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Report – External Evaluation of GEMO Model

Summary

- *The Georgian Economy Model (GEMO) structure reflects well the main transmission channels of monetary policy in Georgia and allows for important characteristics of the Georgian economy. Nonetheless, GEMO is not too large and tractable.*
- *Forecast evaluation analysis shows GEMO does a good job in forecasting Georgian key economic variables. The performance is especially good for CPI inflation, the main output variable of the model in the monetary policy process of the National Bank of Georgia (NBG).*
- *GEMO could be adjusted and extended in some dimensions if time permits. Recommendations for extensions relate to, among others, the design and calibration of the Taylor rule and the modeling of the country risk premium.*

1. Introduction

The NBG operates under an inflation-targeting framework that implies the announcement of an inflation target for the medium term. Because monetary policy affects the economy with a time lag, good forecasting of the economy is of the essence. This requires expert judgement and economic modeling. Therefore the NBG developed a Forecasting and Policy Analysis system (FPAS), which includes a set of short-term models to evaluate the state of the economy and a semi-structural macroeconomic model, GEMO, for the medium-term forecast. The baseline forecast of the model is presented together with a risk and uncertainty section and alternative scenarios in the Monetary Policy Report, which serves the Monetary Policy Committee (MPC) as basis for their decisions.

2. Terms of reference

In this context, NBG Governor Koba Gvenetadze asked for technical assistance (TA) by the SNB to evaluate FPAS and in particular GEMO. Therefore, I[1] spend one week, from August 11th to August 17th 2019 at the NBG to gather information on (i) the structure of GEMO, (ii) the Georgian data and the forecast performance of the model and (iii) how the model is used in the monetary policy process at the NBG. [2]

This report summarizes the key findings of the mission and has the following structure: Section 3 contains the technical evaluation of GEMO. In the first subsection, the overall performance is evaluated. In the second subsection, I list some recommendations for possible extensions of the model. Section 4 concludes.

3. Technical evaluation of GEMO

3.1. Overall performance

In order for GEMO to be a useful forecasting tool in the monetary policy process at the NBG, the model has to be theoretically, institutionally and empirically coherent. That means first, it has to be able to match the main transmission channels of monetary policy in Georgia. Second, it has to resemble the view the MPC has about the Georgian economy. Third, the model has to be a good forecasting tool with a good forecast accuracy.[3]

3.1.1. Theoretical and institutional coherence

Members of the NBG expressed to me the view that they prefer a tractable and transparent model, which is not too large, but covers the main transmission channels of monetary policy in Georgia. GEMO reflects this view. It is a small open economy model à la Gali and Monacelli (2005), which covers a demand curve, a Phillips curve, an uncovered interest rate parity (UIP) condition and a Taylor rule. All equations are adapted to deal with the characteristics of the Georgian economy. That means first, trends of the variables and expectations are time varying and are modelled explicitly in the GEMO model to deal with large movements in trends. This is very relevant in emerging economies.

Second, several special features of the Georgian economy are incorporated into the model, albeit in a more or less ad-hoc way, to strengthen the transmission of monetary policy through the exchange rate channel. The Phillips curve, which is modelled in terms of headline

[1] The opinions expressed in this report are solely the responsibility of the author and do not necessarily reflect the views of the Swiss National Bank.

[2] I like to thank the NBG for their openness, their kind hospitality, and the productive discussions during the mission at the NBG.

[3] The NBG takes already account of that. It presents in the first Monetary Policy Report of each year GEMO's forecast accuracy of the past year. The four GEMO inflation forecasts of the year before are compared with actual realisations of inflation and possible reasons for deviations are explained.

inflation, includes not only imported inflation but also imported intermediate goods inflation. Both depend on the real effective exchange rate. In addition, a large albeit decreasing share of loans in the Georgian economy is denominated in US dollar instead of Georgian lari (liability dollarization). This leads to balance sheet effects on the supply and demand side. If the Georgian lari depreciates relative to the US dollar, firms are facing higher financing costs and they may charge higher prices. On the demand side, households facing higher financing costs may cut consumption. Therefore, the bilateral lari US dollar exchange rate is included in both the Phillips curve and the IS curve.

