ROMANIAN ECONOMY MODELLING IN THE PRESENCE OF FINANCIAL FRICTIONS

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Abstract

The sphere of economic modelling has continuously evolved, revealing new issues to be considered for a more grounded analysis of the features specific to a real economy. Based on the dynamic stochastic general equilibrium class of models and including increasingly important elements, like the price and wage stickiness, the capital utilisation rate or the investment adjustment costs and, last but not least, the financial frictions, this study is dedicated to the estimation of several key parameters of the Romanian economy, outlining the general characteristics of the latter and indicating the direction towards which it is moving. The estimation outcomes, arising on the basis of the Bayesian approach, herein presented and construed, prove to be compliant, to a large extent, with own previous results, as well as with the related specialty literature.

Keywords: stochastic analysis, general equilibrium model, Bayesian estimation, price and wage stickiness, financial frictions

JEL code: C61, C68, D12, D22, D58, E41

1. Introduction

This paper aims at depicting key economic aspects specific to the Romanian economy, dynamically approached in the context of a general equilibrium model.

In order to perform such an analysis, we started from the model rendered by Merola (2015), built on the fundamentals of the model of Smets and Wouters (2003), developed by Smets and Wouters (2007) and improved by the insertion of elements characteristic to the financial field, under the form of financial frictions, in the manner of Bernanke, Gertler and Gilchrist (1996) and of its subsequent variant Bernanke, Gertler and Gilchrist (1999).

The brief description of the model, in the light of the final equations, log-linearised around the steady state, having as purpose to outline the economic analysis space, is followed by the display and interpretation of the results obtained subsequent to the implementation of the specific Dynare code and to the Bayesian estimation, being generated a series of central ideas which, linked altogether, are able to reflect potential directions to follow in coordinating viable macroeconomic policies.

Therefore, this paper structuring is set according to the following pattern: Presentation of Model in section 2, Rendering of Data, Methodology and Results, with three related distinct sub-sections, in section 3 and Conclusions in section 4.
2. Presentation of Model

The model equations, under the final form destined for their transposition for implementation into Dynare (Matlab), are framed hereinafter, being also accompanied by a brief description from an economic perspective.

The equation of the gross domestic product, encompassing, as expected, consumption, investments and governmental expenses, with all related elements, however excluding the foreign sector and, therefore, suggesting the focus on the economy in the absence of any relationship with the exterior, looks like:

\[ y_t = c_t \times \frac{\gamma}{y} + i_t \times \frac{\gamma}{y} + (k_t + f_t + p^t_{\text{fin}}) \times \frac{\gamma}{y} \times f \times \left(1 - \frac{r}{f}\right) \times \left(1 - \frac{1}{\text{lev}}\right) + r^t \times \frac{\gamma}{y} \times c^t_i + \epsilon^g_t \]  

[1]

with \( y_t \) representing the gross domestic product at time \( t \), \( y \), the gross domestic product at steady state, \( c_t \), the consumption at time \( t \), \( c \), the consumption at steady state, \( i_t \), the investments at time \( t \), \( i \), the investments at steady state, \( k_t \), the capital at time \( t \), \( k \), the capital at steady state, \( f_t \), the external financing funds at time \( t \), \( f \), the external financing funds at steady state, \( r^t \), the capital rental rate at steady state, \( p^t_{\text{fin}} \), the capital value at time \( t \), \( \text{lev} \), the leverage ratio at steady state, \( r \), the risk free interest rate at steady state, \( z^t_k \), the capital utilisation rate at time \( t \), and \( \epsilon^g_t \), the shock on governmental expenses at time \( t \).

The aggregate equation of consumption, determined starting from the utility function of households, and considering the weighted average quantum of its past and future level, the number of labour hours to be provided, the next period real interest rate, as well as the shock on the preferences of households, takes the form:

\[ c_t = c_{\text{stat}} \times \frac{h}{\gamma + h} + E\left[c_{\text{stat}}\right] \times \frac{\gamma}{\gamma + h} + (l_t - E[l_{\text{stat}}]) \times \left(\sigma - 1\right) \times \gamma \times w^t_l \times \left(r_t - E[r_{\text{stat}}] + \epsilon^c_t\right) \times \frac{\gamma - h}{\sigma \times (\gamma + h)} \]  

[2]

with \( h \) representing the consumption habits of households, \( \gamma \), the growth rate at steady state, \( \sigma \), the inverse of the elasticity of consumption intertemporal substitution, \( w^t_l \), the income from labour at steady state, \( l_t \), the number of labour hours at time \( t \), \( \pi_t \), the inflation rate at time \( t \), and \( \epsilon^c_t \), the shock on consumption habits at time \( t \).

