation effects.

Figure 2. Deposit leakages in Korea (flows over 12 months, % of deposits)



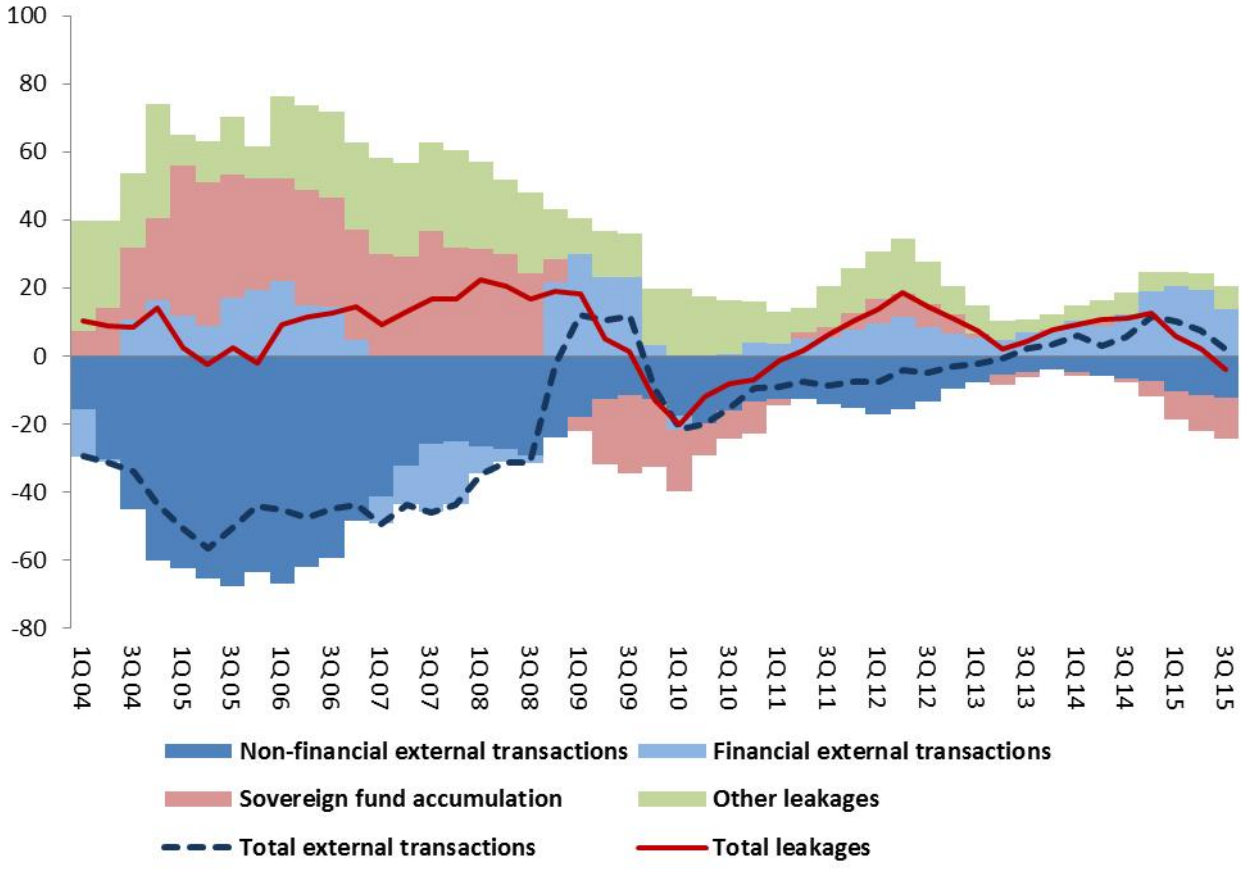
We now proceed to examine the flow of funds in Russia (Figure 3). Notably, external transactions played a very important role in money creation prior to 2009. A large current account surplus, which was not fully balanced by capital outflows, contributed significantly to the accumulation of funds in the non-banking sector. In fact, in 2007-2008 the inflow of funds occurred through both trade and financial channels. Conversely, in late 2008 and early 2009 external transactions resulted in monetary contraction. These developments were made possible by the Bank of Russia's managed exchange rate regime of that period. Foreign reserves were purchased to prevent ruble appreciation prior to the crisis of 2008 and sold during the financial turmoil in late 2008. After 2009 there was a gradual transition to a flexible exchange rate regime, which resulted in a balancing of financial and non-financial transactions of the non-banking sector and predetermined the decline of the role of the foreign sector (or at least of its transactions with the non-banking sector) in money creation. In the current circumstances, it is highly unlikely that, for example, an increase in the revenues of the Russian exporters will have any effect on money stock, since these flows will have be balanced by other outflows from the non-banking sector (i.e. an increase in imports or capital outflow). On the other hand, should Russian commercial banks increase their net foreign assets (e.g. by having to repay their foreign debt) the money stock increase will be predetermined since these outflows will be balanced by inflows to the non-banking sector (e.g. by means of a larger current account surplus).

