STRUCTURAL AND NONSTRUCTURAL MODELS – FORECASTING AND SIMULATION OF ECONOMIC DYNAMICS

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RESUMO

Neste artigo discutimos os resultados simulados para fins de previsão sob duas diferentes abordagens de modelagem econômica.

A primeira é construída sob a lógica dos modelos estruturais, ou seja, resgatamos a teoria econômica e a relação específica entre as variáveis macroeconômicas para construir tal modelo.

A segunda usa a modelagem desenvolvida por Smets-Wounters que é focada na moderna teoria de modelos dinâmicos segundo a premissa de equilíbrio geral (DSGE). Este tipo de modelo é considerado um modelo não-estrutural, devido à relevância da informação contida nos dados das séries temporais. Exploramos a forma linearizada deste modelo dinâmico convertido por meio do VAR.

Neste trabalho utilizamos as séries temporais da economia dos EUA devido à sua extensa e abrangente base de dados.

O alvo principal é proporcionar adequada sensibilidade com ambos os modelos, e mostrar que uma abordagem moderna (DSGE) oferece uma melhor compreensão da realidade para fins de política econômica.

Modelagem da Dinâmica Econômica. Simulação. Monte Carlo. Modelos VAR. Administração Pública. Gestão Financeira. Simulação

ABSTRACT

In this paper we discuss the forecast simulated results of two different approaches of economic modelling.

The first one is built under logic of structural modelling, so we use the economic theory and specific relationship among macroeconomic variables to build this model.

The second uses the modelling developed by Smets-Wounters which is focused in the modern theory of dynamic models under assumption of general equilibrium (DSGE). This kind of model is considered a nonstructural model, due to the relevance of information contained in the time series data. We explored the linearized form of this dynamic model casted by a VAR model.

Thoroughly this paper it was considered time series of USA economy because of its extensive and comprehensive database.

The main aim is to provide a good insight with both models and show that a modern approach (DSGE) offers a better understanding of reality for economic policy purpose.

Dynamic Economic Modelling. Simulation. Monte Carlo. VAR Models. Public Administration, Financial Management, Simulation.

1. Introduction

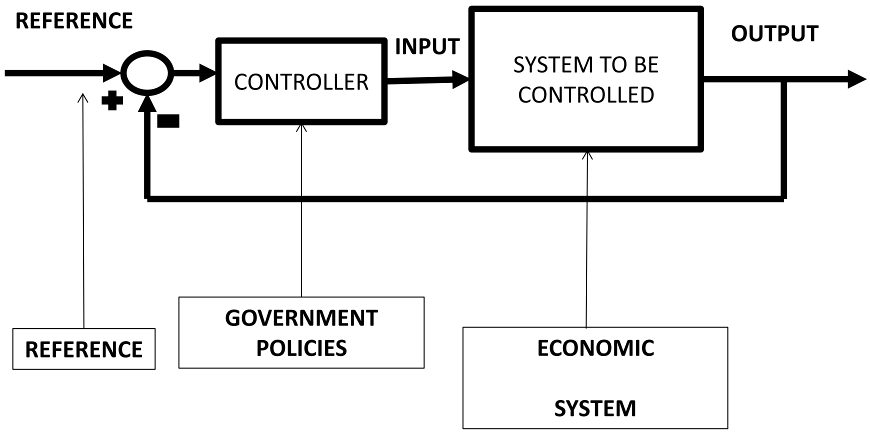
Monetary policymaker aims to reliably reproduce the behavior of an economic environment, and thus make inferences about the behavior of economic variables not only in the context of economic growth, but also in the context of external shocks. So rather than taking advantage of graphics or calculations grounded in partial equilibrium models that are based on incomplete data from the recent past, the modern economic theory seeks to build well-specified macroeconomic models that respond to a logic of internal consistency, and are calibrated to capture the key variables of the real economic world.

