EMPIRICAL VERSUS DSGE-DRIVEN MONETARY POLICY RULE: THE CASE OF UKRAINE

by

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A thesis submitted in partial fulfillment of the requirements for the degree of

MA in Economic Analysis

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Kyiv School of Economics

2020

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Abstract

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In the most recent history of Ukraine, reforms in the banking sector done by the NBU and Parliament of Ukraine had a growing interest in society. Moreover, in the 2016th, the NBU implemented new monetary policy regime concentrated on the inflation targeting. Because of the efforts are done by the policy-makers in Ukraine, the National Bank of Ukraine for the first time in the history received Transparency Award established by the Central Banking Journal. This thesis focused on the estimation and analysis of the NBU behavior in implementing a monetary policy with the use of GMM empirical estimation and estimation with DSGE. We find that the current regime is well in line with inflation targeting regimes, which just implemented such a policy. Empirical and computational estimation shows that the NBU has a significant and fast reaction on the deviations of the inflation from the targeted rate.

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ACKNOWLEDGMENTS

The author wishes to thank his family for their constant support and love throughout my process of writing this thesis. I also thank my thesis advisor, Olesia Verchenko, for her help, support, and so much needed critics of this work. I don't it is possible to put in words all my respect towards her and her time she spent with me.

I also would like to thank my classmates for being the best fellowship I've ever had in my life.

GLOSSARY

DSGE. Dynamic Stochastic General Equilibrium

NBU. National Bank of Ukraine

GMM. Generalized Method of Moments

HP. Hodrick Prescott filter

Fed. Federal Reserve

CNB. Czech National Bank

NBP. National Bank of Poland

IMF. International Monetary Fund

IRF. Impulse Response Functions

NKPC. New Keynesian Phillips Curve

Chapter 1

INTRODUCTION

The National Bank of Ukraine has gone through significant changes in recent years and wants to employ the most modern and sophisticated tools to achieve the most efficient monetary and macroprudential policy. Currently, this central bank has a mandate of price stability via inflation targeting with satellite goals of a strong financial system and efficient macroprudential policy. But how the NBU does achieves these goals? Is NBU doing efficient policy? In my thesis, I want to analyze the NBU's policy with inflation targeting regime. I estimate Taylor rule using the Generalized Method of Moments. Further, using data on Ukraine, I calibrate the DSGE model, which is focused on the banking sector. With DSGE, I estimate most optimal Taylor rule and compare both empirical and optimal rules under same DSGE framework. Finally, I show what information NBU takes into account with is the loss function of current monetary policy. Here, the loss function is a key concept as it shows the trade-off between setting up the appropriate interest rate for inflation targeting and volatility of output, inflation, and other economic variables. For this analysis, I use "R" programming language for econometrical estimation of Taylor rule on the Ukrainian data set. For performance estimation of Taylor rule, I use "Dynare" package for "MatLab" software.

However, economical and econometrical analysis of some policies can be done only on the relatively large samples due to issues with robustness how we can measure the efficiency of inflation targeting if persistency of effect can be observed only with a horizon of a couple of years — especially concerning the estimation of the NBU preferences. Normally, one is expected to estimate Taylor rule and New Keynesian Phillips Curve. In the case of Ukraine, small sample and high distortion of external shock make this task almost impossible.

Under various monetary policies, central banks taking into account a lot of information. Aggregating some of this information cannot be possible, and econometricians use various proxy variables and other approximations of different activities in the economy to perform an econometrical analysis. In monetary economics, researchers use an approximation for inflation targeting regime with so-called forward-looking Taylor rule. There is no available published literature on the estimation of Taylor Rule in Ukraine, and only a few articles on the DSGE model for Ukraine (Matveev 2018, Bondarenko 2018, Semko 2011). DSGE model, which analyzes and has a deep intuition behind monetary policy in Ukraine, has not been published.

Basically, For the performance test of these rules in the case of Ukraine, DSGE should include both monetary regime and the financial sector of Ukraine. I calibrate the DSGE model using the seminal paper by Gertler and Karadi (2011). Their framework includes banking sector with agency problem arising from return on investment and incentives of the bank to deviate from an optimal way of giving loans to firms. Even though a CB cannot directly influence on how commercial banks provide loans in each particular case, financial frictions which are arising from this agency problem affect the transmission mechanism of Central Bank's monetary policy.

The following four papers are the most important and relevant studies that my thesis is built on. First one is the original work of Gertler, Karadi (2011) that shows how the countries economic operate with a fragile banking system. In this model, Central Bank can use special credit policies to have an impact on the commercial bank's balance sheets. I provide a detailed description of the sophisticated structure of this model in the literature review. The second paper is the state-of-art paper by Orphanides and Wieland's (2011). Their paper provides a comprehensive guide on analysis and fine-tuning for robust monetary policies in New Keynesian models. The last two are papers of Clarida, Gali, and Gertler (1998, 2000). Both papers are interlinked and provide a solid ground on understanding how Taylor Rule should be estimated econometrically.

1.1 Motivation

Monetary policy in the NBU is focused on achieving the main target of the NBU – price stability. Inflation, together with GDP, unemployment, and interest rate of deposits and credits have been among the most widely discussed themes by economists. Households, firms, and governments keep a close look at the rate of inflation because of their expectations about future inflation influence their decisions on current and future investment as well as consumption.

In managing inflation, NBU uses a set of specific tools or channels which has an impact on the aggregate demand via the transmission process. The transmission mechanism is occurring as the lagged response of inflation and other economic variables to the actions of NBU. For example, it takes inflation from 7 to 11 quarters (Orphanindes 2001, Orphanides and von Norden, 2005) to reflect the effect of a shock coming from demand or supply sides in the economy. In many modern macroeconomic models, this lag is also referred to as price rigidities. The exact nature of rigidities is a hot discussion in macroeconomics. Firms do not change prices immediately on their goods in response to a movement in another economic variable like taxes. Frequently a change in price happens after large deviations in other macroeconomic variables like the economic output.

The most widely used approach in achieving price stability that deals with such complex behavior are "inflation targeting." The key instrument in inflation targeting is the short-term interest rate. The NBU keeps inflation in the desired corridor of values via rising or decreasing interest rate. Despite the high efficiency of this approach, it comes with a cost which economist call "inflation/disinflation cost."

Spill-overs occurring in the whole economy is enormous when the central bank changes the interest rate in line with their policy regime. Such aspects of the economy like output, wages, deposits, and credits on the balance sheets of commercial banks, domestic investment and FDI, exchange rate and many others are being affected by the interest rate. The knowledge on how to efficiently set the right interest rate to achieve the desired effect essential for a central bank. Also, the ability to anchor expectations of agents in an economy is closely related to the ability of the central bank to efficiently control inflation in the future.

For central banks interest rate is a key instrument for monetary policy. Taylor (1993) contribution led to the introduction of such a concept as interest rate smoothing. Smoothing works in the following manner – a central bank with a mandate on inflation or output targeting changes to interest rate gradually rather than immediately to the optimal level. Interest rate smoothing is the necessity in the economic environment. If a policymaker changes to interest rate often and by a lot, it would lead to substantial volatility in the economy and central bank will become the source of economic instability. Without interest rate smoothing effects of different factors in the economy may have a larger or smaller size or sometimes even uncertain, which makes work policy maker even more challenging. Taylor Rule became the paradigm of modern macroeconomics and the careful and sophisticated approach needed to be done to estimate right coefficients in the equation which would lead to interest rate rule as the best approximation for the NBU's inflation targeting regime.

The main forecasting model of the National Bank of Ukraine is the Quarterly Projection Model (QPM) which Simultaneous Equations Model similar to those in other central banks. Econometrically specified models are efficient but lacking theoretical grounds and cannot capture complex dynamics in the behavior of households or firms. However, many developed and developing countries use Dynamic Stochastic General Equilibrium (DSGE) models which provide higher transparency and microeconomically founded. Out of the list of the most advanced economies in the world, only one model is not DSGE based. This model is NMCM from ECB accompanied by three DSGE models (NAWM, CMR, EAGLE-FLI) though (Binder et al. 2017). Since the financial crisis in 2008, DSGE models received a great revision, and current state-of-art models include various mechanisms of the real economy. As was pointed out by one professor of economics in Chicago, "Good DSGE model can explain 80% of what happening in the economy." Precise estimation of Taylor Rule combined with a test of this rule in modern DSGE model that approximates Ukrainian economy is one of the most efficient ways to get results which captures complex dynamics occurring with the actions of NBU.

Chapter 2

LITERATURE REVIEW

2.1 Monetary policy

In the introduction, I slightly uncover what kind of challenges policymakers in central bank are facing. Each time when we are going through the crisis - economists and bankers see how imperfect our knowledge of the economy is. Great Recession has shown that many things in an economy we were previously relying on have shortfalls. Rational expectations sometimes are not that rational, which raises a question on the efficient regulation and approaches to measuring robust monetary policy. Most of the OECD countries have gone in one or another way through asset purchase programs, and many central banks could not anticipate the future consequences of such a program. Some central banks tried to deleverage their financial sector, some tried to boost the output, and some others tried to keep their exchange rate on the optimal level.

Orphanindes, Weiland (2013) and McCallum (1988), state that efficient monetary policy remains robust after the initial shock helps the economy to stabilize and performs well across similar type macroeconomic models. This is a statement made by the Fed/ECB economists who are in charge of the biggest economies in the world. Moreover, when we are talking about small economies like Ukraine, monetary policy becomes even more important. Ukraine going through the series of serious shocks and the NBU has very limited resources to keep the economy as stable as possible. Similarities between the NBU and the ECB are tractable in this paper. The ECB emphasizes price stability and well-anchored expectations of future inflation. This is almost in line with the NBU, which emphasizes price stability, obtaining trust as the efficient policy maker in Ukraine, as well as in financial and macro stability.

