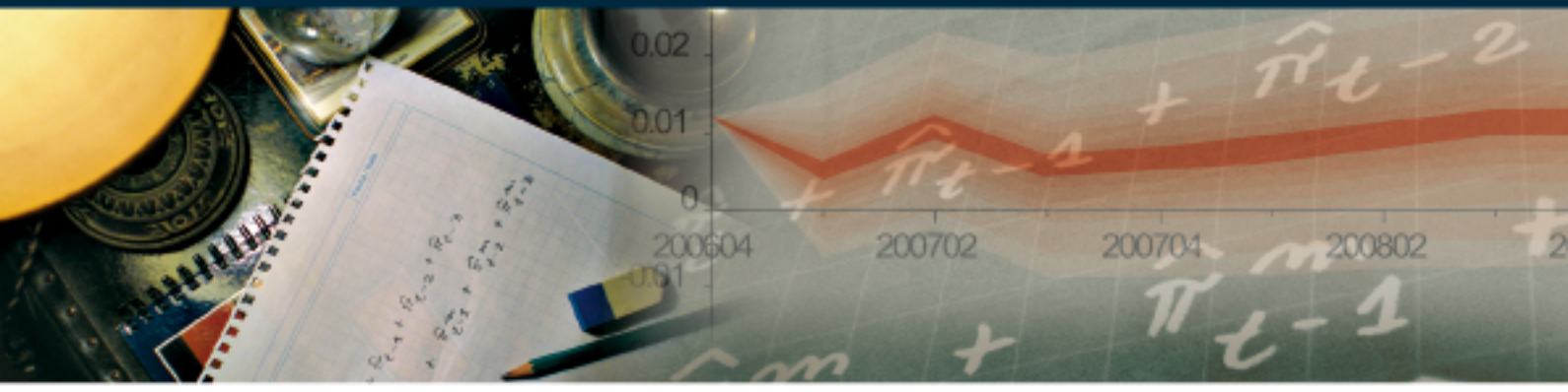

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A Small Economic Model for Argentina

Pedro Elosegui / Guillermo Escudé /

Lorena Garegnani / Juan Martín Sotes Paladino

February 2007

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Investigaciones Económicas
Banco Central
de la República Argentina

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A Small Economic Model for Argentina



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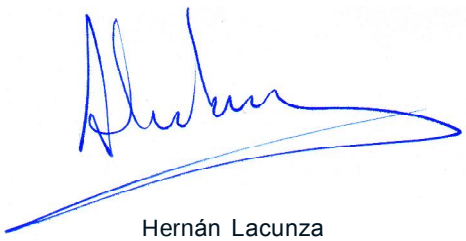
EDITOR'S NOTE

Macroeconomic projection models are widely used in central banks both for analyzing the current economic situation and forecasting the evolution of the main economic variables designed for monetary policy making.

Such developments include highlights such as small-scale macroeconomic models which are structured, but are relatively simple, and take into account the transmission mechanisms of the main variables of interest for central banks: output, inflation, interest rate, and exchange rate. In line with modern macroeconomic developments, these models can be derived from microeconomic fundamentals, especially regarding the role played by expectations in the behavior of economic agents and the existence of nominal price and wage rigidities.

This paper presents the BCRA Small Economic Model (SEM) which describes the macroeconomic dynamics of a small, open economy in a stylized manner. Considering the reality of developing countries, this paper also presents variations on the standard model which allow to simulate different exchange rate and monetary regimes such as, for instance, the simultaneous central bank intervention in the money and foreign exchange markets (managed float).

Naturally, this tool should not be viewed as an essential input at the time of monetary policy making, but as an additional element to a set of instruments which help give more robustness to policy decisions. In fact, disseminating this model intends to add more transparency to the fundamentals and tools of monetary policy, as well as to submit this instrument for discussion and criticism by economic analysts in order to enhance the analytical skills of our expert teams.



Hernán Lacunza
BCRA Head of Economic
Research Division

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A Small Economic Model for Argentina

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A Small Economic Model for Argentina

Pedro Elosegui / Guillermo Escudé / Lorena Garegnani / Juan Martín Sotes Paladino*

Abstract

The uncertainty around monetary policy decision-making requires central banks to make extensive use of macroeconomic models both to analyze the current economic situation and to forecast the evolution of the main economic variables. The Small Economic Model (SEM) for Argentina describes in a stylized manner the macroeconomic dynamic of a small and open economy. This document describes the SEM's structure and its two versions: a first one that includes the model's core equations, and a second version that incorporates the simultaneous intervention in the money and foreign exchange markets by the central bank. The model's main characteristics and limitations, the techniques employed to estimate its parameters and impulse-response functions for both models are presented. Finally, the future research agenda aimed to strengthen the analysis, simulation and forecasting tools for monetary policy purposes is discussed.

JEL Codes: C32, C61, E32, E37, E52, E58.
Key Words: monetary policy, forecasting, New Keynesian models, general equilibrium.

Un Modelo Económico Pequeño para Argentina

Resumen

La incertidumbre que rodea la toma de decisiones de política monetaria hace que la utilización de modelos macroeconómicos sea una práctica común entre los bancos centrales, tanto para el diseño de la política monetaria como para el análisis de la situación económica coyuntural y la realización de proyecciones de mediano y largo plazo. El Modelo Económico Pequeño (MEP) para Argentina describe en forma estilizada y estructurada la dinámica de la macroeconomía de un país pequeño y abierto. Este documento presenta la estructura del MEP en sus dos versiones: una primera que constituye el núcleo del modelo y una versión ampliada que incorpora la intervención simultánea de la autoridad monetaria en los mercados de dinero y de divisas. Se discuten sus principales características y limitaciones, los métodos de estimación de sus parámetros, y las funciones de impulso-respuesta que surgen de ambas especificaciones. Por último, se mencionan las restantes líneas de investigación tendientes a fortalecer las herramientas de análisis, simulación y predicción del BCRA.

Códigos JEL: C32, C61, E32, E37, E52, E58.
Palabras clave: política monetaria, proyecciones, modelos *New Keynesian*, equilibrio general.

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Executive Summary

Monetary policy decision-making under uncertainty requires that expert opinions be supplemented with adequate information regarding the structure of the economy. In particular, it is necessary to understand the relative importance of the various transmission channels of monetary policy. In this sense, central banks make extensive use of macroeconomic models both to analyze the current economic situation and to forecast the evolution of the main economic variables. Among the macroeconomic forecasting models used by central banks, small-scale macroeconomic ones play a main role. This document presents a Small Economic Model (SEM) for Argentina that describes the macroeconomic dynamic features of a small and open economy, contemplating in its two versions different exchange rate and monetary regimes.

In its first version, the SEM consists of a dynamic equation system which includes an equation that describes the dynamics of inflation or "Phillips curve", an equation for output gap or "IS curve", an equation for uncovered interest rate parity or "UIP curve", and a monetary policy equation or "Taylor rule". The four main endogenous variables are inflation rate, output gap, real exchange rate, and real interest rate, measured as deviations from their steady-state values. Central bank intervention in the monetary market is modeled using the interest rate as a policy instrument. This version of the model assumes a pure floating exchange rate regime, although it could be adapted to a fixed exchange rate regime.

In its second version, the SEM incorporates into the core structure of the first version the simultaneous central bank intervention in the money and foreign exchange markets. This addition, which reflects a situation more in line with the reality of developing countries, constitutes a novel contribution to traditional literature on these models. It includes an equation for money market equilibrium or "LM curve", sterilization of the monetary effects of intervention in the foreign exchange market by means of bond issuance, and an additional policy rule. The amount of money, central bank bonds (used for sterilization purposes) and the level of international reserves are also added as endogenous variables. This second version of the SEM makes it possible to model four alternative monetary regimes: a fixed exchange rate against the dollar, a fixed exchange rate against a currency basket, pure-float inflation targeting, and managed float. In the case of the latter, the central bank simultaneously intervenes in the money (interest rates) and the foreign exchange markets (level of international reserves) as instrumental action. For such purpose, an additional policy instrument is introduced, assuming that the central bank can resist changes either in the nominal exchange rate against the dollar, the nominal exchange rate against the basket of currencies, or the multilateral real exchange rate.

The parameters of the crucial equations for the SEM are determined on the basis of empirical estimations in both versions, using data with a quarterly frequency for the 1993-2006 period. The applicable econometric methodology, the Generalized Method of Moments (GMM), not only makes it possible to jointly estimate the model's equations as a system, but also to correct potential problems of endogeneity, and others that arise from modeling the assumption of rational expectations of economic agents.

The results of the econometric estimation of the system show that in the case of the Phillips equation both forward and lagged components are individually significant, being the weight of lagged inflation greater than that of expected future inflation. Output gap has a lagged impact on current inflation, while imported inflation (given by nominal devaluation plus foreign inflation) is significant with lags and has a positive effect. With respect to the IS equation, the lagged value component has a greater weight than the forward component, while the real interest rate has a lagged and significant impact on output gap, reflecting the delay with which changes in the interest rate affect the economy. Fluctuation in the real exchange rate is significant, also with a lag. In the case of the UIP curve, the estimation confirms the presence of a forward and a lagged impact on the exchange rate, while the weight of the past is higher than that of the future.

These results are similar for the SEM in its second version, except in the case of the UIP equation. The stock of bonds issued by the central bank is introduced as a risk measure. This variable has a significant positive lagged impact, with considerable relevance in terms of the goodness of fit of the model. In addition, this second version of the model includes a money demand equation in which the dynamics of the monetary aggregate is explained by its own lagged value, the nominal interest rate and the stock of central bank bonds. It should be noted that in the case of both models the estimations, adjusted quarter by quarter on the basis of new realizations of exogenous variables, show increasing stability and consistency in the key parameters which determine the dynamic stability of the system.

The SEM is a linear system of difference equations with backward as well as forward-looking endogenous variables. This means that the solution of the system requires numerical methods. The projection of macroeconomic variables is derived by resolving the system subject to initial and terminal conditions, and using information on the evolution of all the exogenous variables affecting the model. Given the assumption of consistent expectations with the model, the system can be solved using the future value of endogenous variables in lieu of forward-looking variables. The solution of the model is implemented using the WinSolve software. In addition, it is possible to include exogenous shocks that enable forecasts to be adjusted for changes not considered in the model, improving its predictive power in the short run. Nevertheless, the SEM is a medium-term model that as such, makes it possible to forecast the paths of the main macroeconomic variables during the following two to three years (eight to twelve quarters.)

The possibility of including shocks which may affect the dynamics of endogenous variables makes it possible to analyze their behavior in the face of sudden changes in demand, supply, and the external sector of the economy. A positive shock to aggregate demand can be modeled by means of a disturbance to the IS curve. Subsequent projections of endogenous variables show the adjustment by the economy to such a shock, which will differ according to the model considered. In the second version of the SEM there are major differences in the response of variables, deriving from greater enhancement of transmission mechanisms considered. In particular, monetary intervention in the foreign exchange market lessens the effect of real exchange rate appreciation. In addition, it can be seen that there is a lower impact on the nominal interest rate, reflecting increased liquidity arising from the monetary authority intervention in the foreign exchange, despite sterilization efforts.