The aggregate equation of investments takes into account the past and future investments, the capital value and the investment technological shock, as follows:

\[ i_t = \left(i_{\text{stat}} + \beta \times \gamma \times E\left[i_{\text{stat}}\right] + \frac{p^t_{\text{fin}}}{\gamma^2 \times \varphi}\right) \times \frac{1}{1 + \beta \times \gamma} + \epsilon^i_t \]  

[3]

with \( \beta \) representing the subjective discount factor of households, \( \varphi \), the function of the investment level adjustment cost at steady state, and \( \epsilon^i_t \), the shock on investments at time \( t \).

The equation relating to the capital value considers the level registered by the same at the moment to come, but also the level at moment \( t \) and \( t+1 \) of the capital rental rate and the external financing cost, in this way:

\[ p^t_i = \left(v^t_i \times \frac{c^t_i}{r^t} + p^t_{\text{fin}} \times \frac{t + (1 - \delta)}{r + (1 - \delta)} - f_t - \epsilon^f_t\right) \]  

[4]

with \( \delta \) representing the capital depreciation rate, and \( \epsilon^f_t \), the shock on external financing cost at time \( t \)
Given the financial frictions comprised within the model, starting from the hypothesis of incomplete information, which makes the creditors, represented by private financial institutions, to pay a certain amount of money in order to monitor the incomes of their debtors, represented by entrepreneurs, we have an increased total real cost of the external financing, equalling, at equilibrium, the expected real return on capital:

\[ E_t[f_{t+1}] = (r_t - E_t[\pi_{t+1}]) + \omega \times (\rho_t + k_{t+1} - n_{t+1}) \]  

with \( \omega \) representing the elasticity of the external financing premium in relation to the leverage ratio.

In the light of the inclusion into the model of the idea of crediting of entrepreneurs for investment purposes, it is necessary to consider the discrepancy between the cumulated level of the net assets of entrepreneurs and the total quantum needed for making new acquisitions of capital, this issue being rendered by means of the limited probability of entrepreneurs to survive on the market in the next period:

\[ U = f \times \left[ \text{lev} \times f_f - \omega \times (\text{lev} - 1) \times (\rho_{t+1} + k_t) - (\text{lev} - 1) \times (r_{t+1} + \pi_t) + \omega \times (\text{lev} - 1) + 1 \times n_t \right] \]  

From the perspective of firms, the total production results from the combination of the labour and capital factors, taking also into account the associated fixed costs:

\[ y_t = \phi_p \times \left[ \alpha \times k_t + (1 - \alpha) \times l_t + \varepsilon_t \right] \]  

with \( \phi_p \) representing the fixed production costs, and \( \varepsilon_t \) the shock on total productivity of factors at time \( t \).

The equation relating to the capital services is constructed depending on the accumulated capital used in the previous period, on the capital utilisation rate, on the past investments and on the past investment shock, as follows:

\[ k_t = k_{t-1} \times \left( 1 - \delta \right) + i_{t-1} \times \delta \times \gamma \times \varphi \times \varepsilon_{t-1} + z_t \]  

with \( k_t \) representing the accumulated capital used at time \( t \).

Also, we start from the hypothesis of a certain degree of inelasticity at the level of prices and wages, in the manner of Calvo, just a part of agents resetting the level of the related nominal factors, this leading to the equations:

\[ \pi_t = \frac{\beta \times \gamma \times E_t[\pi_{t+1}] + t_p \times \pi_{t-1} - \pi_{mk} \times \mu_t + \varepsilon_t}{1 + \beta \times \gamma \times t_p} \]  

with \( \mu_t \) representing the price mark-up at time \( t \), \( t_p \) the degree of price indexation, \( \pi_{mk} \) the speed of price mark-up adjustment, and \( \varepsilon_t \) the shock on price mark-up at time \( t \) being determined as:

\[ \mu_t = \text{mpl}_t - w_t \]
with \( MPL_t \) representing the labour marginal product at time \( t \), and \( w_t \) the real wage at time \( t \), respectively.