The authors mention that in 2006, the European Commission stating that the EU output is lower than it is potentially could be, but in reality, the EU was overheated due to high leverage. However, the ECB did not raise interest rate in 2006 to calm down the economy (Trichet 2008). Thus, the output gap potentially is a very important indicator of monetary policy. This statement was confirmed by Clarida et al. (2000) and Walsh (2003). On the other side, Orphanindes et al. (2000) and Orphanindes (2001) states that output gap is difficult to measure, since the potential output is something, which we cannot get in real terms and only approximate econometrically with various approaches, and estimates might be significantly different. Another difficulty in the estimation of the output gap is that real-time data comes with some delay and very often are subject to revisions. Policymakers make their decision based on the real data, and if a revision comes four months later, it could lead to significant changes in policy rules and jeopardize economic stability. Some approaches in measuring the output gap I provide in the section about Taylor Rule.

Nevertheless, when the economy goes through significant structural change, a precise estimation of the output gap could not work due to the economic regime shift. This is exactly the case of Ukraine - we are going through a series of reforms and new regulation dramatically changing the shape of the economy. It would become much easier to impose efficient monetary rule if the NBU knew the reliability of using the output gap in their actions. Orphanindes et al. (2000) solve this problem lowering coefficient on the output gap in the Taylor-style rule or rather concentrate on the output growth factor.

In designing monetary policy rules, policymakers solve an optimization problem to determine the optimal coefficients in Taylor Rule from the preferences of Central Bank. Such an approach or LQ (linear-quadratic) approach became classical as Rotemberg and Woodford (1998) showed that loss function for the central bank could be expressed from the second-order approximation of the household's utility. Their work directly relates the wealth of household to optimal monetary policy.

Further, this approach was extended by Benigno and Woodford (2011), who showed how a central bank could derive optimal policy for new DSGE models with forward-looking expectations. This is in line with typical models from IMF and Fed who believed that most effective monetary policy would work only under central bank commitment (Debortoli et al. 2014, 2016, 2017, Schmitt-Groh´e and Uribe 2007, Weiland et al. 2013, Blanchard 2016). Detailed analysis of the efficient models with elements of backward-looking expectations against forward-looking expectations done in Afanasyeva et al. (2016), which employed a set of different policy rules on the different type of models. This paper, along with Orphanindes and Weiland (2013) and Adalid et al. (2005), shows that models with forward-looking expectations, tend to favor outcome-based rules. Moreover, Afanasyeva et al. (2016) showed that little gain could be added if we estimate LQ with an additional set of financial variables like credit, credit growth and premium, leverage ratio, and asset prices.

Orphanindes (2013) estimate in the total of four models of monetary policy rules and test them across 11 different DSGE models of the Euro Area. Classical Taylor Rule, Gerdersmeier and Roffia (2004) rule, Model-specific forward rule, and Model-specific backward rule. The minimal loss for welfare achieved through the rule, which controls for forward-looking expectations rules such as Taylor rule and Model-specific rule. Further in the article, to understand which policy is more robust they perform Bayesian model averaging which is widely used in the model uncertainty environment (Levin et al. 2003, Brock et al. 2007, Kuester and Weiland 2010). This is a basic extension of usual Bayesian methods, takes the uncertainty of prior and posterior distributions, and delivers a robust estimation of the optimal monetary policy rule.

2.2 Taylor Rule

Unfortunately, academic research on the monetary policy in Ukraine is very scarce. I found only one paper on the estimation of Taylor rule on Ukraine done in IMF by McGettigan et al. (2013). Taylor rule is popular among macroeconomists for already 15 years and became a benchmark in setting up the policy rule for the central bank in modern macro modeling (Clarida et al. (1998, 2000), Smets and Wouters (2005, 2007), Hoffmann and Bogdanova (2012)).

Taylor (1993) estimated the first original rule on the data from the USA on how Fed was doing monetary policy in years 1987-1992 just to find the differences between Volcker and post-Volcker time. "Great Moderation" is a time when Volcker was a Chairman of Federal Reserve. The original rule was just a simple relation of short-term interest rate set-up by Fed and inflation, optimal interest rate, the difference between targeted inflation and real inflation, and output gap with all terms described in percent.

In the estimation of the Taylor rule, I will follow a-la Clarida et al. (1998) approach. This approach is to use the generalized method of moments (GMM), which is standard practice and was done in Chadha et al. (2004) for the USA, Jia (2011) for Sweden, Clarida et al. (2000), Siklos et al. (2004) for Germany. We should also differentiate that there are few types of Taylor rules (Clarida et al. 1998). The first type is backward-looking type where the central bank makes a decision based on the past output and inflation, forward-looking type rule where the central bank is setting up policy according to expected inflation or output. The third rule is hybrid, where we can combine variables from forward- and backward-looking rules. GMM method is the standard approach for estimating forward-looking and backward-looking rules (Gozgor 2012, de Losso 2012). Another approach used in estimation for a backward-looking rule with nonlinear least squares like Hoffmann and Bogdanova (2012) or ordinary least squares that done in original Taylor (1993).

For output, gap measures its standard approach to us Hodrick-Prescott filter. HP filter just an optimization problem, which takes some fixed period and solves optimization for a minimal variance over that period. This is the univariate filter that smoothing output over some time and difference between actual output and output by HP filter is the output gap (Orphanindes 2001, Stock and Watson 2007). There also various approaches like unobserved components (Harvey 1989), or Kalman filter. Some economist can use VAR-based approach (Blanchard and Quah, 1989) or production function approach in estimating the output gap (Giorno et al., 1995). However, extensive analysis of different types on measuring the output gap from Orphanindes and von Norden (2005) showed that HP filter is the best.

2.3 DSGE models

Tinbergen did a first macroeconomic model with mathematical foundations in 1936. Since then, many new exciting developments had taken place, but I would like to mention one of the most important. Work of Robert Lucas Jr. (1973) started a new era of Keynesian-type economics with agents that having rational expectations and inflation/output trade-off. The significance of his work led to a massive change in the different fields in the science of economics. Before Lucas work, the preliminary decision on monetary policy in a country was based on the large-scale macro-econometric models. However, these models cannot capture the change of consumer's behavior under different fiscal and monetary policies. Introduction of rational expectations in the analysis of inflation explains why the change of monetary policy may be ineffective due to the change in the preferences of firms and households. Sargent and Wallace (1975) show that agents with rational expectations can anticipate that the Central Bank would like to increase inflation to decrease the unemployment rate. Thus agents would setup prices according to the new information, and long-term unemployment rate won't change. Moreover, it has serious implication in modern monetary policies. Anchoring expectations to the optimal monetary policy level of inflation created a new framework in a Central Bank transmission mechanism (Christiano and Eichenbaum, 1992). Federal Reserve Chairman Paul Volcker started "Great Moderation" using anchoring expectations as a key target in 1979.

In the 1980s a new wave of economists started discussing some downfalls of economic models. Fischer, Mankiw, Ball, David Romer, Kydland, Prescott, Blanchard, Akerlof, and Yellen are the people behind the New Keynesian approach to economics. They show that effective monetary policy should account for different types of market failures, in particular into such phenomena as price rigidity. Under price rigidity, agents in the economy cannot adjust prices immediately after any change in the economic environment in which case prices in the market called "sticky." The especially important model was done by Calvo (1983) and since then has the name "Calvo pricing." Calvo pricing is the most widely used approach to model price rigidity even for modern macroeconomics of DSGE. In his work, he developed a hazard function that gives the probability that in economy some fraction of firms can fail to adjust prices to an optimal level which would create inefficiency in the market so that nominal inflation would be different from the optimal level targeted by the policymaker. It implies that monetary policy still has an impact even if agents in the economy expect a change in monetary policy.

Kydland and Prescott (1986) introduced the concept of Real Bussiness Cycles. RBC is the type of model where optimal monetary decision rules can be derived from the optimization problem faced by agents in the economy. Further development was done by mentioned Rotemberg and Woodford (1997) and led to so-called The New Neoclassical Synthesis, which unites New Keynesian models and RBC. Policy makers from the Bank of Canada and the Fed implemented in

New Keynesian models Quarterly Projection Model (Poloz et al. 1994) for Canada and FRB-US model (Brayton and Tinsley, 1996) for Fed. Combination of Calvo pricing model, the Taylor rule principle led to the creation of the first DSGE models in Clarida et al. (1999), McCallum et al. (1999).

The second generation of DSGE models comes with Christiano et al. (2005) who added utilization rate of physical capital in firms, investment adjustment costs, habit formation of households, heterogeneous expectations. A state-of-art design on second-generation DSGE modeling of Euro Area done in Smets and Wouters (2003)

After the Great Recession, a new wave of DSGE model appeared. These models include the financial sector. However, first financial frictions in DSGE model was pioneered by Bernanke et al. (1999) with his financial accelerator framework, the most influential model which includes banking sector is the model by Kiyotaki and Moore (2008), Adrian and Shin (2008), Gertler and Karadi (2011). Gertler and Karadi model is the most cited model with financial frictions provides both rigors of macroeconomic foundation and flavored intuition. Basically, this is a model of second-generation DSGE with an additional constraint. The agency problem is the information asymmetry between households and the banking sector as the supply of banking sector connected to the bank's net worth. At some point in time bank may divert part of his assets to the household who owns a bank. Chance on the deviation of bank depended on the bank profitability and expected return on capital.