Another interesting feature in GEMO is the prominent role of the country risk premium. The country risk premium in the model is defined as the spread between the yield on Georgian government debt denominated in USD and the yield on US treasuries. A widening of the risk premium not only drives deviations from the UIP and thereby leads to a depreciation of the lari against the USD but also increases financing costs in the economy and thereby depresses output. A large country risk premium shock therefore leads to a stagflation. Finally, GEMO is characterized by a detailed modeling of the yield curve. Nominal and real interest rates up to 3 years duration are in the model. The lending rate in the economy not only consists of a weighted average of 1 to 3 year interest rates but also depends on a "spread", which reflects a private sector risk premium.

Overall, the model structure seems to reflect well the main transmission channels of monetary policy in Georgia and it allows for several characteristics of the Georgian economy. Nonetheless, GEMO is tractable because it is based on four core equations only.

3.1.2. Empirical coherence

GEMO is operating since 2013Q1 in the monetary policy process. The parameters in the model are calibrated based on impulse response analysis. This is done by comparing theoretical impulse response functions (IRFs) of the main shocks in the model with empirical ones and adjusting the parameters in the model to generate the best fit. In addition, moments of filtered data are compared with moments of model variables. In 2015, the model was extended and recalibrated to fit the data better. In this process, information from Bayesian estimation exercises was used.[4] Some parameters were estimated and the calibration was updated based on the posterior distributions of the estimated parameters.

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N} e_i^2}$$

To gain insights into how well the model structure and calibration of the model performs empirically the "Macroeconomic Research" division of the NBG ran forecasting exercises. Starting in 2013Q1, when the model was introduced, forecasts of horizon 1-8 were run each quarter for the key economic variables in the model. The forecasts were compared with the

[4] An and Schorfheide (2007) contains an overview of Bayesian estimation techniques.

actual realizations of the variables and the forecast error e was computed for each horizon and each quarter i. Afterwards, the forecast errors were averaged over the quarters from 2013Q1 until 2019Q2 along the lines of the equation above.

$$rel.\ RMSE = \frac{RMSE^{GEMO}}{RMSE^{RW}}$$

In the forecasting literature, one usually compares the resulting Root Mean Square Errors (RMSEs) with a benchmark to be better able to judge the size of the RMSEs. This is done because the RMSEs can vary a lot depending on the volatility of the variables under consideration and the sample, which is evaluated. Using a simple model like the "random walk" (RW) as a benchmark is a standard procedure and gives the answer to the question: How much better do we fare by employing the model compared to a scenario where we use no model at all and project the actual value of the variable into the future? [5] Therefore, the relative RMSEs, the ratios of the GEMO RMSEs relative to the RMSEs of a RW, were computed.[6] The equation above shows the formula to compute relative RMSEs. A value smaller than one indicates that the forecasting performance of the model was better than the one of a RW.

Relative RMSEs	1q ahead	2q ahead	4q ahead	8q ahead
GDP growth (y/y)	0.90	0.77	0.57	0.77
CPI inflation (y/y)	0.45	0.57	0.73	0.43
Policy rate	0.83	0.94	0.97	0.65

Table 1: Relative RMSEs for four forecast horizons based on the historical forecasts computed at each quarterly policy round. The one-quarter ahead forecast is the now cast.

Tables 1 and 2 show the results for year-over-year (y/y) GDP growth, CPI inflation (y/y) and the monetary policy rate. Table 1 contains the relative RMSEs based on the historical forecasts computed at each quarterly policy round and table 2 the relative RMSEs based on the "pure" GEMO forecasts. Having both results has some advantages. Although the overall picture in table 1 and table 2 is similar, the underlying forecasts in the two tables were run under different assumptions. The historical forecasts take all the exogenous assumptions at each policy round on board including "tunes", which reflect expected policy changes in the future at the time the forecasts were produced. The pure GEMO forecasts use realized data for the foreign sector, whereas in the historical forecasts the staff forecasts for foreign variables were employed. Finally, because the pure GEMO forecasts were run ex-post, the latest

5 Alternative benchmarks could be a simple estimated AR(1) process for each variable or an empirical model at the NBG, which is at use.