Revisiting the history of econometric models that seek to describe the 'functioning' of an economy, it comes up the Ramsey´s model (1928) which exercised a great influence on economic after World War II, becoming a critical mass of theoretical discussion by economists who study the economic growth theories. His model discussed in detail a question of relevance importance that is the intertemporal allocation of resources, in other words, the question to be answered is how much of national wealth (national product) produced in a given instant of time would be intended for current consumption in order to produce useful power, and how much would be saved or invested in order to expand future production and consumption, and therefore lead to future usefulness for families. In other words, how can be measured an interaction among economic variables as consumption, production, interest rate, monetary supply and so on? Is the economic theory up to date to perfectly represent these interactions? What kind of simulation tool or econometric tool fits better? The economic time series of economic variables contain any kind of richness of information that can be used to economic policy.

To address these questions in this paper we compare two different approaches. The first one is based on a **structural model**, therefore we use the economic theory and specific relationship among variables to build this model. The second approach is different because we let the data, rather than the economic theory, specify the dynamic structure of a model and we use the VAR tool to deploy our test. We conclude comparing both approaches, **structural** and **nonstructural**, under the standpoint of fitness model and forecasting.

At last, like a suggestion of study for following papers it could be considered a parallel approach using the theory of Optimal Control to analyze an economic system that can be represented by a system to be controlled. In Control Theory the key issues are based on how to describe the system to be controlled, in other words, the **modelling**. And, how to design the controller, better said, the **control**, as can be seen below.

Figure 1 – Block diagram economic system



Source: Author

2. Structural Modelling

Our first approach of modelling is a simple example of small macroeconomic model set up by a **multi-equation** model, and like a common approach in macroeconomics, it has been to create "large" empirically-motivated regression models, in this exercise we will deal with only 3 simultaneous equations that can offer a good understanding of economy modelling.

$$C_t = -9{,}454 + 0.054Y_t + 0.926C_{t-1}$$

$$I_t = -66.19 + 0.1684(Y_{t-1} - Y_{t-2}) + 0.218Y_t - 11.256R_{t-4}$$

$$R_t = -0.556 + 0.0005Y_t + 0.013(Y_t - Y_{t-1}) - 0.085(M_t - M_{t-1})$$

As assumption we consider an economic identity that can be used to represent our small economy.

$$Y_t = C_t + I_t + G_t$$

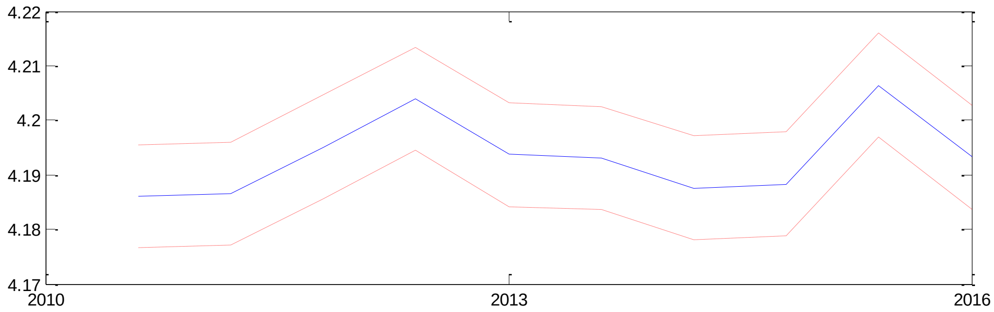
Below we have the description of variables considered:

- C : consumption aggregate
- I : gross investment
- Y : GDP (gross domestic product)
- M : money stock

– R : interest rate on 3-month Treasury

As follow we can see the plots of forecast for GDP and its confidence interval, as we analyze we see a not well defined recovery trend for GDP forecast for the next years.