Moreover, with such constraints, we can track credit spread between free interest rate proposed by the central bank and interest on credits at which banks lend money to firms. As of firms, they need a loan for the bank to acquire a new capital to produce goods which later will be sold to retail firms. In the absence of shock, the central bank does conventional monetary policy and has a similar structure as in Smets and Wouters or Eichenbaum models. But in the case of frictions in the financial sector, banks facing a problem as deposits of households decreasing and loss in financial capital, tightening credit channel to firms, and a significant downturn in the economy. This shock pushes the central bank to do an unconventional monetary policy because banks may require additional credit interventions from the authority. For me, it is a perfect type of model that I want to calibrate for the Ukrainian economy. Effects of banking leverage and bank's appetite for giving loans are more accessible to track in this model. I input my Taylor rule in this model and will be able to estimate Impulse Response Function across the economy.

Gerali et al. (2010) and Dib (2010) build another model which introduces regulation of the Bernanke (1999) type banking sector. In these models, banks take deposits and crediting firms but subject to the leverage ratio and amount of bank deposits, which is endogenously set up by the central bank. Similarly, Meh and Moran (2010) propose a framework in which bank capital is crucial to mitigate informational asymmetries in the banking sector. They assume a double moral hazard problem between banks, entrepreneurs, and households in the spirit of Holmstrom and Tirole (1997). As a result, the capital position of the bank governs its ability to obtain deposits, such that the bank capital channel amplifies business cycles.

Policymakers around the world already using DSGE models with financial frictions. For USA Chung et al. (2010), Del Negro(2013), for EU Christiano (2010, 2015), Dieppe (2011), IMF: Andrle et al. (2015). Ukraine goes through a cleaning and monitoring the banking sector. Impact of monetary policy from NBU on the whole economy and banks, in particular, is a crucial point in today's research.

Chapter 3

DATA

Majority of data taken from the NBU's website via the period from 1st of January 2010 till 1st of December 2018. In the NBU website, Ukraine's monetary and financial statistics are compiled by the Monetary and Financial Statistics Manual and Compilation Guide (IMF, 2016). However, macroeconomic data on Ukraine is very scarce. Before 2014 NBU had fixed foreign exchange regime, and volatility of policy rate had been very low. The NBU introduced inflation targeting regime in 2016, and from this particular period, we can estimate Taylor rule, which approximates decision making by the central bank in Ukraine. Frequently, in the estimation of Taylor rule economists using quarterly data, but in my case, I am using monthly data to increase the number of observations.

As a measure for the short-term nominal interest rate, I use the NBU key policy rate in annual terms. For inflation, I took two measures of the CPI index. First CPI index measures change in prices how to price change per particular is comparing to the same month in the previous year. The second type of CPI index is measured as a percentage change from the previous month. These two variables possess different dynamics and can be useful as estimators and instrumental variables. For foreign exchange, I use two variables: UAHUSD nominal rate, as well as a percentage change from the previous month of UAHUSD. UAHUSD is a good proxy for the nominal value of the domestic currency because the majority of transactions happens in. The last variable is the output gap. Unfortunately, data on Ukrainian GDP can be found only in the yearly and quarterly time series. I use proxy called Index of Key Sectors Output. (Here and further the NBU cited) Index of Key Sectors Output (from now on - IKSO) is a composite index of economic activity calculated by the National Bank of Ukraine. This index is used by the NBU as a proxy for GDP as well. IKSO covers such types of events as agriculture, industry (mining and manufacturing, electricity, gas, steam, and air conditioning supply), construction, trade (wholesale and retail trade turnovers), and transport (passenger and freight turnovers). IKSO calculation is aimed at getting leading estimates of GDP, given that the aggregated share of gross value added, created in the mentioned sectors, exceeds 50% of GDP. IKSO is calculated based on annual rates of output changes in all types of activities, included in a composite index, weighted by relevant weight factors. Weighted values represent contributions of every kind of business to the annual rate of change of IKSO. The sum of the respective contributions makes the yearly change of IKSO. The following formula is used for the calculations:

$$IKSO_{t,t-12} = \sum q_{i,t,t-12} w_{i,t-12} \tag{1}$$

Where $IKSO_{t,t-12}$ – an annual rate of change of IKSO in the month t, $q_{i,t,t-12}$ – annual change in output in i type of activity, $w_{i,t-12}$ – weight factor for i type of activity. Using the Hodrick-Prescott filter, I got detrended series for IKSO. Difference between actual output and Hoddrick-Prescott filter is the output gap. HP filter defined as:

$$\min_{g_t} \left\{ \sum_{t=1}^{T} (y_t - g_t)^2 + \lambda \sum_{t=1}^{T} [(g_t - g_{t-1}) - (g_{t-1} - g_{t-2})]^2 \right\} \tag{2}$$

and λ set to 14400.

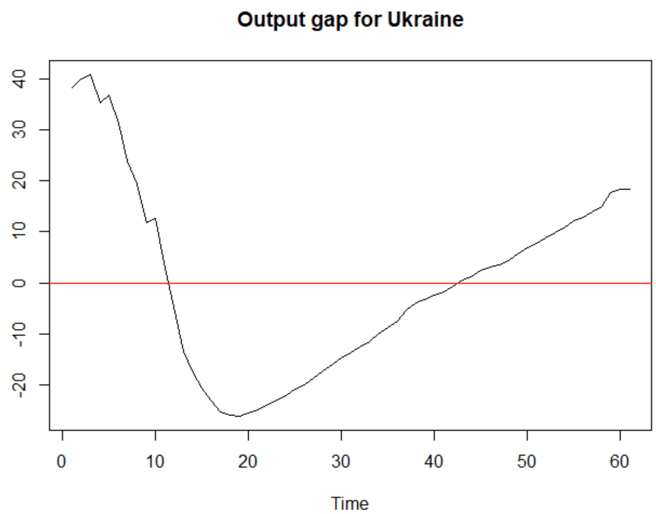

Figure 1. Output

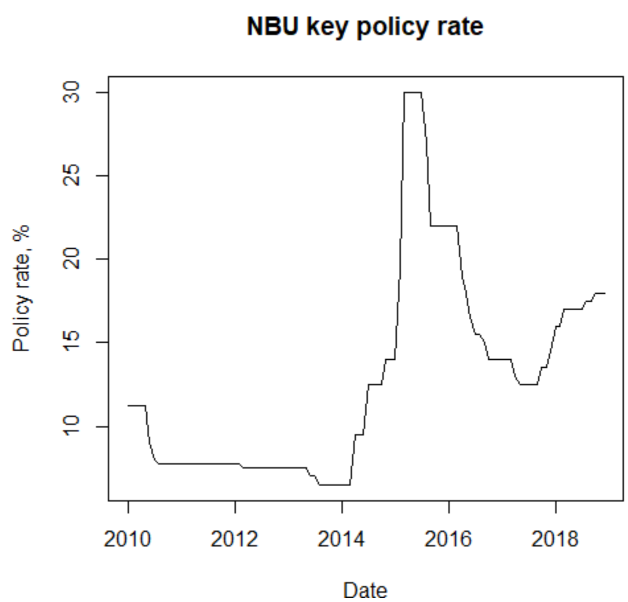

Figure 2. Dynamics of interest rate in Ukraine

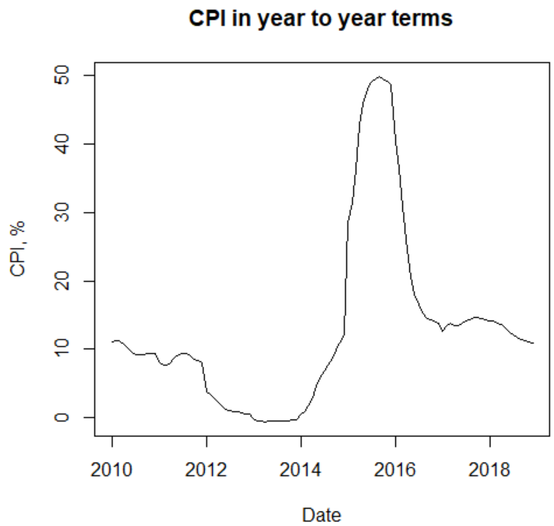

Figure 3. CPI yearly

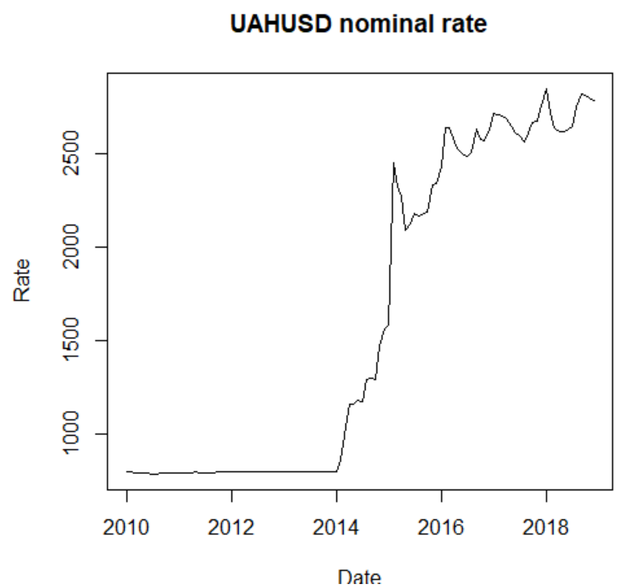

Figure 4. Nominal exchange rate

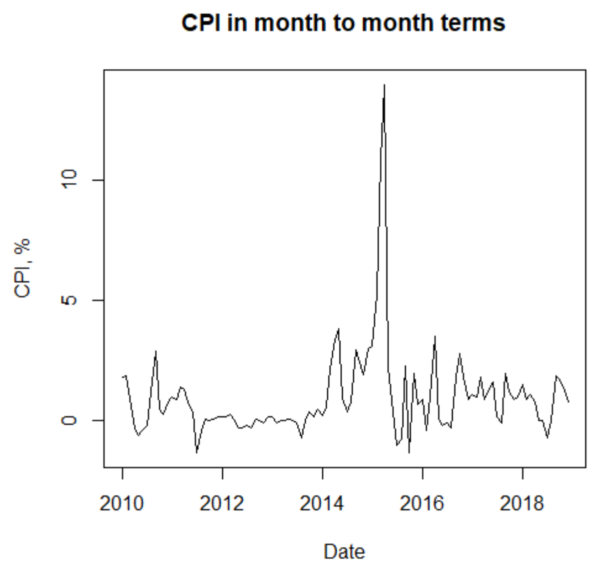

Figure 5. CPI monthly

Table 1. Descriptive statistics

	NBU's policy rate	Exchange rate	IKSO	CPI in monthly terms	CPI in yearly terms
Observations	108	108	60	108	108
Min	6,5	7,89	-26	-1,3	-0,6
Max	30	28,43	17,5	13,965	49,9
Range	23,5	20,5	43,5	15,265	50,5
Median	11,875	17,396	0,4	0,537	10,55
Mean	12,745	16,1	-2,353	1	13,11
SE mean	0,5913	8,2	1,188	0,188	1,28
CI 95% mean	1,17	16,26	-2,353	0,37	2,539
Variation	37,766	72,687	84,72	3,838	177,249