Finally, the SEM, in either of its versions, provides the Central Bank with a simple analytical tool capable of evaluating the macroeconomic implications of different policy options and forecasting relevant variables. In addition, the forecasts can be used as inputs for auxiliary econometric models to forecast other macroeconomic and monetary variables. These tools play an important auxiliary role in the monetary policy decision making process. Nevertheless, because of its low degree of complexity, the model presents limitations, particularly when it comes to evaluating and analyzing monetary policies that function on the basis of more sophisticated transmission mechanisms. For this reason, progress continues to be made on the development of alternative, supplementary models, mainly based on dynamic stochastic general equilibrium (DSGE) models, in line with recent developments in economic literature and research programs of other monetary authorities. This will make it possible to supplement and strengthen the capacity to perform forecasts and analyses of the different monetary policy options in the Argentine economy.

1. Introduction

The complexity and difficulty entailed by the process of monetary policy making and execution requires the utilization of tools which, by making use of the analytical and empirical developments incorporated in macroeconomic models, adequately supplement monetary authority decisions. In this regard, the development and use of tools which may allow to properly forecast the effects of the different monetary policies constitutes one of the objectives of the BCRA Economic Research Division. This is fully consistent with the priorities set in the research agenda of other monetary authorities, in both developing and developed countries, where the use of macroeconomic models is a common practice. Such models serve different purposes, since they are used to analyze the current economic situation in order to quantitatively and empirically evaluate the impact of alternative monetary policies, as well as to perform medium and long-term forecasts.

Among the wide range of macroeconomic models used by monetary authorities, small-scale macroeconomic models play a major role.[2] These models are structured,[3] but are relatively simple, and they have been developed with a view to conducting policy studies in a properly flexible and consistent manner. The relative simplicity makes monetary policy transmission mechanisms more transparent, thereby facilitating their understanding. In particular, such models provide an orderly analytical framework to consider the various monetary policy transmission mechanisms, whereas the possibility of forecasting with quantitative results adds relevant information to the decision-making process. Generally, despite the fact that these are not microfounded models, their equations can usually be derived from microeconomic fundamentals in line with modern macroeconomic literature, especially in relation to the key role played by expectations in the behavior of economic agents. With these ingredients such simple models allow, together with econometric estimates, market forecasts and/or expert judgment, to adequately supplement monetary authority decisions.

The SEM developed by the BCRA describes in a stylized manner the macroeconomic dynamics of a small and open country, such as Argentina. The first version of the SEM follows the most usual guidelines for this type of models that are widely used by different central banks. Typically, such models have been developed for industrialized economies, where central banks execute a monetary policy based on inflation targeting (IT) (whether explicit or implicit), and the exchange rate is generally floating. However, as we will see further on, this first version can be modified in order to consider a fixed exchange rate policy. For its part, the second version of the SEM consists of a greater variety of policies which may be adjusted more directly to those applicable to emerging economies, including not only those mentioned before but also the policy of intervention in the foreign exchange market or managed float.

---

[1] The application of macroeconomic models by the central banks of the main industrialized countries at least dates back to the end of the 1960s. See Price (1996), page 6.

[2] These models have a long-standing tradition in England. See Bank of England (1999). Also see Macroeconomic Models and Projections of the Central Bank of Chile (2003).

[3] These are not partial but general equilibrium models. Within the structure of this model there exists an interrelation among endogenous variables, and it is possible to interpret each of the model's equations, as well as consider causality and the impact of changes in policy variables. For such reasons, according to Berg et al. (2006), these are structural models.

In its first version, the core of the SEM basically consists of a dynamic system of equations which includes an equation that describes the dynamics of inflation or «Phillips curve», an equation for output gap or «IS curve», an equation for uncovered interest rate parity or «UIP curve», and a monetary policy equation or «Taylor rule». The four main endogenous variables are inflation rate, output gap, real exchange rate, and real interest rate. In its second version, the SEM incorporates into the core structure of the first version an equation for money market equilibrium or «LM curve», sterilization of the monetary impact of intervention on the foreign exchange market by means of issuing bonds, and an additional policy rule, which constitutes a novel contribution to traditional literature on these models. In fact, the challenge posed by the SEM's second version is that of modeling simultaneous central bank intervention in both the money and foreign exchange markets. This requires to explicitly re-introduce monetary equilibrium (i.e., an LM equation, as it appears on traditional textbooks) into the model, something that has been generally overlooked in the models of industrialized countries.

A feature of these models, which is also incorporated into the SEM, relates to the assumption that the expectations of economic agents are consistent with the model. This implies that in the model's forward-looking solution the expected or «jump» variable, e.g. inflation, ends up being fully compatible with the one determined by the model itself and, therefore, identical to the one finally recorded. This assumption is stronger than rational expectations, which is relatively easy to model since it avoids arbitrary assumptions on expectations. Thus, it is implied that economic agents are familiar with the model, have access thereto, and use all relevant information efficiently in order to make their forecast on the future evolution of interest variables.

An additional feature distinguishing the SEM from other models is that the parameters of crucial equations are not calibrated but determined on the basis of empirical estimates. The applied econometric analysis methodology allows not only to take into account the system feature of the model's equations, but also to correct potential endogeneity problems, such as those which arise from modeling the assumption of consistent expectations of economic agents.

The SEM uses quarterly frequency data, thereby generating reference values or an average of variables for the relevant quarter. Projection of macroeconomic variables is executed by solving the dynamic equation system on the basis of a series of initial and terminal conditions, and by using information on the evolution of all exogenous variables which affect the model. It should be noted that neither the economy's long-term growth rate nor the long-term equilibrium multilateral real exchange rate are determined endogenously. Long-term growth is incorporated into the model through an exogenous projection of potential output.[4] In turn, the long-term (bilateral or multilateral) equilibrium real exchange rate is introduced by imposing a terminal condition for such variable. For such reasons it is said that the SEM is a medium-term model which, in such capacity, allows to develop projections of the main macroeconomic variables with relative ease over the next two to three years (eight to twelve quarters.)

[4] For such purpose, we use a potential output model developed on the basis of the production function approach. See Elosegui et al. (2006).

This paper describes the SEM´s structure in its first and second versions, indicating its main characteristics and limitations and exemplifying impulse-response functions which arise from such model. It also includes changes that are currently being made to this model, and the remaining research lines designed to strengthen BCRA analytical, simulation and forecasting tools. Section 2 describes the equations of this model in its SEM 1 version, which constitute the core of subsequent developments, such as SEM 2. Section 3 describes the managed float version. Section 4 develops the methodology to estimate the model's parameters and comments on the results in qualitative terms. Section 5 contains a general description of the solution process for this type of models and analyzes the impulse-response functions arising from SEM 1 and SEM 2, thus describing the benefits of this type of models for monetary policy analysis. Finally, the last section contains a final conclusion and lists future lines of work.

2. SEM 1: Model Equations

As mentioned in the introduction, the core of the first version of the SEM consists of a dynamic system of four equations: one describing dynamics of inflation; an equation for output gap; an equation for uncovered interest rate parity which establishes an arbitrage relationship among domestic interest rate, (dollar-denominated) international interest rate, and bilateral real exchange rate with the dollar area; and finally, a monetary policy equation. Additionally, there are two identities: the first one relates the bilateral real exchange rate with the dollar area to the multilateral exchange rate with a currency basket (including the dollar, the Euro, and the real); and the second one relates the inter-quarter inflation rate to the inter-annual inflation rate (which is shown in the policy equation when the interest rate is used as an instrument.) This second identity is included because it is natural for the central bank to think in terms of an inter-annual inflation target, and therefore it is advisable to distinguish the inter-quarter inflation rate (shown in the IS and Phillips equations) from the inter-annual rate (shown in the monetary policy rule). One should note that the SEM works with variables measured as percentage deviations (more precisely, log deviations) from variables with respect to their long-term values. For such purposes dynamic equations, which would be non-linear if the model were explicitly microfounded, are expressed in a log-linear manner (i.e., linear in the logs of variables). As regards notation, it should be noticed that the circumflex (caret) character over a x_t variable means that the variable is measured as a log deviation with respect to its long-term steady-state value, $\overline{x}$.[5]

[5] $\hat{x}_t \equiv \log\left(\frac{x_t}{\overline{x}}\right) = \log x_t - \log \overline{x}$. This is approximately equivalent to percentage deviation, since: $\log\left(\frac{x_t}{\overline{x}}\right) = \log\left(\frac{x_t - \overline{x}}{\overline{x}} + 1\right) \approx \frac{x_t - \overline{x}}{\overline{x}}$.

The main six endogenous variables are: $\hat{\pi}_t, \hat{\pi}^{\circ}_t, \hat{y}^{\circ}_t, \hat{e}_t, \hat{e}^{US}_t$, and $\hat{r}_t$, representing domestic inflation rate in its two versions (inter-quarter $\hat{\pi}_t$ and inter-annual $\hat{\pi}^{\circ}_t$), output gap,[6] multilateral real exchange rate, bilateral real exchange rate with the dollar zone (U.S.A.),[7] and real interest rate. Therefore, in its minimal expression, the model is represented by the following six equations:

$$\hat{\pi}_t = A^1(L)\hat{\pi}_t + A^2 E_t\hat{\pi}_{t+1} + A^3(L)\hat{y}^{\circ}_t + A^4(L)\Delta\hat{e}_t \quad (1)$$

$$\hat{y}^{\circ}_t = B^1(L)\hat{y}^{\circ}_t + B^2 E_t\hat{y}^{\circ}_{t+1} + B^3(L)\hat{r}_t + B^4(L)\Delta\hat{e}_t \quad (2)$$

$$\hat{r}_t = \hat{r}^{*US}_t + E_t\Delta\hat{e}^{US}_{t+1} + \hat{\zeta}_t \quad (3)$$

$$\hat{r}_t = C^1\hat{r}_{t-1} + C^2(\hat{\pi}^{\circ}_t - \hat{\pi}^{\circ m}_t) + C^3\hat{y}^{\circ}_t + (C^1\hat{\pi}_t - E_t\hat{\pi}_{t+1}) \quad (4)$$

$$\Delta\hat{e}_t = \Delta\hat{e}^{US}_t + \hat{\pi}^{*}_t - \hat{\pi}^{*US}_t - \hat{\delta}^{*}_t \quad (5)$$

$$\hat{\pi}^{\circ}_t = \hat{\pi}_t + \hat{\pi}_{t-1} + \hat{\pi}_{t-2} + \hat{\pi}_{t-3}. \quad (6)$$