\[
w_t = \frac{w_{t-1} - (1 + \beta \times \gamma \times t) + \beta \times \gamma \times E_t[\pi_{t+1}] + t_w \times \pi_{t-1} - w_{mk} \times \mu^w_t + \varepsilon^w_t}{1 + \beta \times \gamma} \tag{10}
\]

with \( \mu^w_t \) representing the wage mark-up at time \( t \), \( t_w \) the degree of wage indexation, \( w_{mk} \) the speed of wage mark-up adjustment and \( \varepsilon^w_t \) the shock on wage mark-up at time \( t \)

\[
\mu^w_t = w_t - mr_s_t
\]

with \( mr_s_t \) representing the rate of substitution between labour and consumption at time \( t \).

A last modelling step rendered in this paper concerns the equation specific to the monetary authority, which is based on a Taylor type monetary policy, evolving depending on the previous period interest rate, the current inflation, the past and present output-gap and the current shock on the risk free interest rate, taking the following form:

\[
r_t = \rho \times t_{-1} + \rho_x \times (1 - \rho) \times \pi_t + \rho_x \times (1 - \rho) \times (y_t - y^P_t) + \rho_{d_x} \times (y_t - y_{t-1}) - \left(y^P_t - y^P_{t-1}\right) + \varepsilon^r_t \tag{11}
\]

with \( r_t \) representing the risk free interest rate at time \( t \), \( y^P_t \) the potential gross domestic product at time \( t \), and \( \varepsilon^r_t \) the shock of the risk free interest rate at time \( t \).

3. Rendering of Data, Methodology and Results

3.1 Model-related Data

The model depicted above comprises data relating to a number of 8 variables, analysed quarterly for the period 2000:Q1-2014:Q2.

The variables used, namely: gross domestic product, consumption, investments, all rendered in real values, deflator of gross domestic product, real wage, expressed as wage cost index, and number of labour hours, were adequately adjusted, by logarithmic form turning and differentiation, in view of making them stationary, as the case may be, save for the last two variables, the real interest rate, reflected by ROBOR at 3 months and the spread between the coupons associated with the state contingent securities and the rates related to the credits directed by the private financial institutions towards entrepreneurs, with due date at 6 months.

The data were obtained from officially recognised sources, more specifically: the National Institute of Statistics of Romania, Eurostat, for the wage cost index, considering some divergences met as regards this variable in several statistical databases, the National Bank of Romania, for the real interest rate, respectively for the state contingent securities, and 3 banks acting on the national territory: BCR, BRD and Transilvania Bank, for the rates associated with the investment credits.
3.2 Used Methodology

The estimation of the model approached within this study involved passing across several specific stages, as follows: the selection and transformation of the equations relating to the basic economic blocks of the model and to the markets at equilibrium, by log-linearisation, so as to obtain a form accessible for their implementation, the calibration of some parameters, as the case may be, and the determination of the prior probabilities for the parameters destined for estimation, the last two steps being specific to the Bayesian analysis, the transposition of the model under the form of a Dynare code and its running in Matlab.

If, as for the calibration and setting of priors, where the literature in the matter (Christiano et al., 2010, Adolfson et al., 2013) and the characteristics of the target economy were considered, we analysed each and every element, on the model running, pre-existent specific mechanisms were activated, these ones acting on the model transposed as a compact, non-disparate block within the used instrument.

Its running involved the call of the Metropolis-Hastings algorithm, a method of Monte Carlo with Markov Chains (MCMC) type, generator of sequential estimates of the related parameters, filtered afterwards, based on some associated rules, and decreasingly selected according to their relevance, therefore being sketched specific probabilistic histograms.