Table 2. Dickey-Fuller test

	DF	p-value
Interest rate	-2,6473	0,308
CPI yearly	-2,8464	0,2254
CPI monthly	-3,2341	0,08576
IKSO	-2,1217	0,5256
UAHUSD	-1,7342	0,6869
IKSO in levels	-3,8827	0,02054
T bills	-2,5877	0,3328

Alternative hypothesis: stationary

In 2014, the NBU decided to give up on the fixed exchange rate and turn the exchange rate into the floating rate. From the figures, we can conclude that the exchange rate of UAH depreciated in three times compared to 2013. In order to get the nominal value of the output gap, which we can see on the picture, I transformed data from the IKSO into the index of output with levels. Then, I applied the Hodrick-Prescott filter on the values of output to get the output gap. Figure with output gap shows that signs of economic stagnation could be observed even from 2011. External and internal shocks had drastically reshaped the economy of Ukraine. Variation of variables has a wide range. The initial look may show that it can be difficult to analyze monetary policy in Ukraine in the post-2014 period. However, I use a methodology which shows robust results.

Chapter 4

METHODOLOGY

4.1 Empirical tools

First of all, I need to find what is the Taylor rule for Ukraine with inflation targeting. But, a short time series is a problem. It would be complicated to get robust results. Moreover, since in forward-looking rule, I will have an endogenous explanatory variable. This happens due to the change in the future. To solve problems with non-linear parameters, I estimate time series with Generalized Method of Moments (GMM). GMM is an unbiased estimator for the left and right-hand side variables.

In fact, for us, it is very important to consider interest rate smoothing. Interest rate smoothing makes original Taylor rule as a non-linear equation. For example, Taylor rule that is linear in parameters and could be estimated with linear methods such as ordinary least squares or two-stage least-squares. However, because we include a smoothing parameter, parameters are nonlinear, which is a violation of the OLS-assumptions that ensure unbiased and consistent estimators. Hence non-linear estimation methods should be used in my context.

Because we use a forward-looking rule, we assume that the central bank considers the expected inflation in a future period when changing the interest rate, rather than current inflation. In Clarida, Gali, and Gertler (1998) when checking whether this is true, they find that for none of the central banks they look at, lagged inflation is statistically significant. Hence, they reject the backward-looking specification in favor of their forward-looking specification. When using a forward-looking rule, the expected explanatory variables will be endogenous, i.e., correlated with the error term at time t.

GMM can handle endogenous right-hand side variables in non-linear equations. It can also handle residual heteroskedasticity and residual autocorrelation in equations whose right-hand side variables are correlated with the disturbances. Also, GMM does not rely on strong distributional assumptions for the disturbances.

Clarida, Gali, and Gertler (1998) and Clarida, Gali, and Gertler (2000) start with a target rate i_t^*. What this means is that for each period, the central bank has a target for the nominal interest rate that they wish to get to. The target rate in period t is:

$$i_t^* = i^* + \beta\left(E\left(\pi_{t,k}|\Omega_t\right) - \pi^*\right) + \gamma * E\left(x_{t,q}|\Omega_t\right) \qquad 3$$

where i^* is the "equilibrium" nominal interest rate, i.e., the rate that prevails when both expected inflation and output is on target. $\pi_{t,k}$ is the annual inflation rate between period t and period $t + k$. Note that this implies that the inflation variable series will be slightly different for different horizons. $\pi_{t,k}$ is the average output gap between period t and period $t + q$. Also in this case variable series will be slightly different for different horizons. β and γ are the coefficients for the inflation gap and the output gap respectively, and Ω_t is the information set at time t. This means that the values of expected inflation and expected output is based on all the information the central bank has at that point in time. To simplify the model somewhat, we can introduce a constant term $\alpha = i^* - \beta\pi^*$, so that we get

$$i_t^* = \alpha + \beta E\left(\pi_{t,k}|\Omega_t\right) + \gamma * E\left(x_{t,q}|\Omega_t\right) \qquad 4$$

Now, transforming this equation to the original backward-looking model by setting k and q equal to -1. Setting q and k to be positive numbers will make the equation forward looking.

As there is no explicit horizon for the output gap, set it to be rather short. Hence q is set to 1 and 2 as Clarida, Gali and Gertler (2000).

From the previous equation, the interest rate target, which is decided by expected inflation, expected output, and a constant term. Including interest rate smoothing, we have to create an expression for the actual nominal interest rate. Hence some weight will be put on the target i^* and the rest will be decided by how important it is for the central bank to smooth interest rates, the size of ρ. For the objective function we then have:

$$i_t = (1-\rho)i_t^* + \rho i_{t-1} + v_t \qquad 5$$

Here, ρ is the smoothing coefficient. We also have an exogenous interest rate shock term v_t with zero mean. Now we can insert the target rate to get a rule for the actual nominal interest rate:

$$i_t = (1-\rho)\left(\alpha \; + \; \beta E(\pi_{t,k}|\Omega_t] + \gamma E(x_{t,q}|\Omega_t)\right) + \rho i_t - 1 + v_{1t} \qquad 6$$

(5) is the Taylor rule, which is used as monetary policy rule input into the DSGE model.

We can also check whether other variables have any effect on the interest rate, i.e., whether the NBU consider other variables when setting the interest rate. We can call this additional regressor h_t and its coefficient eta. What we do is to include the expected value of this additional variable to expand the target function and, we get a model specification for the empirical estimation on the data with GMM.

$$i_t = \alpha + \beta E(\pi_{t,k}|\Omega_t) + \gamma E(x_{t,q}|\Omega_t) + \eta E(h_t|\Omega_t) \qquad 7$$

The critical implication of the Generalized Method of Moments (GMM) is that it is efficient estimator on our small sample. Time series modeling (ARIMA, for example) is very dependent on the size of the sample since different information criterions used for lag significance becomes useful only with a large sample. On the other side, GMM allows making a stable assumption for the coefficients on the variables in the time series without the involvement of information criterions.

4.2 DSGE

The main framework of the DSGE model done by Karadi and Gertler (2011). They build a quantitative monetary model with banks that face endogenously determined balance sheet constraints. The authors use the model to analyze unconventional monetary policy measures. In this model, the continuum of heterogeneous household's utility has habit-adjusted consumption, and households dislike variations in consumption. Moreover, households can choose consumption and leisure. Households can postpone their consumption by holding money on the deposits with the financial intermediaries if certainty equivalence is satisfied. This leads to endogenous constrains of the banks such that the households choose the amount of deposits in such a way that guarantees that the bankers' incentive constraint is satisfied. Incentive constraint of the bank build in such way that bankers may shutdown the bank in any time and divert some amount of deposits into the banker's household. This agency problem can be used to introduce special mechanics when the financial system is fragile, and banks might go bankrupt due to the inefficient use of capital. In this case, the central bank has to intervene on the market just to keep control over the health of the financial system. Such mechanics is important in my case since the NBU doing both: monetary policy with inflation targeting regime as well as strict control of the banking sector in Ukraine. During the period, from 2014-2019 the NBU closed or to administer a large number of commercial banks in Ukraine.

The expected-lifetime utility of households maximized by choosing consumption and labor supplied to intermediate firms. The financial intermediaries issue contingent claims to firms, financed by deposits. Heterogeneous competitive firms produce intermediate goods using labor services supplied from households and capital, the latter of which is produced by a capital producer. Retail firms have monopolistic power and re-package intermediate output. Nominal frictions are introduced in the form of Calvo sticky prices. This leads that non-reoptimizing firm's index their prices to the previous period's inflation rate. Various shocks can be analyzed in the model. Capital quality shock, which affects the effective quantity of the capital stock. Monetary policy shock which is in an interest rate rule. Credit policy shock which represents monetary tightening or expansion towards balances of financial intermediaries. Shock in the net worth of banks. The fifth type of shock is a standard shock in total factor productivity. Authors keep the calibration of the conventional parameters in the same way as in Christiano, Eichenbaum, and Evans (2005). I am using pretty much the same setup for equilibrium. I have calibrated critical variables for a better fit of the Ukrainian economy. I have altered and added new lines in Dynare file to get two final pieces of information: solution of the optimization problem for an optimal Taylor rule in Ukraine and coefficients for the loss function of the NBU.

Some conventional parameters I keep unchanged. All variables related to government expenditures, monetary policy rule, and financial intermediaries calibrated for Ukraine. Data on government expenditures I took from the website globaleconomy.com. Lending interest rate from commercial banks, bank to capital assets ratio, and domestic credit provided by the financial sector are the data from the World Bank. A monetary policy rule is discussed in the previous section.