Another peculiar source of deposit leakage in Russia is the sovereign fund. Its accumulation had a substantial restrictive effect on monetary expansion in 2005-2008. It has subsequently been used to finance fiscal deficits in 2009 and 2015. Consequently, countercyclical fiscal policy helped to create money during the contractionary phases of the credit cycle. Arguably, the sovereign fund proved to be a useful addition to both the monetary and fiscal policy toolkits.

Other leakages steadily contributed to deposit outflows. Predictably, these were larger during the credit boom of 2006-2008, when balance sheets were expanding very rapidly.

These two cases illustrate that it is not changes in commercial banks' net foreign assets, but rather changes in net foreign assets of the central bank, that accommodate money creation via external transactions. Once the presence of a central bank on the foreign exchange market diminishes, the net external transactions of the non-banking sector will become more balanced. In the above cases, this occurred via larger net capital outflows from the non-banking sector in both countries in 2011-2015 (as well as via deterioration of the current account surplus in Russia).

Figure 3. Deposit leakages in Russia (flows over 4 quarters, % of deposits)



The following research project that are based on the outlined methodology are part of this dissertation.

We discuss the implications of the link between money creation and changes of banking system's net foreign assets. We illustrate our argument by conducting canonical correlation analysis for a cross-section of emerging markets and presenting the flows of funds in Korea and Russia (Ponomarenko 2017).

We estimate the panel VAR models to analyse the behaviour of money counterparts (as opposed to analysing base money) which arguably gives additional insights on the mechanisms of money creation during foreign reserves accumulation (Ponomarenko 2019)

We develop a stock-flow-consistent microsimulation model that comprises all relevant mechanisms of money creation in Russia (i.e. credit creation, fiscal policy and external transactions). The model predicts that foreign reserve accumulation by a central bank (even when sterilized, meaning that it does not affect the short-term interest rates) will result in acceleration of commercial banks' balance sheet expansion rate. This happens due to an increase in money creation through external transactions that is not fully offset by the reduction in money creation through lending. Importantly, the parsimonious set-up of our microsimulation model (MSM) arguably gives us an opportunity to parametrize the model and predict the foreign exchange interventions' (FXIs) effect even without having to observe the realization of such a policy. We illustrate this point by applying our model to Russian data. We split our time sample into two sub-samples: the first sub-sample comprises the period of active foreign reserve accumulation by the Bank of Russia and the second comprises the period when this policy instrument was scarcely used. We estimate our model using one of the sub-samples and then use it to forecast the effect of commencement/termination of FXIs over another sub-sample. We estimate the MSM and use the model to produce out-of-sample projections of money and credit developments. We use direct forecasts from the MSM as well as the hybrid approach, which consists of using MSM-based artificial data to train the BVAR model (Khabibullin et al. 2022).

We set up a formal microsimulation model to examine in more detail the prerequisites under which it is beneficial for banks to react to changes in retail funding costs when setting loan rates. For this purpose, we used an agent-based approach. This method allows us to create a transparent and intuitively interpretable modeling setup. It is appropriate for implementing the learning algorithm, which is the key component of our analysis (Ponomarenko 2021).

4.2 Financial dollarization

We review some aspects of financial dollarization in Russia, applying the main relevant theories to analyze the dynamics of several dollarization indicators. An econometric model of the short run dynamics of deposit and loan dollarization is estimated for the last decade. We estimate the overall (and sectoral) currency mismatches of the Russian economy (Ponomarenko et al. 2013).