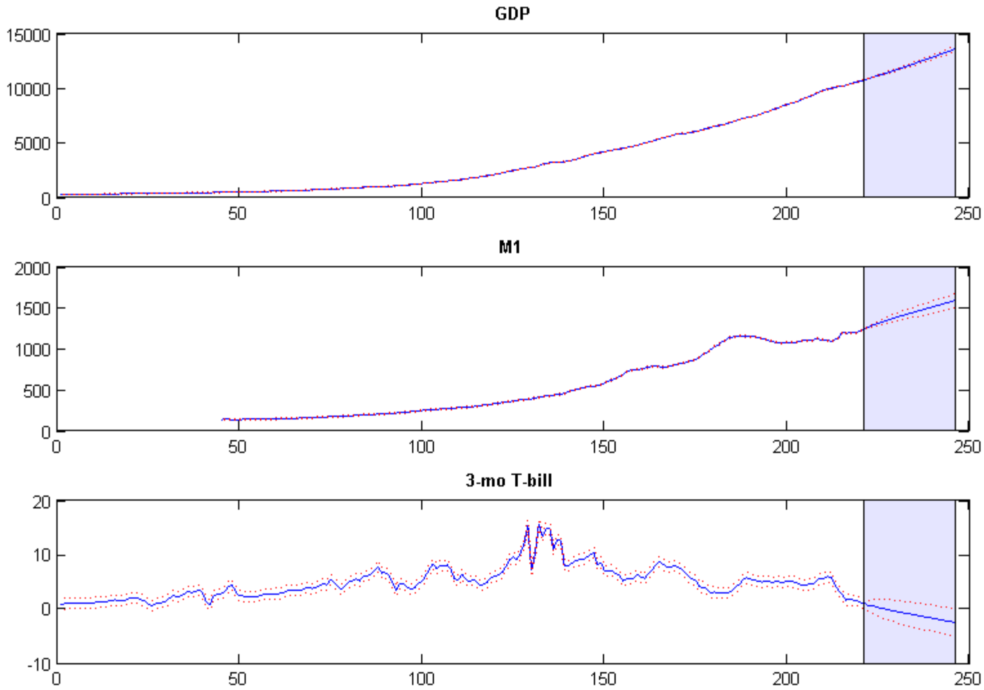
Figure 2 – GDP Forecast



We can improve the forecast offered by our structural model adding a Monte Carlo simulation that enables us to generate simulations of time series based on our model. It can be seen graphically that error bounds are narrower as compared to GDP Forecast show at figure 2.

According to the next forecast for GDP, M1 and Treasury-bill that have been generated the GDP trend is a slope upward corresponding to expansion monetary policy (M1), and for 3 month Treasury-bill the perspective tends to be a low level of interest rate for a wide range of time in the coming years.

Figure 3 – GDP, M1, T-bill Forecast



3. NonStructural Modelling - VAR

As we have seen in the previous session it was presented an economic model considered as structural, by this we mean that the specific relationship between variables are grounded on economic theory. As said in the introduction under the nonstructural view it is given a heavy weight to the data. Another motivation to use the nonstructural approach is the fact that in multi-equation models the lagged structure of the individual equations can affect the behavior of the model, it is particularly seen when lagged variables can conduct to forecast a cyclical price behavior that it is somewhat seen indeed.

In this paper we will use the Smets-Wouters (2003) model that has been built to represent the economy of Europe. It is a nonlinear system of equations in the form of a Dynamic Stochastic General Equilibrium (DSGE) model that seeks to characterize an economy derived from economic principles. The basic model works with 8 time series: output, prices, wages, hours worked, interest rates, consumption, investment and unemployment.

The DSGE approach focuses on "small" theoretically-derived models. It is a combination of normative rigor and parsimony that is one of the main appeals of the DSGE approach.

Currently, DSGE models are frequently used for monetary policy analysis. These are mathematical models that incorporate microeconomic foundations, following a general equilibrium methodology in a dynamic sthocastic environment. We have seen recently the Brazilian Central Bank publishing that will adopt the DSGE characterization for the Brazilian economy, in order to produce economic forecasts that will assist in conducting of economic policy.