Table 3. Calibrated parameters

Param.	Description
1	Intertemporal elasticity of substitution
0,99	Discount rate
0,815	Habit parameter
3,4	Relative utility weight of labor
0,276	Inverse Frisch elasticity of labor supply
0,7805	The fraction of capital that can be diverted
0,02	Proportional transfer to the entering bankers
0,89	The survival rate of the bankers
0,33	Effective capital share
0,025	Steady-state depreciation rate
7,2	Elasticity of marginal depreciation with respect to utilization rate
1,728	Inverse elasticity of net investment to the price of capital
4,167	Elasticity of substitution
0,779	Probability of keeping prices fixed
0,241	Measure of indexation
0,2	Steady-state proportion of government expenditures
0,33	Steady-state labor supply
0,0025	Steady-state premium
4	Steady-state leverage
10	Credit policy coefficient
0,001	Costs of credit policy

In the original DSGE model, authors were not looking into central bank preferences. In my work, I extend the baseline model to find coefficients on the NBU's loss function. In the DSGE model, I treat estimated coefficients in the Taylor rule as exogenous. Then, Dynare approximates policy function with gradient descent technique and find a local minimum. This minimum represents a vector of optimal central bank preferences (which are the coefficients in loss function in our case). Below is the minimization problem for the endogenous coefficients ($\mu_\pi, \mu_x,$ and μ_i) in Central Bank preferences of the form:

$$W = E_t \left\{ \sum_{i=1}^{\infty} \beta^i L \right\} \quad (8)$$

Where loss function has the following form:

$$L = \sum_{t=0}^{\infty} \left\{ \frac{1}{2} [\mu_\pi (\pi_t - \pi^*)^2 + \mu_x (x_t - x^*)^2 + \mu_i (i_t - i^*)^2 \right\} \quad (9)$$

C h a p t e r   5

ESTIMATION RESULTS

5.1 Estimation of regressions

Estimation of the (6) provided the following results. First, results are the results of the baseline model with the lags of CPI, policy rate, and output lags as instrumental variables to avoid autocorrelation of errors in my model.

Table 4. Results of the initial regression. Baseline model (for the inflation targeting regime, 2016-2018):

Constant	Policy rate	CPI	Output gap	J-stat	P-value
1,290	0,879**	0,109**	-0,022	21,243	0,007
(0,879)	(0,0605)	(0,0141)	(0,016)		

Table 5. Results of estimation including exchange rate UAHUSD in levels (for the inflation targeting regime, 2016-2018 and)

Constant	Policy rate	CPI	Output gap	Exch. rate	J-stat	P-value
-2,110	0,823**	0,162**	-0,031*	0,009**	64,459	0,000
(1,256)	(0,075)	(0,0153)	(0,0152)	(0,0004)		

Table 6. Results of the estimation including Federal Reserve policy rate (2016-2018)

Constant	Policy rate	CPI	Output gap	Fed rate	J test	P stat,
-1,230	1,050**	0,166**	0,317**	4,878**	6,360	0,170
(3,08)	(0,167)	(0,069)	(0,0834)	(0,088)		

Table 7. Estimation results of the linear regression model

Constant	Policy rate	CPI	Output gap	F-stat.	R multip.	R adjust,
1,950	0,690**	0,166**	0,055	31,580	0,766	0,741
(2,4)	(0,2)	(0,06)	(0,067)	(0,0004)		

Results are quite in line with each other. Coefficients in the first estimation are in line with the standard coefficient in other estimated Taylor rules (Smets and Wouters 2007, Christianno 2005 and 2014) and shouldn't be a surprise. However, the output gap is insignificant. In general, the output gap parameter is insignificant in many empirical estimations of Taylor rule (see estimation of Taylor rule for Norway and Czech Republic). Significance can be achieved through some tuning of instrumental variables in the GMM estimation. Nonetheless, the output gap will appear in the estimation of Taylor rule with DSGE model. The low p-value in J-Test tells us that our model is well specified. Adding foreign exchange rate in second regression doesn't change much in our model. However, the exchange rate is significant. Also, I checked the Federal reserve rate as the additional regressor, but high p-value tells us that the model is misspecified or needs other instrumental variables. Just out of curiosity, I made OLS regression. In OLS coefficients are slightly different, but the significance is almost the same in my baseline model.

An interesting picture can be found once we compare fitted values from GMM with the actual policy rate setup form the NBU during inflation targeting. Black dots are fitted values of the baseline model, and the red line is the actual policy rate of the NBU. Fitted values taking into account forecast of inflation one quarter ahead has a small lag comparing to the actual rate set up by the NBU. From this observation, we can conclude that policymakers were responding to the change in inflation at a faster rate and were targeting inflation with policy rate effect on the one or two months ahead.

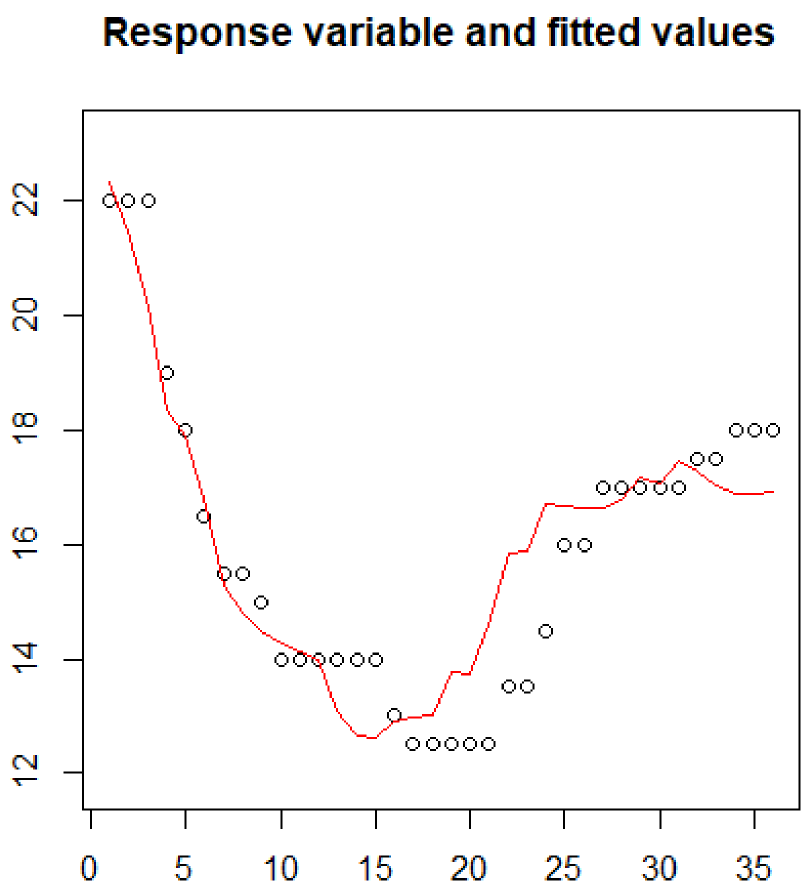

Figure 6. Estimation for the inflation targeting regime.

5.2 IRF and Central Bank loss function estimation

Let's discuss DSGE simulation of the monetary shock and description of variables from the output. The direction of shock is set to produce a downturn in the economy, and the NBU employs aggressive inflation targeting regime.

Estimation of this model in the Mat Lab environment provided following endogenous rule:

$$i_t = 0.05(0\pi_{t,t+1} + \ -0.51x_{t,t}) + 0.95i_{t-1} \qquad 10$$

Optimally, our interest rate smoothing parameter should be higher than we have now. More interesting is the coefficient for inflation, which is zero. We might be surprised by this, but further in the text, I will provide more information on this. The last one is the coefficient in from of output gap, which is negative and much higher than estimated empirically.

From the above, we can conclude that policy makers should favor higher smoothing parameters. High smoothing parameters benefits the economy due to the lower and more predictable magnitude of change in aggregate demand due to the changes in the policy rate. Moreover, policy makers should more aggressively react to the overheated economy since we have large coefficient in front of the output gap.

The coefficient for inflation is zero might be illogical. When I get this estimation, I set up coefficients in loss function to be equal to 1. However, in reality, we don't know how the loss function of the NBU looks like. We can resolve this model with exogenous coefficients in empirical Taylor rule to uncover what is the loss function of a central bank is.

These are the coefficients for loss function. $\mu_\pi = 1$ and tend to increase; $\mu_i = 1$ and tend to decrease; $\mu_x = 0.1$ and tend to increase. Tend to increase means that increasing μ_π above 1 would lead to a smaller loss compare, to decreasethe of this coefficient.

Determination of coefficients in loss function is not easy, and even slight change in parameters might lead to an infinite number of solutions and undetermined steady state. Higher reaction to the volatility of inflation is a vital part of inflation targeting. Countries, which just started inflation targeting, have a similar picture. For example, Norway had those coefficients around similar to Ukraine in 2011, once they implement inflation targeting.

Table 8. Comparison of the coefficients on a Loss Functions

	USA, Fed (2018)	CNB, IMF (2017)	NBP, Brzozowski (2004)	Norges bank (2011)	Ukraine (2019)
μ_π	1	1	1	1	1
μ_i	0,1	0,5	0,3	0,25	1
μ_x	0,25	1	1	0,1	0,1

Here is important to mention that these coefficients were estimated on the data when central banks just implemented inflation targeting. In each case, the authors treated the preferences of the central bank as constant. However, over time, preferences and loss function of policy makers changes together with the shape of the economy. Unfortunately, out of all countries, I compare only in Norway we can find a public report of the policy maker on their preferences. In reality, the central bank often changes loss function due to a different factor.