We have applied a modelling set-up developed to capture the hysteresis effect in dollarization for a panel of emerging markets. For this purpose we estimate a nonlinear relation that allows us to calculate the deposit dollarization equilibrium depending on its current value and the episodes of largest depreciation of national currency over the past five years (Krupkina and Ponomarenko 2017).

We use the behavioral concept to endogenously model the evolution of the link between households' deposit dollarization and exchange rate developments in Russia. We estimate the model empirically and show that the reaction of households to exchange rate appreciation weakens when exchange rate developments become more volatile (Khabibullin and Ponomarenko 2022).

We review the standard balance sheet mechanics of cross-border payments. Settlements in national currencies are understood to be the functioning of the bilateral foreign exchange market without the use of the banking system of a third country. Settlements should not be confused with the choice of the currency of trade contracts, the reserve currency, or the currency of domestic banking products (Ponomarenko 2023).

4.3 Exploring the link between monetary developments and key macroeconomic variables

4.3.1 Money and underlying inflation rate

We suggest an agent-based modelling approach where the parameters of firms' pricing heuristics are determined through evolutionary learning. In this modelling set-up the expected relationship between money growth and inflation is likely to emerge naturally (Deryugina and Ponomarenko 2021).

We set up a dynamic factor model in a state space representation which we estimated (over the dataset comprising 10 monetary and nine price variables) using Bayesian methods. Based on this model, we estimated the common part of the dataset's fluctuations which we further decomposed into a number of structural shocks. We extract the common part of the

dataset's fluctuations and decompose it into structural shocks (Deryugina and Ponomarenko 2017).

We compare the properties of the money-based underlying inflation measure with the set of alternative indicators. Namely, we calculated 20 underlying inflation measures, using four alternative approaches: exclusion, re-weighing, trimming and estimation of an unobservable trend on the basis of dynamic factor models. We assessed the obtained indices with tests characterizing three aspects of their properties: technical properties, usefulness for forecasting future inflation and economic interpretability (Ponomarenko et al. 2018).

4.3.2 **Credit cycle and potential output**

We specify a state-space model representing a multivariate HP filter that links cyclical fluctuation in GDP with several indicators of macroeconomic imbalances. The latter include financial variables as well as conventional CPI inflation and the unemployment rate. We obtain the parameterization of the model by estimating it jointly for a cross-section of emerging market economies (Deryugina et al. 2015).

4.3.3 **Credit cycle and natural rate of interest**

We set up an ad-hoc New Keynesian model and a tractable agent-based model. This allows our model to generate realistic credit cycles. It also means that the relationship between the interest rate and aggregate macroeconomic variables (e.g. output and inflation) varies across different phases of the credit cycle. Accordingly, the fluctuations in the implicit measures of the natural rate of interest (obtained using a simple linear model) may occur without any underlying changes in fundamentals (e.g. in the long-term growth potential or consumer preferences). We cross-check our findings using the empirical data (Deryugina et al. 2022).

4.4 Credit cycle models

We conduct Monte Carlo experiments to evaluate the reliability of credit gap measures estimated over time samples of different lengths. This approach allows us to generate a large number of artificial credit-to-GDP ratio series and examine the reliability of their trend-cycle decomposition under different circumstances (i.e. depending on the initial time sample availability and proximity to the change in the financial deepening process). The Monte Carlo approach is commonly applied for the analysis of output trend-cycle decomposition (see e.g. Nelson 1988, Basistha 2007, Gonzalez-Astudillo and Roberts 2016) and is not unprecedented for credit gap analysis (Drehmann and Tsatsaronis 2014). Our contribution to the literature in this regard is that instead of using a simple time series model as a data generator process, we employ

a structural agent-based model that is arguably well suited for credit cycle modelling (Deryugina et al. 2020).

We set up an early warning system for financial crises based on the Random Forrest approach. We use a novel set of predictors that comprises financial development indicators (e.g. the levels of credit to GDP ratio) in addition to conventional imbalances measures (e.g. the credit gaps). The evaluation of the model is conducted using a three-step procedure (i.e. over train, validation and testing sub-samples) (Ponomarenko and Tatarintsev 2023).

We employ conventional state-of-the-art early warning systems and apply them to the cross-section of emerging markets (Ponomarenko 2013, Deryugina and Ponomarenko 2019).