The DSGE model as a nonlinear system of equations needs to be linearized in order to be handle. It is known that a linearization imply in somewhat lack of accuracy conducting in error prediction. So, there is a trade-off between accuracy and illustrative character, therefore to the purpose of this paper we will use the linearization because we look forward to offer an illustration of the nonstructural modelling under VAR.

The linearized form of a DSGE model can be cast as a VAR model that can be handled with standard methods of multiple time series analysis. It is an unrestricted form of this VAR model that we will examine subsequently.

A VAR model can be represented by an auto regressive model p order by a vector n-variable endogenous, X_t, that are linked by a matrix A as follows:

$$AX_t = B_0 + \sum_{i=1}^{p} B_i X_{t-i} + B\varepsilon_t$$

Where:

- A is a matrix $n \times n$ that define contemporary restrictions among the variables that constitute the vector $n \times 1$, X_t;
- B_o is a constant vector $n \times 1$;
- B_1 are matrix $n \times n$;
- B is a standard deviation diagonal matrix $n \times n$;
- ε a uncorrelated random perturbation to each other simultaneously or temporally vector $n \times 1$, namely: $\varepsilon_t \approx$ i.i.d. $(0; I_n)$

The equation above expresses the relationship among endogenous variables often due to an economic model theoretically structured, so called structural form. The ε_t shocks are denominated structural shocks because they individually affect each of the exogenous variables.

The structural shocks are considered independent of each other because the interrelationships between a shock and others are indirectly captured by the matrix A. Therefore, the independence of shocks takes place without loss of generality. Because of the endogenous variables of this model is usually estimated in its reduced form, i.e., it is estimated the following model.

$$X_t = A^{-1}B_0 + \sum_{i=1}^{p} A^{-1}B_i X_{t-i} + A^{-1}B\varepsilon_t$$

$$= \Phi_0 + \sum_{i=1}^{p} \Phi_i X_{t-i} + e_t$$

Where

$\Phi_i = A^{-1}B_i, i = 0,1,\ldots, p$ and $B\varepsilon_t \equiv Ae_t$

It is a reasonably good specification, for which the variables are mutually influenced by another one, both contemporaneously and by its lagged values.

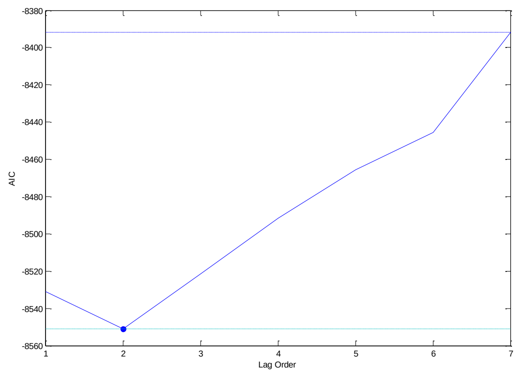
The model developed in this paper is an unrestricted VAR model in the form: $y_t = a + \sum_{i=1}^{p} A_i y_{t-i} + W_t$ with, $y_t = (y_1;\ldots;y_8)$ as follows $y_1 = GDP$; ...; $y_8 = UNEMP$

And $W_t \approx N(0,Q)$, W – represents the innovations data.

3.1. Fitting the Model

In this section we seek to answer a question about how to define the optimal lag order of a VAR model, and what criteria can be used in this task. It is a tough task because indeed the optimal lag to obtain 'white residuals' related to the first endogenous variable is not the same to obtain to the second variable. The rule is using as much as necessary the lags to obtain the 'white residuals' in all endogenous variables. In practice it is quite unlikely because there is a higher odd that autocorrelation function for any variable be zero different even if the lag order be high. It happens because probabilistically 5 percent of estimated values would be out of the confidence interval. On the other hand, using a high lag order, in a model highly complex in which estimate too many crossed coefficients become the power of the statistical test quite poor. The AIC is defined as follow, $AIC = 2 \cdot k - 2 \cdot \ln(L)$, where k is the number of parameters in the statistical model, and L is the maximized value of the likelihood function for the estimated model. The logic under AIC is not only rewards goodness of fit, but also includes a penalty that is an increasing function of the number of estimated parameters.