Interesting here that in my estimation, the NBU has put significant weight on the volatility of interest rate. For the period 2014-2015, we saw a significant a large changes in the interest rate. Of course, this happened due to different factors as Ukraine was on the edge of default. Once macroeconomic situation stabilized, changes in interest rate became moderate and targeted towards inflation.

I was surprised by the coefficient of the interest rate set up by the Fed. But it worth noting that this estimation was captured Quantitative Easing policy in the USA. The loss function for the Fed might have a different form than I imply in my thesis work. I wouldn't be surprised to see current loss function of the Fed where only inflation, output, and employment taking into account.

Graphs generated by Mat Lab can be found in Appendix 3. From those graphs, we can confirm our empirical estimation that the NBU is acting very aggressively towards deviation in inflation. The shape of the response of interest is similar to the inflation. Another interesting observation that the NBU sacrifice a large chunk of output to handle inflation. The decrease in output comes together with decrease in capital and investment on capital. Drop in available capital forces firms to increase utilization of the current capital and firms actively substituting labor for capital as the marginal value of capital increasing. On the other side, effective capital is decreasing at a higher rate. Drop in labor and welfare pushes households to reduce consumption up until the point when labor stabilizes, and households slowly adjust consumption. Another interesting observation is that financial intermediary's markup price exactly on the same share as inflation deviation.

Please note, as DSGE is not log linearized, I have taken exponents from the coefficients taken from Table 5.

Table 9. Description of DSGE's variables for the IRF

Variable	Description
Lambda	Stochastic discount rate
Rk	Return to capital
R	Real gross return for the household from the Deposit in bank
N	Bank net worth
Ne	Existing bank net worth accumulation
Nn	New banks net worth
nu	Value of banks capital
eta	Value of banks net wealth
phi	Optimal leverage for banks
Y	Final goods output
Ym	Wholesale, retail output (intermediate output)
K	Accumulated capital
Keff	Effective capital
L	Labor
I	Total investment by a capital producing firm
C	Total consumption by household
Q	Optimal investment decision (value of a unit of new capital)
varrho	Marginal Utility of Consumption
i	Interest rate
prem	The premium on the rent of capital
delta	Depreciated capital
In	Net investment
Welf	The welfare of the households
infl	Price index as Pt+1/Pt
inflstar	Optimal price for output goods
psi	Credit policy
QKg_Y	Bought capital value over GDP
z	The growth rate of banks capital
x	The growth rate of banks net wealth
Pm	Price of intermediate goods
w	Wages
VMPK	The marginal product of capital
U	Utilization rate
X	Mark up on the intermediate goods
F	Optimal reset price intermediate goods
Z	Discounted profit of the retailer

Chapter 6

CONCLUSIONS

I estimated Taylor rule for the NBU in the most recent policy regime in Ukraine. Additionally, I supplied my work with a computational estimation of the NBU's loss function using a monetary DSGE model with financial intermediaries that face endogenously determined balance sheet constraints. Empirical estimation with GMM even on the small sample has shown robust results which were expected. In the case when we cannot build neo-Keynesian Phillips Curve with empirical methods, a computational approximation can be a very efficient tool in analyzing monetary policy rules. After some time, we can obtain a large number of observations and compare loss function, which can be derived from NKPC and computational estimation from DSGE.

The NBU has achieved significant progress in controlling inflation within its inflation-targeting framework. This finding proved by the estimation from the DSGE. Policymakers put substantial efforts into fighting inflation that can be concluded from the weights of the NBU's loss function. Reduction of the weight on the variance of inflation would lead to a less subtle change of the policy rate, which is evident from both empirical estimation from GMM and computational estimation in Dynare.

The reactive response of the NBU on the deviation of inflation from the optimal level tells us that the NBU strictly following their mandate on the price stability. Another finding is that the NBU ready to sacrifice output in the economy to achieve a desirable level of prices. High interest rate smoothing parameter can tell us that the NBU may want to tell agents in the economy that they commit to the declared targets and in the same time anchor expectations of agents to their actions towards price stabilization.

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APPENDIX A. GENERALIZED METHOD OF MOMENTS

Basic principles of the GMM model nicely done in Chaussé (2010). In GMM model, I want to estimate a vector of parameters θ_0 from the model based on the following q × 1 vector of unconditional moment conditions:

$$E[g(\theta_0, x_i)] = 0 \qquad \text{A.1}$$

In general, the moment conditions $E[g(\theta_0, x_i)] = 0$ is a vector of nonlinear functions of θ_0 and the number of conditions is not limited by the dimension of θ_0. Since efficiency increases with the number of instruments q is often greater than p, which implies that there is no solution to

$$\bar{g}(\theta) \equiv \frac{1}{n}\sum_{i=1}^{n} g(\theta, x_i) = 0. \qquad \text{A.2}$$

Quadratic function $\bar{g}(\theta)^{\top} W \bar{g}(\theta)$ should be minimized in order to make A.2 close to zero, where W is a $q \times q$ matrix of weights. The optimal matrix W of efficient estimators can be written as:

$$W^{*} = \left\{\lim_{n\to\infty} Var(\sqrt{n}\bar{g}(\theta_0)) \equiv \Omega(\theta_0)\right\}^{-1} \qquad \text{A.3}$$

2

In this case, matrix W is heteroscedasticity and autocorrelation consistent (HAC) thus, optimal. This type of matrices were proposed by Newey and West (1987):

$$\hat{\Omega} = \sum_{s=-(n-1)}^{n-1} k_h(s)\Gamma_s(\theta^*) \quad \text{A.4}$$

$k_h(s)$ is a kernel, h is the bandwidth which can derive in the same way as it was proposed in Newey and West (1987) and Andrews (1991),

$$\hat{\Omega}_s(\theta^*) = \frac{1}{n}\sum_i g(\theta^*, x_i) g(\theta^*, x_{i+s})^\top \quad \text{A.5}$$

3

And θ^* is a convergent estimate of θ_0. There are many choices for the HAC matrix which rely on the kernel and bandwidth selection. However, any selevtion does not have an effect on the asymptotic properties of GMM. The GMM estimator $\hat{\theta}$ is therefore defined as:

$$\hat{\theta} = \underset{\theta}{\operatorname{argmin}}\, \bar{g}(\theta)^\top \hat{\Omega}(\theta^*) \bar{g}(\theta) \quad \text{A.6}$$

The original version of GMM proposed by Hansen (1982) is called two-step GMM (2SGMM). It computes θ^* is minimizing $\bar{g}(\theta)^\top \bar{g}(\theta)$. The algorithm is therefore:

1. Compute $\theta^* = \underset{\theta}{\operatorname{argmin}}\, \bar{g}(\theta)^\top \bar{g}(\theta)$.
2. Compute the HAC matrix $\widehat{\Omega}(\theta^*)$.
3. Compute the 2SGMM $\hat{\theta} = \underset{\theta}{\operatorname{argmin}}\, \bar{g}(\theta)^\top [\widehat{\Omega}(\theta^*)]^{-1} \bar{g}(\theta)$

APPENDIX B. DSGE MODEL BY GERTLER AND KARADI

Each household can be any of two types of members: workers and bankers. Workers supply labor and return the wages they earn to the household. Each banker manages a financial intermediary and similarly transfers any earnings back to the household. The household thus effectively owns the intermediaries that its bankers manage. The deposits it holds, however, are in intermediaries that is does not own.

At any moment in time, the fraction $1 - f$ of the household members are workers and the fraction f are bankers. Individual may switch between the two occupations. Worker can become a banker in any period with probability θ. Survival time for a banker in any given period is thus $1/(1-\theta)$. Thus every period $(1-\theta)f$ bankers exit and become workers. Bankers who exit the market, give their retained earnings to their respective household. On the other hand, provides its new bankers with some start up funds.

Let C_t be consumption and L_t family labor supply. Then households' preferences are given by

$$\max E_t \sum_{i=0}^{\infty} \beta^i \left[\ln(C_{t+i} - hC_{t+i-1}) - \frac{\chi}{1+\varphi} L_{t+i}^{1+\varphi} \right] \quad \text{A.7}$$

with $0 < \beta < 1, 0 < h < 1$ and $\varphi, \chi > 0$. As in CEE and SW, we allow for habit formation to capture consumption dynamics. Both intermediary deposits and government debt are one period real bonds that pay the gross real return Rt from $t-1$ to t. In the equilibrium, the instruments are both riskless and are thus perfect substitutes. Let B_{t+1} be the total quantity of short term debt the household acquires, W_t, be the real wage, $P_t$net payouts to the household from ownership of both non-financial and financial firms and, T_t lump sum taxes. Then the household budget constraint is given by

$$C_t = W_t L_t + \Pi_t + T_t + R_t B_t - B_{t+1} \qquad \text{A.8}$$

Note that P_t is net the transfer the household gives to its members that enter banking at t. Let R_t denote the marginal utility of consumption. Then the household's first order conditions for labor supply and consumption/saving are standard:

$$\varrho_t W_t = \chi L_t^{\varphi} \qquad \text{A.9}$$

with

$$\varrho_t = (C_t - hC_{t-1})^{-1} - \beta h E_t (C_{t+1} - hC_t)^{-1} \qquad \text{A.10}$$

and

$$E_t \beta \Lambda_{t,t+1} R_{t+1} = 1 \qquad \text{A.11}$$

with

$$\Lambda_{t,t+1} \equiv \frac{\varrho_{t+1}}{\varrho_t} \qquad \text{A.12}$$

Financial intermediaries are channeling funds from savers to investors. Banks hold long-term assets and fund these assets with short-term liabilities. Let N_{jt} be the amount of wealth – or net worth – that a banker/intermediary j has at the end of period $t+1$. B_{jt+1} the deposits the intermediary obtains from households, S_{jt} the quantity of financial claims on non-financial firms that the intermediary holds and Q_t the relative price of each claim. The intermediary balance sheet is then given by

$$Q_t S_{jt} = N_{jt} + B_{jt+1} \qquad \text{A.13}$$

Household deposits with the intermediary at time t, pay the non-contingent real gross return R_{t+1} at $t+1$. Thus B_{jt+1} is the intermediary's debt and N_{jt} as its equity capital. Intermediary assets earn the stochastic return R_{kt+1} over this period. Both R_{kt+1} and R_{t+1} will be determined endogenously. Over time, the banker's equity capital evolves as:

$$N_{jt+1} = R_{kt+1}Q_tS_{jt} - R_{t+1}B_{jt+1}$$
$$= (R_{kt+1} - R_{t+1})Q_tS_{jt} + R_{t+1}N_{jt} \quad \text{A.14}$$

Any growth in equity above the riskless return depends on the premium $(R_{kt+1}-R_{t+1})$ the banker earns on his assets, as well as his total quantity of assets, Q_tS_{jt}.