5. Contribution

5.1 Money creation

We discuss the money creation mechanisms with special focus on external transactions. We pay special attention to the analysis of emerging markets, as we believe there may be important differences here compared to the recent literature on advanced countries. In particular, we believe that the importance of external transactions in money creation may be conditional on the central bank's foreign reserves policy (Ponomarenko 2017).

Unlike most of previous studies in the field of sterilization of foreign exchange interventions in our paper we analyse the behaviour of money counterparts (as opposed to analysing base money) which arguably gives additional insights on the mechanisms of money creation during foreign reserves accumulation (Ponomarenko 2019).

We set up a stock-flow-consistent microsimulation model (MSM) that explicitly accounts for the process of money creation. Another novelty of our approach is the fact that we use our model in actual forecasting exercises. Note that, in the related literature, economically interpretable models usually only serve as a theoretical foundation for time series models. Even in rare cases in which structural models are estimated using actual data, they are not used to produce forecasts. Contrarily, we believe that the objective of forecasting the consequences of (previously unobserved) policy measures' implementation is particularly favourable for structural models in terms of competitiveness with time series models. We illustrate this point by producing out-of-sample forecasts of the effect of the changes in the Bank of Russia's foreign reserve policy on the money and credit supply (Khabibullin et al. 2022).

We examine a potential case of interdependence in loan and deposit interest rate-setting. For this purpose we set up a theoretical microsimulation model with endogenous loan interest rate determination via a learning algorithm. We show that in certain environments, it may be beneficial for large banks to incorporate information on retail funding costs into the lending rate-setting decision. The main novelty of our approach is that our model is based on the realistic money creation mechanism (Ponomarenko 2021).

5.2 Financial dollarization.

We obtain estimates of long-run dollarization levels using non-linear models in the spirit of Oomes (2003). Secondly, we measure the effect of the shift in the long-run equilibrium dollarization levels on short-run changes of dollarization by estimating standard linear models (e.g. Neanidis and Savva (2009)). To the best of our knowledge such approach was not applied before. We cross-check the results obtained with this two-step method by estimating threshold regressions (Krupkina and Ponomarenko 2017).

In order to model and predict the evolution of the relationship between exchange rate movements and deposit dollarization we set up a behavioral model that allows the households to switch between different strategies.We empirically estimate the model using the novel stochastic gradient variational Bayes with normalizing flows method. The model's performance is evaluated via a forecasting exercise and compared with the results obtained by employing a set of contemporary nonlinear time series models. The results indicate that the behavioral elements facilitated the model's faster adjustment to the new environment while the non-structural models required a relatively large number of observations to alter the parameters for the new regime. As far as we know this is a pioneering example of a practical application of behavior finance concepts in this area (Khabibullin and Ponomarenko 2022).

The current discussion centered around the transition to the international settlements that is based on national currencies often does not focus on specific elements of the international financial system but represent an eclectic set of considerations regarding various aspects of the ongoing transformation. This approach seems counterproductive, but it can be explained by the fact that the need to distinguish between different purposes for using reserve currencies may be unusual and that it may be difficult to do. We contribute to this discussion by examining in detail the modern mechanisms of international settlements. Understanding these mechanisms is a prerequisite both for setting the research goals effectively and, of course, for the correct formulation of relevant proposals and recommendations (Ponomarenko 2023).

5.3 Exploring the link between monetary developments and key macroeconomic variables

5.3.1 Money and underlying inflation rate

We suggest a modelling approach and show that in an agent-based model, the expected relationship between money growth and inflation is likely to emerge naturally. We show that in this environment, the set of the main lag-lead correlations presented in the literature may be recreated. To the best of our knowledge, this is the first paper that uses the micro approach to address this research question, although the paper is related to a broader strand of literature that studies the relationship between microeconomic structures and outcomes of money supply increases (i.e. the issues sometimes referred to as 'Cantillion effects') (Deryugina and Ponomarenko 2021).

We estimated a range of measures (including the novel money-based indicator) of underlying inflation in Russia and examined their performance by means of several tests used in practice by central banks and/or proposed in the academic literature in an attempt to find the best-performing indicators. To our knowledge, this paper presents the broadest set of examined measures among those applied to Russian data previously (e.g., in Dementiev and Bessonov (2012) and Tsyplakov (2004)) (Deryugina and Ponomarenko 2017, Ponomarenko et al. 2018).

