

NATIONAL BANK OF GEORGIA

The National Bank of Georgia's Forecasting and Policy Analysis System

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Introduction

In recent years, the National Bank of Georgia (NBG) has gradually adopted an inflation targeting regime. The regime implies the announcement of an inflation target that should be maintained in the medium term. The target level of inflation is defined according to the current state of the Georgian economy. In the long-run, the desirable rate of inflation for the Georgian economy is 3%. However, since Georgia is an emerging market economy, it is characterized by relatively high inflation and economic growth is mainly due to higher growth of productivity. For that reason, the NBG adopted an inflation target of 6% until 2015. It has set an inflation target of 5% for 2015-2016 and 4% for 2017. The NBG plans to adjust the inflation target to its long-run level from 2018 onwards and from that point the inflation target rate will be 3%.

While the monetary policy progressed from monetary targeting to inflation targeting, the main policy instrument became short-term interest rate and the main question became what the interest rates should be over time? Changes in the short-term interest rate are transmitted to long-term interest rates and are ultimately reflected in the economy. However, in the modern economic environment, the monetary transmission mechanism operates with a time lag of around 4-6 quarters for emerging markets¹. Thus, changes in monetary policy instruments only have an effect on future inflation. Accordingly, monetary policy decisions should be based on macroeconomic forecasts, which require a synthesis of economic modeling and data analysis with relevant expert judgment. Developing analytical tools to serve that purpose has been the main focus for the research endeavors of many central banks around the world.

The successful implementation of monetary policy in the context of inflation targeting requires detailed analysis of the current economic climate and a comprehensive forecast for the economy. This process requires a synthesis of analytical tools and expert judgment. For this purpose, the NBG, working in collaboration with leading international institutions, developed a forecasting and policy analysis system (FPAS) for Georgia. This system combined existing and new models for economic analysis. The models that form the FPAS are occasionally tweaked and improved upon so as to give the most accurate and holistic diagnosis.

¹see Havraken and Rusnak (2013) for a review of the modern literature on transmission lags of monetary policy

The NBG's FPAS incorporates a number of analytical instruments that can be classified into three categories: short-term forecasting tools; a medium-term forecasting tool (the Georgian Economy Model); and additional satellite models. The latter are used to evaluate the cyclical stance of the economy and are used for forming expert judgments on various issues. Short-term forecasting instruments are econometric models that are used to forecast the short-term dynamics of the main macroeconomic variables. The results of these models are then utilized for medium-term forecasting. For now-casting or short-term forecasting, the use of econometric models are considered superior to structural macro models, while for medium-to-long term analysis macro models clearly have the advantage.

The Georgian Economy Model (GEMO), which is the main part of the FPAS, is a semi-structural model based on the New-Keynesian approach. The model is balanced by desired empirical properties and the Dynamic Stochastic General Equilibrium (DSGE) approach. The model was designed to meet modern policy requirements and to incorporate special characteristics that fit the Georgian economy, but at the same time to be easily operable and manageable. It utilizes quantitative results from the short-term forecasting and satellite models, as well as expert judgment. In addition to forecasting, this model can be used to analyze the baseline and alternative scenarios; to study the effect of various exogenous and endogenous shocks on the models results; to analyze different risk scenarios, etc. It is also important to note that the structure of the model allows for the constant development and improvement of its forecasting abilities.

The main feature of this kind of structural modeling is to allow endogenous monetary policy to be incorporated. Based on a certain rule, interest rates are set in a way to get inflation back to the target in the medium term. In this setting, the forecasting exercise entails identifying the current stance of the economy and how it may evolve over time to go back to its steady state. Given the nature of the model, the forecast assumes a certain path for interest rates, consistent with the economy going back to equilibrium. Consequently, the interest rate trajectory suggested by the forecast plays an important role in monetary policy discussions.

Assessing the current state of the economy always contains uncertainties, as we do not directly observe the shocks that drive the economy off the equilibrium. Identifying the cyclical position of the economy includes estimation of unobserved factors, which can never be absolutely precise. At the same

time, uncertainty prevails in both the economic parameters and transmission of the policy. As all these assumptions are inherent to the forecast, varying and experimenting with the assumptions to analyze risks associated with forecast, can be very useful for policy analyses.

Besides producing forecasts, which quantitatively (but not qualitatively) almost always differ from reality, the role of the model is to structure thinking about how the economy works. This means jointly analyzing various economic assumptions and judgments in a consistent way, studying the effects of certain shocks in the economy, assessing what the consequences for the monetary policy response are, and examining what the implications of changing the policy rule parameters will be (for example, if the weight on the output gap changes or the monetary policy becomes more persistent by putting more weight on the previous interest rate level). In reality all macroeconomic factors dynamically and simultaneously interrelate to each other. Single equation approaches or spreadsheet analyses, often lack the internal consistency required for this sort of analysis. Alternatively, macro models provide a coherent framework and have thus become main tools for policy analysis in many central banks.

The key aspect of inflation targeting is to influence public expectations towards the desired outcome, so to reduce the social costs associated with bringing inflation back to its' target after various shocks to the economy. Economic agents form their expectations based on new information. Therefore, clear communication around the forecast facilitates an understanding of information in such a way as to increase the central bank's credibility in achieving its objectives. For that reason, communication with the public regarding monetary policy is an essential element in the successful implementation of inflation targeting. The models to be used in policy analysis must be included in this kind of communication. In particular, models can be used to guide market expectations by estimating and structuring the story about how the economy may evolve from the current stance in the medium term, what are the actions the central bank will take in the future and how these may affect the economy.

Communication of its main tasks, policy decisions and measures undertaken represent one of the main priorities for the NBG. By developing existing channels and introducing new means of communication, the NBG will be able to improve its credibility and to manage inflation expectations, which will lead to more efficient monetary policy. For this purpose, the NBG has revised the structure of its publications, renewed the monetary policy section

of its official website and developed a new communication strategy. In addition, to ensure the transparency of the NBG and to keep the public informed, information regarding the NBG's decisions, monetary operations and FX interventions is published in the form of timely press releases. According to the new communication cycle, press conferences are held once a quarter following the monetary policy committee meetings and there is a meeting with analysts when publishing the Monetary Policy Report. Press conferences and meetings represent an efficient tool of communication during which the NBG can introduce group of analysts to the issues that were discussed at the monetary policy committee meetings and the justifications for the decisions made. To enhance public awareness of the economy and the credibility of the National Bank of Georgia, in the future it is also planned to continue a series of presentations and seminars regarding topics important to participants of financial market operations and other members of society.

This paper is divided into three main parts: the first part will present short-term forecasting tools; the second part will discuss the Georgian Economy Model as a tool for medium-term forecasting; and the third part will review satellite tools. The Appendix contains the technical details of the models.

Models Used in the FPAS

Since monetary policy affects the economy with a time lag, macroeconomic forecasts and forward-looking economic analyses are key to the effective implementation of monetary policy. Forecasting requires the synthesis of economic modeling, the analysis of past and current trends, and expert judgment.

The NBG forecasting and monetary policy analysis system incorporates several analytical tools that can be classified into three categories: short-term forecasting instruments, a medium-term forecasting tool (GEMO) and additional satellite models.

1 Short-Term Forecasting Tools

Short-term forecasting instruments are empirical models that incorporate an Error Correction Model (ECM), a Factor model and an Autoregressive Integrated Moving Average Process (ARIMA) model. The ECM is attached to the vector autoregression by empirically testing theoretical assumptions. It accounts for both the long-term cointegrating relationship between non-stationary variables and short-term deviations from this relationship. The Factor model is based on a principal components approach and is used for forecasting GDP on a quarterly basis. ARIMA is used for inflation forecasting. Short-term forecasts (of one to two quarters) of the main macroeconomic variables are based on the output of these models and expert judgment. The results are utilized further for medium-term forecasting.

1.1 Error Correction Model for Inflation (ECM)

The NBG uses a dynamic inflation model for short-term inflation forecasting. The model rests on a IMF working paper prepared by W. Maliszjevski (2003) that describes inflation behavior in Georgia.

Estimating the error correction model enables us to construct both long-run relationships and short-term links. The inflation forecast is made according to the estimated equation. A long-run equation linking prices to money, the exchange rate and real income rests on an assumption that prices in the long run are determined by the deviation from the equilibrium of money, foreign exchange and commodity markets.

The Johansen (1998) procedure is used to test for the existence of cointegration vectors. The weak exogeneity of money and the exchange rate, the neutrality of money and the weak endogeneity of prices in the long run are also tested.

The results of the test show that there is only one cointegration vector; there is weak exogeneity of money and the exchange rate; that the neutrality of money in the long-run cannot be rejected, and that exogeneity of prices is rejected.

In addition to the variables entering the long run equation, the relative price of fruits and vegetables and the oil price are added in the short-run equation. These variables are used as a proxy for supply shocks from the agricultural sector and input prices respectively.

The inflation equation has the following form:

$$\begin{aligned} \Delta p_t = & \sum_{i=1}^{k_p} \rho_i^p \Delta p_{t-i} + \sum_{i=1}^{k_m} \rho_i^m \Delta m_{t-i} + \sum_{i=1}^{k_e} \rho_i^e \Delta e_{t-i} + \rho^f \Delta p_t^{food} + \rho^o \Delta p^{oil} \\ & + \mu ecm_{t-1} + \sum_{i=1}^{k_d} D_i + u_t \end{aligned} \quad (1.1.1)$$

where

$$ecm_{t-1} = p_{t-1} + \beta_1 m_{t-1} + \beta_2 e_{t-1} + \beta_3 y_{t-1} + c \quad (1.1.2)$$

where, y is real GDP, p Consumer Price Index, e the Nominal Effective Exchange Rate, m Broad Money M3, p^{food} Fruit and Vegetable Prices, p^{oil} Oil Price, D_i seasonal dummy for i -th Month, ecm Error Correction Term, and c Constant Term.

The model is estimated using monthly data that starts from January 1996. Domestic CPI and real GDP are available from the National Statistics Office of Georgia. The available quarterly GDP series are interpolated. The exchange rate is measured by the nominal effective exchange rate, available from the NBG. Money is measured by M3, which includes money outside banks plus deposits in both national and foreign currency and is also available from the NBG. the fruit and vegetable price is obtained from disaggregated CPI data and is divided by total CPI to obtain relative prices. Oil prices are from the Bloomberg database. All series are in logs and are not seasonally adjusted. Instead, monthly dummy variables are used to model seasonality.

The inflation forecast is made for six months. The fan-chart produced from the model enables us to observe the probability distribution of the forecast variable.

1.2 Principal Component Analysis for Forecasting GDP Growth (PC)

Official estimates of GDP are published with a substantial delay (in the case of Georgia, this delay is almost one quarter after the end of a quarter), therefore short-term forecasting is well motivated for a variety of needs.

We use a simple principal components approach for the short term forecasting of the quarterly GDP growth of Georgia.

The advantage of principal components analysis is that after choosing the right linear combination of an original data set, it is possible to reduce the number of variables and increase the degree of freedom without losing the information needed. However, the number of explanatory variables should not exceed the number of observations.

To construct the principal components needed for estimating the GDP equation, we use about 20 variables from different sectors of the economy. These variables are: VAT turnover, loans issued by banks, deposits in banks, overdue loans, deposits of individuals and legal entities in banks, current accounts (of banks), cash outside banks (M0), monetary aggregates (M1, M2 and M3), reserve money, state budget expenditures, total exports, total imports, and money remittances from abroad.

All data are logged and annual differenced to eliminate deterministic seasonality. We calculate the principal components and estimate the following equation for GDP growth:

$$Y_t^Q = \mu + \sum_{k=0}^p \alpha_k Y_{t-k-1}^Q + \sum_{i=0}^l \sum_{s=0}^q \beta_{i,s} PC_{i,t-s} + e_t \quad (1.2.1)$$

where, Y^Q stands for GDP growth and PC_i for principal component.

We estimate each principal component entering the GDP growth equation separately as an autoregression process and use their predicted output for

forecasting GDP growth. The final forecast for GDP growth for two quarters (i.e. the now-cast and near-term forecast) is used as the input for other models in the FPAS.

1.3 Inflation Forecast by Autoregressive Integrated Moving Average process (ARIMA)

In the autoregressive integrated moving average (ARIMA) model, the time series of variables are expressed in terms of their past values (the autoregressive component) plus the current and lagged values of a 'white noise' error term (the moving average component). Some findings suggest that the disaggregated ARIMA model for CPI performs better than the relevant benchmarks (Marco Huwiler, and Daniel Kaufmann, 2013).

For modeling short term dynamics of inflation in Georgia, the ARIMA approach is used alongside with the ECM. The CPI is disaggregated in twelve sub components (see Table 1.1) and is modelled as ARIMA processes. We then use the forecast from these estimations to aggregate them in five sub-components and the final CPI forecast. More specifically, for disaggregation we use correlations and their individual features. All components are integrated processes of order one (except for a few of them: fish, fat) and they are used in log differences. During the modelling process, we take into account one-time shocks such as the increase in the education price index in September 2009, the rise in meat prices in January 2011, and the strong seasonality in the milk, cheese, and eggs subcomponents. We then automatically select lag length according to the lag length criteria.

For assessing the forecasting result, we compared the disaggregated results to ARIMA for the CPI, using Root Mean Square Forecasted Error:

$$RMSFE = \sqrt{\frac{1}{T} \sum_{t=1}^T (\pi_{t+f} - \pi_{t+f|t})^2} \quad (1.3.1)$$

where, $\pi_{t+f|t}$ is the inflation forecast for $t + f$ period with t period information set; T is the forecast period. According to the results, the disaggregated model performs better in forecasting than the total CPI ARIMA model.

Table 1.1: CPI Disaggregation by Components

Bread	Bread	Food
Meat		
Fish		
Sugar		
Fat		
Diary and Eggs	Diary	
Fruit	Fruit and Vegetable	
Vegetables		
Non Alcoholic Beverages	Non-alcoholic Beverages	
Other Food		
Alcoholic Beverages and Tobacco	Alcoholic Beverages	
Clothes and Shoes	Clothes	Clothes
Housing, Electricity, Water Supply, Gas	Housing	Housing
Communication	Communication	
Health Care	Services	Services
Leisure, Entertainment		
Hotels, Cafe and Services		
Transport		
Education	Education	
Furniture, Household Equipment	Other	Other
Other Goods and Services		

2 Medium Term Forecasting Tool - the Georgian Economy Model (GEMO)

2.1 Introduction

This part describes the small semi-structural model for Georgia that is intended to assist the National Bank in assessing the monetary policy interest rate and its' future path necessary to achieve the inflation target. The GEMO (Georgian Economy Model) is a small and relatively simple quarterly model that is suitable for describing the monetary policy transmission mechanism in a small open economy like Georgia. The model was designed to meet modern policy requirements and to have special characteristics to fit the Georgian economy but at the same time to be easily operable and manageable. An advantage of using a small model is the ability to describe the interrelationships among the main macroeconomic variables in a clear and simple way, while still maintaining theoretical consistency. It also helps to make the forecasting process more transparent and easy to communicate both within and outside the national bank.

The model blends the New Keynesian emphasis on nominal and real rigidities and the role of aggregate demand in output determination, with New Classical real business cycle traditional methods of DSGE modeling with rational expectations. It embodies the basic principle that the fundamental role for monetary policy is to provide an anchor for inflation and inflation expectations.²

There are four main blocks and interlinkages that characterize the basic functioning of the model. These blocks are the real economy (modeled via a dynamic IS curve), inflation (a new hybrid Phillips curve, that incorporates inflation expectations), interest rates (and the corresponding yield curve) and exchange rates (determined through a type of uncovered interest rate parity). This type of structure is standard for small open economies.³ However, in addition to the standard features found in the literature, GEMO also includes special transmission channels that are particularly interesting for countries like Georgia. The main special features captured by the model are the presence of imported intermediate goods (that increases firms dependence on exchange rates) and balance sheet effects (due to liability dollarization).

²For a thorough discussion on the importance of a nominal anchor see Bernanke et al. (2001).

³For example, see Monacelli (2004) or Gali and Monacelli (2005).

The inclusion of imported intermediate inputs has received increased attention in small open economy DSGE models. For example, in Christiano et al. (2011), exporters use domestic as well as imported inputs for production (i.e. global value chains), and in Curdia (2007) wholesale firms use local labor force as well as imported inputs to produce domestic goods. Indeed, as empirical evidence indicates taking into account the imported intermediate inputs channel is especially important for emerging market countries.⁴ Another important feature of some open emerging economies (and also included in the transmission mechanism of GEMO) is a high share of foreign currency debt, even though the pricing of most goods is in local currency. This type of currency mismatch resulting from liability dollarization produces balance sheet effects on the borrowers' side when the exchange rate fluctuates. As Krugman (1999) and Aghion et al. (2001) argue, large exchange rate depreciations and balance sheet effects are important reasons leading to emerging market crises. This feature has thus been incorporated into many DSGE models. For example, Batini et al. (2010) consider foreign currency debt in an otherwise standard small open economy DSGE model with a financial accelerator.⁵

The current parameterization of the model is mainly based on calibration, a practice that is widely adopted by central banks. To calibrate the model's parameters, information from different sources and various empirical methods were used, including stylized facts about the Georgian economy. The advantage of calibration is that it is easier to make the model relevant for policy analysis. Even though there is little experience with monetary policy under an inflation targeting regime in Georgia, it is still possible to parameterize the model, based on judgment, so that it is consistent with models used in the literature and those of other central banks that have similar characteristics. Another advantage of calibration (and a drawback of pure empirical estimations) for countries like Georgia is that the data sample is very short and describes a period of major structural changes in the economy and policy regimes. Calibration is thus the first step for the parameterization of the model, however, more elaborate methods, including a Bayesian estimation, are planned for the future.⁶ One advantage of adopting a more formal approach is that it gives an estimate of the uncertainties associated with the chosen parameter values.