Let $\beta\Lambda_{t+1}$ be the stochastic discount the banker at t applies to earnings at $t+1$. Bankers, to operate in period i the following inequality must apply:

$$E_t\beta^i\Lambda_{t,t+1+i}(R_{kt+1+i} - R_{t+1+i}) \geq 0;\ i \geq 0 \quad \text{A.15}$$

An intermediary can earn a risk-adjusted return that is greater than or equal to the return the household can earn on its deposits; it pays for the banker to keep building assets until exiting the industry. Banker's objective is to maximize expected terminal wealth, given by

$$V_{jt} = \max E_t\sum_{i=0}^{\infty}(1-\theta)\theta^i\beta^{i+1}\Lambda_{t,t+1+i}(N_{jt+1+i}) \quad \text{A.16}$$
$$= \max E_t\sum_{i=0}^{\infty}(1-\theta)\theta^i\beta^{i+1}\Lambda_{t,t+1+i}[(R_{kt+1+i}$$
$$- R_{t+1+i})Q_{t+i}S_{jt+i} + R_{jt+1}N_{jt+i}]$$

In any period $\beta\Lambda(R_k)$ is positive; the intermediary will want to expand its assets indefinitely by borrowing additional funds from households. At the beginning of the period, the banker can choose to divert the fraction λ of available funds from the project and instead transfer them back to the household of which he or she is a member. The cost to the banker is that the depositors can force the intermediary into bankruptcy and recover the remaining fraction $1-\lambda$ of assets.

So, the following incentive constraint must be satisfied:

$$V_{jt} \geq \lambda Q_t S_{jt} \qquad \text{A.17}$$

The left side is what the banker would lose by diverting a fraction of assets. The right side is the gain from doing so. We can express V_{jt} as follows:

$$V_{jt} = \nu_t \cdot Q_t S_{jt} + \eta_t N_{jt} \qquad \text{A.18}$$

with

$$\upsilon_t = E_t\{(1-\theta)\beta\Lambda_{t,t+1}(R_{kt+1} - R_{t+1}) + \beta\Lambda_{t,t+1}\theta x_{t,t+1}\nu_{t+1}\} \qquad \text{A.19}$$

$$\eta_t = E_t\{(1-\theta) + \beta\Lambda_{t,t+1}\theta z_{t,t+1}\eta_{t+1}\}$$

where $x_{t+i} = Q_{t+i}S_{jt+i}/Q_t S_{jt}$, is the gross growth rate in assets between t and $t + i$, and z_t is the gross growth rate of net worth. The variable υ_t has the interpretation of the expected discounted marginal gain to the banker of expanding assets $Q_t S_{jt}$ by a unit, holding net worth N_{jt} constant, and while η_t is the expected discounted value of having another unit of N_{jt}, holding S_{jt} constant. With frictionless competitive capital markets, intermediaries will expand borrowing to the point where rates of return will adjust to ensure υ_t is zero. We can express the incentive constraints as

$$\eta_t N_{jt} + \upsilon_t Q_t S_{jt} \geq \lambda Q_t S_{jt} \qquad \text{A.20}$$

If constraint binds, then the assets the banker can acquire will depend positively on equity capital:

$$Q_t S_{jt} = \frac{\eta_t}{\lambda - \upsilon_t} N_{jt} = \phi_t N_{jt} \qquad \text{A.21}$$

where ϕ_t is the ratio of privately intermediated assets to equity or leverage ratio. Holding constant N_{jt}, expanding S_{jt} raises the bankers' incentive to divert funds.. Given $N_{jt} > 0$, the constraint binds only if $0 < \upsilon_t < \lambda$. In this instance, it is profitable for the banker to expand assets (since $\upsilon_t > 0$). Note that in this circumstance the leverage ratio that depositors will tolerate is increasing in υ_t. The larger is υ_t, the greater is the opportunity cost to the banker from being forced into bankruptcy. If υ_t increases above λ, the incentive constraint does not bind so the franchise value of the intermediary always exceed the gain from diverting funds. In the equilibrium, under reasonable parameter values the constraint, always binds. Evolution of the banker's net worth is

$$\eta_t N_{jt} + \upsilon_t Q_t S_{jt} \geq \lambda Q_t S_{jt} \quad \text{A.22}$$

Importantly, all the components of ϕ_t do not depend on firm-specific factors. Thus we can obtain

$$Q_t S_t = \phi_t N_t \quad \text{A.23}$$

where S_t reflects the aggregate quantity of intermediary assets and N_t denotes aggregate intermediary capital. In the general equilibrium of modethe l, variation in N_t, will induce fluctuations in overall asset demand by intermediaries. Indeed, a crisis will feature a sharp contraction in N_t.

After derivations the following equation of motion for N_t:

$$N_t = \theta[(R_{kt} - R_t)\phi_{t-1} + R_t]N_{t-1} + \omega Q_t S_{t-1} \quad \text{A.24}$$

For intermediate firms, we are applying the following conditions:

Production function

$$Y_t = A_t(U_t \xi_t K_t)^{\alpha} L_t^{1-\alpha} \qquad \text{A.25}$$

Return on capital

$$R_{kt+1} = \frac{[P_{mt+1}\alpha \frac{Y_{t+1}}{\xi_{t+1}K_{t+1}} + Q_{t+1} - \delta(U_{t+1})]\xi_{t+1}}{Q_t} \qquad \text{A.26}$$

Where Q_t is the effective unit of capital. Efficiency is given by utilization rate of capital U, and δ is the depreciation rate of capital.

Discounted profits for capital producing firms is given by

$$\max E_t \sum_{\tau=t}^{\infty} \beta^{T-t} \Lambda_{t,\tau} \{(Q_\tau - 1)I_{n\tau} - f\left(\frac{I_{n\tau} + I_{ss}}{I_{n_{\tau-1}} + I_{ss}}\right)(I_{n\tau} + I_{ss})\} \qquad \text{A.27}$$

with

$$I_{nt} \equiv I_t - \delta(U_t)\xi_t K_t \qquad \text{A.28}$$

Where I is the investment and I_{ss} denotes steady state investment rate.

Retail firms problem is set to choose the optimal price P_t^*

$$\max E_t \sum_{i=0}^{\infty} \gamma^i \beta^i \Lambda_{t,t+i} [\frac{P_t^*}{P_{t+i}} \prod_{k=1}^{i} (1+\pi_{t+k-1})^{\gamma_p} - P_{mt+i}] Y_{ft+i} \qquad \text{A.29}$$

π_t is inthe flation rate. Evolution of prices in the levels given by the Calvo pricing scheme:

$$P_t = [(1-\gamma)(P_t^*)^{1-\varepsilon} + \gamma(\Pi_{t-1}^{\gamma_p} P_{t-1})^{1-\varepsilon}]^{\frac{1}{1-\varepsilon}} \qquad \text{A.30}$$

Government resource constraints are the following:

$$Y_t = C_t + I_t + f\left(\frac{I_{nt} + I_{ss}}{I_{n_{t-1}} + I_{ss}}\right)(I_{nt} + I_{ss}) + G + \tau \psi_t Q_t K_{t+1} \qquad \text{A.31}$$

Capital evolves with the following rule:

$$K_{t+1} = \xi_t K_t + I_{nt} \qquad \text{A.32}$$

Government expenditures financed by lump-sum taxes and government intermediation

$$G + \tau\psi_t Q_t K_{t+1} = T_t + (R_{kt} - R_t)B_{gt-1} \qquad \text{A.33}$$

With government bonds, B_{gt-1}, finance total intermediate assets, $Q_t \psi_{t-1} S_{t-1}$