5.3.2 Credit cycle and potential output

We present a model that incorporates the information contained in diverse variables when estimating sustainable output growth. For this purpose, we specify a state-space model representing a multivariate HP filter that links cyclical fluctuation in GDP with several indicators of macroeconomic imbalances. We obtain the parameterization of the model by estimating it over a cross-section of emerging market economies (Deryugina et al. 2015).

5.3.3 Credit cycle and natural rate of interest

The objective of this paper is to show that the fluctuations of the estimated natural rates of interest do not necessarily indicate changes in macroeconomic fundamentals. Note that the standard filters assume a constant linear relationship between interest rate, inflation and output. Therefore, if this is not the case and the models are misspecified, the standard approach will give indication of the changes in the unobserved trend value of the interest rate even when there is no change in the true data generating process. Interestingly, there is ample evidence on the instability of the relationship between the main macroeconomic variables depending on the state of financial conditions. Such instability cannot be captured by a simple linear relationship

between output, inflation and observed interest rate and will be accommodated by the fluctuations in the natural interest rate estimate.

These concerns are not unprecedented. In a related strand of research, Juselius et al. (2017), Krustev (2018) and Belke and Klose (2019) also claim that conventional models for natural interest rate estimation may be misspecified and augment them with financial variables. We contribute to this type of analysis by examining the properties of conventional natural interest over different phases of the credit cycle.

Admittedly, this task is extremely data demanding. We therefore augment purely empirical analysis with Monte Carlo experiments, which are commonly applied in the analysis of trend/cycle decomposition. This approach allows us to generate a large number of artificial credit cycles and examine the fluctuations of the natural rate of interest in the proximity of credit cycle peaks. Therefore, our contribution to the literature in this regard is that, instead of augmenting an ad-hoc filter model with financial variables, we employ a tractable theoretical model that is arguably well suited to credit cycle modelling (Deryugina et al. 2022).

5.4 Credit cycle models

We evaluate the reliability of credit gap measures estimated over time samples of different lengths. We augment our empirical analysis (which turned out to be somewhat inconclusive) with Monte Carlo experiments. For this purpose we build an agent-based model that realistically reproduces credit cycles and use it to generate the artificial data set. We also compare the properties of the standard credit gap measures estimated over time samples of different lengths with those of some alternative credit cycle indicators. Specifically, we test the 'projection gap' based on Hamilton (2018) and 20-quarter change in credit/GDP ratio (used in e.g. Jordà et al 2011, 2017) (Deryugina et al. 2020).

We develop an early warning indicators model by combining the traditional set of cyclical financial imbalances measures with the set of financial development indicators. The novelty of our approach is that for this purpose we use the machine learning algorithms in the spirit of Holopainen and Sarlin (2017), Alessi and Detken (2018), Beutel et al. (2019). Namely, we employ the Random Forest modelling approach, which is arguably well suited for capturing the potential non-linear relationship between financial development, financial imbalances and the probability of a financial crisis. We also use a substantially more demanding three-step procedure (i.e. training, validation and testing sub-samples) to validate our results (Ponomarenko and Tatarintsev 2023).

We contribute to the existing literature in several ways. Firstly, we concentrate on the applicability of credit gap-based early warning systems to the cross-section consisting exclusively of emerging market economies (25 in total). The sample obtained is large enough for interpretable econometric analysis, although its informational content is limited, since, for the most part, only one (most recent) wave of credit cycle peaks can be analysed. Therefore in order to verify our findings we apply the cross-sectional validation approach which is rarely used in the literature (Deryugina and Ponomarenko 2019).

We also contribute to the literature by investigating whether early warning indicator models that were initially estimated for advanced economies can be used for predicting asset price boom/bust occurrences in a cross-section of 29 emerging markets. We identify booms/busts using different approaches. The sample obtained is large enough for interpretable econometric analysis although its informational content is limited since, for the most part, only one (most recent) wave of booms/busts can be analysed (Ponomarenko 2013).

6. Main findings

6.1 Money creation.

In an emerging market (which is not in a monetary union) fluctuations in banks' net foreign assets are associated with changes in currency mismatches. Arguably, the scope of such fluctuations is thus limited unless driven by changes in the foreign reserves of the central bank. Under this assumption, the importance of external transactions for money creation in emerging markets may be conditional on the monetary policy set-up. We show that the role of external transactions in money creation has diminished under the flexible exchange rate regime in which the central bank is not trying to accumulate foreign reserves (Ponomarenko 2017).