⁴For the discussion, see Fraga et al. (2003) or McCallum and Nelson (2000).

⁵See also Gertler et al. (2003) or Cespedes et al. (2004).

⁶For a review of Bayesian estimation methods see An and Schorfheide (2007).

For assessing the properties of the model and the appropriateness of its calibration, impulse responses of the model's variables to key structural shocks are calculated. Monetary policy rate, demand (with both immediate and delayed policy reaction), cost-push (i.e. domestic supply) and risk premium shocks are discussed in the main text. Finally, in order to study the reaction of the economy to the reduction of the inflation target, permanent disinflation shock is also simulated. The results of those simulations are in line with the stylized facts and empirical estimates, which justifies the use of GEMO for medium-term forecasting and policy analysis.

This part of this report is organized as follows: Section 2.2 gives an overview of the model by describing the channels of the transmission mechanism. Section 2.3 provides a detailed description of the model's main equations. Section 2.4 examines the model's properties by discussing the impulse response functions for the main structural shocks, while section 2.5 concludes. The full list of equations, variables, shocks, parameters and data used for filtering (with sources) can be found in the Appendix.

2.2 Overview of the Model - the Transmission Mechanism

For inflation targeting central banks, the main role of monetary policy is to provide an anchor for inflation and inflation expectations. To achieve this objective, central banks use monetary policy rates (i.e. short-term nominal interest rates) as a policy instrument. The central bank's key decision is to select the interest rate path that will guarantee achievement of the inflation target. The resulting price stability is, in turn, a necessary condition for sustainable economic growth. For this reason, the NBG, like many other central banks, uses its own core forecasting and policy analysis model (GEMO) to formulate its current as well as the expected future monetary policy. Because the model contains expectations, it is not a forecasting model in the traditional sense. It is not predicting inflation per se, rather it suggests where the monetary policy rate should be over time in order to reach and maintain inflation at its target. Therefore, in order to use the model in the right way, one must be aware of its structure and the transmission mechanism incorporated in it.

The New Keynesian framework, which this model is based on, describes the major relationships characterizing the monetary policy transmission mechanism – the process by which changes in policy interest rates work their way through the economy, to ultimately affect the rate of inflation. In these kinds of models, if the monetary policy follows accordingly, over time the economy converges to equilibrium (i.e. real variables are at their potential levels and the inflation target is achieved). When monetary policy is carried out responsibly (i.e. with the main aim of price stability), the levels of real variables are independent of monetary policy in the long run. In the short run, however, monetary policy does have real effects because of nominal rigidities.

Empirical studies on nominal rigidities do, indeed, show that prices are not fully flexible. For example, Nakamura and Steinsson (2008) estimate that price stickiness implies an 8- to 11-month duration of regular price changes. This is well in line with most sticky-price monetary models. On the other hand, some studies found less persistence (but not complete flexibility) of prices. Bils and Klenow (2004) find that the duration of price changes is under 5.5 months excluding sales and 4.3 months including them. In addition, Morande and Tejada (2008) estimate the duration of price spells for four emerging market countries and conclude that the frequency of price changes was between 1.5 and 3 months. However, one should take into account that these are estimates of micro-level price stickiness. As Kehoe and Midrigan (2012) discuss, for macro-level price stickiness only regular price changes are relevant and not temporary ones. Therefore, they conclude that even the 4-month duration of price changes estimated by Bils and Klenow (2004) is still in line with the level of stickiness assumed in many monetary models.⁷

Consequently, GEMO assumes a moderate level of price stickiness and, thus, implies that changes in nominal interest rates are transmitted to real interest rates, which lead to temporary deviations of real variables from their trends. In the long run, however, the effect of price stickiness vanishes and real variables converge back to their potential levels. In the long run, supply side factors define the equilibrium levels of real variables and monetary policy does not have an impact on them. On the other hand, monetary policy is the only factor that governs the inflation rate in the long run. Indeed, Bullard (1999) reviews the literature and finds little evidence against the long-run neutrality of money.

⁷A related issue is wage stickiness (however, GEMO does not model wages explicitly). For the discussion of wage stickiness see Heckel et al. (2008) or Taylor (1999), which concludes that "staggered price and wage setting models provide the most satisfactory match with the data".

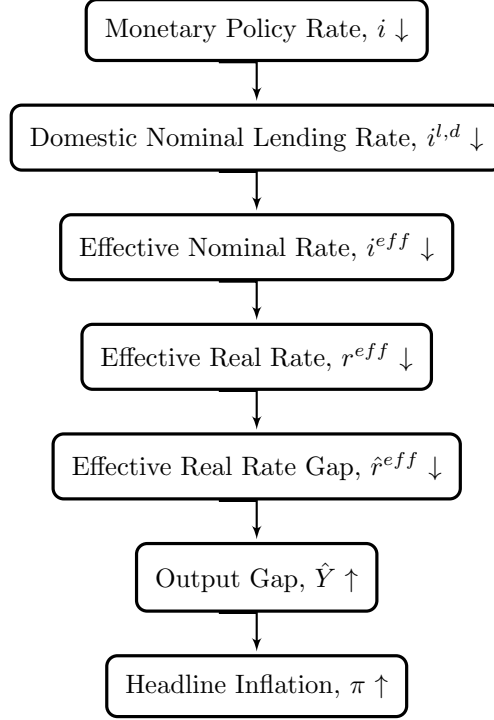
In the model, changes in the policy rate are transmitted to various kinds of economic activity (and, thereby, to inflation over time) through different channels. Suppose the central bank decides to reduce its policy interest rate; the effect on inflation would mainly come through the interest rate and exchange rate channels, even though other channels are also at work (e.g. expectational, credit or asset prices).

2.2.1 Interest Rate Channel

Official interest rate decisions affect market interest rates (such as mortgage and bank deposit rates), to varying degrees. At the same time, policy actions and announcements affect expectations about the future course of the economy and the confidence with which these expectations are held. As a result of price stickiness in the short run, a decrease in the nominal rate leads to a lower real interest rate. These changes in turn affect the spending, saving and investment behavior of individuals and firms in the economy. For example, other things being equal, lower interest rates tend to encourage spending and discourage saving⁸. Therefore, changes in the official interest rate affect the demand for goods and services. Furthermore, the level of demand relative to domestic supply capacity has a key influence on domestic inflationary pressure. For example, if demand exceeds the available supply, some firms may be able to charge higher prices to consumers. Indeed, Bolt and Els (2000) conclude that output gaps significantly explain changes in inflation for eleven EU countries. Thus, a decrease in the policy rate leads to higher output and, therefore, inflation through the interest rate channel (see Figure 1).

⁸For example, see Elmendorf (1996).

Figure 1: Interest Rate Channel

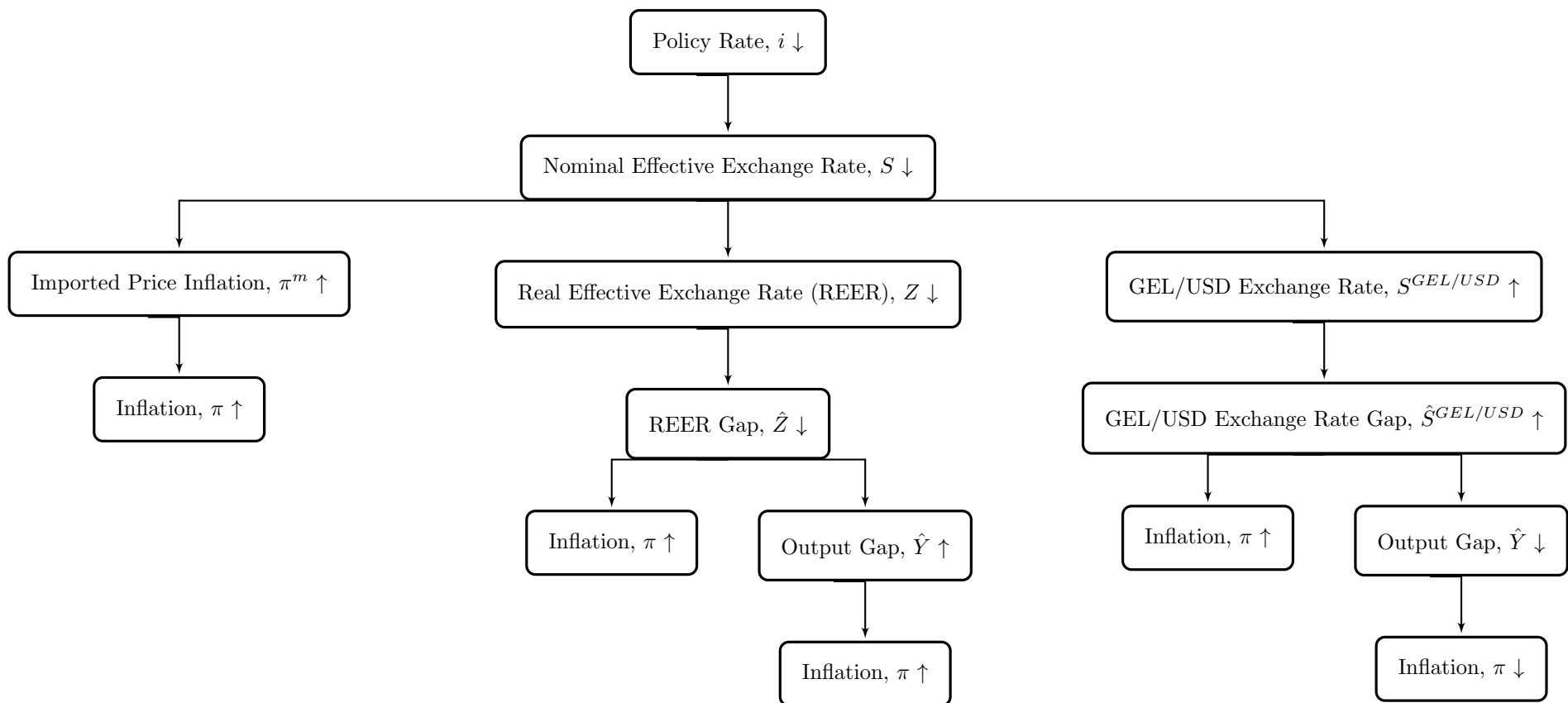


2.2.2 Exchange Rate Channel

A decrease in the interest rate increases the relative attractiveness of holding foreign currency assets compared to lari assets. The public will therefore tend to convert lari to foreign currency, and the exchange rate will depreciate on impact. A depreciation of the lari exchange rate affects inflation through four different sub-channels: the imported inflation channel (capturing the prices of imported final consumption goods), the imported intermediate inputs channel (through the real exchange rate as one part of firms marginal costs), the net exports channel (also through the real exchange rate as a measure of countries competitiveness) and the balance sheet effects channel (through the GEL/USD exchange rate, which works from both the supply as well as the demand side). These sub-channels are summarized in Figure 2.⁹

⁹In order for the variables to be consistent with the conventions of the actual data, increase of the effective exchange rates S_t and Z_t mean appreciation of the lari, while increase of the GEL/USD exchange rate $S_t^{GEL/USD}$ means the depreciation of lari.

Figure 2: Exchange Rate Channel



More specifically, a depreciated exchange rate would affect inflation through these four sub-channels:

1. Depreciation of the lari exchange rate will have a direct impact on local currency prices of imported consumption goods, including imported food and oil prices. In line with the share of imported consumer goods in the overall consumption basket of a small open economy, this increase in imported inflation will subsequently be transmitted to headline inflation.

2. Due to incomplete pass-through¹⁰, nominal depreciation also causes real depreciation, which affects inflation in two different ways. Depreciation of the real effective exchange rate (REER) increases the relative prices of imported inputs that local firms use for domestic production (see McCallum and Nelson, 2000). This increase in marginal costs for domestic producers subsequently leads to upward pressure on domestic prices, thus increasing inflation.

3. REER depreciation has a secondary, albeit indirect, effect on inflation through the net exports channel. Namely, REER depreciation increases the competitiveness of the open Georgian economy. Over time, this translates into lower imports and higher exports, which means higher net exports and increased demand for domestic goods. This point is backed up by historical evidence. For example, the IMF (2015) analyzed whether exchange rates have become disconnected from trade flows, and concluded that they have not (i.e. that exchange rate movements have sizable effects on net exports in the medium term). Finally, the increase in demand through net exports puts upward pressure on inflation.

4. The effective depreciation of the lari means, other things being equal, the depreciation of the lari relative to the US dollar as well. Due to high levels of financial dollarization in Georgia, the GEL/USD exchange rate depreciation has additional effects on inflation and the macroeconomy in general. Most Georgian firms have loans in foreign currency (in US dollars), however the pricing of their products is mostly in the local currency. This currency mismatch exposes these firms to GEL/USD exchange rate fluctuations. In particular, when the GEL/USD exchange rate depreciates, the debt service burden increases and, therefore, costs relative to income rise. These balance

¹⁰Mdivnishvili (2015) estimates the long-run exchange rate pass-through for Georgia at 50%.

sheet effects restrain economic activity (for financially dollarized firms) ¹¹ and thus lead to downward pressure on inflation from the demand side. On the other hand, from the supply side, balance sheet effects mean higher debt servicing costs for firms and hence put upward pressure on prices.

Therefore, while most of the sub-channels of the exchange rate channel reflect the strictly positive influence of lari depreciation on inflation, balance sheet effects imply an ambiguous response. Carranza et al. (2009) performed an empirical analysis of the effects of the exchange rate on inflation for more than a hundred economies with different levels of dollarization. They found that balance sheet effects tend to restrain the pass-through of the exchange rate on prices through weaker demand. However, balance sheet effects for firms also mean higher debt servicing costs, which strengthen inflation. Despite this theoretical ambiguity, empirical estimates for Georgia and other dollarized economies suggest that the negative impact on demand from the balance sheet effects channel is offset by the positive impact on demand from the net exports channel for highly dollarized economies¹², while the latter actually outweighs the former for moderately dollarized economies. Thus, even if some sub-channels offset each other, the exchange rate channel still implies a strictly positive relationship between exchange rate depreciation and inflation. If we add the interest rate channel to this, then the link between the monetary policy rate and inflation becomes even stronger.

On the other hand, the link between the monetary policy rate and aggregate demand is less strong, due to balance sheet effects. As has already been mentioned above, the exchange rate channel only has a moderate positive effect on aggregate demand for considerably dollarized open economies like Georgia. For example, Mkhatriashvili (forthcoming) estimate that 10% real effective depreciation increases real GDP by 1-1.5% in Georgia, while increase would have been 2.5-3% had there been no liability dollarization. However, the link between policy loosening and higher demand, on the other

¹¹The empirical study of Levy-Yeyati (2005) estimates balance sheet effects and, among other results, finds that financially dollarized economies tend to have more volatile output due to those effects.

¹²For example, Melander (2009) empirically estimates these balance sheet effects for extremely dollarized Bolivian economy (with 95% loans dollarization) and finds that after depreciation of the local currency negative influence of balance sheet effects on demand used to be completely offset by the increase in net exports. Share of dollar-denominated loans in Georgia is around 65% (Bolivia even has higher private sector credit-to-GDP than Georgia), while the ratios of trade turnover to GDP for these two countries are roughly the same. Therefore, balance sheet effects should be stronger for Bolivia, while net export effect should be roughly the same for the two countries.

hand, is clearly positive in the interest rate channel. Hence, it may well be argued that monetary policy accommodation for countries like Georgia still unambiguously implies higher demand, albeit less so than one would expect in a non-dollarized economy.

2.2.3 Other channels

The main avenues through which monetary policy affects inflation in the GEMO are the interest rate and exchange rate channels, however there are other channels at work as well, some of them are explicitly included in the model, others are only implicitly present.

Expectations are explicitly modeled in the GEMO. These expectations strengthen the effect of monetary policy on inflation. Namely, reducing the nominal monetary policy rate would increase inflation expectations, which would further reduce real interest rates and stimulate demand and, on the other hand, would make firms price in higher future inflation and contribute to higher inflation even today. Indeed, expected inflation is seen to be one of the main determinants of current inflation in contemporary macroeconomics.¹³

In addition, the GEMO can also claim to have implicitly included credit and asset price channels.¹⁴ For instance, expansionary monetary policy reduces adverse selection and moral hazard problems, which supports lending and economic activity. In addition, increasing asset prices, caused by accommodative monetary policy, eases financial positions and activates wealth effects, which stimulate demand.¹⁵ These two additional channels are captured in the GEMO in a reduced form, by calibrating parameters that govern the effect of interest rates accordingly.

To summarize, although being a small economic model, GEMO still captures a handful of important issues governing the structure of the Georgian economy. Interest rates and exchange rates are the main transmission channels, which imply a strong link between monetary policy and overall inflation, but only a moderately strong link between the monetary policy stance and economic growth.

¹³For example, see Clarida et al. (1999).

¹⁴Balance sheet effects discussed above also belong to these type of channels.

¹⁵For more discussion of all of these monetary transmission channels see Mishkin (1996).