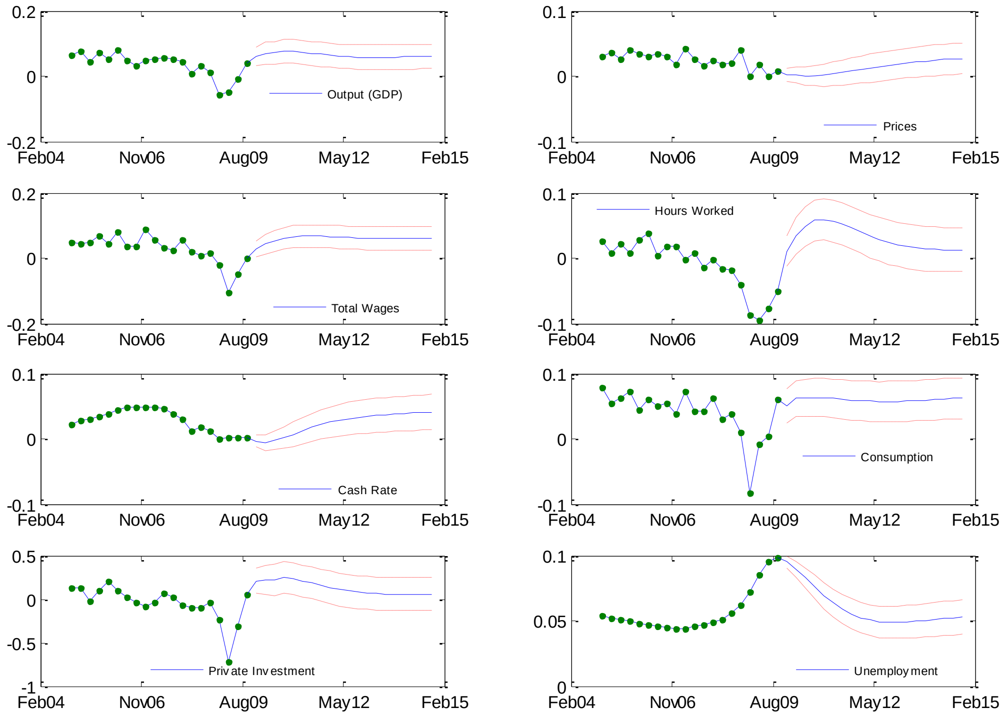
Figure 4 – Optimal Lag Order with Akaike Information Criterion



3.2. Model Calibration

So, the optimal number of autoregressive lags is determined to assure the forecast accuracy of our model. As next step we performed a Monte-Carlo simulation for each year from the beginning until to the most recent prior year for the case of USA economy data. For this analysis, the forecast horizon used was 1 year and analyzing subplots we can be conducted to make some inferences about the key economic variables relationships. It is worth to point that a value of 1 on the plot corresponds with a one percent forecast error.