We find that the accumulation of foreign exchange reserves by a central bank in emerging markets commonly leads to adjustment through the non-banking sector's transactions. We therefore conclude that it is very unlikely that in emerging markets broad money stock may be fully insulated from the effects of foreign exchange interventions. The existence of the described mechanism implies that the accumulation of foreign exchange reserves by a central bank (sterilized or not) is likely to create purchasing power. They may have an expansionary effect that is potentially inconsistent with the desired monetary stance. This effect should not be overlooked when assessing the macroeconomic consequences of foreign reserve accumulation policies (Ponomarenko 2019).

We develop a stock-flow-consistent microsimulation model that comprises all relevant mechanisms of money creation and parametrize it to fit actual data. The model is used to make out-of-sample projections of broad money and credit developments under the commencement/termination of foreign reserve accumulation by the Bank of Russia. We use direct forecasts from the miscrosimulation model as well as the two-step approach, which implies the use of artificial data to pre-train the Bayesian vector autoregression model. We conclude that the suggested approach is competitive in forecasting and yields promising results (Khabibullin et al. 2022).

The conventional view of banks' interest rate-setting strategy implies that decisions on deposit and loan rates may be made independently. There are seemingly good reasons for this approach. An alternative approach (stating that banks incorporate changes in retail funding costs into loan rate setting) assumes a bank's predetermined liabilities structure, which in turn requires that the availability of deposits automatically increases (decreases) when more (fewer) loans are granted. We argue that this may be partially true, considering that deposits are created via lending. However, this effect is noticeable only for big banks (with large deposit market shares), and in an environment where leakages from deposits into cash are small. Therefore, a complete pass-through of retail funding costs into loan rates is unlikely. The sensitivity of the aggregate loan demand to interest rates also encourages banks to incorporate information on retail funding costs into the loan rate-setting decision. This finding may provide important insights into the role of the banking sector's structure in the determination of monetary policy transmission, efficiency of regulation, and the effects of changes in bank funding composition on interest rates (Ponomarenko 2021).

6.2 Financial dollarization.

We found that, prior to transition to floating exchange rate regime, the ruble appreciation rate (against the USD and euro) was the main driving factor for the deposit de-dollarization that occurred and also for the later episodes of deposit dollarization. This means that exchange rate fluctuations in Russia are usually amplified by changes in currency preferences. Such behavior, together with substantial borrowing from abroad, has led to the large currency mismatches in the real sector's balance sheet. The banking sector may seem to be less vulnerable to exchange rate risk, but, after taking into account the fact that a large part of banks assets are claims on domestic unhedged borrowers, we conclude that not only the private nonbanking sector but also the banking sector was subject to currency risk prior to the financial crisis of 2007-2008. In conditions of financial turmoil (and ensuing capital-flow reversals and downward pressure on the

domestic currency), this situation could threaten the macroeconomic stability of the Russian economy (Ponomarenko et al. 2013).

We concluded that there may be two deposit dollarization equilibria for transition economies: a low one of about 15% and a high one of about 75%. When the yields on foreign and national currency deposits are equal, convergence towards higher dollarization begins when the 45-50% threshold is exceeded.Modelling short-run deposit dollarization shows that the transition from the low dollarization equilibrium to the high one results in a quarterly increase in the deposit dollarization ratio of 1.2 to 3 p.p. Estimations obtained via an alternative econometric method (threshold regression) confirmed the presence of two regimes in deposit dollarization (Krupkina and Ponomarenko 2017).

We argue that the behavioral concepts that address the issue of agents' endogenous switching between strategies is an appropriate tool to employ in these circumstances. We demonstrated that by estimating an empirical model that features two types of exchange rate expectations formation. The adaptive extrapolating approach proves to be misleading in the noisy exchange rate environment and is abandoned in such periods. This result suggests that adopting a floating exchange rate regime stabilizes rather than amplifies fluctuations in dollarization. Importantly, we argue that with the help of the behavioral model such analysis could have been made in pseudo-real time and show that the model's forecasts are more accurate than those of the time series models during the transition to the floating exchange rate regime (Khabibullin and Ponomarenko 2022).