6 See Table 3.G on page 40 in Bank of England (2015) for an example, where this approach is used to evaluate the forecast performance of the BOE staff forecast.

version of GEMO was used. The historical forecasts on the other hand are based on the real-time version of the model, which was available at the time of the respective policy round.

Relative RMSEs	1q ahead	2q ahead	4q ahead	8q ahead
GDP growth (y/y)	0.70	0.84	1.14	0.75
CPI inflation (y/y)	0.62	0.61	0.59	0.73
Policy rate	1.10	1.04	0.96	1.03

Table 2: Relative RMSEs for four forecast horizons based on the pure GEMO model forecasts. The one-quarter ahead forecast is the now cast.

Although a sample period of six and a half years (26 quarters) from 2013Q1 to 2019Q2 is not long, this is all we have and the results are insightful. I would like to emphasize three key takeaways:

- First, the GEMO forecast beats the RW easily over the whole forecast horizon. This is especially true for CPI inflation, where the RMSEs of the historical forecasts have roughly half the size of the RW leading to a ratio of around 0.5.
- Second, the historical forecast performs better than the pure GEMO forecast. This finding is surprising at first glance, given that the pure model forecast uses realized foreign data and employs the latest version of the model. However, the result points to the important role of the now cast or short-term forecast for the performance of the overall forecast. In the historical forecast, the short-term GEMO forecast is conditioned on forecasts by satellite econometric models in the FPAS suite and this improves the forecasting performance even at the two-year horizon.
- Third, the forecast for the monetary policy rate cannot beat a RW especially in the case of the pure model forecast. I think the result can be explained as follows. Whereas the Phillips curve and the IS curve in the model are tailored towards accommodating the idiosyncrasies of the Georgian economy, this is not so much the case for the Taylor rule in the model, which governs the behavior of the monetary policy rate. In the next subsection, I will make a suggestion on how the forecast performance of the Taylor rule could potentially be improved.

To sum up, the forecast evaluation exercise shows that although GEMO is not large it performs well in terms of RMSEs relative to a RW. The model is especially well designed to explain and forecast movements in inflation, which is the main output variable of the model for the monetary policy process of the NBG. In the next subsection, I list some suggestions of what could be done if one wants to extend the model. The suggestions are ordered by theoretical and empirical topics but not by priority and can be tackled independently from each other.

3.2. Recommendations for possible extensions

The following four recommendations relate to the structure of GEMO i.e. the design of the model equations and possible extensions thereof.

3.2.1. Design of the Taylor rule

The first idea is linked to the third finding above, the design of the Taylor rule. In the current version of GEMO, the monetary policy rate reacts to the lagged monetary policy rate to account for interest rate smoothing, the time-varying neutral interest rate, the deviation of inflation expectations four-quarters ahead from the time-varying inflation target, the output gap and a monetary policy shock. With this design, the Taylor rule takes care of trends in the neutral real interest rate and in the inflation target, which can be adjusted by monetary policy. Furthermore, it reflects the inflation-targeting regime under which the NBG operates. However, because it's a simple rule it can only approximate to some degree the complex monetary policy process, in which the central banks sets the monetary policy rate. Therefore, augmenting the Taylor rule could improve the forecasting performance to some degree.

- One suggestion relates to the existing calibration of the Taylor rule. Whereas the coefficient on the lagged monetary policy rate is with 0.75 relatively small, the reaction to the inflation gap is with a coefficient of 2.5 forceful. Under this calibration, the Taylor rule would predict a strong easing of monetary policy, whenever inflation undershoots the inflation target of the NBG. This is indeed the case in the period 2015-2016. Inflation was undershooting the inflation target of 5% most of the time and the model was predicting a stronger easing than materialized. One way to crosscheck the calibration of the Taylor rule could be an estimation of the Taylor Rule outside the model.
- A second way to improve the forecasting performance of the Taylor rule could be an augmentation by additional variables. One candidate is the exchange rate. Adolfson et al. (2007) utilize and estimate a Taylor rule with real exchange rate in the DSGE model of the Swedish Riksbank. The equation below shows the Taylor rule in their model, where $\hat{R}_t$ is the nominal interest rate, $\hat{\pi}_t^c$ CPI inflation, $\bar{\pi}_t^c$ the time-varying inflation target, $\hat{y}_t$ the output gap, $\hat{x}_t$ the real exchange rate and $\varepsilon_{R,t}$ an uncorrelated monetary policy shock.