2.3 Main Equations of the Model

This section presents the main equations of the model and explains the economics behind them. The complete model consists of around one hundred equations, many of which are just definitions and identities. Here we only present the main parts that describe the essence of the model, while the full list of the models equations, variables, exogenous shocks, parameters and data used, with their descriptions, are presented in the Appendix. The main equations are semi-structural and, even though most of them could very well be derived from microeconomic principles, the model does not strictly belong to the class of fully micro-founded DSGE models as we do not explicitly show those micro-foundations and derivations here.

The main equations of the model can be divided into four main categories: inflation (supply side), output (demand side), exchange rates and monetary policy. These equations describe the core structure of the system and the propagation mechanisms.

2.3.1 Inflation

The inflation target in Georgia is based on headline CPI inflation. Hence, the new hybrid Phillips curve-type equation (with some modifications to reflect the Georgian economy, as discussed below) directly models headline inflation, π . The variable π in the equation is measured as an annualized, quarter-on-quarter percentage change in the CPI index. The main inflation equation (the components of which are discussed below) reads:

$$\begin{aligned} \pi_t = & \beta_5 \left(\beta_1 \pi_t^m + (1 - \beta_1) \left[\beta_2 \pi_{t-1} + (1 - \beta_2) \pi_t^e \right] \right) + \\ & + (1 - \beta_5) \left(\beta_6 \pi_t^{oil} + (1 - \beta_6) \pi_t^{food} \right) + \\ & + \beta \left(\beta_4 \frac{\bar{y} \hat{Y}_t}{\bar{y} - \hat{Y}_t} - \beta_5 \hat{Z}_t + \beta_{13} \hat{S}_t^{GEL/USD} \right) + \varepsilon_t^\pi + \varepsilon_t^{u^\pi} + \rho_l \varepsilon_{t-1}^{u^\pi} \end{aligned} \quad (2.3.1)$$

where π^m is imported inflation, π_{t-1} and π_t^e - past and future expected inflations, π_t^{oil} and π_t^{food} - oil and food inflations, while $\hat{Y}_t$, $\hat{Z}_t$ and $\hat{S}_t^{GEL/USD}$ represent output, real effective exchange rate and GEL/USD nominal exchange rate gaps, respectively. The parameters in this equation do not have

a direct structural interpretation, instead they are functions of "deep structural" parameters. Namely, to derive an equation like 2.3.1 from microeconomic principles, one can start from the standard profit maximization problem of the firm with sticky prices and indexation and extend the production function of firms with imported production factors (on top of labor input). In addition, if lending is included as one of the production "inputs" (since almost all firms use external financing for their operation), then one could very well arrive at an equation very similar to 2.3.1 from the first principles.¹⁶

Imported inflation (π^m) is defined in terms of foreign inflation (π^*) and nominal exchange rate depreciation (ΔS), adjusted for the rate at which domestic productivity is catching up with the productivity of trade partners (approximated by the real exchange rate trend appreciation, $\Delta \bar{Z}$, i.e. the Balassa-Samuelson effect¹⁷). Moreover, shocks effecting imported inflation are also taken into account (ε^{π^M}):

$$\pi_t^m = \beta_9 \pi_{t-1}^m + (1 - \beta_9)[\Delta S_t + \pi_t^* - \Delta \bar{Z}_t] + \varepsilon_t^{\pi^m} \quad (2.3.2)$$

Dependence on lagged values is consistent with the empirical findings.¹⁸ Therefore, in the main equation the current inflation rate is assumed to also be influenced by the previous period's inflation (π_{t-1}). This effect reflects the existence of intrinsic dynamics, such as indexation arrangements, contractual lags, and other factors that cause price inertia. Thus, while inflation reacts to many factors discussed here, it does so in a gradual manner. Similar to headline inflation, imported inflation also shows some persistence, which is captured by its lagged value.

As for inflation expectations (π^e), they are formed as a weighted combination of backward-looking (one quarter lag of year-on-year headline inflation) and forward-looking (one quarter lead of year-on-year headline inflation) expectations. The reason for including a backward-looking component in inflation expectations is the presence of adaptive agents (see Evans and Honkapohja, 2001).¹⁹ If the model is run in its non-linear form, the weights are time-varying and depend on the credibility of the monetary policy (discussed

¹⁶Imported, oil and food inflation have a direct effect on headline CPI inflation according to their shares in the CPI basket, however they may also have second-round effects.

¹⁷Mihaljek and Klau (2008) estimate Balassa-Samuelson effects for central and eastern European transition countries and find them to be significant.

¹⁸E.g. Calvo et al. (2001) presents a theory of rational inflation inertia and the supporting empirical evidence.

¹⁹Gali and Gertler (1999) find backward-looking component in inflation expectations to be statistically significant, but they also find that forward-looking component still remains the dominant part.

below). The higher the credibility of monetary policy the more economic agents become forward looking (i.e. central banks' inflation forecast target becomes more meaningful). Branch (2004) provide the theory and evidence on this issue. In addition, in times of low credibility inflation expectations are augmented by inflation bias (i.e. the time-inconsistency problem of Kydland and Prescott, 1977):

$$\pi_t^e = \delta C_t E_t \pi_{4,t+1} + (1 - \delta C_t) \pi_{4,t-1} + (1 - C_t) \pi^{bias} \quad (2.3.3)$$

The process of monetary policy credibility (C) depends on the record of the central bank's performance in terms of achieving its inflation objective. Even though credibility has some persistence, it erodes whenever the central bank persistently misses its inflation target (conversely, it strengthens when the bank is persistently close to the target)²⁰:

$$C_t = \rho_c C_{t-1} + (1 - \rho_c) \frac{(\pi_t^{err,h})^2}{(\pi_t^{err,h})^2 + (\pi_t^{err,l})^2} + \varepsilon_t^C \quad (2.3.4)$$

where ρ_c measures persistence of credibility, $\pi_t^{err,h}$ is the deviation of current inflation from the previous period inflation, while $\pi_t^{err,l}$ is the deviation of current inflation from the central bank's target. Whenever the latter is closer to zero than the former (i.e. whenever the central bank does a good job at attaining its inflation target so that the inflation target is a better forecast of future than past inflation) the stock of credibility gradually increases, however in the opposite case, it falls. Cukierman and Melnick (2015) have used a similar approach to empirically estimate the credibility of monetary policy for Israel.

In addition, the main inflation equation also explicitly incorporates the effects that food (π^{food}) and oil (π^{oil}) prices may have on headline inflation. If strong enough, these could have second-round effects²¹. These are modeled as simple processes that show some persistence, but are largely dependent on world food and oil prices and the lari exchange rate.

Furthermore, as in other similar equations, when economic activity is boosted and marginal costs rise, inflation should increase. These inflationary pressures that exist from the demand side are captured by the output gap ($\hat{Y}_t$) in the main equation above.²² Furthermore, when the model is run in its

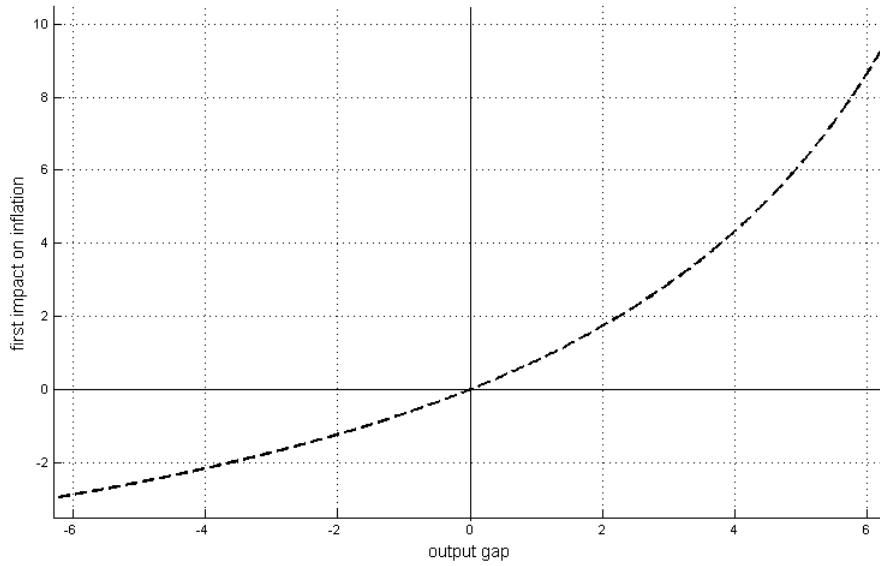
²⁰E.g. see Scott Davis (2014).

²¹E.g. see Mija et al. (2013).

²²Gali (2008) is a standard reference here.

non-linear form, inflation exhibits asymmetric response to the output gap being, stronger in times of boom and weaker in times of recession (i.e. a convex curve), reflecting stronger downward wage stickiness and an asymmetric reaction of firms' profit margins to demand conditions. Akerlof et al. (1996) argue that this is the reason to prefer a low inflation target to a zero inflation target (in order to avoid inefficiencies in the allocation of resources). Laxton et al. (1998) argue that even if the functional form of the curve is unknown, then it is still safer to err on the side of convexity rather than on linearity or concavity. This (convex) non-linear relationship between the output gap and inflation is depicted in Figure 3.

Figure 3: First-Round Impact of Output Gap on Inflation



On the other hand, the real effective exchange rate gap ($\hat{Z}_t$) reflects the marginal costs of imported intermediate inputs.²³ Depreciation of $\hat{Z}_t$ tends to increase imported production factor prices and, thus, inflation. Hence, both the direct (π^m) and indirect effects of imported inflation are captured.

As for the GEL/USD exchange rate gap, this enters the inflation equation in order to capture balance sheet effects working on the supply side. Namely, since most business loans in Georgia are dollarized, the lari depreciation

²³Sendeta (2011) incorporates imported intermediate goods into an otherwise standard DSGE model.

against the US dollar means higher debt-servicing costs for firms. This, in turn, puts upward pressure on prices and forces firms to try and pass some of their burden to consumers. We should note here, however, that this effect on actual inflation (and not on pressure) is neither immediate nor very short-lived. In order to capture the persistence of this (because of longer-maturity FX business loans), we define the pressure from the GEL/USD nominal exchange rate ($\hat{S}_t^{GEL/USD}$) as the following persistent process:

$$\hat{S}_t^{GEL/USD} = \rho_s \hat{S}_{t-1}^{GEL/USD} + (1 - \rho_s) \left(\Delta S_t^{GEL/USD} + (\Delta \bar{Z}_t - \pi_t^{tar} + \pi_{ss}^{US}) \right) \quad (2.3.5)$$

where $\Delta S^{GEL/USD}$ is nominal GEL/USD exchange rate depreciation, $\Delta \bar{Z}$ - is the real exchange rate appreciation trend, while π^{tar} and π_{ss}^{US} are domestic and US inflation targets.

Finally, domestic inflation is assumed to be influenced both by standard cost-push shocks (ε_t^π) as well as high-frequency supply side shocks ($\varepsilon_t^{u^\pi} + \rho_l \varepsilon_{t-1}^{u^\pi}$, with $-1 < \rho_l < 0$).

For illustration purposes, after discussing the details of the equations in each of the four parts of the model, we provide figures showing the model variables relevant for the corresponding part of the model²⁴. For example, Figure 4 shows headline inflation and the output gap in Georgia from 2004 to 2015. As can be seen, before 2010 inflation in Georgia was mainly driven by demand, while after that time it's main drivers were supply side factors.

²⁴For estimating the time series of unobservables variables (and for observable variables for which data has not been available for certain periods) Kalman smoother has been used. For a review of Kalman smoother see Movellan (2011).

Figure 4: Headline Inflation and the Output Gap



2.3.2 Output

The output gap $\hat{Y}$ is modeled through a dynamic IS-type equation, that, even though not explicitly shown here, may also be derived from first principles. Output, as well as other, gap variables are defined as the percentage deviations of actual levels from their trend levels, where the latter are estimated together with the whole model. This has the advantage of reflecting the information contained in trend-cycle interactions in the estimates of the variables (as opposed to, for instance, HP pre-filtering). The importance of this information for emerging markets has been discussed in Andrle (2008).²⁵ Clearly, the equations are structured and parameters calibrated in such a way that the gap variables converge to zero over a sufficiently long horizon. In other words, economy tends to converge to equilibrium in the long-term.

In the model, the output gap is affected by the effective real interest rate gap ($\hat{r}^{eff}$), the country risk premium gap ($\hat{pr}^m$), net export effects (through the real effective exchange rate $\hat{Z}$) balance sheet effects (through the GEL/USD nominal exchange rate gap $\hat{S}^{GEL/USD}$), and extra government spending (G). The degree of persistence that aggregate demand may reveal (e.g. because of habit formation²⁶) is represented by the lagged value ($\hat{Y}_{t-1}$). Furthermore, as

²⁵Cayen et al. (2009) also used this approach for estimating model-consistent trends.

²⁶Christiano et al. (2005) consider internal habit formation into a medium-sized DSGE model, while Smets and Wouters (2003) incorporate external habit formation (i.e. "keeping up with the Joneses").

in every standard dynamic IS curve, economic outlook ($E_t \hat{Y}_{t+1}$, i.e. expected output gap based on time t information) also affects current demand conditions. The disturbance term ($\varepsilon^{\hat{Y}}$) is interpreted as a shock hitting demand (e.g. consumers preference shock²⁷). Hence, the output equation reads:

$$\begin{aligned} \hat{Y}_t = & \alpha_1 \hat{Y}_{t-1} + \alpha_2 E_t \hat{Y}_{t+1} - \alpha_3 (\hat{r}_t^{eff} + \alpha_4 \hat{pr}em_t) - \alpha_5 \hat{Z}_t + \alpha_6 \hat{Y}_t^* + \\ & + \alpha_7 \hat{G}_t - \alpha_8 \hat{S}_t^{GEL/USD} + \varepsilon_t^{\hat{Y}} \end{aligned} \quad (2.3.6)$$

In order to obtain more realistic interactions, instead of relying solely on the central bank's interest rate, the effective interest rate gap is defined as a weighted average of domestic and foreign interest rates that affect demand conditions through credit and capture the interest rate channel of monetary policy in this way. For example, an increase in the monetary policy rate is transmitted to domestic interest rates and, then correspondingly, to effective interest rate that reduces credit and domestic demand (while through the new Philips curve, this forces inflation to fall).

Domestic and foreign interest rates relevant for demand, in turn, are modeled through explicitly building a yield curve in the model. Domestic 1-year and 3-year interest rates are weighted averages of current and future expected monetary policy rates²⁸ in Georgia. The same is the case for foreign rates, which depend on the Fed's policy rate and its expectations (which are exogenous to the domestic economy). All these longer term rates are augmented by time-varying term premiums.²⁹ For example, the 1-year domestic interest rate ($i_t^{1y,d}$) is given by:

$$i_t^{1y,d} = \frac{i_t + E_t i_{t+1} + E_t i_{t+2} + E_t i_{t+3}}{4} + tp_t^{1y} \quad (2.3.7)$$

where i_t is the monetary policy rate in Georgia for period t , E_t - is the (rational) expectational operator based on information available in time- t and tp^{1y} is the term premium for 1Y interest rate.

As already mentioned, another determinant of output is the risk premium

²⁷See e.g. Smets and Wouters (2005), which compares different type of shocks estimated within a DSGE model.

²⁸Woodford (2003) argues that this is the reason why smoothing monetary policy rate changes may be desirable, in the sense of still having the same impact on aggregate demand, but at the same time having lower short-term interest rate volatility.

²⁹For instance, see Kim and Orphanides (2007) on this issue.

gap (*prêm*). Exogenous factors causing higher risk premium constrain investment activity and shrink aggregate demand. However, these have other repercussions as well because risk premium is directly related to the exchange rate, which will be discussed below. In this way, risk premiums are familiar for developing countries, and could be interpreted as a certain type of supply side shock.

Since Georgia is an open economy, it is crucial to take into account the effect of the real exchange rate on aggregate demand by observing its effect on net exports. Exchange rate depreciation increases the competitiveness of domestic exporters and stimulates external demand for Georgian products. In addition, the switch of local consumers from imported goods and services to domestic ones further reinforces this rise in demand. The IMF (2015) estimates these effects to be significant, statistically as well as economically. Hence the real effective exchange rate gap ($\hat{Z}$) in the output equation above.

On the other hand, there is a high degree of financial dollarization in Georgia. Therefore, the standard demand equation is extended with the balance sheet effect to take into account this specification. In particular, loans are mainly denominated in US dollars, while economic agents receive their income mostly in domestic currency. Therefore, because of this currency mismatch, when the GEL/USD nominal exchange rate depreciates, the costs relative to income rise, which, in turn, restrain domestic demand. For instance, Krugman (1999) and Aghion et al. (2004) argue that this is the mechanism by which an economy may experience a self-fulfilling crisis, with depreciated currency and lower output. Tovar (2006) estimates this effect to be significant.³⁰ This makes the Georgian economy especially exposed to the possibility of a global appreciation of the US dollar, something which happened in the recent past. Exposure comes from the fact that in this case the lari depreciates against the US dollar (and experiences painful balance sheet effects), but remains unchanged with respect to its trading partners currencies (i.e. the real effective exchange rate does not depreciate correspondingly and net exports do not get much stimulus). In order to capture these balance sheet effects, the output equation above includes the GEL/USD nominal exchange rate gap ($\hat{S}^{GEL/USD}$) as well (this is defined above in the Equation 2.3.5).

In Georgia, fiscal sector also plays a significant role in creating demand. This is the reason why government spending (G) explicitly enters the equation.

³⁰Although he also finds that the net exports effect outweighs this balance sheet effect in the event of effective depreciation.