Exogenous variables, $\hat{r}^{*US}$, ζ, π^{*}, π^{*US}, δ^{*} and $\pi^{\circ m}$ represent U.S. real interest rate, risk premium, multilateral foreign inflation rate, U.S. inflation rate, nominal dollar appreciation rate against an international currency basket (dollar, real, and euro), and the (inter-annual) inflation target that the central bank takes into account to determine the interest rate. In turn $A^i(L)$ and $B^i(L)$, $i = 1,2,3,4$ represent polynomials in the lag operator *(L)*. For their part, A^i_i and B^i_i indicate the coefficients that accompany the lagged component j with $j = 0,1,2,..$ of the variable i. These coefficients, including the number of lagged components, are determined econometrically.[8] Meanwhile, parameters C^1, C^2, C^3 are also exogenous and respectively represent the importance given by the central bank to lagged interest rate value, inflation rate deviation against inflation target and output gap at the time of determining the interest rate. Equation (4) summarizes in a stylized manner, and by means of the interest rate as an instrument, central bank intervention in the money market. The last term of (4) derives from expressing the policy equation,

[6] As the SEM introduces long-term growth through potential output (which is exogenous), it is advisable to define output gap as a ratio relative to potential output. Thus, output gap is defined as follows:

$$y^{\circ}_t \equiv \frac{y_t}{y^{\bullet}_t},$$

where $y^{\bullet}_t$ is potential output. Additionally, the SEM imposes a terminal condition so that in the long term (steady state) output is equal to potential output ($\overline{y} = \overline{y}^{\bullet}$). Then, the percentage deviation of output gap relative to its long-term value is:

$$\hat{y}^{\circ}_t = \hat{y}_t - \hat{y}^{\bullet}_t = \log\frac{y_t}{\overline{y}} - \log\frac{y^{\bullet}_t}{\overline{y}^{\bullet}} = \log\frac{y_t}{\overline{y}} - \log\frac{y^{\bullet}_t}{\overline{y}} = \log y_t - \log y^{\bullet}_t = \log\frac{y_t}{y^{\bullet}_t}.$$

[7] The Appendix includes a detailed description of the various definitions applicable to the real exchange rate.

[8] See Section 4 for specific details.

which is usually presented in nominal terms,[9] in terms of the real interest rate in order to have a version of the model with the least number of variables.

In the system (1)-(6) we have chosen to work with real depreciation rates ($\Delta\hat{e}_t, \Delta\hat{e}_t^{US}$) and real interest rates ($\hat{r}_t, \hat{r}_t^{*US}$). Using definitions of these variables, the same may be replaced with nominal depreciation and interest rates:

$$\hat{r}_t = \hat{i}_t - E_t\hat{\pi}_{t+1} \tag{7}$$

$$\hat{r}_t^{*US} = \hat{i}_t^{*US} - E_t\hat{\pi}_{t+1}^{*US} \tag{8}$$

$$\Delta\hat{e}_t = \hat{\delta}_t - \hat{\delta}_t^* + \hat{\pi}_t^* - \hat{\pi}_t \tag{9}$$

$$\Delta\hat{e}_t^{US} = \hat{\delta}_t + \hat{\pi}_t^{*US} - \hat{\pi}_t. \tag{10}$$

Here $\hat{i}_t$, $\hat{i}_t^{*US}$, $\hat{\delta}_t$ represent the peso-denominated nominal interest rate, the U.S. nominal interest rate, and the nominal depreciation rate of the peso against the dollar.[10] Upon determining the domestic real interest rate and the real depreciation rate against the dollar and the currency basket, it is possible to derive the corresponding nominal variables from these equations. Making use of such definitions, equations (3) and (4) can be replaced with the following:

$$\hat{i}_t = \hat{i}_t^{*US} + E_t\hat{\delta}_{t+1} + \hat{\zeta}_t \tag{11}$$

$$\hat{i}_t = C^1\,\hat{i}_{t-1} + C^2\,(\hat{\pi}_t^{\circ} - \hat{\pi}_t^{\circ m}) + C^3\,\hat{y}_t^{\circ}. \tag{12}$$

The first equation expresses the risk-adjusted interest rate parity equation in terms of nominal variables. The second equation expresses monetary policy in terms of a rule for the nominal interest rate. The inclusion in the Taylor rule of a term with the interest rate lagged one period responds to the tendency of central banks to avoid excessive volatility in the nominal interest rate. The coefficient's relative magnitude C^i $(i = 1,2,3)$ specifies the strength given to each factor by the central bank.[11] The equations of this model are scrutinized in greater detail in the following sub-sections.

2.1 Phillips Curve

The model's first equation reflects inflation rate evolution in a peculiar «Phillips curve» version. In microfounded models, this equation arises from optimizing companies, assuming that they determine their prices (on the basis of expected marginal cost) in a context of

[9] See (12).

[10] Notice that (5) derives from subtracting (10) from (9) on a term-by-term basis.

[11] As an alternative, the inter-annual rate deviation from the inflation target may be replaced with the expected deviation for a future period.

nominal price rigidity. This makes companies consider prices at the time of making their decisions. As shown by Roberts (1995), several *New Keynesian* models derive relations of this type, whether with staggered Taylor-type contracts (1979, 1980) or by means of Calvo-style (1983) contracts, based on the premise that only a (random) group of companies will optimize in each period, whereas the other enterprises merely index their price according to backward inflation. The configuration arising from this type of models describes the dynamics of inflation stemming from the expectation on future prices and the inertia captured by backward inflation. Additionally, the model includes output gap, net effect of foreign («imported») inflation, and fluctuation in exchange rates over fluctuation in the multilateral real exchange rate (see equation (9)).

This equation represents «the supply side» of the model in a stylized manner, and it is econometrically estimated with quarterly data.[12] The same is specified with a lagged and a forward-looking component in the inflation rate,[13] a lagged component in output gap, and one or two lagged terms in real depreciation rate:

$$\hat{\pi}_t = A_1^1 \hat{\pi}_{t-1} + A^2 \, E_t \hat{\pi}_{t+1} + A_1^3 \hat{y}^{\circ}_{t-1} + A_1^4 (\hat{e}_{t-1} - \hat{e}_{t-2}) + A_2^4 (\hat{e}_{t-2} - \hat{e}_{t-3}).$$

If real depreciation is replaced with its equivalent counterpart consistently with (9) and terms are grouped with inflation rates, the equation becomes:

$$\begin{aligned} \hat{\pi}_t = {} & A_1^{'1} \hat{\pi}_{t-1} + A_2^1 \hat{\pi}_{t-2} + A^2 \, E_t \hat{\pi}_{t+1} + A_1^3 \hat{y}^{\circ}_{t-1} \\ & + A_1^4 \left(\hat{\delta}_{t-1} - \hat{\delta}^*_{t-1} + \hat{\pi}^*_{t-1} \right) + A_2^4 \left(\hat{\delta}_{t-2} - \hat{\delta}^*_{t-2} + \hat{\pi}^*_{t-2} \right) \end{aligned} \qquad (13)$$

where it was defined

$$A_1^{'1} \equiv A_1^1 - A_1^4, \qquad A_2^1 \equiv -A_2^4. \qquad (14)$$

It can be noted that the terms in brackets show the trade-weighted foreign inflation rate («imported» inflation) plus the depreciation rate of the peso against the trade-weighted currency basket ($\hat{\delta}_t - \hat{\delta}^*_t$). The latter is, in turn, defined as the nominal depreciation rate of the peso against the dollar less the appreciation rate of the dollar against the three-currency basket (i.e., the nominal depreciation rate against the dollar plus the depreciation rate of the dollar against the currency basket.)

2.2 IS Equation

The second equation shows the dynamics of output gap and the equilibrium of the commodities market and it is a version of the «IS curve». In microfounded models, this

[12] See Section 4 for technical details on econometric estimations.

[13] Lagged as well as forward-looking inflation rate coefficients aggregate into a single unit, so that in the long term there is no relation between inflation and output gap, even though the presence of significantly backward-looking inflation indicates that such relation exists in the short term.

equation arises from the inter-temporal optimization of household consumption and the equilibrium condition of the commodities market. Consequently, this equation describes the dynamic relationship among output gap, real interest rate, and real exchange rate from the viewpoint of demand. The specification arising from the parameters identified by the econometric estimation indicates that output gap positively depends on both its one-quarter lagged value and its expected value for the next quarter. Additionally, it depends on the real interest rate and the real depreciation rate of the peso with various lagged components:

$$\hat{y}^{\circ}_{t} = B^{1}_{1}\hat{y}^{\circ}_{t-1} + B^{2}\ E_{t}\hat{y}^{\circ}_{t+1} - B^{3}_{2}\hat{r}_{t-2} - B^{4}_{1}(\hat{e}_{t-1} - \hat{e}_{t-2}) + B^{4}_{2}(\hat{e}_{t-2} - \hat{e}_{t-3}). \quad (15)$$

As shown by Arreaza et al (2003), this equation can include exogenous variables such as government spending.[14] This would allow to consider the potential independent impact of fiscal policy on the dynamics of output. As estimates include the deviation of government spending relative to its trend, there results a significant, independent, positive effect on output gap, which enhances the applicability of this model for monetary policy analysis and the projection of macroeconomic variables.[15]

2.3 Uncovered Interest Rate Parity Equation

Derivation of the Risk-Adjusted Uncovered Interest Rate Parity (UIP) equation arises from the assumption that there are domestic assets denominated in dollars and pesos. Additionally, it is assumed that international investors do not invest in peso-denominated dollars and that they have the possibility of investing in dollar-denominated foreign bonds which are risk-free and yield i^{*US}_{t}, as well as in Argentine (government or corporate) bonds, also denominated in dollars, which are risky and less liquid than foreign bonds. The corresponding risk/liquidity premium (ζ_{t}) is exogenous and variable over time. The log-linear version of the formation of the dollar-denominated domestic rate is:

$$\hat{i}^{US}_{t} = \hat{i}^{*US}_{t} + \hat{\zeta}_{t} \quad (16)$$

where in the case of interest rates the circumflex (caret) character means the percentage interest factor variation relative to its steady-state value.[16] Note that it $\hat{\zeta}_{t}$ may reflect the international liquidity scenario, beyond any other consideration on the risk or liquidity of dollar-denominated domestic bonds.

On the other hand, it is assumed that domestic agents may invest in dollar-denominated domestic bonds (issued by the Government since inter-corporate bonds are settled on a one-to-one basis) and peso-denominated bonds issued by the central bank whose bond

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[14] Also defined as a deviation from a long-term steady state value.

[15] It should be noted that this variable is not endogenous, and therefore the steady-state real exchange rate must be compatible with the long-term value of government spending. In the practical use of the SEM, forecasts for government spending deviations relative to their long-term value are temporary, and they do not affect the real exchange rate.