$$\hat{R}_t = \rho_R \hat{R}_{t-1} + (1\text{-}\rho_R)\left[\bar{\pi}_t^c + r_\pi(\hat{\pi}_{t-1}^c - \bar{\pi}_t^c) + r_y \hat{y}_{t-1} + r_x \hat{x}_{t-1}\right] + r_{\Delta\pi}\Delta\hat{\pi}_t^c + r_{\Delta y}\Delta\hat{y}_t \; + \varepsilon_{R,t}$$

3.2.2. Country risk premium

The second suggestion relates to the country risk premium (PREM) in the model, which is defined as the spread between the yield on Georgian government debt denominated in USD and the yield on US treasuries. The risk premium gap (PREMg), the deviation of the risk

premium from its trend, is modeled as an *exogenous* AR(1) process.[7] That means, when the risk premium goes up in the data this leads to adverse consequences for the forecast of the Georgian economy. The exchange rate is expected to depreciate and financing costs in Georgia are expected to go up, leading to higher expected inflation and lower expected output growth. However, over the forecast horizon, the risk premium is expected to revert to trend gradually. Agents in the model expect that and this reversion back to trend is reflected in the overall forecast. Therefore making the process for the risk premium gap *endogenous* could change the evolution of the risk premium over the forecast period and thereby the evolution of the other key variables. Bi (2012) and Corsetti et al. (2013) relate the country risk premium to fiscal conditions. A fiscal limit is calculated, which is defined as the maximum debt level the country is able to service. Fiscal limits can vary a lot between countries as they depend on multiple factors: How much more taxes can be raised before lowering tax revenues (Laffer curve), the growth potential of the country and the size of government spending and transfers. If the actual debt level approaches the fiscal limit, the risk premium goes up.[8]

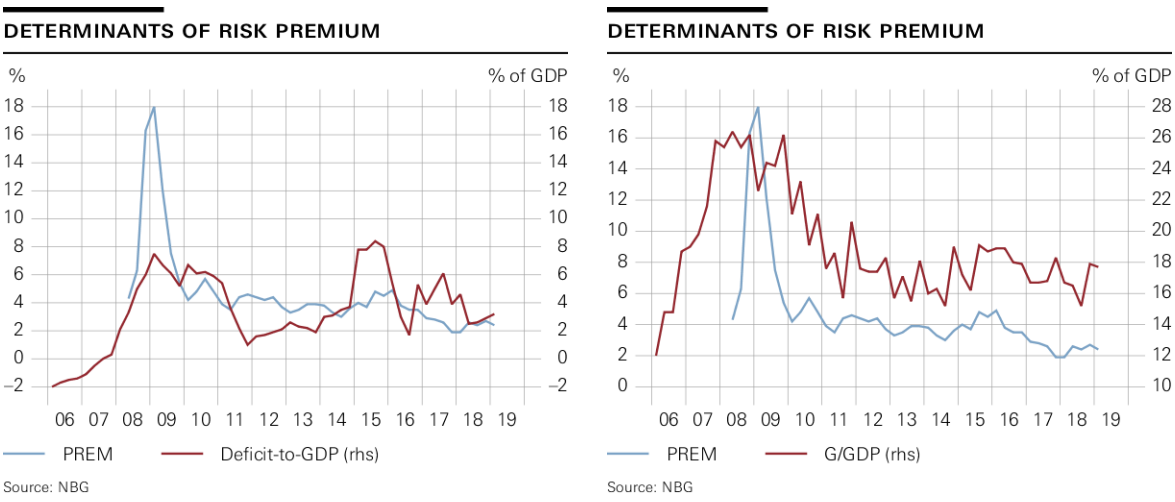

Figure 1: Determinants of the Georgian risk premium.