3.3 Obtained Results

The results, obtained after having resorted to the estimation process performed in compliance with those briefly mentioned above, are rendered in Table 1 below:

### Table 1

<table>
<thead>
<tr>
<th>Description of parameters</th>
<th>Posterior mean</th>
<th>Confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumption habits</td>
<td>0.6014</td>
<td>0.6010 - 0.6018</td>
</tr>
<tr>
<td>Investment adjustment cost</td>
<td>3.3320</td>
<td>3.3299 - 3.3341</td>
</tr>
<tr>
<td>Leverage ratio</td>
<td>1.2913</td>
<td>1.2919 - 1.2948</td>
</tr>
<tr>
<td>Wage stickiness</td>
<td>0.8041</td>
<td>0.8019 - 0.8046</td>
</tr>
<tr>
<td>Price stickiness</td>
<td>0.7838</td>
<td>0.7833 - 0.7842</td>
</tr>
<tr>
<td>Wage indexation factor</td>
<td>0.5824</td>
<td>0.5821 - 0.5827</td>
</tr>
<tr>
<td>Price indexation factor</td>
<td>0.4383</td>
<td>0.4273 - 0.4487</td>
</tr>
<tr>
<td>Elasticity coefficient associated with consumption</td>
<td>0.9846</td>
<td>0.9825 - 0.9866</td>
</tr>
<tr>
<td>Elasticity coefficient associated with labour supply</td>
<td>1.3533</td>
<td>1.3507 - 1.3559</td>
</tr>
<tr>
<td>Elasticity of production to capital</td>
<td>0.1947</td>
<td>0.1945 - 0.1949</td>
</tr>
<tr>
<td>Elasticity of external financing premium to leverage ratio</td>
<td>0.0254</td>
<td>0.0253 - 0.0255</td>
</tr>
<tr>
<td>Taylor rule coefficient associated with inflation</td>
<td>1.6237</td>
<td>1.6231 - 1.6243</td>
</tr>
<tr>
<td>Taylor rule coefficient associated with interest rate smoothing</td>
<td>0.7168</td>
<td>0.7166 - 0.7169</td>
</tr>
<tr>
<td>AR element of the shock on total productivity of factors</td>
<td>0.5254</td>
<td>0.5223 - 0.5285</td>
</tr>
<tr>
<td>AR element of the shock on external financing cost</td>
<td>0.6283</td>
<td>0.6269 - 0.6298</td>
</tr>
<tr>
<td>AR element of the shock on consumption habits</td>
<td>0.6460</td>
<td>0.6457 - 0.6463</td>
</tr>
<tr>
<td>AR element of the shock on governmental expenses</td>
<td>0.9855</td>
<td>0.9854 - 0.9857</td>
</tr>
<tr>
<td>AR element of the shock on investments</td>
<td>0.5559</td>
<td>0.5550 - 0.5568</td>
</tr>
<tr>
<td>AR element of the shock on risk free interest rate</td>
<td>0.2851</td>
<td>0.2824 - 0.2880</td>
</tr>
<tr>
<td>AR element of the shock on wage mark-up</td>
<td>0.8745</td>
<td>0.8740 - 0.8750</td>
</tr>
<tr>
<td>MA element of the shock on wage mark-up</td>
<td>0.7409</td>
<td>0.7397 - 0.7419</td>
</tr>
<tr>
<td>MA element of the shock on price mark-up</td>
<td>0.9227</td>
<td>0.9218 - 0.9236</td>
</tr>
<tr>
<td>MA element of the shock on price mark-up</td>
<td>0.5619</td>
<td>0.5616 - 0.5622</td>
</tr>
</tbody>
</table>

Source: Own estimations
The persistence of the consumption preferences of households, with an estimated average of 0.60, even if slowly inferior to the one generally established, by calibration, at the level of the Romanian economy, indicates a quite conservative consumption position. Also inferior to the speciality literature, this time to a larger extent, proves to be the mean of the investment adjustment cost, which has a value of just 3.33, stimulating, if regarded from the investment viewpoint.

The relationship of influence between the financial sources attracted as investment credits and the return to the own capitals of the debtor-entrepreneurs, expressing the effect of the financial leverage ratio, with a quantum of 1.29, reflects, overall, a rate of economic return superior to the interest rate, therefore having beneficial effects on investments.

In compliance with the related literature, including own results previously obtained during similar estimation processes, the wage stickiness is significant, exceeding the threshold of 0.80, this being translated into a truncated modification of wages, under the circumstances of various changes occurred in the real world, which, naturally, would generate more alert adjustments of the same.