Monetary policy rule provided by the Taylor rule from the specification provided before in my thesis. In this DSGE model, the steady state output provided by the frictionless economy. The link between nominal and real interest rate is given by Fisher relation:

$$1 + i_t = R_{t+1} \frac{E_t P_{t+1}}{P_t} \qquad \text{A.34}$$

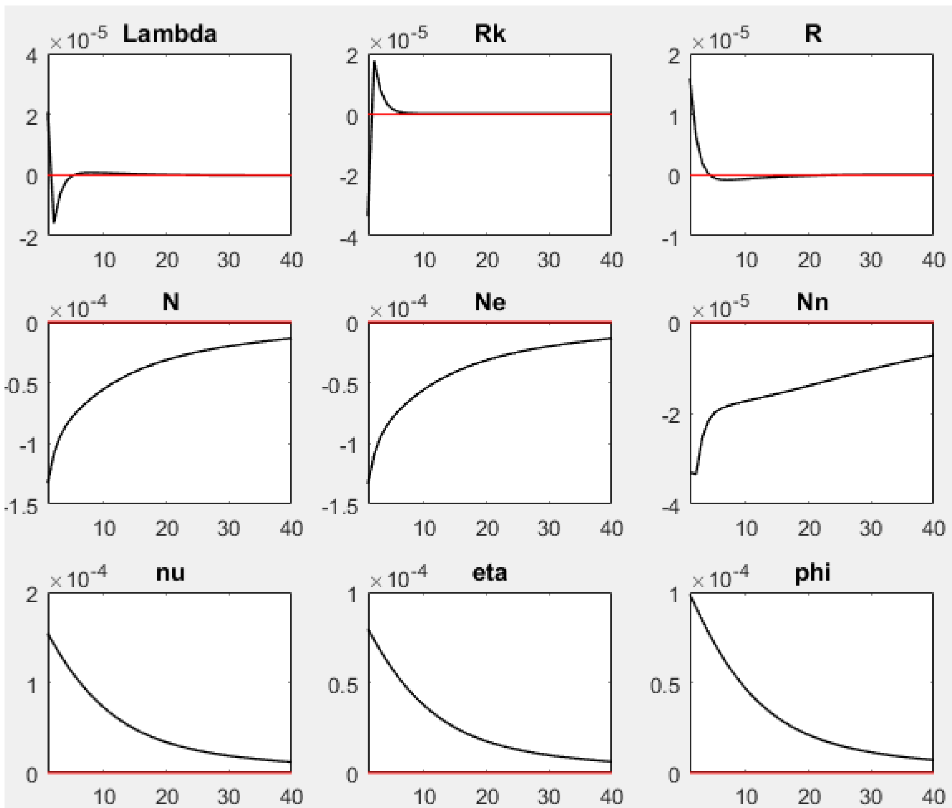

Figure 7. IRF for the current monetary policy

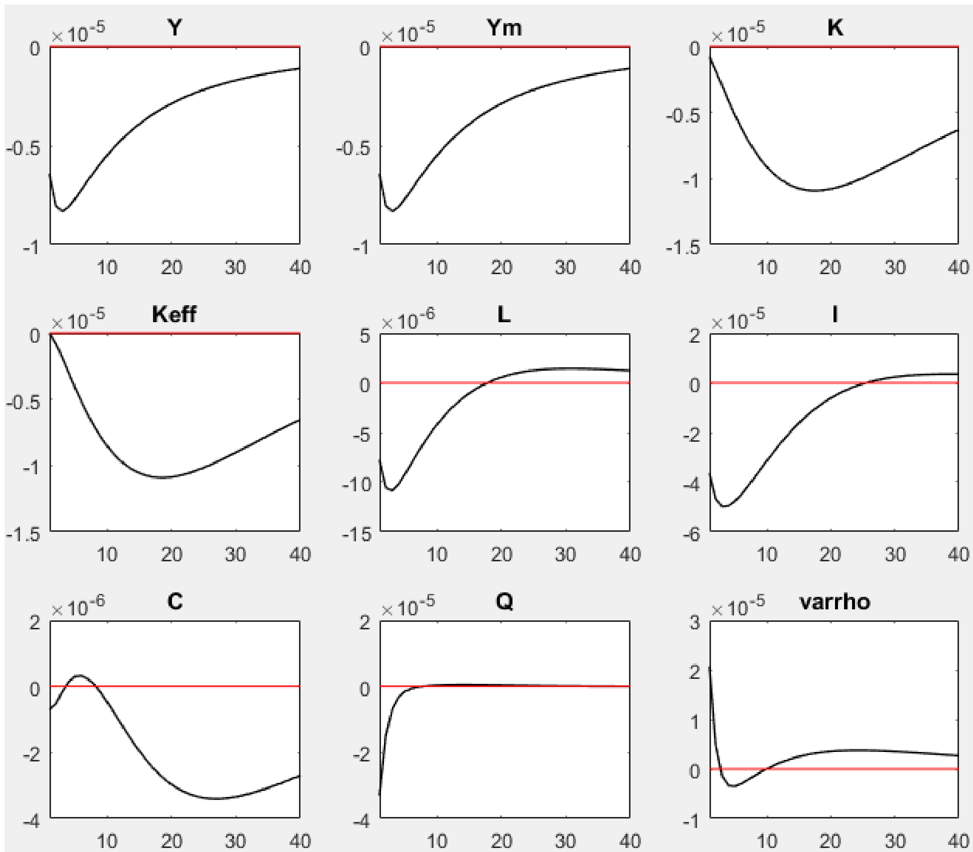

Figure 8. IRF for the current monetary policy

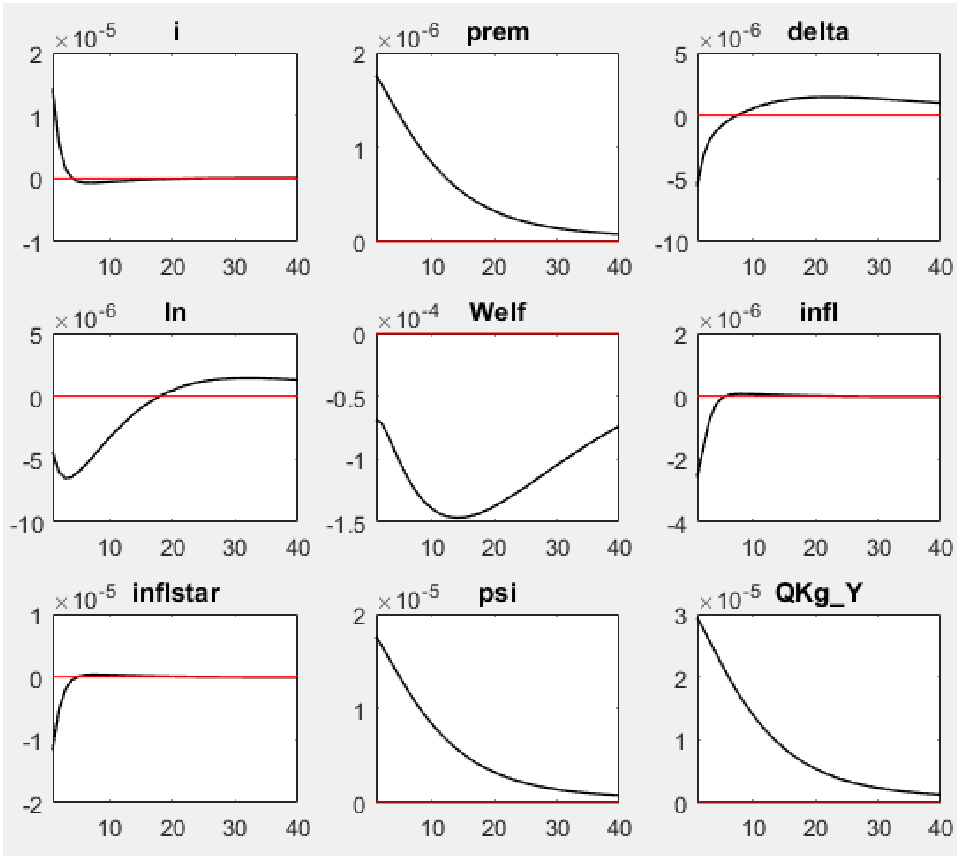

Figure 9. IRF for the current monetary policy

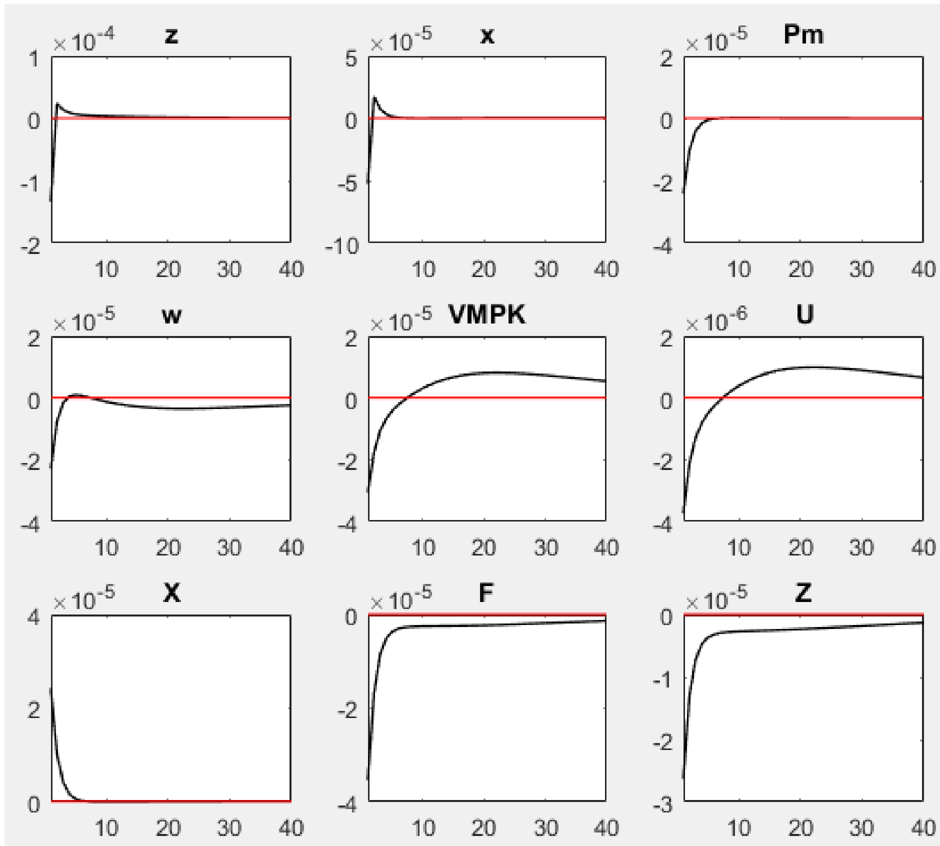

Figure 10. IRF for the current monetary policy