Figure 1 plots the country risk premium for Georgia, the blue line, together with fiscal variables from 2006Q1 until 2019Q2.[9] The chart on the left shows the risk premium and the deficit-to-GDP ratio (red line), the chart on the right the risk premium and the government spending to GDP ratio (red line). One can see two episodes. The strong rise of the risk premium in 2008 followed by the moderation in 2009 and a mild rise in 2015. In both episodes we see a rise in the deficit-to-GDP ratio and the government spending-to-GDP ratio too, suggesting that there is a connection.

[7] This is the case in the linear version of the model. In the nonlinear version, the risk premium gap can react to the output gap.

[8] The risk premium reacts in a nonlinear way. When fiscal conditions deteriorate, the risk premium stays flat for some time until financial market participants lose confidence and sell government bonds. This nonlinear reaction could be simulated with the nonlinear version of GEMO.

[9] Data for the risk premium, the "JPMorgan EMBI Global Georgia Sovereign Spread", are only available since 2008Q2.

Making the risk premium endogenous would also allow for second round effects. When a risk premium shock hits the economy, GDP growth worsens and fiscal policy might respond by increasing government spending leading to an increase in the government spending-to-GDP ratio. At the same time, the budget deficit deteriorates due to lower tax revenues.[10] A higher budget deficit-to-GDP ratio and a higher government spending-to-GDP ratio then lead to an additional increase in the risk premium. Having this additional channel would be interesting in the GEMO model because of the prominent role the country risk premium plays as a determinant of the output gap in the IS curve and of the exchange rate in the UIP equation.

3.2.3. Foreign economy variables

In the same spirit, the third suggestion pertains to the way the foreign economy variables enter GEMO. So far, foreign variables are modeled as exogenous AR(1) processes. When a new forecast is computed, the foreign variables are conditioned on the paths of the staff forecast for the foreign economies. This leads to spillover effects into the Georgian economy. However, modeling the foreign economies explicitly as 3-equation economies (IS curve, Phillips curve, Taylor rule) would change the expectations in the model and thereby potentially the forecast for the Georgian economy.

3.2.4. Inflation expectations

The fourth suggestion refers to the link between the time-varying inflation target of the NBG and inflation expectations of private agents in the model. In the current setting, the central bank sets the monetary policy rate in the model to close the gap between expected inflation in the future and the inflation target. By changing the interest rate, monetary policy influences the real economy and inflation, which affects expected inflation in the future and thereby the inflation gap in the Taylor rule closes. However, there is no direct link between the inflation target and inflation expectations of private agents in the model. One could expect that there is a direct link given that the NBG was able to credibly lower inflation in the Georgian economy by gradually lowering the inflation target in the past.

Coming to the empirical part of the recommendations, the next two recommendations pertain to the setting of the parameters in the model and a possible filtering of quarterly investment and consumption within the model.

3.2.5. Estimation vs. calibration

An obvious recommendation is to estimate the parameters of GEMO instead of calibrating them. The “Macroeconomic Research” division has run preliminary Bayesian estimation exercises and incorporated the results into the recalibration of the model in 2015. Pros and cons of a switch to Bayesian estimation of the parameters are:

[10] In order for second-round effects to influence government spending and the budget deficit, the fiscal sector in GEMO would have to be augmented. So far government spending is modeled as an exogenous AR(1) process and there are no taxes and government debt in the model. However, second-round effects could work through GDP, which is in the denominator.

Cons

- The data sample for most of the Georgian observables is not long and a minimum of observations is needed in order to get meaningful estimation results. In addition, there are some structural breaks in the data. For example, the switch of monetary policy to an inflation-targeting regime is reflected in the data.
- Currently the model has many parameters, although the core model only consists of four equations. The core equations are augmented by additional variables and trends and expectations are modeled explicitly. This blows up the parameter space. Therefore, only a subset of parameters could be estimated.

Pro

- A big advantage of estimating the parameters is that they are updated slowly over time, when the model is estimated every policy round. Thereby the model adapts gradually to new incoming developments in the data.