A pattern of this kind also transpires as concerns the price stickiness, which, with an imperceptibly lower value, of 0.78, indicates a restraint of the national producers to quickly adapt their prices to the perpetually changing world context, adopting, in the short run, rather an expectative attitude.

As for the persistence of inflation, reflected in the next period wages, their level, of 0.58, seems to be reasonable, surprisingly, the heavy updating of wages being compensated, to a certain extent, by the covering of a consistent part of the inflation manifested during the previous stage.

With a mean of just 0.42, the producers look like being reserved when adjusting their prices to the past inflation, the justification being related, the most probably, to their fear for the preponderantly monopolistic competition manifested on the market, which could put into danger their affairs by the loss of a part of the already existing clientele.

The elasticities comprised within the model, often calibrated in similar analyses, but estimated in this case, do not significantly deviate from the common values established at the level of the studied economy, neither as regards the consumption intertemporal substitution, which, with a mean of 0.98, reflects a high aversion of consumers to risk, nor as for the labour supply, reaching a value of 1.35.

In exchange, the elasticity of production in relation to the capital factor, with a level of 0.19, is below the expected threshold, revealing a much more reduced influence of capital on production as to the one manifested on it by the labour factor.

Although it does not have a high value, the elasticity of the external financing premium in relation to the leverage ratio underlines the impact of the financial frictions on the model shocks, in the sense of their amplification.

The Taylor rule coefficient associated with inflation, of 1.62, reflects, in the light of its supra-unitary value, the observance of the classical principle of the above-mentioned rule, while the coefficient associated with the interest rate smoothing, in
a quantum of 0.71, captures, to a large extent, the persistence of the risk free interest rate inserted in the model as entry variable.

As regards the Taylor rule coefficient associated with output-gap, with a value of 0.03, it proves not to be really relevant within the model, the interest rate reacting rather to its adjustment speed.

Finally, the autoregressive terms associated with the 8 shocks of the model, with values significantly varying, between 0.28 and 0.98, suggest a low persistence of the shock on risk free interest rate, a medium persistence of the shock on total productivity of factors, on investments, on external financing cost and on consumption habits, and a high to very high persistence of the shock on price mark-up, on wage mark-up and on governmental expenses from the previous period, while the moving average terms associated with the shock on price mark-up, respectively on wage mark-up, reveal a medium persistence of the first and a consistent persistence of the latter.

4. Conclusions

This study pursues to briefly render several issues of large interest relating to the characteristics of the Romanian economy, seen from the perspective of a suggestive model belonging to a series of state-of-the-art models, namely the dynamic stochastic general equilibrium models.

After the calibration of certain parameters, taken as such within the model, and after the setting of priors for the remainder of parameters, subject to estimation, operations necessary considering the Bayesian approach being at the basis of the current analysis, we obtained relevant estimations, in compliance both with own previous results and with results provided by the specialty literature.

Thus, households manifest a conservatory tendency in consumption, showing an increased risk aversion, attitude also found at the level of producers, who, under the pressure of the competitive environment, adjust in a relatively heavy rhythm the prices of their goods.

Not the same fear is observed as concerns the wages of their employees, these being kept rigid to a large extent, despite of the risk of loosing a part of such workers. What is really dangerous, is represented by the fact also revealed by previous analyses, that this stickiness of wages on a relatively long run is accompanied by an incomplete adjustment of the same in relation to the inflation level, this generating a low purchasing power for households. Yet, in our case study, the covering of the inflationist adjustment seems to be present at a quite satisfactory level, without aggressively inhibiting consumption.

Concerning investments, the adjustment cost is relatively reduced as compared to our expectations, this obviously having beneficial investment effects, issue also strengthened by the value of the financial leverage ratio, which indicates the superiority of the rate of economic return in relation to the interest rate.

Speaking about the interest rate, modelled, at the level of the monetary authority, according to a Taylor type rule, this one clearly reacts to inflation, to the
interest rate smoothing coefficient and to the output-gap adjustment speed, but less to the effective movement of the latter.

Overall, the results obtained are encouraging, revealing tendencies of economic revival, both in the direction of a slow increase of the consumption-oriented purchasing power and from the investment-related perspective.

This research is to be continued with the capturing of the modification of variables under the impact of the shocks considered within the model, as well as with the identification, by variance decomposition, of the elements having a consistent influence on the same.

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