[16] $\hat{i}_{t} \equiv \log\left(\frac{1+i_{t}}{1+\overline{i}}\right) = \log(1+i_{t}) - \log(1+\overline{i}).$

stock (as a proportion of output) is constant. It could be assumed that economic agents perceive that the peso-denominated bond is risky and that risk increases consistently with the total bond amount issued as a proportion of output. As such proportion is assumed to be constant, the risk premium in question is also constant, and therefore its percentage deviation relative to its long-term value is zero. Investors demand to be offset for expected depreciation by the peso-denominated interest rate. Therefore, the log-linear version of this arbitrage equation corresponds to the Uncovered Interest Rate Parity equation:

$$\hat{i}_t = \hat{i}_t^{US} + E_t\hat{\delta}_{t+1}. \qquad (17)$$

By inserting (17) in (16), it can be seen that the peso-denominated domestic rate is affected by the risk premium and, consequently, the resulting equation can be called *Risk* (and/or *International Liquidity*)*-Adjusted Uncovered Interest Rate Parity*:

$$\hat{i}_t = \hat{i}_t^{*US} + E_t\hat{\delta}_{t+1} + \hat{\zeta}_t. \qquad (18)$$

Additionally, it may be assumed that not all players who intervene in the foreign currency market necessarily optimize period after period based on the fundamentals which determine the equilibrium exchange rate, at the time of defining its excess demand. On the contrary, it can be demonstrated that there are players who decide market intervention after analyzing the (past) average evolution of foreign currency. These players, known as «Chartists», intervene in the market without necessarily following the evolution of fundamentals.[17] With this aggregate, it is possible to derive an equation for *Risk-Adjusted Uncovered Interest Rate Parity*, which may include a lagged and/or contemporaneous component of the nominal depreciation rate:

$$\hat{i}_t = \hat{i}_t^{*US} + E_t\hat{\delta}_{t+1} + D^3(L)\hat{\delta}_t + \hat{\zeta}_t. \qquad (19)$$

In fact, the econometric estimation validates the presence of this additional term.

2.4 Monetary Policy Equation

The specification of the monetary policy equation allows to complete the basic structure of the model. In the first model under study, this equation models the evolution of the instrument variable of the monetary authority, the interest rate, as a function of the remaining endogenous variables, with weights indicating the marginal effect that deviations from these endogenous variables have upon the instrument variable. In particular, in the SEM's first version, it is assumed that the central bank accommodates its intervention in the money market so that the interest rate be adjusted on the basis of a feedback rule (or «Taylor rule») stemming from a linear combination of inflation rate deviations relative to a target inflation rate, output deviation relative to its potential (or long-term) level, and the interest rate one-quarter lagged value. This specification, which strictly speaking assumes pure float,[18] can easily be modified to assume a fixed exchange rate regime.

[17] See Schmidt and Wollmershauser (2004).

[18] It is assimilated into a Pure Float Inflation Targeting (PF-IT) regime. See Escudé (2006).

When monetary policy is modeled after a Taylor rule, the central bank uses the nominal interest rate as an instrument by establishing an operational target for the short-term interest rate, and also by accommodating its intervention in the money market so that the interest rate may reach such target. To such effect, it follows a feedback rule which linearly and positively responds to deviation of current-quarter inter-annual inflation relative to target inter-annual rate, deviation of current-quarter output to potential output, and also one-quarter lagged interest rate.

$$\hat{i}_t = C^1\ \hat{i}_{t-1} + C^2\ (\hat{\pi}^{\circ}_t - \hat{\pi}^{\circ m}_t) + C^3\ \hat{y}^{\circ}_t. \qquad (20)$$

In order to derive $\hat{\pi}^{\circ}_t$ inter-annual based on $\hat{\pi}_t$ inter-quarterly values the following definitions are used:

$$\begin{aligned}\pi^{\circ}_t &\equiv P_t/P_{t-4} = (P_t/P_{t-1})(P_{t-1}/P_{t-2})(P_{t-2}/P_{t-3})(P_{t-3}/P_{t-4}) = \\ &= \pi_t\pi_{t-1}\pi_{t-2}\pi_{t-3}, \\ \pi^{\circ m}_t &\equiv P^m_t/P^m_{t-4} = \pi^m_t\pi^m_{t-1}\pi^m_{t-2}\pi^m_{t-3}.\end{aligned}$$

Consequently, if the steady-state quarterly inflation is $\overline{\pi}$, percentage deviations relative to the steady-state values of the inter-annual inflation rate and its target are the following:

$$\hat{\pi}^{\circ}_t = \hat{\pi}_t + \hat{\pi}_{t-1} + \hat{\pi}_{t-2} + \hat{\pi}_{t-3} \qquad (21)$$

$$\hat{\pi}^{\circ m}_t = \hat{\pi}^m_t + \hat{\pi}^m_{t-1} + \hat{\pi}^m_{t-2} + \hat{\pi}^m_{t-3}. \qquad (22)$$

2.4.1 Fixed Exchange Rate against the Dollar

The SEM may be adapted to a context of fixed exchange rate regime (whether against the dollar or a trade-weighted currency basket). It should be noted that each regime strictly defines an alternative model, since the system's dynamics changes depending on the type of exchange rate and monetary policy regime. Under a fixed exchange rate against the dollar, the central bank uses foreign exchange market intervention with enough swiftness and intensity so as to maintain the exchange rate against the dollar fixed on its initial value:

$$S_t = S_0.$$

Consequently, the policy equation becomes:

$$\hat{\delta}_t = 0 \qquad (23)$$

and the system is confined to the following four equations, which determine the variables' paths π, y°, e, i:

$$\begin{aligned}\hat{\pi}_t = {} & A^{'1}_1\hat{\pi}_{t-1} + A^1_2\hat{\pi}_{t-2} + A^2\ E_t\hat{\pi}_{t+1} + A^3_1\hat{y}^{\circ}_{t-1} + \\ & + A^4_1\left(\hat{\delta}_{t-1} - \hat{\delta}^*_{t-1} + \hat{\pi}^*_{t-1}\right) + A^4_2\left(\hat{\delta}_{t-2} - \hat{\delta}^*_{t-2} + \hat{\pi}^*_{t-2}\right)\end{aligned} \qquad (24)$$

$$\begin{aligned}\hat{y}^{\circ}_t = {} & B^1_1\hat{y}^{\circ}_{t-1} + B^2\ E_t\hat{y}^{\circ}_{t+1} - B^3_2(\hat{i}_{t-2} - \hat{\pi}_{t-1}) - B^4_1(\hat{e}_{t-1} - \hat{e}_{t-2}) + \\ & + B^4_2(\hat{e}_{t-2} - \hat{e}_{t-3})\end{aligned} \qquad (25)$$

$$\hat{e}_t - \hat{e}_{t-1} = \hat{\pi}_t^* - \hat{\delta}_t^* - \hat{\pi}_t \qquad (26)$$

$$\hat{i}_t = i_t^{*US} + \hat{\zeta}_t. \qquad (27)$$

It can be noticed that the peso real depreciation ($\hat{e}_t - \hat{e}_{t-1}$) is determined by international (trilateral) inflation adjusted for the nominal dollar appreciation against the currency basket of trading partners and domestic inflation.[19] Furthermore, the peso-denominated local interest rate is exclusively determined by the U.S. interest rate and the risk premium. Therefore, there is no equation which may reflect determination of the interest rate by the central bank.

2.4.2 Fixed Exchange Rate against a Trade-Weighted Currency Basket

Alternatively, the central bank could use foreign exchange market intervention with enough swiftness and intensity so as to maintain the exchange rate against the dollar fixed on its initial value:[20]

$$S_t/\rho_t = S_0/\rho_0.$$

Consequently, the peso nominal depreciation rate remains equal to the dollar appreciation rate against a trade-weighted currency basket:

$$\hat{\delta}_t = \hat{\delta}_t^*. \qquad (28)$$

This is the equation which now replaces the Taylor rule. Therefore, the system is confined to the following equations, which again determine the paths of variables π, y°, e, i.

$$\hat{\pi}_t = A_1^{'1}\hat{\pi}_{t-1} + A_2^1\hat{\pi}_{t-2} + A^2\, E_t\hat{\pi}_{t+1} + A_1^3\hat{y}_{t-1}^\circ + A_1^4\hat{\pi}_{t-1}^* + A_2^4\hat{\pi}_{t-2}^* \qquad (29)$$

$$\hat{y}_t^\circ = B_1^1\hat{y}_{t-1}^\circ + B^2\, E_t\hat{y}_{t+1}^\circ - B_2^3(\hat{i}_{t-2} - \hat{\pi}_{t-1}) - B_1^4(\hat{e}_{t-1} - \hat{e}_{t-2}) + \\ + B_2^4(\hat{e}_{t-2} - \hat{e}_{t-3}) \qquad (30)$$

$$\hat{e}_t - \hat{e}_{t-1} = \hat{\pi}_t^* - \hat{\pi}_t \qquad (31)$$

$$\hat{i}_t = i_t^{*US} + E_t\hat{\delta}_{t+1}^* + \hat{\zeta}_t. \qquad (32)$$

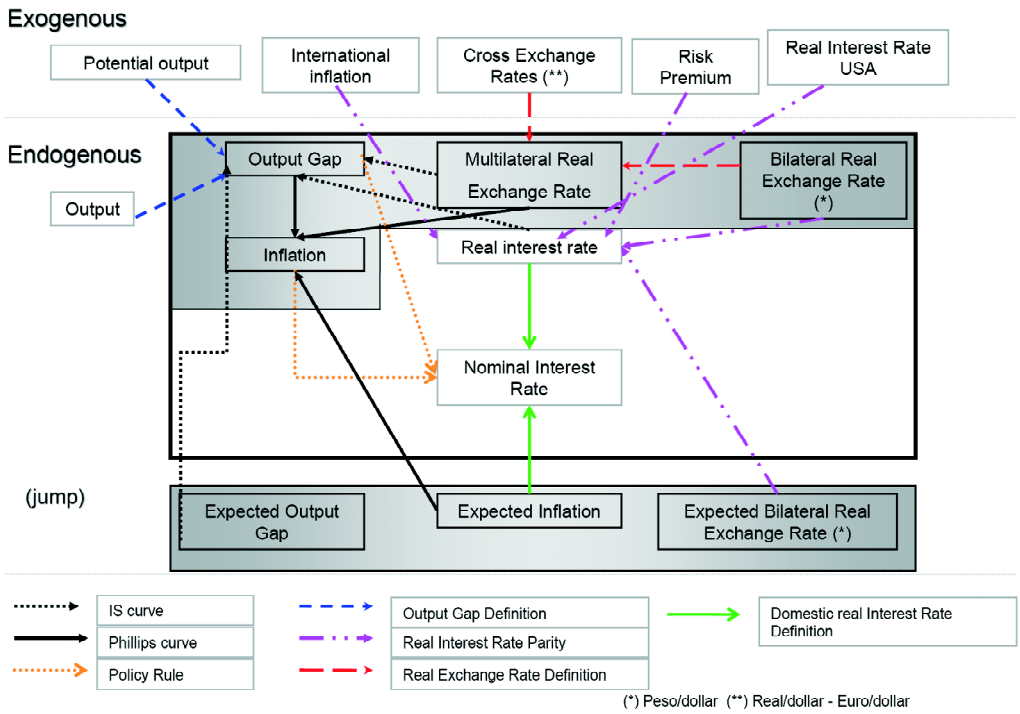
[19] Notice that this formula clearly reflects the events occurred during the last Currency Convertibility period (1995-2001), in which the real depreciation of the peso was negative (i.e., real appreciation was positive) due to the fact that the dollar appreciated against all the remaining currencies in a context of slightly negative and/or low inflation. Such deflation was insufficient to offset the exchange rate decline.