If a switch to Bayesian estimation is not appropriate at the current junction, utilizing the impulse response function matching technology could be an intermediate step. Impulse response function matching was used by Altig et al. (2011) or Cwik et al. (2011). It is an algorithm to estimate parameters by minimizing the distance between empirical impulse response functions of a VAR and the theoretical counterparts in the model.

3.2.6. Filtering quarterly consumption and investment

A second empirical suggestion relates to incorporating the Real National Account Components' Forecasting Model (FRNA) of the NBG into GEMO. So far, real consumption and investment growth are only available on an annual frequency. Figure 2 shows real year-over-year GDP growth (blue line) together with real consumption growth (red bars) and real investment growth (yellow bars).

The FRNA model is used to filter real consumption and investment growth on a *quarterly* frequency. However, GEMO could also filter quarterly consumption and investment growth. A prerequisite would be to model consumption, investment and the other demand components explicitly in GEMO. The structure of the model allows then to separate overall GDP growth into its components and the Kalman filter would deal with the missing quarterly observations in consumption and investment growth.[11] This would make the process of filtering and forecasting consumption and investment easier.

[11] Schorfheide and Song (2015) explain how to write down the measurement equations in the case of data with mixed-frequency. They estimate a VAR with monthly and quarterly data. Here, one would use quarterly and annual data.

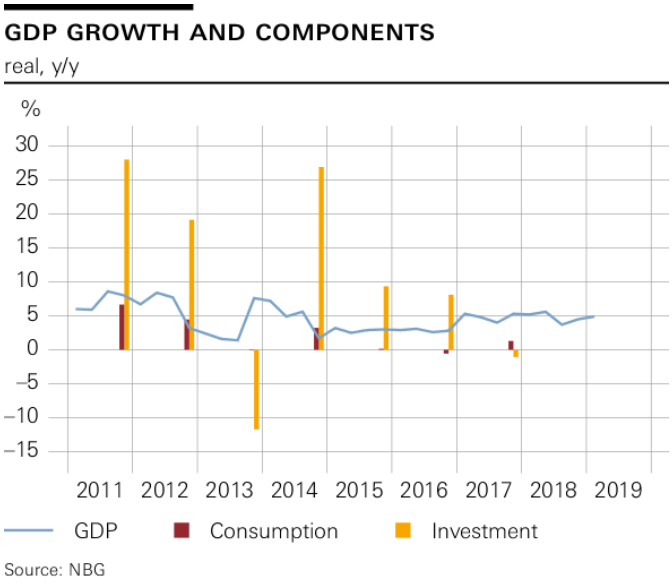

Figure 2 shows year-over-year real GDP growth (blue line) and two components real consumption growth (red bars) and real investment growth (yellow bars).

4. Conclusion

GEMO is an integral part in the monetary policy process of the NBG. The model structure is based on a small-open economy model à la Gali and Monacelli (2005) and is adapted to take on board important characteristics of the Georgian economy like imported intermediate goods, liability dollarization and the country risk premium. Forecast evaluation analysis shows, GEMO does a good job in forecasting Georgian key economic variables. The performance is especially good for CPI inflation, the main output variable of the model in the monetary policy process of the NBG, given that the NBG adopted an inflation-targeting framework. Overall, the model is theoretically, institutionally and empirically coherent, although some adjustments and extensions could be made if time permits.

Given the good performance of GEMO, I think, it would be worthwhile to discuss, if the model should be published. If GEMO is publicly available, the public would better understand how the NBG sees the main transmission channels of monetary policy. The public could therefore better foresee NBG behavior. This could lead to a smoother implementation of monetary policy measures, because private sector expectations would adjust faster. Several ways of publishing GEMO are possible. The Federal Reserve Board, for example, provides updates of the FRB/US model, their workhorse model, on their homepage. [12] In order for outsiders not to be able to replicate exactly the FED forecast, the dataset does not contain the latest quarters of data. In a similar fashion, one could publish GEMO code with a lag or without tunes. Other central banks provide the code of their forecasting models upon request.

[12] The EViews code can be downloaded on the following website along with documentation of the model: https://www.federalreserve.gov/econres/us-models-about.htm

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