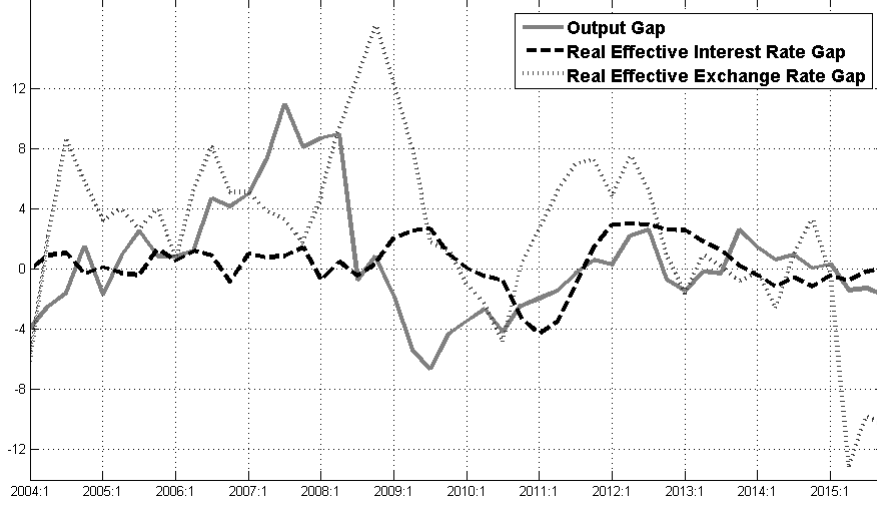
However, for now, it is modeled as a simple autoregressive process. Mkharishvili and Zedginidze (2015) estimate the contributions of fiscal impulses into the output gap for Georgia.

The foreign output gap, represented by the euro area output gap in the equation ($\hat{Y}^*$), positively affects external demand on domestic goods. A positive foreign output gap means that demand for domestically produced goods from abroad increases, which in turn improves the trade balance. For example, even if the GEL/EUR exchange rate remains unchanged, higher economic growth in Europe would also increase Georgian exports to Europe. In addition, this term also represents the remittances Georgia receives from abroad. Remittances also affect domestic demand in Georgia, and depend on economic growth abroad.

Figure 5 shows the main relationship captured by the output equation. It plots the output gap, the real effective interest rate gap and the real effective exchange rate gap. The figure reveals that the interest rate behavior, which combines domestic (controlled by the NBG) and foreign components, was essentially acyclical up until 2009. At that time, even though the output gap was high, the real effective interest rate gap was close to zero (i.e. neutral). However, after 2009 interest rates significantly decreased and the real effective exchange rate, which was overvalued before 2009, depreciated. Both of these preceded the recovery of the output gap post-2010. It was a story of demand shock.³¹ The year 2015, on the other hand, was a different case. Georgia experienced risk premium shock, which depressed demand, but depreciated the lari and created upward pressure on inflation (especially on core inflation). This explains why the interest rate gap did not decrease in 2015 even though the output gap did.

³¹In 2010 headline inflation also increased, but that was mainly caused by supply side factors (oil and food price increases in international markets), so that core inflation had hardly moved.

Figure 5: Output Gap, Real Effective Interest Rate Gap and REER Gap



2.3.3 Exchange Rate

The nominal exchange rate is modeled via a version of uncovered interest rate parity (UIP), which is essentially a no-arbitrage assumption stating that risk-adjusted yields should be the same in both domestic and foreign capital markets³²:

$$\theta(i_t - i_t^*) + (1 - \theta)[(\bar{r}_t + \pi_t^{tar}) - (\bar{r}_t^* + \pi_{ss}^{US})] = 4(S_t^{GEL/USD,e} - S_t^{GEL/USD}) + prem_t + \varepsilon_t^S \quad (2.3.8)$$

The left-hand side is the weighted sum of the differential between two interest rates. The first part of this sum is the difference between the Georgian (i) and US (i^*) nominal short-term interest rates, while the second is the difference in equilibrium nominal interest rates (the long-run real rate plus the inflation target) in Georgia ($\bar{r}_t + \pi_t^{tar}$) and in the US ($\bar{r}_t^* + \pi_{ss}^{US}$). The more the Georgian financial market is developed, the more the exchange rate reacts to short-term nominal interest rates set by the NBG. On the other hand, the more the NBG tries to smooth the exchange rate around its long-run level, the more the exchange rate is determined by long-term real rates and inflation. Therefore, the weight (θ) in the equation may measure either the level of development of the domestic financial system or the extent to which the domestic monetary authority manages exchange rate. Benes et al.

³²This is the standard approach of modeling exchange rates (see e.g. Dornbusch, 1976).

(2008) provide some microfoundations for this approach and argue that it produces more realistic results.³³

The right-hand side indicates that the interest rate differential should compensate (annualized) expected future exchange rate depreciation, $4(S_t^{GEL/USD,e} - S_t^{GEL/USD})$, and country risk premium ($prem$). That is, if foreign investors expect the GEL to depreciate, they will demand higher returns from Georgian assets to compensate for the expected depreciation. However, if the country risk premium rises, even if investors do not expect any depreciation, they will still demand higher interest rates in Georgia to make up for the increased risk. Therefore, a higher risk premium and unchanged interest rates in Georgia mean depreciation pressures.

In the case of developed financial markets and a freely floating exchange rate, θ is equal to one and the expression becomes a standard UIP equation:

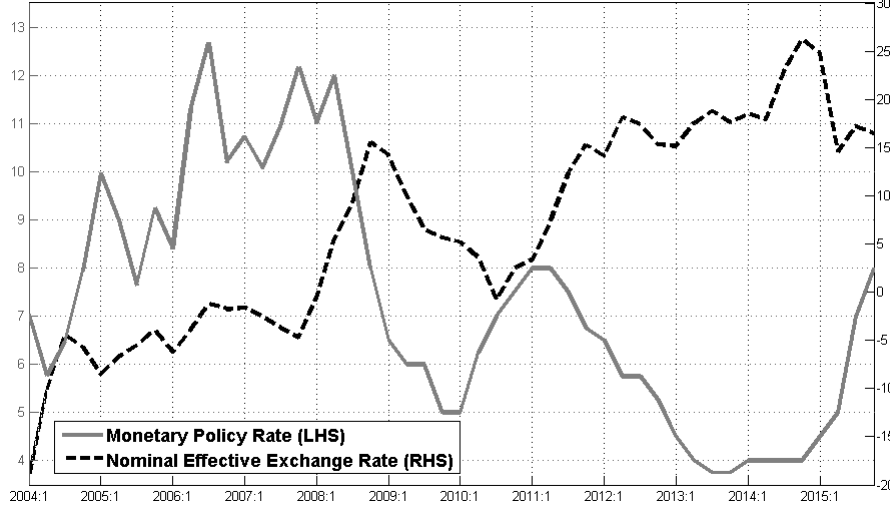
$$(i_t - i_t^*) = 4(S_t^{GEL/USD,e} - S_t^{GEL/USD}) + prem_t + \varepsilon_t^S \quad (2.3.9)$$

The main relationship in the exchange rate equation (lari exchange and interest rates) is seen in Figure 6. This shows that the NBG has tended to increase interest rates when the lari effective exchange rate was depreciating (a decrease means depreciation) and tended to lower it when the exchange rate was appreciating. This reaction of the interest rate on exchange rates has somewhat decreased recently. In particular, in 2012-2013 interest rates were substantially eased, even when the exchange rate did not exhibit appreciation pressure; whereas in 2015 monetary policy reversed course even when the lari effective exchange rate did not move that much instead, monetary policy reacted to severe supply side factors (risk premiums) to offset any potential second-round effects. This story supports the view that the exchange rate pass-through, which used to be quite high, has somewhat decreased in recent years. This could be the result of the inflation targeting regime (to which Georgia switched after 2009) bringing lower inflation rates.³⁴

³³Charry et al. (2014) also use similar type of UIP equation for their semi-structural model.

³⁴E.g. see Cukierman and Melnick (2015).

Figure 6: Monetary Policy Rate and Nominal Effective Exchange Rate



2.3.4 Monetary Policy

The NBGs monetary policy is modeled endogenously as one of the factors of the macroeconomic environment. The model thus incorporates the current and expected future stance of the central bank. The monetary policy rule is based on a Taylor-type rule and is in accordance with the objective of the National Bank as defined by the Organic Law of Georgia.

The specification of the monetary policy rule ensures that the policy rate changes to a greater extent in response to a deviation of expected inflation from the target (so that it satisfies the Taylor principle³⁵) and to a lesser extent in response to the output gap. However, for various reasons, interest rates do not change immediately and have certain inertia.³⁶ In particular, the monetary policy rule has the following (mostly standard) functional spec-

³⁵The result of not satisfying Taylor principle is studied by Clarida et al. (2000), both theoretically as well as empirically, where they find that not satisfying Taylor principle produces unnecessary fluctuations in macroeconomic variables and also makes monetary policy shock-propagator.

³⁶Woodford (2003) discusses why assigning a central bank the interest rate smoothing objective may be optimal. Sack and Wieland (1999) discuss some other practical reasons why interest rate smoothing may be optimal (e.g. uncertainty about the structure of the economy and the impact of monetary policy on it or measurement errors of some variables). See also Christiano (2015), which shows how smoothing the interest rate changes contribute to satisfying the Taylor principle.

ification:

$$i_t = \gamma_1 i_{t-1} + (1 - \gamma_1) \left[i_t^N + \gamma_2 E_t(\pi_{4,t+4} - \pi_{t+4}^{tar}) + \gamma_3 \hat{Y}_t \right] + \varepsilon_t^i - \gamma_4 \varepsilon_t^{tar} \quad (2.3.10)$$

where i_t^N is the neutral nominal interest rate, $\pi_{4,t+4}$ - year-on-year inflation expected in the next year, π_{t+4}^{tar} - the inflation target for the next year (which could differ from the current one, if target changes are planned). In addition to standard monetary policy shock (ε^i), the policy rate negatively reacts to changes in the inflation target (e.g. as a disinflation trigger, ε^{tar}).

This functional specification may well approximate to the optimal monetary policy (in the sense of minimizing social welfare loss) when zero lower bound (ZLB) is not an issue.³⁷ Here we abstract from ZLB, since the monetary policy rate in Georgia is well above that level and is unlikely to fall to zero in the foreseeable future.

According to this equation, when the economy is in equilibrium (i.e. is not subject to shocks), the monetary policy rate is at its neutral level, which itself is the equilibrium real interest rate plus the inflation target:

$$i_t^N = \bar{r}_t + \pi^{tar} \quad (2.3.11)$$

When the policy rate is equal to this neutral level monetary policy is neither expansionary nor contractionary.

The equilibrium real interest rate depends on such fundamental factors as productivity growth (captured by the real exchange rate trend) and risk premiums in Georgia. The higher the productivity growth, the stronger the real exchange rate appreciation, which drives real interest rates down.³⁸ On the other hand, the higher the risk premiums, the higher the compensation investors in Georgia demand, which drives long-run interest rates up. All of these factors have direct implications for the current monetary policy stance by altering the neutral rate.

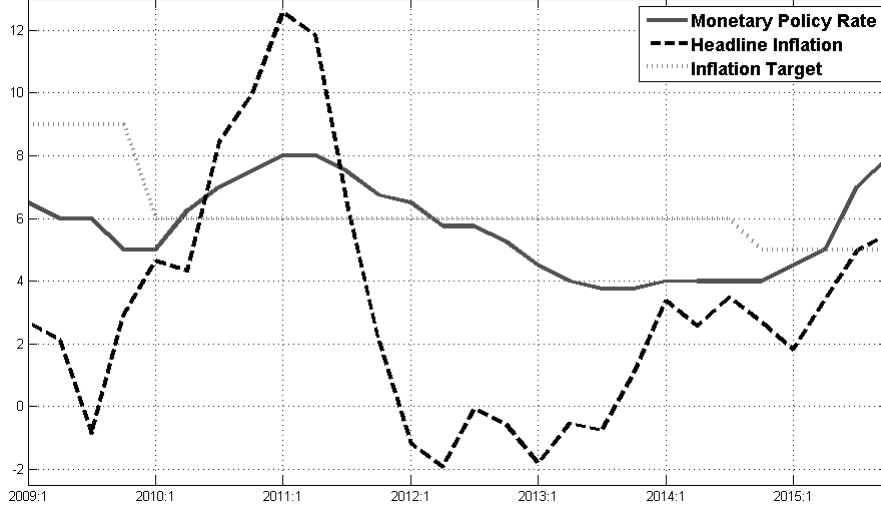
Figure 7 shows that, as expected, the monetary policy rate tended to decrease when inflation was expected to stay below the inflation target and tended to increase when inflation was expected to remain above the target.³⁹

³⁷For the discussion of global indeterminacy of Taylor rules when ZLB may bind see Benhabib et al. (2001).

³⁸For example, see Lee and Tang (2003).

³⁹Since monetary policy instruments in Georgia were activated in 2009 and only after that became monetary policy rate observable, the graph only includes 2009-2015 period.

Figure 7: Monetary Policy Rate and Inflation



2.4 Model Properties - Impulse Response Functions

One of the best and easiest ways to assess the models properties is to examine the impulse responses of the main macroeconomic variables to various shocks that the economy may face. The theoretical impulse responses can then be compared, formally or informally, to empirical counterparts estimated with vector autoregressions. Indeed, Christiano et al. (2005), for example, follow this type of limited information econometric strategy to estimate their DSGE model (i.e. choosing parameter values to minimize the distance between model impulse responses and their VAR counterparts). Therefore, in this section we provide impulse response functions to the main structural shocks (for now, without formal econometric evaluation), so that the appropriateness of the calibration can be validated by comparing the responses to that of other models and to stylized facts regarding the Georgian economy.

At the beginning of the simulation, the economy is assumed to be in the long-run equilibrium and then one-period shocks are introduced, one at time. Of course, in reality the economy is hit by a number of different in shocks each period and it is never in a steady-state equilibrium. However, for the purpose of studying the models properties, it is reasonable to keep things as simple as possible and to examine one issue at a time.

This section describes the responses of the main endogenous variables – headline inflation, the output gap, policy interest rate, inflation expectations and both nominal and real exchange rates (all in terms of deviations from long-run equilibrium values) – to the exogenous shocks of the policy interest rate, demand (with and without delayed policy reactions), cost-push and risk premium shocks. Furthermore, we discuss the disinflation scenario, which should be interesting given that Georgia plans to reduce its inflation target from the current level of 5% to 4% in 2017 and to 3% from 2018 onwards.

2.4.1 Monetary Policy Shock

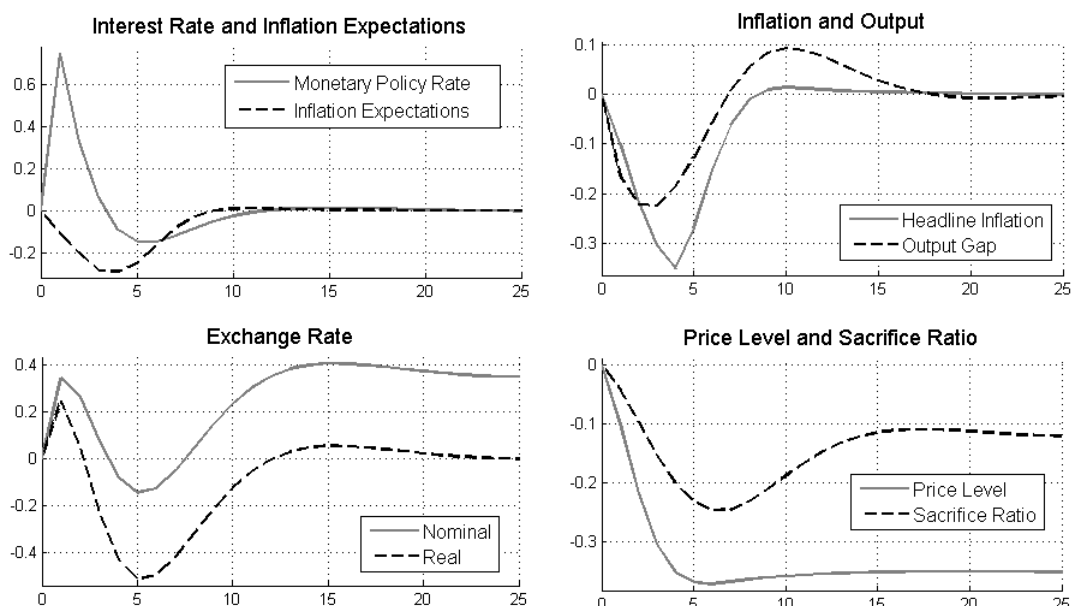
A monetary policy shock is initially represented by a one percentage point increase in the monetary policy interest rate, which then adjusts according to the policy rule. This simulation is only done for comparison purposes, as is the case in most macroeconomic models. Understanding how monetary policy may affect the macroeconomy should be helpful for policy making. Figure 8 shows the responses of the relevant variables to this type of shock, so that the broad picture of the interest rate, exchange rate and expectational channels at work are visible.

The initial increase in the policy rate is transmitted to the effective nominal interest rate. A higher nominal rate leads to an even higher real interest rate, since inflation expectations fall due to tight policy. Even though the monetary authority does not perfectly govern foreign interest rates (which is part of the effective interest rate relevant for credit), the real effective interest rate still increases strongly enough for two reasons. On the one hand, initially higher lari rates mean an appreciated lari on impact and expected depreciation afterwards, but the latter, in turn, means that even unchanged foreign currency rates are effectively tightened in domestic currency units. On the other hand, lower inflation expectations (due to tighter policy) further increase real rates. The resulting higher real interest rates, in turn, lower aggregate demand, which leads to a negative output gap. Reduced demand then puts downward pressure on domestic prices and inflation starts to fall.