[20] Notice that ρ_t is defined in the Appendix, Section A.1.

In this case, the real peso depreciation is determined by excess foreign inflation on domestic inflation. Furthermore, the peso-denominated local interest rate is determined by the U.S. interest rate plus the expected dollar appreciation against the (trade-weighted) currency basket of trading partners plus the risk premium.

Figure 1 synthetically shows SEM 1 variables and their transmission mechanisms, identifying exogenous and endogenous variables, and distinguishing jump variables or expectations.

Figure 1
SEM 1: Transmission Mechanisms



In order to analyze the way of transmitting changes to the model's variables, it should be taken into account that modifications are defined as a deviation from their steady-state or long-term level. For example, an interest rate change will generate a direct effect on the current exchange rate through the UIP. In turn, it rebounds on the deviation of output gap relative to stationary state, through the IS curve. This effect operates on both expected and current inflation, through the Phillips equation. In turn, exchange rate fluctuation has an impact on such two variables also in a direct manner. Finally, changes in these variables originate an interest rate reaction through the Taylor equation. Therefore, the final effect depends on the interaction of these mechanisms in the general equilibrium of this model. Shock impacts are dealt with in Section 5, including initial impulse and response of the model in each of its main endogenous variables.

3. SEM 2: Simultaneous Intervention in the Money and Foreign Exchange Markets

In its second version the SEM has been modified so as to incorporate a broader spectrum of exchange rate and monetary policies. In particular, it is deemed to be relevant that the SEM may reflect the simultaneous monetary authority intervention in the money and foreign exchange markets. For such purpose, it is necessary to introduce the money market and the central bank balance sheet explicitly. Traditionally, the monetary equilibrium equation has occupied a prominent position in monetary macroeconomics through the LM equation. However, a recent development has been the so-called «Macroeconomics without LM», this essentially being the result of the prevailing policy in most industrialized countries (at least for normal times), i.e. inflation targeting (IT) with free exchange rate float. In a certain sense, the Taylor rule replaced the LM equation. Nevertheless, the need to reflect the typical scenario in developing countries, where money market intervention coexists with foreign exchange market intervention, can be dealt with by re-introducing the LM equation in the basic macroeconomic model.

3.1 Monetary Equilibrium and Central Bank Balance Sheet

Monetary equilibrium is given by an LM equation which, in a general (non-linear) format, may be written as follows:

$$m_t = \ell(1 + i_t, b_t^\circ, y_t),$$

where m_t is the monetary base, or more plainly, money in circulation (notes and coins), $\ell(.)$ is a declining function of the interest rate and an increasing function of output and the peso-denominated real bond stock (proxied by debt issued by the central bank) as a $b_t^\circ \equiv (B_t/P_t)/y_t$ proportion of output. This equation reflects that demand for circulating money depends positively on the level of economic activity (measured by GDP) and negatively on the opportunity cost for maintaining idle balances. The opportunity cost for maintaining idle balances reflects the imperfect substitution between circulating money and alternative interest-bearing assets. Such imperfect substitution implies that for the market to absorb an increase in the volume of interest-bearing bonds (given the level of economic activity and the volume of money in circulation) it is necessary to increase the interest rate. For modeling purposes, the effect is similar to a scenario where risk is taken into consideration. In such a case, it is assumed that owing to risk the market demands a higher nominal interest rate whenever the existing bond stock is higher as a proportion of output b_t°.[21] Assuming unit output-elasticity of demand for circulating money, a plausible specification is the following:

$$m_t = (1 + i_t)^{-\varepsilon_{b1}} (b_t^\circ)^{\varepsilon_{b2}} y_t.$$

[21] The above-mentioned assumption of inter-temporal sustainability also implies a sustainable path for public-sector debt, thus bypassing the effects of interest rate increases on the sustainability of government debt.

Dividing both sides of this equation by output, the result is:

$$m_t^\circ = (1 + i_t)^{-\varepsilon_{b1}} (b_t^\circ)^{\varepsilon_{b2}}.$$

And if it is approximated linearly (with variables in logarithms), the result is

$$\widehat{m}_t^\circ = -\varepsilon_{b1}\left(\widehat{i}_t - \varepsilon_{b2}\widehat{b}_t^\circ\right) = -G^1\,\widehat{i}_t + G^2\,\widehat{b}_t^\circ, \qquad (33)$$

where $G^1 = \varepsilon_{b1}$ and $G^2 = \varepsilon_{b1}\varepsilon_{b2}$ are fixed positive coefficients. Notice that on the right hand side of (33) a positive term is subtracted from the interest rate, consistently with the assumption that the market «discounts» the nominal interest rate by way of imperfect substitution. No matter which is the monetary policy, the central bank must always take into account the money market equilibrium represented by this equation.

It is assumed that the public considers that dollar-denominated bonds issued by the central bank are imperfect substitutes for dollar-denominated bonds issued in the U.S.A. Therefore, the risk/liquidity premium of the Uncovered Interest Rate Parity equation must include not only the purely exogenous component (ζ_t), but also a component reflecting the need to increase the peso interest rate, given the dollar interest rate and the expected depreciation rate of the peso relative to the dollar, whenever the peso-denominated bond stock increases as a fraction of output.[22] It is assumed that this component changes linearly with the bond stock ($\widehat{b}_t^\circ$). Consequently, equations (17), (18), and (19) become:

$$\widehat{i}_t = \widehat{i}_t^{US} + E_t\widehat{\delta}_{t+1} + \varepsilon_{b2}\widehat{b}_t^\circ \qquad (34)$$

$$\widehat{i}_t = \widehat{i}_t^{*US} + E_t\widehat{\delta}_{t+1} + \widehat{\zeta}_t + \varepsilon_{b2}\widehat{b}_t^\circ \qquad (35)$$

$$\widehat{i}_t = \widehat{i}_t^{*US} + E_t\widehat{\delta}_{t+1} + D^3\,\widehat{\delta}_t + \widehat{\zeta}_t + \varepsilon_{b2}\widehat{b}_t^\circ. \qquad (36)$$

It is assumed that the central bank pursues a policy of transferring any surplus or «quasi-fiscal» deficit to the government, so that central bank's «net worth» invariably remains at zero.[23] This is to say that, in every period, the central bank maintains total backing of its monetary liabilities (monetary base plus peso-denominated bonds) in international reserves:

$$(S_t/P_t)R_t = m_t + b_t.$$

Dividing both sides by output and using the definition of real bilateral exchange rate with the U.S.A. (61), the result is:

$$e_t^{US}R_t^\circ = m_t^\circ + b_t^\circ, \qquad (37)$$

[22] See Escudé (2006).

[23] For model operation purposes, it is enough to assume that such "net worth" remains constant but, for simplification's sake, we have made it zero.

where the stock of international reserves was defined in constant dollars by output unit:

$$R_t^{\circ} \equiv \frac{R_t / P_t^{US}}{y_t}. \tag{38}$$

Here, for simplification's sake, it is assumed that international reserves are invested in risk-free, dollar-denominated foreign bonds. In log-linear terms, equation (37) becomes:

$$\hat{R}_t^{\circ} = \alpha_m \hat{m}_t^{\circ} + (1 - \alpha_m)\hat{b}_t^{\circ} - \hat{e}_t^{US}, \tag{39}$$

where α_m is the participation of m in peso-denominated liabilities of the central bank in a deterministic stationary state.

3.2 Need to Incorporate Two Policy Equations

To simplify the analysis, it is assumed that the interest rate parity equation only includes the contemporaneous (in addition to the expected) depreciation rate, without considering monetary and/or exchange policy. The resulting equations are the following:

$$\begin{aligned}\hat{\pi}_t = {} & A_1^{'1}\hat{\pi}_{t-1} + A_2^1\hat{\pi}_{t-2} + A^2\, E_t\hat{\pi}_{t+1} + A_1^3\hat{y}_{t-1}^{\circ} + \\ & + A_1^4\left(\hat{\delta}_{t-1} - \hat{\delta}_{t-1}^{*} + \hat{\pi}_{t-1}^{*}\right) + A_2^4\left(\hat{\delta}_{t-2} - \hat{\delta}_{t-2}^{*} + \hat{\pi}_{t-2}^{*}\right)\end{aligned} \tag{40}$$

$$\begin{aligned}\hat{y}_t^{\circ} = {} & B_1^1\hat{y}_{t-1}^{\circ} + B^2\, E_t\hat{y}_{t+1}^{\circ} - B_2^3(\hat{i}_{t-2} - \hat{\pi}_{t-1}) - B_1^4(\hat{e}_{t-1} - \hat{e}_{t-2}) + \\ & + B_2^4(\hat{e}_{t-2} - \hat{e}_{t-3})\end{aligned} \tag{41}$$

$$\hat{i}_t = \hat{i}_t^{*US} + E_t\hat{\delta}_{t+1} + D^3\,\hat{\delta}_t + \hat{\zeta}_t + \varepsilon_{b2}\hat{b}_t^{\circ} \tag{42}$$

$$\hat{m}_t^{\circ} = -G^1\hat{i}_t + G^2\hat{b}_t^{\circ} \tag{43}$$

$$\hat{R}_t^{\circ} = \alpha_m\hat{m}_t^{\circ} + (1 - \alpha_m)\hat{b}_t^{\circ} - \hat{e}_t^{US} \tag{44}$$

$$\Delta\hat{e}_t = \hat{\delta}_t - \hat{\pi}_t + \hat{\pi}_t^{*} - \hat{\delta}_t^{*} \tag{45}$$

$$\Delta\hat{e}_t^{US} = \hat{\delta}_t - \hat{\pi}_t + \hat{\pi}_t^{*US}. \tag{46}$$

These seven equations are not enough to determine the evolution of the nine variables of interest for us , $\hat{\pi}_t$, $\hat{y}_t^{\circ}$, $\hat{e}_t$, $\hat{e}_t^{US}$, $\hat{\delta}_t$, $\hat{i}_t$, $\hat{m}_t^{\circ}$, $\hat{R}_t^{\circ}$, $\hat{b}_t^{\circ}$, or endogenous variables, given the (expected) paths of exogenous variables $\hat{\delta}_t^{*}$, $\hat{i}_t^{*US}$, $\hat{\pi}_t^{*US}$, $\hat{\pi}_t^{*}$, $\hat{\zeta}_t$. Therefore, at least two additional equations are needed, which may reflect the central bank's exchange rate and monetary policy.

3.3 Exchange Rate and Monetary Policy Equations

This more general framework for this «second generation» of the SEM version allows to accommodate various exchange rate and monetary regimes, including some that could not be included in the first version. Each regime is now specified by means of two policy equations, and again each regime defines an alternative model. Two additional equations are presented below, each respectively corresponding to one of the four alternative regimes: 1) Fixing the exchange rate relative to the dollar (U-FIX, for Unilateral FIXing), 2) Fixing the exchange rate relative to a trade-weighted currency basked (M-FIX, for Multilateral FIXing), 3) Inflation Targeting with Pure Float (IT-PF), and 4) Inflation Targeting with Managed Float (IT-MF.)