International settlements in national currencies require as a bilateral foreign exchange market that does not make use of the banking system of a third country. This concept should not be confused with the choice of the trade contracts currency, the reserve currency, or the currency of domestic banking products. In the case of the effective functioning of bilateral foreign exchange markets and the possibility of arbitrage transactions, the transition to settlements in national currencies does not affect the exchange rate or monetary indicators. With an imbalance in bilateral cash flows, market mechanisms (e.g exchange rate fluctuations) prevent the systematic accumulation of foreign financial assets on the balance sheet of the banking system of one of the countries. In addition, there are quasi-market schemes in the foreign trade, which involve the accumulation of foreign financial assets on the balance sheets of specialised banking institutions (Ponomarenko 2023).

6.3 Exploring the link between monetary developments and key macroeconomic variables

6.3.1 Money and underlying inflation rate

We argue that there are several ingredients that result in the emergence of the lead-lag pattern. First, a realistic representation of the money creation mechanism is essential. Money should be created by lending and not be (entirely) driven by developments in the consumption goods market. Once created, new deposits circulate in the economy, influencing consumption via the wealth effect. Second, there must be considerable heterogeneity at the individual firm level in the associated changes in demand. In this model, these features are implemented via uneven distribution of newly created deposits and market search frictions (which may also be regarded as consumer preferences). If such uncertainty exists, immediate price adjustment to realized aggregate money growth is suboptimal, and firms rely on micro-level demand indicators. Arguably, both of these assumptions are realistic, intuitive and implicitly confirmed by empirical findings, such as those on the observed credit structure and intensity of product-specific price fluctuations (Deryugina and Ponomarenko 2021).

We set up a dynamic factor model in a state space representation which we estimated (over the dataset comprising 10 monetary and nine price variables) using Bayesian methods. Based on this model, we estimated the common part of the dataset's fluctuations which we further decomposed into a number of structural shocks. Importantly, one of the shocks has empirical properties (in terms of impulse response functions for example) that are fully in line with the theoretically expected money growth–inflation relationship, confirming that the process identified may have the capacity for economic interpretation. This process is relevant for the dynamics of CPI as well as other price indices (in particular for core inflation and housing prices). The leading properties of monetary shocks for prices are also observed. Therefore, it is possible to separate the inflationary developments that are associated with changes in money supply from shorter-lived shocks. The results obtained indicate that monetary factors had an accelerating effect on inflation prior to the recent financial crisis and a restrictive effect after it. Inflation fluctuations associated with shocks to food and administered prices were correctly filtered out as non-monetary (Deryugina and Ponomarenko 2017).

We calculated 20 underlying inflation measures, using four alternative approaches: exclusion, re-weighing, trimming and estimation of an unobservable trend on the basis of dynamic factor models. We concluded that underlying inflation measures calculated using the dynamic factor models (including the money-based underlying inflation measure) are the best performers according to formal tests. In particular, these indicators remained stable in the period

of price shocks in 2010 and 2012 but reflected greater inflationary pressure in 2007–2008 and its decrease in 2009. As a result, these indicators remained informative in all the periods with regard to future inflation dynamics in the medium term and were closely related to aggregate demand fluctuations. We believe these indicators possess the necessary properties for the purposes of monetary policy (Ponomarenko et al. 2018).

6.3.2 Credit cycle and potential output

The output gaps obtained based on the model that incorporates financial variables differ substantially from those calculated with the univariate version of the HP filter. Most notably, trend output growth rates are more stable and therefore more consistent with the notion of sustainable output. Cumulative output losses after the recession in 2008, estimated on the basis of a multivariate filter, are (unlike those estimated by using the univariate version) comparable with typical episodes reported in the literature. Employing the multivariate filter may thus help improve the real-time robustness of the model, although our approach is still quite sensitive to the end-point problem associated with the transformation of the imbalance variables (Deryugina et al. 2015).

6.3.3 Credit cycle and natural rate of interest

The simulation analysis predicts the existence of a certain pattern in the developments of natural interest rate measures in the vicinity of credit cycle peaks. The empirical analysis generally confirms the predictions of the theoretical model. The measures of the natural interest rate tend to increase prior to a credit cycle peak and decrease afterwards. The drop in the natural interest rates after the Great Financial Crisis does not appear to be dramatically different from those observed during previous credit crunch episodes. We conclude that the current decline in the measures of the natural rate of interest does not necessarily indicate changes in the macroeconomic fundamentals. Instead, it may simply reflect the innate properties of the measurement technique in the vicinity of credit cycle peaks (Deryugina et al. 2022).