In addition to this interest rate channel (supported by the expectational channel), following the unexpected increase in interest rates, both the nominal and real exchange rate appreciate on impact. This decreases import prices, from both the direct channel (imported consumption goods) and indirect channel (through lower imported input costs for domestic firms) and contributes to lower headline inflation.

The responses are broadly in line with the empirical studies on monetary policy shocks.⁴⁰ Inflation and output respond to the shock in a hump-shaped pattern (i.e. the vigorous response does not occur immediately, but a few quarters after the shock). The monetary policy tightening thus leads to output contraction, nominal exchange rate appreciation and, ultimately, to disinflation. These effects disappear after two to three years and the economy then converges back to the long-run equilibrium.

Figure 8: Monetary Policy Shock



2.4.2 Demand Shock

Demand shock is simulated as a one percentage point positive shock to the output gap that lasts for just one quarter. It is assumed that the central bank immediately knows that this type of shock has occurred. A positive shock that increases demand for output may originate from an exogenous increase in private consumption, investment or public consumption. Figure 9 presents the results of this simulation.

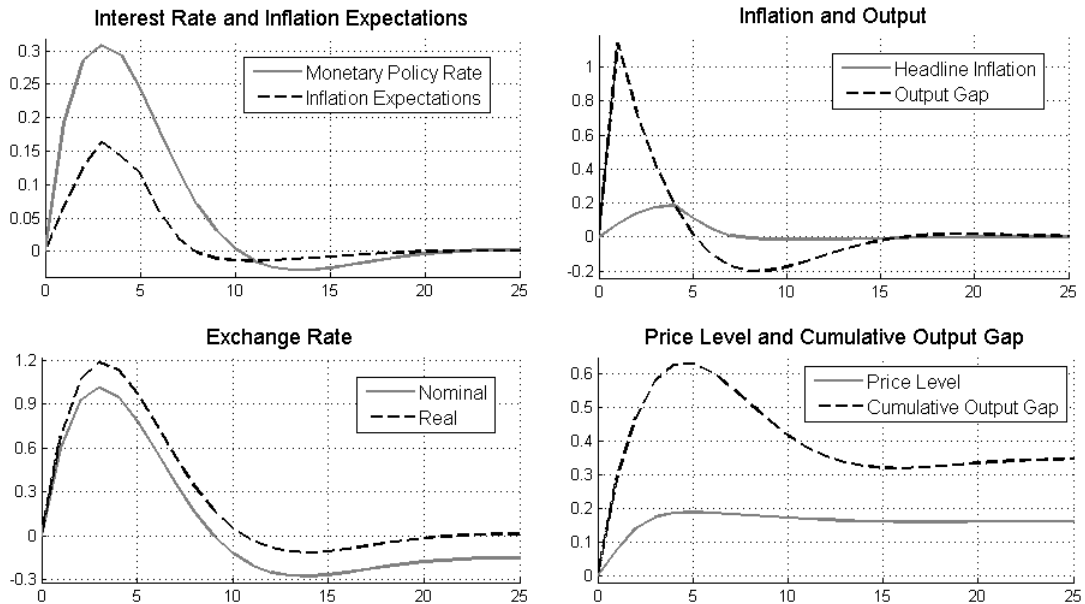
The initially positive output gap (due to the shock) puts upward pressure on inflation and the central bank thus raises the short-term nominal interest rate

⁴⁰See Christiano et al. (1998) for a literature review on the empirical estimates of the effects exogenous monetary policy shocks may have on the economy.

in response to the positive demand shock. Since the nominal rate increase is greater than the increase in inflation expectations, the real interest rate also climbs, which in turn leads to both nominal and real exchange rate appreciation that somewhat offsets the inflationary pressure from aggregate demand.

Even though excess demand tends to increase inflation, the price level remains only moderately above the pre-shock level, which is a reflection of exchange rates being another major factor that drives inflation, in addition to the output gap. Finally, after two to three years, almost all variables are essentially back to their steady states.

Figure 9: Demand Shock

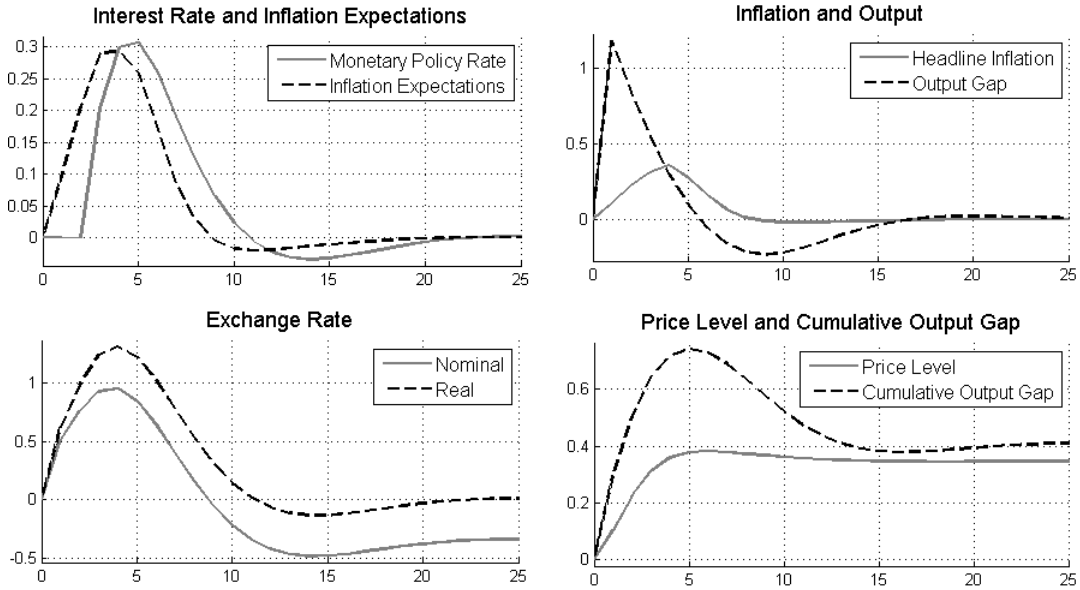


2.4.3 Delayed Policy Response to Demand Shock

The above simulation assumed that the central bank acted immediately in response to the demand shock. However, in some cases this may not be a plausible assumption, as monetary authorities may not immediately realize that the shock happened, only doing so after a couple of quarters. This type of delayed policy response simulation may be interesting in order to see how far a postponed reaction may weaken the stability of the economy. It is assumed that monetary policy does not react in the first two quarters and only starts acting accordingly in the third quarter. Figure 9 summarizes the outcome of this simulation.

As was expected, a delayed reaction implies a higher output gap and higher inflation (essentially twice as large). As the shock hit, the output gap became positive, thereby increasing inflation and, hence, inflation expectations. Higher inflation expectations and an unchanged nominal policy rate made the real policy rate expansionary (i.e. further stimulating the output gap and inflation). This is in line with the work of Clarida et al. (2000), where it is shown how a passive monetary policy (that does not satisfy the Taylor principle) may contribute to excessive fluctuations. However, once the monetary authority realizes that the demand shock has hit and thus starts to increase nominal policy rate accordingly, then interest rates stop being a shock propagator and start contributing to the stability of the system. Finally, the variables clearly go back to their steady states, but do so a couple of quarters later than in the case of immediate policy reaction.

Figure 10: Demand Shock with Delayed Policy Response



2.4.4 Cost-Push Shock

Cost-push (i.e. supply side) pressure is modeled as a positive one percentage point increase in the exogenous shock of inflation equation. This type of shock may originate from different sources. Gali (2008) lists two standard ones: exogenous variations in wage markups or firms price markups.

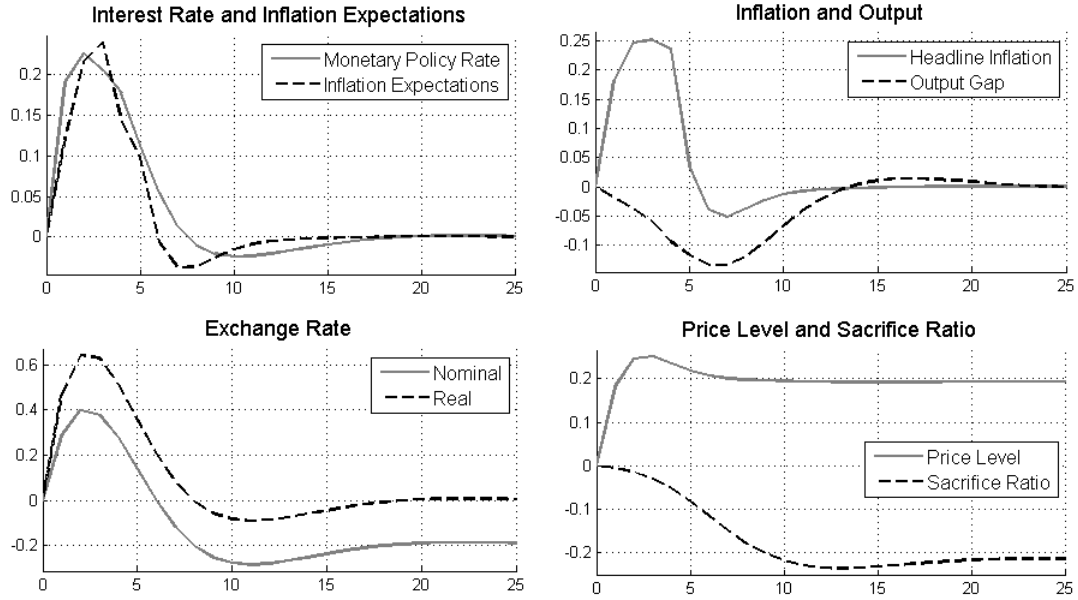
The cost-push shock raises headline inflation on impact, while causing output to contract. However, the latter effect is smaller because the monetary policy rate only increases to offset any rise in inflation expectations (hence real interest rates are essentially unchanged at the steady state). The nominal rate rise still causes nominal appreciation and partly offsets the rise in inflation (see Figure 11).

Given that real interest rates are practically unchanged, the reason why the output gap becomes negative is that higher prices hurt domestic competitiveness (the real exchange rate appreciates even more than the nominal one) and output drops somewhat, only recovering after the REER returns to its equilibrium.

Thus, after the adverse supply side shock, the economy foregoes some of its output (as seen by sacrifice ratio in the figure), while it gets a permanent, albeit moderate, higher price level. Since monetary policy reacts to inflation expectations, the supply shock only causes a one-time increase in prices (first-round effect), while it avoids second-round effects, so that inflation returns back to its target.⁴¹ This approach to the first- and second-round effects of supply shocks is well supported by both the academic literature (Clarida et al., 1999; Bernanke et al., 2001) and among monetary authorities (Mishkin, 2007; Davig et al., 2011; Broadbent, 2015).

⁴¹This is clearly seen in the impulse response of headline inflation, which increases on impact and practically vanishes after the first year (i.e. when the base effect disappears).

Figure 11: Cost Push Shock



2.4.5 Risk Premium Shock

The country risk premium is a very important variable for economies like Georgia. Risk premiums may exhibit substantial volatility for emerging markets, particularly for countries that are dollarized and especially exposed to sudden stops of foreign currency inflow. During sudden stops, risk premiums increase strongly and create depreciation pressure on the domestic currency. On the other hand, this also translates into lower investment in the economy, so that one gets a typical picture of supply side disturbances if inflation is greatly influenced by the exchange rate (as is the case for most small, open and financially dollarized economies, like Georgia).⁴²

Figure 12 presents the results of simulating risk premium shock in our model. A higher risk premium causes the domestic currency to immediately depreciate, which creates inflationary expectations. For this reason, monetary policy has to be tightened by increasing nominal and, to a lesser extent, real interest rates, which further depress demand to contain inflation in the medium run. Furthermore, since the domestic currency also depreciates with respect to the US dollar, balance sheet effects initially represent another deterrent

⁴²Curdia (2007) studies the small open financially dollarized economies' possible responses to sudden stops and increased country risk premiums in the context of a DSGE model.

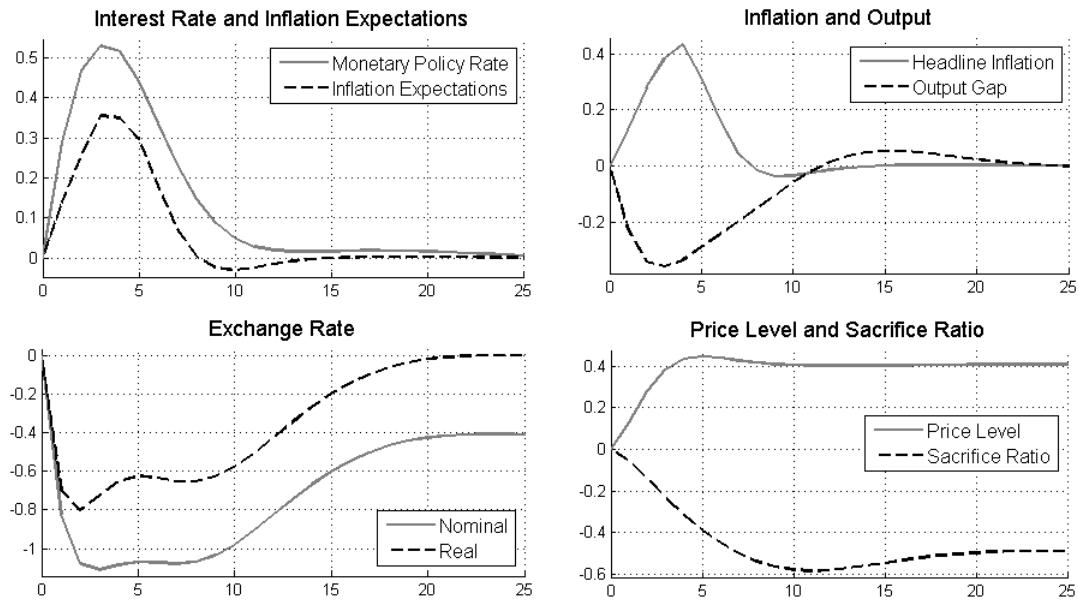
factor for aggregate demand.

On the other hand, in addition to the nominal exchange rate, the REER also depreciates, since prices adjust slowly compared to exchange rates. REER depreciation, in turn, increases the competitiveness of the economy in the medium term (it takes time to fully benefit from increased competitiveness) and gradually recovers output.

Finally, it is worth noting that, even though the magnitude of the shocks were the same in both simulations (for the risk premium and cost-push shocks), in the case of risk premium shock, the cost that the economy pays as a whole is much higher than in the case of domestic supply shock. This is evident by the twice as large sacrifice ratio and price level adjustment in the case of risk premium shock. This is the result of high liability dollarization and demonstrates how important external factors can be for countries like Georgia.

As with the previous simulations, after a risk premium shock it takes roughly three years for the economy to settle at its steady state.

Figure 12: Risk Premium Shock



2.4.6 Disinflation

The inflation target of the National Bank of Georgia is 5%, however, it is planned to reduce this to 4% in 2017 and to 3% from 2018 onwards. It is thus natural to analyze how the economy might react to this kind of permanent disinflation. The simulation of the central bank introducing a new inflation target that is one percentage point lower is carried out in the following way: the model economy starts at the equilibrium of the old inflation target and then realizes that it has to converge to the new equilibrium with new inflation target. The dynamics along the two equilibria show the reaction of the economy to this structural change. Figure 13 shows the main results of this simulation.⁴³

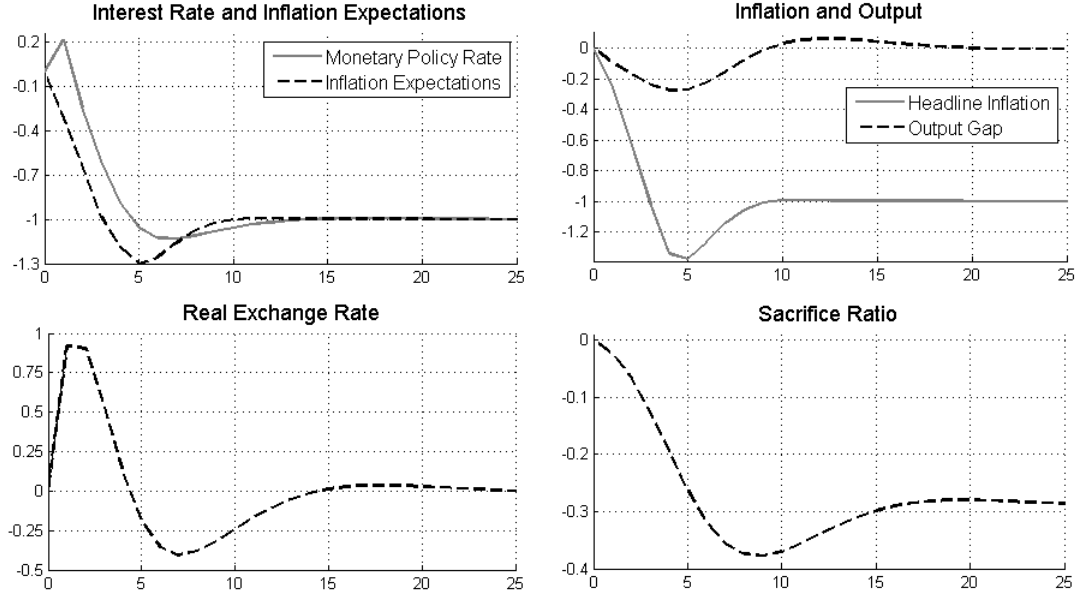
In order to achieve the desired (lower) new inflation target, the central bank has to initially raise the monetary policy rate in order to give credibility to its intention of reducing inflation. This triggers an appreciation of the domestic currency and an increase in the real interest rate. The appreciated currency and higher real rates lead to a negative output gap. Reduced imported inflation due to appreciation and the negative output gap both create deflation pressure, so that inflation also starts to fall (and reaches the new target after a slight undershooting).