1) **U-FIX:** The central bank uses intervention in the foreign exchange market with enough swiftness so as to maintain the exchange rate against the dollar pegged at its initial value. Additionally, the central bank keeps the stock of peso-denominated real bonds constant as a proportion of output. Consequently, one may derive the following equations:

$$\hat{\delta}_t = 0,$$

$$\hat{b}^{\circ}_t = 0.$$

2) **M-FIX:** The central bank uses intervention in the foreign exchange market with enough swiftness so as to maintain the exchange rate against the trade-weighted currency basket at its initial value. Additionally, the central bank keeps the stock of peso-denominated real bonds constant as a proportion of output:

$$\hat{\delta}_t = \hat{\delta}^{*}_t,$$

$$\hat{b}^{\circ}_t = 0.$$

3) **IT-PF:** The central bank has an operational target for the short-term interest rate, and it accommodates its intervention in the money market so that the interest rate may reach (or closely approach) such target; in other words, so that the Taylor rule may be verified.

$$\hat{i}_t = C^1 \, \hat{i}_{t-1} + C^2 \, (\hat{\pi}^{\circ}_t - \hat{\pi}^{\circ m}_t) + C^3 \, \hat{y}^{\circ}_t. \qquad (47)$$

Moreover, where there is pure float it is assumed that the central bank confines its intervention in the foreign exchange market to maintaining the stock of international reserves constant as a proportion of output: [24]

$$\hat{R}^{\circ}_t = 0.$$

[24] Obviously, reserves might additionally change because of a policy relating to international liquidity prudential reasons. To simplify, here we abstain from addressing such issue.

4) **IT-MF:** In this case, the central bank uses money market intervention (interest rate) and foreign exchange market intervention as instruments on a simultaneous basis.

$$\hat{i}_t = C^1\ \hat{i}_{t-1} + C^2\ (\hat{\pi}^{\circ}_t - \hat{\pi}^{\circ m}_t) + C^3\ \hat{y}^{\circ}_t,$$

$$\hat{R}^{\circ}_t = K^o \hat{R}^{\circ}_{t-1} - K^1\left[\hat{\delta}_t - a\hat{\delta}^*_t - b(\hat{\pi}_t - \hat{\pi}^*_t)\right]. \qquad (48)$$

Here the foreign currency market intervention rule has been expressed in a generic manner which has several possible sub-cases depending on whether *a* and *b* take one or zero values. The central bank offers resistance to changes in the nominal exchange rate against the dollar (IT-MF-UN) ($a = b = 0$) or to changes in the nominal exchange rate against the currency basket (IT-MF-MN) ($a = 1,\ b = 0$) or to changes in the multilateral real exchange rate (IT-MF-MR) ($a = b = 1$.) To be specific, let's take the IT-MF-UN case, and assume that the interest rate parity equation only includes the contemporaneous depreciation rate (in addition to the expected rate.)

The equations of this system are the following:

$$\hat{\pi}_t = A^{'1}_1\hat{\pi}_{t-1} + A^1_2\hat{\pi}_{t-2} + A^2\ E_t\hat{\pi}_{t+1} + A^3_1\hat{y}^{\circ}_{t-1} + \\ + A^4_1\left(\hat{\delta}_{t-1} - \hat{\delta}^*_{t-1} + \hat{\pi}^*_{t-1}\right) + A^4_2\left(\hat{\delta}_{t-2} - \hat{\delta}^*_{t-2} + \hat{\pi}^*_{t-2}\right) \qquad (49)$$

$$\hat{y}^{\circ}_t = B^1_1\hat{y}^{\circ}_{t-1} + B^2\ E_t\hat{y}^{\circ}_{t+1} - B^3_2(\hat{i}_{t-2} - \hat{\pi}_{t-1}) - B^4_1(\hat{e}_{t-1} - \hat{e}_{t-2}) + \\ + B^4_2(\hat{e}_{t-2} - \hat{e}_{t-3}) \qquad (50)$$

$$\hat{i}_t = \hat{i}^{*US}_t + E_t\hat{\delta}_{t+1} + D^3\ \hat{\delta}_t + \hat{\zeta}_t + G^2\hat{b}^{\circ}_t \qquad (51)$$

$$\hat{m}^{\circ}_t = -G^1\hat{i}_t + G^2\hat{b}^{\circ}_t \qquad (52)$$

$$\hat{R}^{\circ}_t = \alpha_m\hat{m}^{\circ}_t + (1-\alpha_m)\hat{b}^{\circ}_t - \hat{e}^{US}_t \qquad (53)$$

$$\hat{i}_t = C^1\ \hat{i}_{t-1} + C^2\ (\hat{\pi}^{\circ}_t - \hat{\pi}^{\circ m}_t) + C^3\ \hat{y}^{\circ}_t \qquad (54)$$

$$\hat{R}^{\circ}_t = K^0\ \hat{R}^{\circ}_{t-1} - K^1\hat{\delta}_t \qquad (55)$$

$$\Delta\hat{e}_t = \hat{\delta}_t - \hat{\pi}_t + \hat{\pi}^*_t - \hat{\delta}^*_t \qquad (56)$$

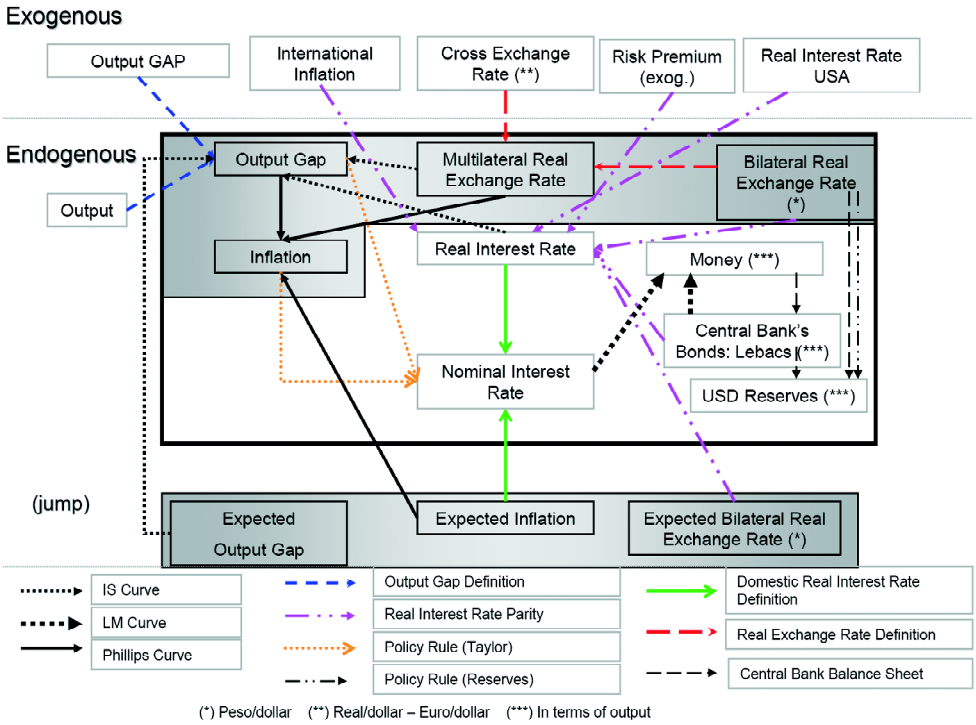
$$\Delta\hat{e}^{US}_t = \hat{\delta}_t - \hat{\pi}_t + \hat{\pi}^{*US}_t \qquad (57)$$

$$\hat{\pi}^{\circ}_t = \hat{\pi}_t + \hat{\pi}_{t-1} + \hat{\pi}_{t-2} + \hat{\pi}_{t-3}. \qquad (58)$$

These ten equations must determine the evolution of the ten endogenous variables[25] $\hat{\pi}_t$, $\hat{\pi}^{\circ}_t$, $\hat{y}^{\circ}_t$, $\hat{e}_t$, $\hat{e}^{US}_t$, $\hat{\delta}_t$, $\hat{i}_t$, $\hat{m}^{\circ}_t$, $\hat{R}^{\circ}_t$, $\hat{b}^{\circ}_t$, stemming from the (expected) paths of the exogenous variables $\hat{\pi}^{\circ m}_t$, $\hat{\delta}^{*}_t$, $\hat{i}^{*US}_t$, $\hat{\pi}^{*US}_t$, $\hat{\pi}^{*}_t$, $\hat{\zeta}_t$. This is the system which corresponds to the second version of the SEM.

Figure 2 shows SEM 2 variables, both endogenous and exogenous, and their transmission mechanisms. Unlike SEM 1, these mechanisms involve more complex relations, including interaction between monetary and real variables.

Figure 2
SEM 2: Transmission Mechanisms



Incorporating the central bank balance sheet and the demand for money adds greater complexity to transmission mechanisms. This fact may clearly be seen in the simultaneous intervention by the monetary authority in the money and foreign exchange markets. A core aspect relates to the risk premium in the UIP equation and the demand for money, since its presence (or more generally the imperfect substitution between local currency and foreign currency-denominated assets) enhances the interaction between the real and monetary blocks of this model in terms of transmission mechanisms.

[25] The policy rule on the interest rate introduces an additional endogenous variable to the nine ones considered in the system (38) to (44), the inter-annual inflation rate, all of which requires the introduction of equation (58).

4. Econometric Estimations

Upon evaluating the theoretical model there are two additional issues to be resolved, as pointed out by Favero (2001). One is model parametrization, and the other is model simulation. In this Section we are going to focus in detail on the first of these two issues and the technical challenges implied by them, whereas simulation shall be studied in the following Section.

In fact, as a prior step to its solution and application in order to make projections and policy analysis, it is necessary to define the parameters corresponding to the variables which determine the dynamics of this model, and therefore its stability. In any microfounded model these coefficients are defined on the basis of the values corresponding to its own underlying parameters. This is not possible in the case of non-microfounded macroeconomic models, such as the SEM. An alternative approach consists in using parameter values from similar models of other economies and calibrate them based on empirical data on the economy in question. Another alternative is to determine parameter values consistently with econometric estimations.

Traditional literature does not show clear consensus relating to parametrization models since there are pros and cons in every case. Using parameters from other economies may not be advisable whenever these economies have different economic structure and macroeconomic performance (e.g., models of developed economies to make projections in developing economies) and, especially, if the economy under study has suffered major external shocks.

This paper follows the econometric estimation of parameters approach. The most important restrictions on its implementation comprised the need to have available statistical series with adequate time coverage fully consistent with model variables, and the presence of institutional breakups and regime changes within the period. Both restrictions are present in the case under study, and therefore the econometric estimation requires a suitable treatment of them so as to minimize their potential impact on the predictive capacity of this model.