6.4 Credit cycle models

We found that 12−15 years of available data is sufficient for the estimation of reliable credit gaps (i.e. the reliability of credit gap estimates will not improve substantially as more data are added to the sample). These results may be regarded as supportive for credit gap-based guidance for setting countercyclical capital buffers even in emerging markets, where the time samples of this length are generally available. In cases where only shorter time samples are present the growth-based measures may be preferable. The standard credit gap measure generally

outperforms the 'projection gap' based on Hamilton (2018) unless a very long time sample (at least 35-40 years) is available. A pronounced change in the underlying pace of financial deepening leads to the deterioration of the credit gaps' reliability. Nevertheless, the credit gaps remain useful in real-time identification of credit cycle phases even in the presence of such structural breaks. Attempting to exclude the pre-break observations from the time sample may be unadvisable as their presence still improves the credit gaps' reliability (compared to those obtained using a shorter time sample) (Deryugina et al. 2020).

The results' of our research indicate that combining financial imbalances and financial development indicators helps to improve the out-of-sample accuracy of the early warning system. The probability of a crisis is generally higher at later stages of financial development. The interaction between financial imbalances and financial development indicators is also captured by the model: as financial development increases, the crisis probability estimates become more sensitive to the fluctuations of financial imbalances indicators. Most importantly, this paper provides a practical tool that may be used by regulators in the evaluation of financial crisis risks. Arguably, the presented findings also convey important messages to regulators. The results confirm (albeit depending on interpretation) the potential destabilizing effect of financial development leading to systemic banking crises. The findings hence support the implementation of regulatory measures, such as capital requirements and access control to loans and deposits for financial institutions, in order to stabilize the system. The results show that regulation should not be unique but that it should take into account the degree of development of the country. Regulators should monitor credit developments closer as financial development of the economy progresses (Ponomarenko and Tatarintsev 2023).

Our results confirm that the standard credit gap indicator performs satisfactorily in real time. In fact we find that in emerging market economies it seems to be rather difficult to outperform this indicator by means of augmented multivariate models. This is our main finding. Nevertheless, we also report several indicators that may be useful in real-time identification of credit cycle's phase. Specifically, the growth rates of the credit-to-GDP ratio perform equally well as a stand-alone indicator, although there is no gain in combining them with the gap measure. We argue that credit growth is more likely to be unsustainable if accompanied by higher real growth rates. The robustness of real-time credit cycle determination may also be improved by monitoring banks' non-core liabilities, the financial sector's value added and (to a lesser extent) the change in the debt-service-ratio by means of a multivariate discrete choice model (although with a risk of overfitting the data) (Deryugina and Ponomarenko 2019).

Our results are generally inconclusive as to which exact approach to predicting asset price boom/bust is superior. But we argue that the concept that relies on monitoring the combined set of asset prices, real activity and financial indicators is widely applicable to emerging markets and its efficiency is confirmed under the different model setups. According to our estimates credit growth and investment (in either growth rates or ratio to GDP) turned out to be particularly reliable indicators for forecasting asset prices cycle. We also find that, in addition to this set of variables, early warning indicator systems for emerging countries may be augmented with capital flows indicators (Ponomarenko 2013).

7. Theoretical and practical implications

The theoretical significance of the developed monetary analysis tools are described in Section 6.

Practical results of the presented research were employed as part of the author's work at the Bank of Russia as well as during his stays as a visiting researcher at the European Central Bank, Bank of Finland and Bank for International Settlements.

8. Approbation of research results

The tools developed in the course of the presented research projects were put into practice during the author's work at the Bank of Russia as well as during his stays as a visiting researcher at the European Central Bank, Bank of Finland and Bank for International Settlements.

The results of the research were presented at more numerous conferences, including flagship conferences of the Society for Computational Economics, the Society for Economic Measurement, the Society for Economic Science with Heterogeneous Interacting Agents, International Symposium on Forecasting, ESCB Workshops on emerging markets, the HSE April conference, Russian Economic Congress.

9. List of author's original articles

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