After the initial tightening in the first quarter, the central bank starts to lower its policy rate, which allows the output gap and the REER gap to start recovering. In the end, there is no change to any real variable and only nominal variables are affected, with a moderate sacrifice ratio. All inflation rates are then lower by one percentage point and this is true for nominal rates as well.⁴⁴

⁴³Ascari and Ropele (2012) review the empirical literature on the costs of disinflation and then study this issue within a medium-scale DSGE model.

⁴⁴Since a lower inflation target means higher trend appreciation of the nominal exchange rate and a lower trend of price level, the latter two are not plotted on the figure since they now do not converge to any specific number, instead they change the slopes of their trends.

Figure 13: Disinflation



2.5 Conclusions

We have discussed the structure of Georgian Economy Model (GEMO) a semi-structural model used by the National Bank of Georgia for forecasting and monetary policy analysis. It is a relatively small macro model, albeit rich enough in features specific to the open Georgian economy to conduct forecasting and policy analysis and support monetary policy communication within and outside the central bank. The model, like modern estimated and fully micro-founded DSGE models, blends the New Keynesian emphasis on nominal and real rigidities with the approach of New Classical methods of general equilibrium modeling with rational expectations.

The core structure of the model is similar to other general equilibrium open economy models. The output gap is modeled using a dynamic IS-type equation, while inflation is determined through a new hybrid Phillips curve-type equation. Short-term interest rates are set by the monetary authority according to the monetary policy rule that satisfies the Taylor principle and reveals the optimal smoothing of rate changes. In addition, the GEMO includes some special transmission channels that are particularly important to take

into account in countries like Georgia. The main special features included in the model are the presence of imported intermediate goods (to reflect the increased dependence of firms on exchange rates) and balance sheet effects (due to liability dollarization and currency mismatches). These affect both demand and the supply side; the former dampens the exchange rate effect on inflation, while the latter strengthens it. Finally, a yield curve is explicitly included in the model to derive an effective interest rate relevant for credit and demand and thus to make monetary policy transmission more realistic.

The model is calibrated based on stylized facts, the properties of other models and some empirical estimates. Even though the availability of data does not provide a sufficiently good basis for formal parameter estimation, a Bayesian estimation of the model is planned in the future. In order to assess the model's properties and the calibration used, the impulse responses of the model to key structural shocks are provided. Policy interest rate, demand (with and without delayed policy reaction), cost-push (supply) and risk premium shocks have been discussed above. The reaction of the economy to permanent disinflation (i.e. inflation target reduction) was also discussed. Each of those simulations are well in line with the stylized facts and empirical findings that justify the use of the GEMO.

3 Satellite Tools

3.1 Real National Account Components' Model (RNA)

The National Statistics Office of Georgia (GeoStat) recently started to publish real growth rates for national account components. However, the data is yearly and publication has a 3-4 quarter time lag. The Real National Account Components Model (RNA) is a satellite model that aims to fill the gap and estimate real components as soon as official nominal numbers are published. The model is designed to be simple and is used to get quarterly estimates of real GDP components: real consumption, real government spending, real investment and real exports and imports over time.⁴⁵ The model is written in deflator terms and by applying a Kalman smoother a deflator for each component is estimated. Real components are obtained by deflating the official nominal numbers with the models estimated deflators. To make the results consistent with GeoStats yearly numbers, additional constraints are introduced in the model.

The result of the model will be used for current economic analysis as well as serving as an input for another satellite model to get forecasts for each component.

3.1.1 Model Equations

This section presents the model's equations together with some explanations. The model consists of five main equations - one for each deflator.

The output deflator (π^Y), is the weighted sum of the components' deflators, where the weights are corresponding nominal shares in total output.

$$\pi_t^Y = \omega_C \pi_t^C + \omega_I \pi_t^I + \omega_G \pi_t^G + \omega_X \pi_t^X - \omega_M \pi_t^M + \varepsilon_t^{\pi^Y} \quad (3.1.1)$$

The equation for the consumption deflator, (π^C) is an auto-regression process of order one.

$$\pi_t^C = \rho_C \pi_{t-1}^C + \varepsilon_t^{\pi^C} \quad (3.1.2)$$

The investment deflator, (π^I), depends on the import deflator and output deflator.

$$\pi_t^I = \rho_I \pi_t^M + (1 - \rho_I) \pi_t^Y + \varepsilon_t^{\pi^I} \quad (3.1.3)$$

⁴⁵Another satellite model, GDP Components Model, is used to forecast these components (see Section 3.2)

The government spending deflator, (π^G) is also a function of the import and output deflators.

$$\pi_t^G = \rho_G \pi_t^Y + (1 - \rho_G) \pi_t^M + \varepsilon_t^{\pi^G} \quad (3.1.4)$$

The determinants for the export deflator, (π^X) are the import and output deflators.

$$\pi_t^X = \rho_X \pi_t^Y + (1 - \rho_X) \pi_t^M + \varepsilon_t^{\pi^X} \quad (3.1.5)$$

The equation for the import deflator, (π^M) , like the consumption deflator, is also an auto regression process.

$$\pi_t^M = \rho_m \pi_{t-1}^M + \varepsilon_t^{\pi^M} \quad (3.1.6)$$

A detailed description of all the variables and shocks of the model is presented in the Appendix (see Table B.1).

3.1.2 Model Data

The model uses quarterly data that is mainly taken from GeoStat and the NBG. The input variables for estimation are the output deflator, the consumption deflator and the import deflator. All variables are given in annual growth rate terms. In addition, the model uses the yearly growth rates for GDP components published by GeoStat. These are imposed as constraints in the model to ensure consistent results.

The output deflator is calculated as the year-on-year growth rate. The consumption deflator is the annual growth rate of CPI inflation.

The calculation for the import deflator is more complex. It is a weighted sum of commodity and non-commodity import prices, where the weights are corresponding shares in Georgian imports (calculations are done using 2013-2015 data). Each component is denominated in GEL. The equation for the import deflator can be written in the following form:

$$\pi^{IM} = \omega^{com} \pi^{com} S_{US} + \omega^{noncom} \pi^F S^F \quad (3.1.7)$$

where, π^{IM} is the import deflator, π^{com} - commodity price inflation, S_{US} - the GEL/USD bilateral exchange rate ⁴⁶, π^F - effective foreign inflation and S^F - effective exchange rate. ω^{com} and ω^{noncom} correspond to commodity and

⁴⁶An increase means depreciation of the GEL

non-commodity shares in Georgian imports, respectively.

For commodity prices, the IMF's All Commodity Price Index is used, assuming that it captures all commodities relevant for Georgia. As for the non-commodity part, this is approximated by effective foreign inflation. Effective foreign inflation, in turn, is the weighted sum of the CPI inflation of Georgias main trading partners, where the weights are the corresponding shares in Georgias non-commodity imports. The trading partners include the United States, the European Union, Russia, Ukraine, Turkey and China. These countries accounted for almost 75% percent of Georgian non-commodity import in 2013-2015. The remaining 25% is distributed proportional among these six countries. Weights are calculated using the latest years (2013-2015) data. It can be expressed by the following equation:

$$\begin{aligned}\pi^F = & \omega_{US}^{noncom} \pi_{US} + \omega_{EU}^{noncom} \pi_{EU} + \omega_{RU}^{noncom} \pi_{RU} + \omega_{UA}^{noncom} \pi_{UA} \\ & + \omega_{TR}^{noncom} \pi_{TR} + \omega_{CH}^{noncom} \pi_{CH}\end{aligned}\quad (3.1.8)$$

As for the effective exchange rate, this is calculated as the weighted sum of GEL bilateral exchange rates with respect to Georgias main trading partners. The weights are again the countries corresponding share in Georgian non-commodity imports:

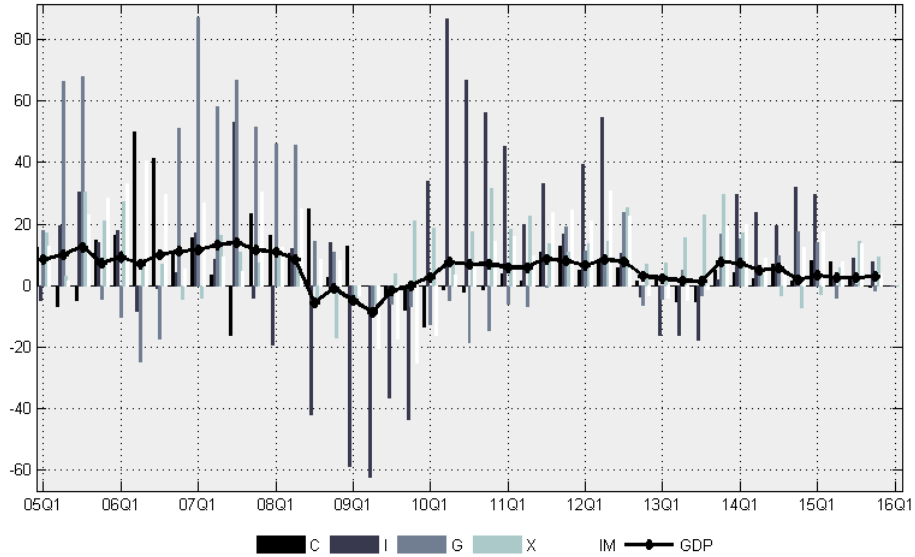
$$\begin{aligned}S^F = & \omega_{US}^{noncom} S_{US} + \omega_{EU}^{noncom} S_{EU} + \omega_{RU}^{noncom} S_{RU} + \omega_{UA}^{noncom} S_{UA} \\ & + \omega_{TR}^{noncom} S_{TR} + \omega_{CH}^{noncom} S_{CH}\end{aligned}\quad (3.1.9)$$

A detailed description of the data is given in the Appendix (Table B.2).

3.1.3 Model Calibration and Estimation

The models calibration is based on stylized facts for Georgia and is supported by both statistical and empirical analyses. The parameter values are also validated by a Bayesian estimation. The value of the parameters together with brief explanations are presented in the Appendix (Table ??)

Figure 14: RNA Components, YoY %



Estimation is done from the first quarter of 2005 using a Kalman smoother. Estimation of the model gives a historical series of deflators for each component. These series are used to deflate nominal components and thus get estimates of real GDP components over time. The estimation (March 2016) result is presented on Figure 14.

3.2 Real National Account Components' Forecasting Model (FRNA)

The Real National Account Components Model (RNA) provides a series of real output components over time. However, for analysis and policy decisions the forecast of these components is also necessary. The Real National Account Components Forecasting Model (FRNA) is a simple quarterly model based on fundamental economic concepts. The model has two main purposes. First, taking the output gap from the Georgian Economy Model (GEMO) and conditioned with the real components from the RNA model, the model gives the output gap division into its components gaps over history. Second, conditioned on the forecast for the output gap, the effective real interest rate gap and the effective real exchange rate gap from the GEMO, the model forecasts real output components, in both level and gap terms. During the forecasting procedure, it also takes feedback from history by using real output components data from the RNA model. Thus, results of the FRNA model are consistent with other models in the FPAS.

The results of the FRNA model combined with the GEMO outcome will be used for policy analysis and decision making.

3.2.1 Model Equations

This section presents the models equations together with brief explanations. The model consists of five main equations: one for the output gap and one for each of the four components.

The output gap, $(\hat{Y})$ is the weighted sum of its components' gaps, where weights are the corresponding real shares in real output.

$$\hat{Y}_t = \delta_C \hat{C}_t + \delta_I \hat{I}_t + \delta_X \hat{X}_t - \delta_M \hat{M}_t \quad (3.2.1)$$

The consumption gap, $(\hat{C})$, includes both private and public consumption. It positively depends on the output gap and negatively on the real effective interest rate gap $(\hat{r}^{eff})$.

$$\hat{C}_t = \alpha_{C_1} \hat{Y}_t - \alpha_{C_2} \hat{r}_t^{eff} + \varepsilon_t^{\hat{C}} \quad (3.2.2)$$

The investment gap, $(\hat{I})$, is determined by the output gap and effective interest rate gap. Both have a positive effect on investment.

$$\hat{I}_t = \alpha_{I_1} \hat{Y}_t + \alpha_{I_2} \hat{r}_t^{eff} + \varepsilon_t^{\hat{I}} \quad (3.2.3)$$

The export gap, $(\hat{X})$, is positively affected by the effective real exchange rate gap $(\hat{Z})$ and the effective foreign demand gap for non-commodity goods $(\hat{FD})$. The export component and its weights require more explanation. Export is divided into commodity and non-commodity parts. It is assumed that the commodity export gap is zero, meaning that it is mainly stable over the years. Analyses in gap terms are thus done using the non-commodity export gap, and its weight in the first equation is also adjusted by the share of non-commodity goods in total exports.

$$\hat{X}_t = \alpha_{X_1} \hat{Z}_t + \alpha_{X_2} \hat{FD}_t + \varepsilon_t^{\hat{X}} \quad (3.2.4)$$

The import gap, $(\hat{M})$, is determined by the output gap and the real effective exchange rate gap.

$$\hat{M}_t = \alpha_{M_1} \hat{Y}_t - \alpha_{M_2} \hat{Z}_t + \varepsilon_t^{\hat{M}} \quad (3.2.5)$$

A detailed description of all variables and shocks of the model is presented in the Appendix (see Table C.1).

3.2.2 Model Data

In order to get a forecast for real GDP components, the model mainly uses results from other models. In particular, real consumption, real investment, real export and real import are taken from the RNA model; the output gap, effective real exchange rate gap and effective real interest rate gap are outcomes of the GEMO estimation; and effective foreign demand is calculated separately. All input data for the models estimation is of a quarterly frequency.

Effective foreign demand for non-commodity goods is the weighted sum of Georgias main trade partners GDPs, where the weights are the corresponding share in Georgias non-commodity exports. The countries used to calculate effective foreign demand are the USA, the EU, Russia, Turkey, Ukraine and China. These countries accounted for almost 60% of Georgian non-commodity export during 2013-2015. Effective foreign demand can be expressed by the following equation:

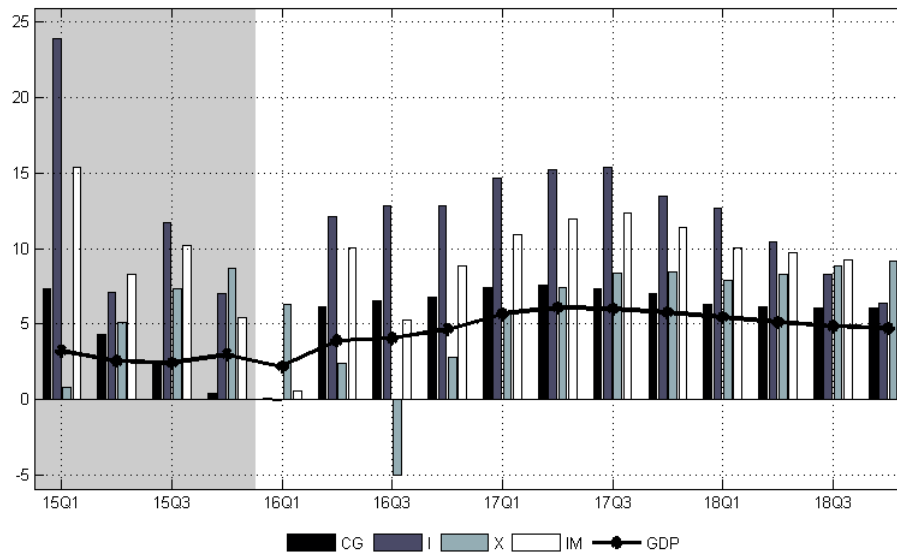
$$\begin{aligned} FD = & \omega_{US}^{X,noncom} Y_{US} + \omega_{EU}^{X,noncom} Y_{EU} + \omega_{TR}^{X,noncom} Y_{TR} + \omega_{RU}^{X,noncom} Y_{RU} \\ & + \omega_{UA}^{X,noncom} Y_{UA} + \omega_{CH}^{X,noncom} Y_{CH} \end{aligned} \quad (3.2.6)$$

where Y_i is country i 's real GDP and $\omega_i^{X,noncom}$ country i 's share in Georgia's non-commodity export. The detailed description of data is given in the Appendix (Table C.2).

3.2.3 Model Calibration and Forecasting

The models calibration is based on stylized facts for Georgia and is supported by both statistical and empirical analyses. The parameter values are also validated by a Bayesian estimation.

Figure 15: FRNA Components, YoY %



Estimation of the FRNA model serves two purposes. First, taking the output gap from the GEMO conditioned with the real components from the RNA model, the model gives the output gap division into its components gaps over time. Second, conditioned on the forecast for the output gap, the effective real interest rate gap and effective real exchange rate gap from the GEMO, the model forecasts real output components in both level and gap terms. During the forecasting procedure it also takes feedback from history by using real output components data from the RNA model. The estimation result (March, 2016) is presented on Figure 15.