The underlying theoretical model behind the reduced size of the Small Economic Model gains importance whenever the appropriate econometric methodology is considered for purposes of estimating parameters. In particular, models such as the SEM which may rationally be conceived on the basis of micro-fundamentals and inter-temporal optimization decisions result in different parameters from those estimated through traditional macro-economic models, since they are ultimately based on the deep parameters described by them, for example, preferences and technology. If the inter-temporal optimization paradigm is enhanced with consistent expectations or expectations that are created rationally, prediction errors shall not be related to the information which is, at the time of making the forecast, available to the individual making inter-temporal decisions. If it is possible to see the subset of information held by economic agents at the time of making their decisions, the rational expectations approach suggests the use of orthogonality conditions which lead to the econometric estimation method known as Generalized Method of Moments.[26]

[26] Hansen (1982).

This methodology encompasses a generalization of methods for instrumental variables and implies two essential advantages: (i) it does not require to impose a specified probability distribution on variables, and (ii) it is consistent with the inter-temporal optimization behavior of economic agents. With a view to correcting the endogeneity problem in which one normally incurs whenever each equation is estimated on an individual basis, estimation based on the GMM system is used in order to consider equations on a simultaneous basis.

The following sub-sections deal with the results from parameter estimation. For interpreting purposes, it should be taken into account that: (i) the specifications of SEM 1 and SEM 2 models arising from parameter estimations are compatible with the structure of backward components of the models developed hereinbefore, that is to say, with equations {(13), (15), and (19)} and {(49), (50), (51) and (52)};[27] (ii) estimations are adjusted quarter after quarter based on new runs of exogenous variables, including several binary control variables for different periods. For such reason, and considering that in both SEM 1 and SEM 2 cases, the estimations of key parameters (those which determine the system's dynamics) show a certain degree of stability and consistency, a descriptive analysis will be made of the main transmission mechanisms and their relevance stemming from the most recent estimation of this model. However, it must be considered that, quarter after quarter, there may be changes in the estimated values for these parameters deriving from the systemic relationship between variables.[28]

4.1 Estimation of SEM 1

The estimations of SEM core equations were performed using quarterly data for the 1993-2005 period. Although the length of this period is enough to carry out the estimations, it must be considered that the Argentine economy experienced different stages during such period. In particular, the country suffered two major economic crises: in 1995 with the regional impact of the Mexican devaluation («Tequila Effect»), and by the end of 2001 with the exit from the Currency Convertibility regime. Likewise, it must be considered that there were substantial differences in the prevailing economic regimes: Convertibility Plan (1991-2001), a period of crisis since the exit from the Convertibility regime (first quarter of 2002) until the first quarter of 2003, and the post-crisis period since the second quarter of 2003 until the end of the sample. The influence of the above-mentioned crises on the values of the parameters was held under control by means of using binary variables.

Additionally there is one of the most important restrictions in terms of data availability, relating to the absence of lengthy and robust interest rate series for the entire period under study. In fact, the ex-ante real interest rate used in equations IS and UIP is calculated on the basis of a monthly series of the annual nominal rate for time deposits at 30-59

[27] Equations (20), (53), (54), (55) reflect policy rules and/or balance sheet equations, the parameters of which are calibrated rather than estimated.

[28] See, for example, Polovnov and Nikolaychuk (2006).

days, an average weighted by amounts of daily data for the month. This rate is calculated in real terms on the basis of the monthly series of expected inflation.[29] In relation to the remaining variables, the reference international interest rate used is 3-month LIBOR. The domestic rate calculation was made on the basis of Consumer Price Index (CPI), the applicable real exchange rate is the multilateral rate with the three main trading partners of Argentina (Brazil, the U.S.A., and the Euro-zone), and imported inflation is calculated on the basis of consumer prices for such partners.

Among the most important results from the system's econometric estimation one may highlight that in the Phillips equation case (equation (13)) both forward and lagged components are individually significant, while the weight of the past is slightly higher than that of the future. This determines a hybrid specification of the Phillips curve, in which the backward component is associated with the inertial behavior of inflation and the forward component reflects the impact of expected price fluctuations on current inflation. Testing does not reject the verticality of this equation in the long term, i.e. that the sum of the values of both coefficients is one. The lagged value of output gap affects current inflation, but in a different way depending on the period under study.[30] The value of the coefficient for the post-crisis period, which was taken for the simulations made in the following sub-section, indicates that the transmission channel of economic activity to prices is significant. The incorporation of imported inflation (an approximate figure based on nominal depreciation plus foreign inflation) proves to be significant having backward components and total positive effect. This variable's transmission channel to prices is substantially lower than the one observed for the case of economic activity in the post-crisis period.[31]

In relation to the IS equation (equation (15)), the lag of the output gap is more highly weighted than the forward component. Most empirical studies impose that both coefficients should aggregate one. In the case study, this restriction is verified without being imposed. As regards the real interest rate, lagged values are significant which, as usual, reflect the delay with which interest rate fluctuations affect output gap. On the other hand, the lagged real exchange rate fluctuation is also significant. Although both variables affect output gap with a two-period lag, the most important transmission channel is the exchange rate.

In the Interest Rate Parity case (equation (19), it can be noticed that the results from the estimations validate the presence of backward as well as forward components in the exchange rate fluctuation, while the weight of the past is higher than that of the future.

Generally, it is necessary to include specific binary variable for several periods, in particular for the fourth quarter of 2001, the first quarter of 2002, and also for other quarters of 2003 only in the case of UIP.

[29] It should be advisable to incorporate a long-term interest rate in the IS equation, which may more appropriately reflect the impact of monetary authority intervention on investment. However, rates series with such features are not available.

[30] Convertibility regime, crisis period (first quarter of 2002 to first quarter of 2003), and post-crisis period (second quarter of 2003 to end of sample.)

[31] In the SEM framework it is convenient to use real depreciation plus domestic inflation in lieu of nominal devaluation plus "imported" inflation, since they are identical by definition.

4.2 Estimation of SEM 2

As mentioned before, the second version of the SEM model enhances the equation system with additional variables, and adds the money demand equation (LM) and the balance sheet position of the central bank. The inclusion of additional variables and the money demand equation in the system to be estimated by the GMM does not generate substantial alterations in the estimated parameters.

In particular, in the Phillips equation case (equation (49)), again both forward and backward components are individually significant, while the weight of the past is slightly higher than that of the future. The weight of both terms is not significantly different from the one observed in the case of SEM 1.[32] Likewise, the lagged value of output gap affects present inflation, but in a different way depending on the period under study, the positive impact increasing against SEM 1 for the post-crisis period. The parameter relevant to imported inflation is significant with lags and total positive effect as it occurs in SEM 1. Again, the transmission channel of output gap to prices is more relevant than that of imported inflation.

In relation to the IS equation (equation (50)), as it occurs in SEM 1, the lag of the output gap is more highly weighted than the forward component. The real interest rate affects output gap with two lags, like the real exchange rate fluctuation, even though the impact of the latter is significantly greater. This equation additionally includes the effect of a fiscal variable, Government Spending/Gross Domestic Product, [33] which improves the goodness of fit of the equation against SEM 1 with a highly significant positive effect of the lagged value of such variable on output gap. Despite the inclusion of such variable, the estimations of the remaining coefficients of this equation remain stable in relation to SEM 1.

In the UIP equation case (equation (51)), again the results from the estimations validate the presence of a backward component in the exchange rate fluctuation, while the weight of the past is much higher than that of the future compared with SEM 1. Unlike SEM 1, this equation incorporates the stock of government bonds (an approximate figure based on the stock of LEBACs)[34] as a proxy for the endogenous risk premium. This variable has become –statistically and economically- significant as from 2003. It has a positive impact, as well as great relevance to the explanatory capacity of the model.

Additionally, SEM 2 includes the equation of the demand for money where a dependent variable is considered to be monetary aggregate M1 as a proportion of nominal GDP.[35] This variable is explained by its own lags, the lag of the nominal interest rate, with a negative sign, and the risk proxy (LEBAC stock), with a positive sign.

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[32] Again there is no rejection of the hypothesis on the verticality of the Phillips curve in the long term.

[33] This variable is expressed in deviations from its long-term trend, by using the filter developed by Hodrick and Prescott (1980).

[34] LEBACs or Central Bank Bills start being issued in the first quarter of 2002, and they become relevant as monetary control instruments in 2003.

[35] For the period under study, monetary aggregate M1 (cash plus checking account deposits) presents advantages compared with monetary base in terms of the goodness of fit of the demand for money. Therefore, the econometric estimation is performed by considering this monetary aggregate which contemplates the transactions component of the theoretical specification of the LM curve. It is fulfilled the implicit assumption that checking account deposits change proportionally with money in circulation, since there is no modeling of the banking system.

Finally, it should be noted that, as suggested by Favero (2001), in the implementation of the GMM the stability of deep parameter estimations with time-series aggregate data is a key issue. This property is verified in the SEM case, since core parameters show increasing stability and consistency.[36]

5. SEM Resolution and Impulse-Response Analysis

The SEM model described in the foregoing section constitutes a linear system of difference equations, with backward and forward-looking endogenous variables. The presence of forward-looking variables in the system implies that the solution to the model, and the possibility of using it to make projections, require assumptions on how such expectations are formed. A suitable way of solving this difficulty is to assume that economic agents shape their expectations in a consistent manner. Thus, it may be assumed that economic agents are familiar with the model and make their forecasts on the future evolution of variables consistently with such model and the available information (including the potential presence of shocks in the equations of the system). With this assumption in mind, the model may be resolved by using the future value of endogenous variables in lieu of forward-looking variables.

The resolution of these models is not always univocal and/or stable, and requires the use of numerical methods. In particular, the evaluation of the dynamics of this model requires an appropriate study of the characteristics imposed by the estimations, also considering the potential impact that may arise from the execution of the economic policy, that is to say, including the estimated parameters and those consistent with the policy decisions made by the monetary authority. It should be noted that for purposes of shaping a single dynamic equilibrium path it is necessary to prove that the amount of explosive eigenvalues exactly coincides with the number of forward-looking variables in the system, in which case there is a single path of dynamic equilibrium. For the numerical solution the applicable software is WinSolve, specifically designed for solving and simulating models.

Likewise, the resolution of the system of dynamic equations to make projections of macroeconomic variables requires initial conditions, usually taking the value corresponding to the last period included in the estimation for the applicable endogenous variables. On the other hand, the solution also requires the imposition of the long-term values of the non-predetermined variables of the model. Thus, there is a definition of final values for inflation π_{∞}, output gap y_{∞},[37] real interest rate r_{∞}, and peso-dollar real e_{∞}^{USA} exchange rate. The numerical values relevant to these variables may be modified according to the requirements for the policy exercise.

[36] Simulation studies focusing research into small-sample distribution of GMM estimators and associated statistical tools (see, for example, Hayashi (2000)) have shown that statistical estimators usually applied to evaluate the significance of variables too often reject the null hypothesis (absence of) significance. This breakthrough can also affect constant parameter testing since estimations that are so accurate make confidence intervals be excessively narrow, and therefore testing could increase the probability of detecting parameter changes.

[37] As mentioned before, it is assumed that output gap is zero in the long term.