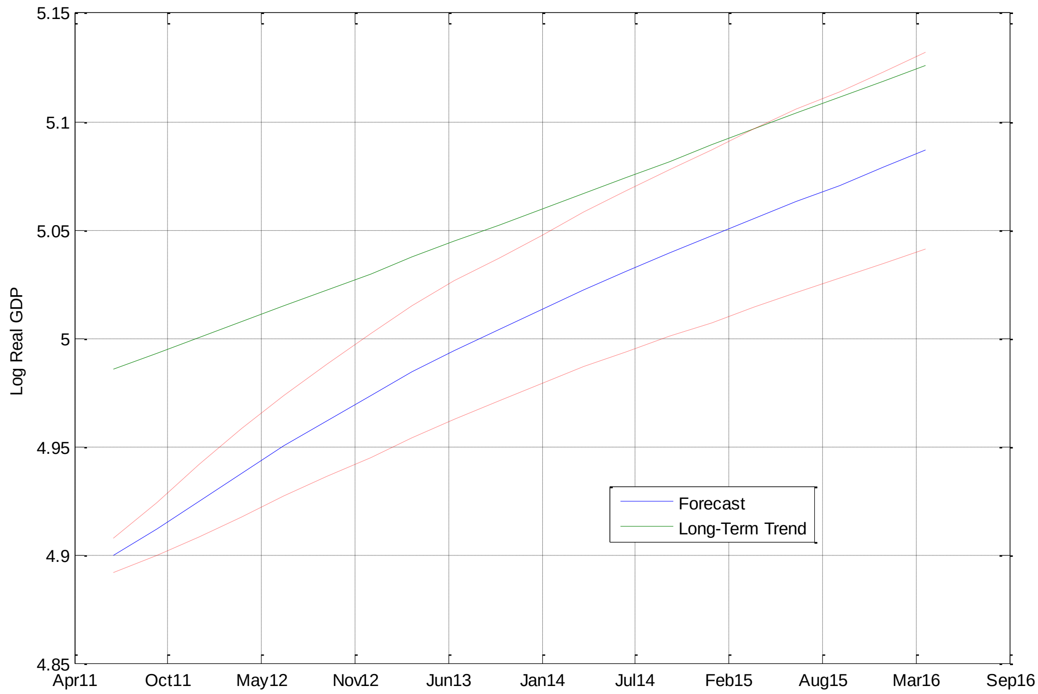
Figure 5 – Model Calibration



3.3. Forecast

The last analysis for a VAR modelling to DSGE nonstructural model is a forecast of real GDP based on the calibrated model to the current available date. The projected value is compared with a long-term trend value based on the past years of real GDP data. It possible to see that trend line suggest a continued economic recovery for the next years.

Figure 6 – GDP Forecast



4. Conclusion

In this exercise it has been proposed to discuss two different classes of models, structural and nonstructural models. The main point that differ the nonstructural model is the assumption that *data* can offer a richness of information, and it is better than build a model based on economy theory that can be not enough for a perfect understanding of economic reality. In terms of forecast both models are able to attain this goal, but it is worth to see graphically that VAR models offered a more accurate forecast for GDP.

References

Blanchard, Olivier - The State of Macro, NBER, Working Paper, No. 14259.

Bueno, Rodrigo De Losso da Silveira - Econometria de Séries Temporais.

Christiano, Lawrence J. - Linear-Quadratic Approximation and Value Function Iteration: A Comparison. American Statistical Association.

Canova, Fabio - Sensitivity Analysis and Model Evaluation in Simulated.

DeJong, David and Dave, Chetan - Structural Macroeconometrics.

Dib, Ali - An estimated Canadian DSGE model with nominal and real rigidities. The Canadian Journal of Economics.

DiCecio,Riccardo and Nelson, Edward - An Estimated DSGE Model for the United Kingdom.

Enders, Walter - Applied Econometrics Time Series.

Hamilton, James - Time Series Analysis.

Harvey, Andrew C. - Time Series Models.

Lim, G.C. and McNelis, Paul D. - Computational Macroeconomics for the Open Economy.

Matlab - The MathWorks, Inc.

Ramsey, F. P. A Mathematical Theory of Saving. The Economic Journal, Volume 38, Issue 152 (Dec., 1928), 543-559

Santos, Manuel S. and Peralta-Alva, Adrian - Accuracy of Simulations for Stochastic Dynamic Models.Econometrica.

Sims, Christian - Models and Their Uses - American Journal of Agricultural Economics.

Smets and R. Wouters. An estimated dynamic stochastic general equilibrium model of the euro area. Journal of the European Economic Association., 1 (5):11231175, 2003.

Wieland, Volker - Model Comparison and Robustness: A Proposal for Policy Analysis after the Financial Crisis.