Appendices

A Details of GEMO

A.1 Model Equations

A.1.1 Demand Side

Output Gap:

$$\begin{aligned}\hat{Y}_t = & \alpha_1 \hat{Y}_{t-1} + \alpha_2 E_t \hat{Y}_{t+1} - \alpha_3 (\hat{r}_t^{eff} + \alpha_4 \hat{pr}\hat{e}m_t) - \alpha_5 \hat{Z}_t + \alpha_6 \hat{Y}_t^* + \\ & + \alpha_7 \hat{G}_t - \alpha_8 \hat{S}_t^{GEL/USD} + \varepsilon_t^{\hat{Y}}\end{aligned}\tag{A.1.1}$$

Balance Sheet Effects:⁴⁷

$$\hat{S}_t^{GEL/USD} = \rho_s \hat{S}_{t-1}^{GEL/USD} + (1 - \rho_s) \left(\Delta S_t^{GEL/USD} + (\Delta \bar{Z}_t - \pi_t^{tar} + \pi_{ss}^{US}) \right)\tag{A.1.2}$$

Extra Government Spending:

$$\hat{G}_t = \rho_g \hat{G}_{t-1} + \varepsilon_t^{\hat{G}}\tag{A.1.3}$$

A.1.2 Supply Side

Headline Inflation:⁴⁸

$$\begin{aligned}\pi_t = & \beta_5 \left(\beta_1 \pi_t^m + (1 - \beta_1) \left[\beta_2 \pi_{t-1} + (1 - \beta_2) \pi_t^e \right] \right) + \\ & + (1 - \beta_5) \left(\beta_6 \pi_t^{oil} + (1 - \beta_6) \pi_t^{food} \right) + \\ & + \beta \left(\beta_4 \frac{\bar{y} \hat{Y}_t}{\bar{y} - \hat{Y}_t} - \beta_5 \hat{Z}_t + \beta_{13} \hat{S}_t^{GEL/USD} \right) + \varepsilon_t^\pi + \varepsilon_t^{u^\pi} + \rho_l \varepsilon_{t-1}^{u^\pi}\end{aligned}\tag{A.1.4}$$

⁴⁷For any variable Δ means annualized quarter-on-quarter change: $\Delta x_t = 4(x_t - x_{t-1})$.

⁴⁸For all measures of inflation $\pi_t = 4(P_t - P_{t-1})$ is an annualized quarter-on-quarter change in (log) price level, while $\pi_{4,t} = (P_t - P_{t-4})$ is an year-on-year change.

Imported Inflation:

$$\pi_t^m = \beta_9 \pi_{t-1}^m + (1 - \beta_9)[\Delta S_t + \pi_t^* + \Delta \bar{Z}_t] + \varepsilon_t^{\pi^m} \quad (\text{A.1.5})$$

Oil Inflation:

$$\pi_t^{oil} = \beta_7 \pi_{t-1}^{oil} + (1 - \beta_7)[\pi_t^{oil,int} + \Delta S_t^{GEL/USD} + \Delta \bar{Z}_t] + \varepsilon_t^{\pi^{oil}} \quad (\text{A.1.6})$$

$$\pi_t^{oil,int} = \rho_{oil} \pi_{t-1}^{oil,int} + (1 - \rho_{oil}) \pi_t^{oil,int} + \varepsilon_t^{\pi^{oil,int}} \quad (\text{A.1.7})$$

Food Inflation:

$$\pi_t^{food} = \beta_8 \pi_{t-1}^{food} + (1 - \beta_8)[\pi_t^{food,int} + \Delta S_t^{GEL/USD} + \Delta \bar{Z}_t] + \varepsilon_t^{\pi^{food}} \quad (\text{A.1.8})$$

$$\pi_t^{food,int} = \rho_{food} \pi_{t-1}^{food,int} + (1 - \rho_{food}) \pi_t^{food,int} + \varepsilon_t^{\pi^{food,int}} \quad (\text{A.1.9})$$

Inflation Expectations:

$$\pi_t^e = \delta C_t E_t \pi_{4,t+1} + (1 - \delta C_t) \pi_{4,t-1} + (1 - C_t) \pi^{bias} \quad (\text{A.1.10})$$

Credibility of the Central Bank:

$$C_t = \rho_c C_{t-1} + (1 - \rho_c) \frac{(\pi_t^{err,h})^2}{(\pi_t^{err,h})^2 + (\pi_t^{err,l})^2} + \varepsilon_t^C \quad (\text{A.1.11})$$

$$\pi_t^{err,h} = \pi_{4,t} - \left(\rho_h \pi_{4,t-1} + (1 - \rho_h) \pi_t^h \right) \quad (\text{A.1.12})$$

$$\pi_t^{err,l} = \pi_{4,t} - \left(\rho_l \pi_{4,t-1} + (1 - \rho_l) \pi_t^{tar} \right) \quad \text{with} \quad \pi_t^{tar} < \pi^h \quad \text{and} \quad \rho_l < \rho_h \quad (\text{A.1.13})$$

A.1.3 Monetary Policy

Monetary Policy Rule:

$$i_t = \gamma_1 i_{t-1} + (1 - \gamma_1) \left[i_t^N + \gamma_2 E_t (\pi_{4,t+4} - \pi_{t+4}^{tar}) + \gamma_3 \hat{Y}_t \right] + \varepsilon_t^i - \gamma_4 \varepsilon_t^{tar} \quad (\text{A.1.14})$$

Neutral Policy Rate:

$$i_t^N = \bar{r}_t + \pi_{4,t} \quad (\text{A.1.15})$$

Inflation Target:

$$\pi_t^{tar} = \pi_{t-1}^{tar} + \varepsilon_t^{tar} \quad (\text{A.1.16})$$

A.1.4 Uncovered Interest Rate Parity

Nominal UIP:

$$\begin{aligned} \theta(i_t - i_t^*) + (1 - \theta)[(\bar{r}_t + \pi_t^{tar}) - (\bar{r}_t^* + \pi_{ss}^{US})] = & 4(S_t^{GEL/USD,e} - S_t^{GEL/USD}) + \\ & + prem_t + \varepsilon_t^S \end{aligned} \quad (\text{A.1.17})$$

$$S_t^{GEL/USD,e} = \kappa E_t S_{t+1}^{GEL/USD} + (1 - \kappa) \left[S_{t-1}^{GEL/USD} - 2(\Delta \bar{Z}_t - \pi_t^{tar} + \pi_t^{US,tar})/4 \right] \quad (\text{A.1.18})$$

Real UIP:

$$\bar{r}_t = \rho_{\bar{r}} \bar{r}_{t-1} + (1 - \rho_{\bar{r}}) \left(\bar{r}_t^* + pr\bar{e}m_t - E_t \Delta \bar{Z}_{t+1} \right) + \varepsilon_t^{\bar{r}} \quad (\text{A.1.19})$$

A.1.5 Yield Curve

1Y Domestic Nominal Interest Rate:

$$i_t^{1y,d} = \frac{i_t + E_t i_{t+1} + E_t i_{t+2} + E_t i_{t+3}}{4} + t p_t^{1y} \quad (\text{A.1.20})$$

1Y Domestic Real Interest Rate:

$$r_t^{1y,d} = \frac{r_t + E_t r_{t+1} + E_t r_{t+2} + E_t r_{t+3}}{4} + t p_t^{1y} \quad (\text{A.1.21})$$

1Y Domestic Equilibrium Real Interest Rate:

$$\bar{r}_t^{1y,d} = \frac{\bar{r}_t + E_t \bar{r}_{t+1} + E_t \bar{r}_{t+2} + E_t \bar{r}_{t+3}}{4} + \bar{t} p_t^{1y} \quad (\text{A.1.22})$$

Term Premium (1Y over Short-Term):

$$t p_t^{1y} = \rho_{tp,1y} t p_{t-1}^{1y} + (1 - \rho_{tp,1y}) \bar{t} p_t^{1y} + \varepsilon_t^{tp,1y} \quad (\text{A.1.23})$$

$$\bar{t} p_t^{1y} = \bar{t} p_{t-1}^{1y} + \varepsilon_t^{\bar{t}p,1y} \quad (\text{A.1.24})$$

3Y Domestic Nominal Interest Rate:

$$i_t^{3y,d} = \frac{i_t^{1y,d} + E_t i_{t+4}^{1y,d} + E_t i_{t+8}^{1y,d}}{3} + t p_t^{3y} \quad (\text{A.1.25})$$

3Y Domestic Real Interest Rate:

$$r_t^{3y,d} = \frac{r_t^{1y,d} + E_t r_{t+4}^{1y,d} + E_t r_{t+8}^{1y,d}}{3} + t p_t^{3y} \quad (\text{A.1.26})$$

3Y Domestic Equilibrium Real Interest Rate:

$$\bar{r}_t^{3y,d} = \frac{\bar{r}_t^{1y,d} + E_t \bar{r}_{t+4}^{1y,d} + E_t \bar{r}_{t+8}^{1y,d}}{3} + \bar{t} p_t^{3y} \quad (\text{A.1.27})$$

Term Premium (3Y over 1Y):

$$t p_t^{3y} = \rho_{tp,3y} t p_{t-1}^{3y} + (1 - \rho_{tp,3y}) \bar{t} p_t^{3y} + \varepsilon_t^{tp,3y} \quad (\text{A.1.28})$$

$$\bar{t}p_t^{3y} = \bar{t}p_{t-1}^{3y} + \varepsilon_t^{\bar{t}p,3y} \quad (\text{A.1.29})$$

Short-Term USD Nominal Interest Rate (in Georgia):

$$i_t^{fx} = i_t^* + prem_t \quad (\text{A.1.30})$$

Short-Term USD Nominal Interest Rate (in lari units):

$$i_t^{fx,gel} = i_t^{fx} + 4(S_t^{GEL/USD,e} - S_t^{GEL/USD}) \quad (\text{A.1.31})$$

1Y USD Nominal Interest Rate:

$$i_t^{1y,fx,gel} = \frac{i_t^{fx,gel} + E_t i_{t+1}^{fx,gel} + E_t i_{t+2}^{fx,gel} + E_t i_{t+3}^{fx,gel}}{4} + tp_t^{1y} \quad (\text{A.1.32})$$

1Y USD Real Interest Rate:

$$r_t^{1y,fx,gel} = \frac{r_t^{fx,gel} + E_t r_{t+1}^{fx,gel} + E_t r_{t+2}^{fx,gel} + E_t r_{t+3}^{fx,gel}}{4} + tp_t^{1y} \quad (\text{A.1.33})$$

3Y USD Nominal Interest Rate:

$$i_t^{3y,fx,gel} = \frac{i_t^{1y,fx,gel} + E_t i_{t+4}^{1y,fx,gel} + E_t i_{t+8}^{1y,fx,gel}}{3} + tp_t^{3y} \quad (\text{A.1.34})$$

3Y USD Real Interest Rate:

$$r_t^{3y,fx,gel} = \frac{r_t^{1y,fx,gel} + E_t r_{t+4}^{1y,fx,gel} + E_t r_{t+8}^{1y,fx,gel}}{3} + tp_t^{3y} \quad (\text{A.1.35})$$

Domestic Nominal Lending Rate:

$$i_t^{l,d} = \omega_s i_t + \omega_{1y} i_t^{1y,d} + (1 - \omega_s - \omega_{1y}) i_t^{3y,d} + spread_t \quad (\text{A.1.36})$$

Domestic Real Lending Rate:

$$r_t^{l,d} = \omega_s r_t + \omega_{1y} r_t^{1y,d} + (1 - \omega_s - \omega_{1y}) r_t^{3y,d} + spread_t \quad (\text{A.1.37})$$

USD Nominal Lending Rate:

$$\begin{aligned} i_t^{l,fx,gel} = & \omega_{s,fx} i_t^{fx,gel} + \omega_{1y,fx} i_t^{1y,fx,gel} + (1 - \omega_{s,fx} - \omega_{1y,fx}) i_t^{3y,fx,gel} + \\ & + spread_t + spread_t^{fx} \end{aligned} \quad (A.1.38)$$

USD Real Lending Rate:

$$\begin{aligned} r_t^{l,fx,gel} = & \omega_{s,fx} r_t^{fx,gel} + \omega_{1y,fx} r_t^{1y,fx,gel} + (1 - \omega_{s,fx} - \omega_{1y,fx}) r_t^{3y,fx,gel} + \\ & + spread_t + spread_t^{fx} \end{aligned} \quad (A.1.39)$$

Nominal Effective Interest Rate:

$$i_t^{eff} = \sigma i_t^{l,d} + (1 - \sigma) i_t^{l,fx,gel} \quad (A.1.40)$$

Real Effective Interest Rate:

$$r_t^{eff} = \sigma r_t^{l,d} + (1 - \sigma) r_t^{l,fx,gel} \quad (A.1.41)$$

Equilibrium Real Effective Interest Rate:

$$\begin{aligned} \bar{r}_t^{eff} = & \sigma \left(\omega_s \bar{r}_t + \omega_{1y} \bar{r}_t^{1y,d} + (1 - \omega_s - \omega_{1y}) \bar{r}_t^{3y,d} \right) + \\ & + (1 - \sigma) \left(\omega_{s,fx} \bar{r}_t + \omega_{1y,fx} \bar{r}_t^{1y,d} + (1 - \omega_{s,fx} - \omega_{1y,fx}) \bar{r}_t^{3y,d} \right) + \\ & + \bar{spread}_t + (1 - \sigma) spread_t^{fx} \end{aligned} \quad (A.1.42)$$

Real Effective Interest Rate Gap:

$$\hat{r}_t^{eff} = r_t^{eff} - \bar{r}_t^{eff} \quad (A.1.43)$$

A.1.6 Trends and Identities

Output (accommodating time-varying steady state):

$$Y_t = \bar{Y}_t + \hat{Y}_t \quad (A.1.44)$$

$$\Delta \bar{Y}_t = 4(\bar{Y}_t - \bar{Y}_{t-1}) \quad (A.1.45)$$

$$\Delta \bar{Y}_t = \rho_{\bar{Y}} \Delta \bar{Y}_{t-1} + (1 - \rho_{\bar{Y}}) \Delta \bar{Y}_{ss,t} + \varepsilon_t^{\Delta \bar{Y}} \quad (A.1.46)$$

$$\Delta \bar{Y}_{ss,t} = \Delta \bar{Y}_{ss,t-1} + \varepsilon_t^{\Delta \bar{Y}_{ss}} \quad (A.1.47)$$

Nominal Effective Exchange Rate:

$$\begin{aligned}
S_t = & - \left(\omega_{US} S_t^{GEL/USD} + \omega_{EU} \left(S_t^{GEL/USD} + S_t^{USD/EUR} \right) + \right. \\
& + \omega_{TR} \left(S_t^{GEL/USD} - S_t^{TRY/USD} \right) + \omega_{RU} \left(S_t^{GEL/USD} - S_t^{RUB/USD} \right) + \\
& \left. + (1 - \omega_{US} - \omega_{EU} - \omega_{TR} - \omega_{RU}) \left(S_t^{GEL/USD} - S_t^{UAH/USD} \right) \right)
\end{aligned} \tag{A.1.48}$$

REER (level, gap and trend):

$$Z_t = S_t - P_t^* + P_t \tag{A.1.49}$$

$$\hat{Z}_t = Z_t - \bar{Z}_t \tag{A.1.50}$$

$$\Delta \bar{Z}_t = 4(\bar{Z}_t - \bar{Z}_{t-1}) \tag{A.1.51}$$

$$\Delta \bar{Z}_t = \rho_{\bar{Z}} \Delta \bar{Z}_{t-1} + (1 - \rho_{\bar{Z}}) \Delta Z_{ss,t} + \varepsilon_t^{\Delta \bar{Z}} \tag{A.1.52}$$

$$\Delta \bar{Z}_{ss,t} = \Delta \bar{Z}_{ss,t-1} + \varepsilon_t^{\Delta \bar{Z}_{ss}} \tag{A.1.53}$$

Real Short-Term Interest Rates (domestic and USD):

$$r_t = i_t - \pi_t^e \tag{A.1.54}$$

$$r_t^{fx, gel} = i_t^{fx, gel} - \pi_t^e \tag{A.1.55}$$

Country Risk Premium (level, gap and trend):

$$prem_t = pr\bar{e}m_t + pr\hat{e}m_t \tag{A.1.56}$$

$$pr\hat{e}m_t = \rho_{pr\hat{e}m_1} pr\hat{e}m_{t-1} + \varepsilon_t^{pr\hat{e}m} \tag{A.1.57}$$

$$pr\bar{e}m_t = \rho_{pr\bar{e}m} pr\bar{e}m_{t-1} + (1 - \rho_{pr\bar{e}m}) prem_{ss,t} + \varepsilon_t^{pr\bar{e}m} \tag{A.1.58}$$

$$prem_{ss,t} = prem_{ss,t-1} + \varepsilon_t^{pr\bar{e}m_{ss}} \tag{A.1.59}$$

Lending Spread (domestic and USD):

$$spread_t = spr\bar{e}ad_t + spr\hat{e}ad_t \tag{A.1.60}$$

$$spr\hat{e}ad_t = \rho_{spr\hat{e}ad} spr\hat{e}ad_{t-1} + \varepsilon_t^{spr\hat{e}ad} \tag{A.1.61}$$

$$spr\bar{e}ad_t = \rho_{spr\bar{e}ad} spr\bar{e}ad_{t-1} + (1 - \rho_{spr\bar{e}ad}) spread_{ss} + \varepsilon_t^{spr\bar{e}ad} \tag{A.1.62}$$

$$spread_t^{fx} = \rho_{spread^{fx}} spread_{t-1}^{fx} + (1 - \rho_{spread^{fx}}) spread_{ss}^{fx} + \varepsilon_t^{spread^{fx}} \tag{A.1.63}$$

A.1.7 Foreign Variables

Foreign Output Gap:

$$\hat{Y}_t^* = \rho_{\hat{Y}^*} \hat{Y}_{t-1}^* + \varepsilon_t^{\hat{Y}^*} \quad (\text{A.1.64})$$

Foreign Inflation:

$$P_t^* = \omega_{US} P_t^{US} + \omega_{EU} P_t^{EU} + \omega_{TR} P_t^{TR} + \omega_{RU} P_t^{RU} \\ (1 - \omega_{US} - \omega_{EU} - \omega_{TR} - \omega_{RU}) P_t^{UA} \quad (\text{A.1.65})$$

$$\pi_t^{US} = \rho_{\pi^{US}} \pi_{t-1}^{US} + (1 - \rho_{\pi^{US}}) \pi_{ss}^{US} + \varepsilon_t^{\pi^{US}} \quad (\text{A.1.66})$$

$$\pi_t^{EU} = \rho_{\pi^{EU}} \pi_{t-1}^{EU} + (1 - \rho_{\pi^{EU}}) \pi_{ss}^{EU} + \varepsilon_t^{\pi^{EU}} \quad (\text{A.1.67})$$

$$\pi_t^{TR} = \rho_{\pi^{TR}} \pi_{t-1}^{TR} + (1 - \rho_{\pi^{TR}}) \pi_{ss}^{TR} + \varepsilon_t^{\pi^{TR}} \quad (\text{A.1.68})$$

$$\pi_t^{RU} = \rho_{\pi^{RU}} \pi_{t-1}^{RU} + (1 - \rho_{\pi^{RU}}) \pi_{ss}^{RU} + \varepsilon_t^{\pi^{RU}} \quad (\text{A.1.69})$$

$$\pi_t^{UA} = \rho_{\pi^{UA}} \pi_{t-1}^{UA} + (1 - \rho_{\pi^{UA}}) \pi_{ss}^{UA} + \varepsilon_t^{\pi^{UA}} \quad (\text{A.1.70})$$

Exchange Rates:

$$\Delta S_t^{USD/EUR} = \Delta S_{ss}^{USD/EUR} + \varepsilon_t^{\Delta S^{USD/EUR}} \quad (\text{A.1.71})$$

$$\Delta S_t^{USD/TRY} = \Delta S_{ss}^{USD/TRY} + \varepsilon_t^{\Delta S^{USD/TRY}} \quad (\text{A.1.72})$$

$$\Delta S_t^{USD/RUB} = \Delta S_{ss}^{USD/RUB} + \varepsilon_t^{\Delta S^{USD/RUB}} \quad (\text{A.1.73})$$

$$\Delta S_t^{USD/UAH} = \Delta S_{ss}^{USD/UAH} + \varepsilon_t^{\Delta S^{USD/UAH}} \quad (\text{A.1.74})$$

Foreign Interest Rate:

$$i_t^* = \rho_{i^*} i_{t-1}^* + (1 - \rho_{i^*}) (\bar{r}_t^* + \pi_{ss}^{US}) + \varepsilon_t^{i^*} \quad (\text{A.1.75})$$

$$\bar{r}_t^* = \rho_{\bar{r}^*} \bar{r}_{t-1}^* + (1 - \rho_{\bar{r}^*}) r^{*ss} + \varepsilon_t^{\bar{r}^*} \quad (\text{A.1.76})$$

A.2 Description of Variables

Table A.1: Transition Variables

Variable	Description
Y	Output
ΔY	Output Growth Q/Q @ar
ΔY_4	Output Growth Y/Y
$\bar{Y}$	Real GDP Trend
$\Delta \bar{Y}$	Real GDP Trend Growth
$\hat{Y}$	Output Gap
P	Price Level
π	Inflation Q/Q @ar
π_4	Inflation Y/Y
π^e	Inflation Expectations Q/Q @ar
π^M	Imported Inflation Q/Q @ar
π^{tar}	Inflation Target
i	Monetary Policy Rate
i^N	Neutral Policy Rate
r	Real Policy Rate
$\bar{r}$	Money Market Real Rate Trend
$i^{1y,d}$	Domestic 1Y Nominal Rate
$i^{3y,d}$	Domestic 3Y Nominal Rate
$i^{l,d}$	Domestic Nominal Lending Rate
$i^{1y,fx,gel}$	USD 1Y Nominal Rate
$i^{3y,fx,gel}$	USD 3Y Nominal Rate
$i^{l,fx,gel}$	USD Nominal Lending Rate
i^{eff}	Effective Nominal Interest Rate
r^{eff}	Effective Real Interest Rate
$\bar{r}^{eff}$	Effective Real Interest Rate Trend
$\hat{r}^{eff}$	Effective Real Interest Rate Gap
$prem$	Country Risk Premium
$\bar{prem}$	Country Risk Premium Trend
$\hat{prem}$	Country Risk Premium Gap
$spread$	Domestic Lending Spread
$\bar{spread}$	Domestic Lending Spread Trend
$\hat{spread}$	Domestic Lending Spread Gap
$spread_{fx}$	USD Lending Spread

Table A.2: Transition Variables, continued

Variable	Description
S	Effective Nominal Exchange Rate
ΔS	Effective Nominal Exchange Rate Appreciation Q/Q @ar
$S^{GEL/USD}$	GEL/USD Nominal Exchange Rate
$\Delta S^{GEL/USD}$	GEL/USD Nominal Exchange Rate Depreciation Q/Q @ar
$S^{GEL/USD,e}$	GEL/USD Nominal Exchange Rate Expectation
Z	Effective Real Exchange Rate
$\bar{Z}$	Effective Real Exchange Rate Trend
$\Delta \bar{Z}$	Effective Real Exchange Rate Trend Appreciation Q/Q @ar
$\hat{Z}$	Effective Real Exchange Rate Gap
$\hat{G}$	Extra Government Spending
Y^*	Foreign Output Gap
P^*	Effective Foreign Price Level
P^{US}	US Price Level
P^{EU}	EU Price Level
P^{TR}	TR Price Level
P^{RU}	RU Price Level
P^{UA}	UA Price Level
π^*	Effective Foreign Inflation Q/Q @ar
π^{US}	US Inflation Q/Q @ar
π^{EU}	EU Inflation Q/Q @ar
π^{TR}	TR Inflation Q/Q @ar
π^{RU}	RU Inflation Q/Q @ar
π^{UA}	UA Inflation Q/Q @ar
i^*	Foreign Nominal Interest Rate
$\bar{r}^*$	Foreign Real Interest Rate Trend
$S^{USD/EUR}$	USD/EUR Nominal Exchange Rate
$S^{USD/TRY}$	USD/TRY Nominal Exchange Rate
$S^{USD/RUB}$	USD/RUB Nominal Exchange Rate
$S^{USD/UAH}$	USD/UAH Nominal Exchange Rate

Table A.3: Transition Shocks

Variable	Description
$\varepsilon^{\hat{Y}}$	Demand Shock
ε^{π}	Cost Push Shock
ε^{π^m}	Imported Inflation Shock
$\varepsilon^{u^{\pi}}$	High-Frequency Shock to Inflation
$\varepsilon^{\pi^{oil}}$	Domestic Oil Price Shock
$\varepsilon^{\pi^{oil,int}}$	International Oil Price Shock
$\varepsilon^{\pi^{food}}$	Domestic Food Price Shock
$\varepsilon^{\pi^{food,int}}$	International Food Price Shock
$\varepsilon^{\pi^{tar}}$	(Permanent) Inflation Target Shock
ε^i	Monetary Policy Shock
ε^C	Central Bank Credibility Shock
$\varepsilon^{tp,1y}$	Temporary 1Y Term Premium Shock
$\varepsilon^{\bar{tp},1y}$	Permanent 1Y Term Premium Shock
$\varepsilon^{tp,3y}$	Temporary 3Y Term Premium Shock
$\varepsilon^{\bar{tp},3y}$	Permanent 3Y Term Premium Shock
ε^S	Exchange Rate Portfolio (UIP) Shock
ε^G	Extra Government Spending Shock
$\varepsilon^{\Delta \bar{Y}}$	Temporary Output Trend Shock
$\varepsilon^{\Delta \bar{Y}_{ss}}$	Permanent Output Trend Shock
$\varepsilon^{\Delta \bar{Z}}$	Temporary Real Appreciation Trend Shock
$\varepsilon^{\Delta \bar{Z}_{ss}}$	Permanent Real Appreciation Trend Shock
$\varepsilon^{\bar{r}}$	Real Interest Rate Trend Shock
$\varepsilon^{pr\bar{e}m}$	Temporary Country Risk Premium Trend Shock
$\varepsilon^{pr\bar{e}m_{ss}}$	Permanent Country Risk Premium Trend Shock
$\varepsilon^{pr\hat{e}m}$	Country Risk Premium Gap Shock
$\varepsilon^{spr\bar{e}ad}$	Domestic Lending Spread Trend Shock
$\varepsilon^{spr\hat{e}ad}$	Domestic Lending Spread Gap Shock
$\varepsilon^{spread_{fx}}$	USD Lending Spread Gap Shock

Table A.4: Transition Shocks, continued

Variable	Description
$\varepsilon^{\hat{Y}^*}$	Foreign Demand Shock
$\varepsilon^{\pi^{US}}$	US Inflation Shock
$\varepsilon^{\pi^{EU}}$	EU Inflation Shock
$\varepsilon^{\pi^{TR}}$	TR Inflation Shock
$\varepsilon^{\pi^{RU}}$	RU Inflation Shock
$\varepsilon^{\pi^{UA}}$	UA Inflation Shock
ε^{i^*}	Foreign Nominal Interest Rate Shock
$\varepsilon^{\bar{r}^*}$	Foreign Real Interest Rate Trend Shock
$\varepsilon^{\Delta S^{USD/EUR}}$	USD/EUR Exchange Rate Depreciation Shock
$\varepsilon^{\Delta S^{USD/TRY}}$	USD/TRY Exchange Rate Depreciation Shock
$\varepsilon^{\Delta S^{USD/RUB}}$	USD/RUB Exchange Rate Depreciation Shock
$\varepsilon^{\Delta S^{USD/UAH}}$	USD/UAH Exchange Rate Depreciation Shock

A.3 Data Description and Sources

Table A.5: Observed Variables

Variable	Name	Note
Y_t	Real GDP	Real Gross Domestic Product of Georgia in constant 2010 prices in national currency (GEL). Time series from National Statistics Office of Georgia (GeoStat).
π_t	Inflation	Annualized Q/Q CPI inflation. Time series from GeoStat.
π_t^{oil}	Domestic Oil Inflation	Annualized Q/Q domestic oil inflation. Time series from GeoStat.
$\pi_t^{oil,int}$	International Oil Inflation	Annualized Q/Q international oil inflation. Time series from Bloomberg.
π_t^{food}	Domestic Food Inflation	Annualized Q/Q domestic food inflation. Time series from GeoStat.
$\pi_t^{food,int}$	International Food Inflation	Annualized Q/Q international food inflation. Time series from Bloomberg.
i_t	Monetary Policy Rate	Time series from the National Bank of Georgia (NBG).
i_t^l	Domestic Lending Rate	Market nominal interest rates on loans in national currency (GEL). Time series from (NBG).
$S_t^{GEL/USD}$	GEL/USD Exchange Rate	Bilateral nominal exchange rate GEL per USD, monthly average. Time series from (NBG).
$S_t^{USD/EUR}$	USD/EUR Exchange Rate	Bilateral nominal exchange rate USD per EUR, monthly average. Time series from Bloomberg.
$S_t^{USD/TRY}$	USD/TRY Exchange Rate	Bilateral nominal exchange rate USD per TRY, monthly average. Time series from Bloomberg.
$S_t^{USD/RUB}$	USD/RUB Exchange Rate	Bilateral nominal exchange rate USD per RUB, monthly average. Time series from Bloomberg.
$S_t^{USD/UAH}$	USD/UAH Exchange Rate	Bilateral nominal exchange rate USD per UAH, monthly average. Time series from Bloomberg.
$prem_t$	Country Risk Premium	JPMorgan EMBI Global Georgia Sovereign Spread. Time series from Bloomberg.
Y_t^*	Foreign Output Gap	Weighted average of trading partner countries' output gaps estimated in the RNA model.
P_t^{US}	US Price Level	US CPI Index. Time series from Bloomberg.
P_t^{EU}	EU Price Level	Euro Area Harmonized CPI Index. Time series from Bloomberg.
P_t^{TR}	TR Price Level	Turkey CPI Index. Time series from Bloomberg.
P_t^{RU}	RU Price Level	Russia CPI Index. Time series from Bloomberg.
P_t^{UA}	UA Price Level	Ukraine CPI Index. Time series from Bloomberg.
i_t^*	Foreign Interest Rate	Monthly average of 3 months London-Interbank Offered Rate- British Bankers Association fixing for US Dollar. Time series from Bloomberg.

B RNA Descriptive Tables

Table B.1: Transition Variables and Shocks, RNA

Variable	Description
π^Y	Output Deflator
π^C	Consumption Deflator
π^I	Investment Deflator
π^G	Government Spending Deflator
π^X	Export Deflator
π^M	Import Deflator
ε^{π^Y}	Output Deflator Shock
ε^{π^C}	Consumption Deflator Shock
ε^{π^I}	Investment Deflator Shock
ε^{π^G}	Government Spending Deflator Shock
ε^{π^X}	Export Deflator Shock
ε^{π^M}	Import Deflator Shock

Table B.2: Data, RNA

Variable	Name	Unit	Note	Source
π^Y	GDP Deflator	% YoY	Calculated using nominal GDP over Real GDP ratio	GeoStat
π^C	Consumption Deflator	% YoY	Calculated using CPI index	NBG
π^M	Import Deflator	% YoY	Import Deflator	NBG calculations
π^{com}	Commodity Price	% YoY	All Commodity Price Index	IMF
π_{US}	Inflation, USA	% YoY	Calculated using USA CPI index	Bloomberg
π_{EU}	Inflation, EU	% YoY	Calculated using EU CPI index	Bloomberg
π_{RU}	Inflation, Russia	% YoY	Calculated using RU CPI index	Bloomberg
π_{UA}	Inflation, Ukraine	% YoY	Calculated using UA CPI index	Bloomberg
π_{TR}	Inflation, Turkey	% YoY	Calculated using TR CPI index	Bloomberg
π_{CH}	Inflation, China	% YoY	Calculated using CH CPI index	Bloomberg
S_{US}	GEL/USD	% YoY	Calculated using GEL/USD exchange rate	NBG
S_{EU}	GEL/EURO	% YoY	Calculated using GEL/EU exchange rate	NBG
S_{RU}	GEL/Rubble	% YoY	Calculated using RU/USD exchange rate	Bloomberg
S_{UA}	GEL/Hryvnia	% YoY	Calculated using UA/USD exchange rate	Bloomberg
S_{TR}	GEL/Lira	% YoY	Calculated using TR/USD exchange rate	Bloomberg
S_{CH}	GEL/Yuan	% YoY	Calculated using CH/USD exchange rate	Bloomberg

C FRNA Descriptive Tables

Table C.1: Transition Variables and Shocks, FRNA

Variable	Description
$\hat{Y}$	Output Gap
$\hat{C}$	Consumption Gap
$\hat{I}$	Investment Gap
$\hat{X}$	Export Gap
$\hat{M}$	Import Gap
$\hat{Z}$	Effective Real Exchange Rate Gap
$\hat{r}^{eff}$	Effective Real Interest Rate Gap
$\hat{FD}$	Effective Foreign Demand Gap
$\varepsilon^{\hat{C}}$	Consumption Gap Shock
$\varepsilon^{\hat{I}}$	Investment Gap Shock
$\varepsilon^{\hat{X}}$	Export Gap Shock
$\varepsilon^{\hat{M}}$	Import Gap Shock

Table C.2: Data, FRNA

Variable	Name	Unit	Note	Source
C	Real Consumption	Level	RNA Model Result	NBG estimations
G	Real Government Spending	Level	RNA Model Result	NBG estimations
I	Real Investment	Level	RNA Model Result	NBG estimations
X	Real Export	Level	RNA Model Result	NBG estimations
M	Real Import	Level	RNA Model Result	NBG estimations
$\hat{Y}$	Output Gap		GEMO Result	NBG estimations
$\hat{Z}$	Effective Real Exchange Rate Gap		GEMO Result	NBG estimations
$\hat{r}^{eff}$	Effective Real Interest Rate Gap		GEMO Result	NBG estimations
FD	Effective Foreign Demand for Non-commodity Goods	Level		NBG calculations
Y_{US}	Real Output, USA	Level	Real GDP Index	Bloomberg
Y_{EU}	Real Output, EU	Level	Real GDP Index	Bloomberg
Y_{TR}	Real Output, Turkey	Level	Real GDP Index	Bloomberg
Y_{RU}	Real Output, Russia	Level	Real GDP Index	Bloomberg
Y_{UA}	Real Output, Ukraine	Level	Real GDP Index	Bloomberg
Y_{CH}	Real Output, China	Level	Real GDP Index	Bloomberg

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