It is also necessary to estimate the evolution of all the exogenous variables which affect the model. The exogenous variables intervening in the model are the CPIs of the U.S.A., Eurozone, and Brazil, real-dollar and euro-dollar nominal exchange rates, and a reference international interest rate (3-month LIBOR).[38] The Appendix includes a detailed description of the applied methodology. Finally, it is possible to include exogenous shocks in the model. These shocks allow to incorporate existing information on probable future changes in the economy which cannot be captured internally in the endogenous variables of the model (e.g., wage/rate increases, changing international conditions, etc.), including seasonal variations. Under the assumption of consistent expectations, once these shocks are established, they will be internalized by the agents of the economy themselves at the time of forecasting the future expectations of endogenous variables. The possibility of introducing such shocks allows to adjust the projections to changes that were not considered in the model, thereby improving the prediction capabilities of the model in the short term.

5.1 Shock Impact: Impulse-Response Analysis

The projections of the endogenous variables of the SEM are conditioned by three types of factors: the adopted policy rule (or rules in the SEM 2 model), the projection of exogenous variables, and the presence of unanticipated shocks affecting endogenous variables. Through the latter, it is possible to analyze the reaction of the model's endogenous variables to exogenous disturbances. In particular, it is feasible to analyze the presence of exogenous disturbances on the supply side, the demand, or the foreign sector, insofar as those shocks operate through the Phillips equation, the IS equation, or the UIP equation. The so-called impulse-response analysis provides information on the model's consistency in terms of the interrelation among the system's variables, and at the same indicates the persistence level of such variables, considering that shocks disturb variables measured as deviations from their long-term general equilibrium values.The latter characteristic becomes a particularly important contribution at the time of evaluating monetary policy options.

By way of example, this section shows and analyzes the impact of a demand shock. Stemming from steady state the model is disturbed by a a positive shock of one percentage point on the IS equation. The impact of such disturbance therefore propagates to the whole system, since endogenous variables respond by deviating from their long-term equilibrium values (this is measured in the ordinates' axis) according to the systemic relation of general equilibrium among the model's variables through the transmission mechanisms illustrated in Figures 1 and 2. This simulation is performed for both SEM 1 and SEM 2.

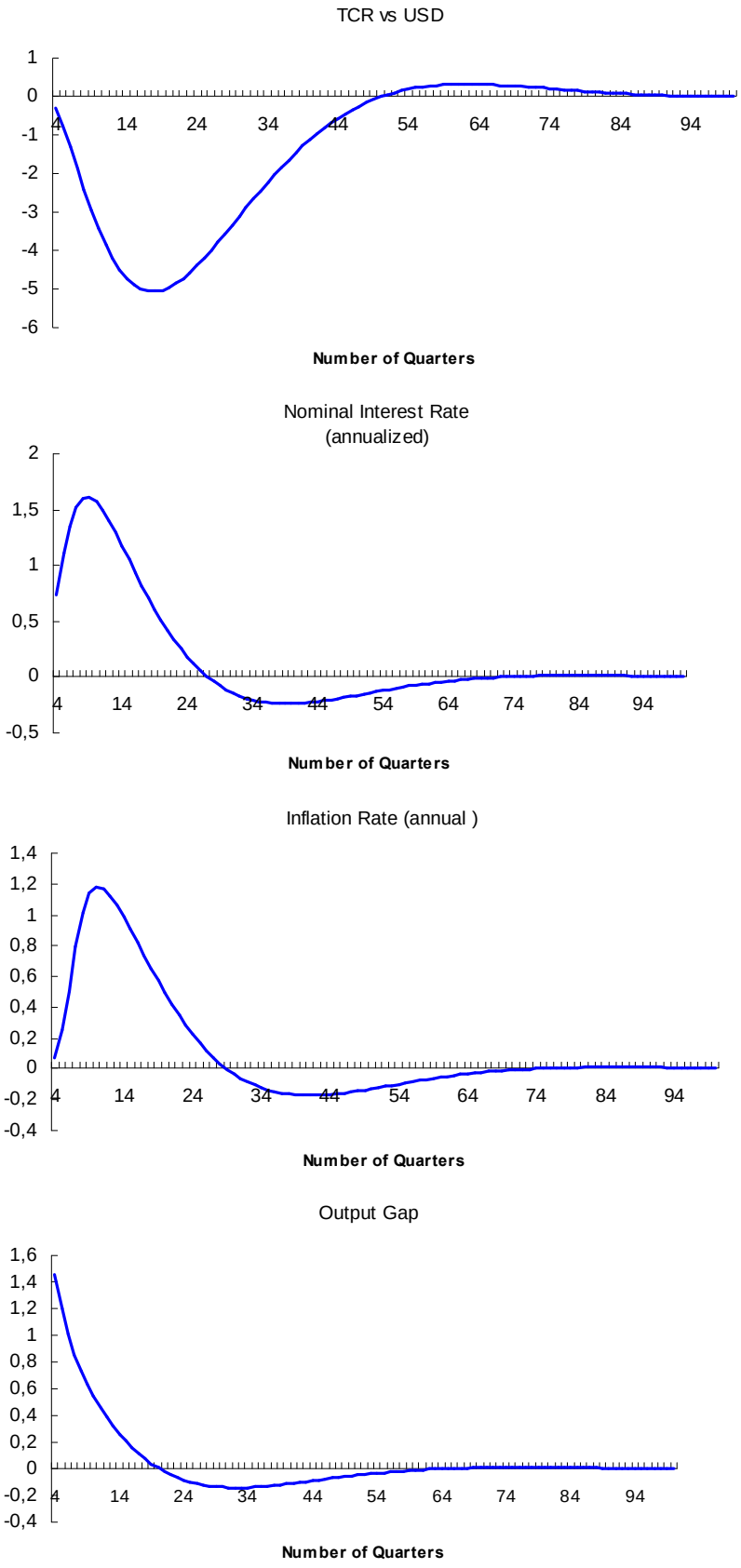
[38] Given the difficulties in forecasting the exogenous component of the risk/liquidity premium, it is assumed that the latter is zero across the forecast horizon for the model.

Graph 1 shows impulse-response reactions for SEM 1. The effect of a disturbance on the IS equation originates a positive deviation of output gap relative to its steady-state value, which in first instance is higher than the value of the initial disturbance because the gap's expected value also affects the current value of this deviation. Notice that there is a rise in the nominal interest rate, an increase in inflation, a hike in the real interest rate (given the level of fluctuation in the above-mentioned variables), and an appreciation of the real exchange rate. For its part, the axis of abscises indicates the number of quarters required by each of these variables to recover their long-term equilibrium value.

Graph 2 shows the response of SEM 2 faced with the same initial impulse. In this case, the reaction of variables is similar in qualitative terms. However, there are sizeable differences in the response of variables relating to the enhancement of transmission mechanisms and the operation of monetary authority intervention in the foreign exchange market. In particular, one should note that there is a lesser effect on the appreciation of the real exchange rate and the nominal interest rate, which reflects greater liquidity deriving from monetary authority intervention in the foreign exchange market despite sterilization efforts. On the other hand, there is more reaction in the inflation rate and greater persistence in the output gap response, since in this SEM version such reaction remains positive for a longer period of time after the initial impulse.

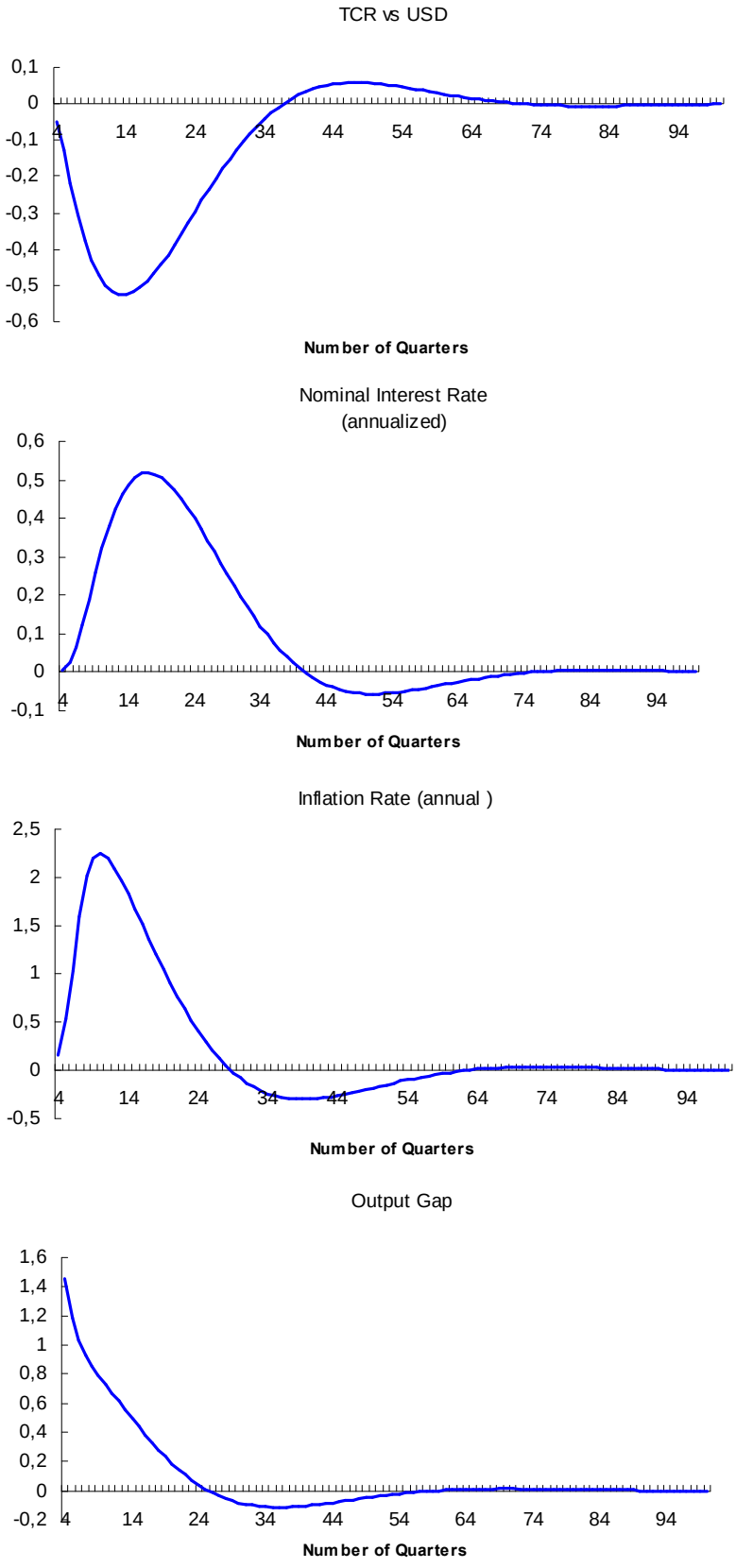
Graph 1

SEM I - Impulse-response to a 1% shock on IS curve (%)



Graph 2

MEP II - Impulse-response to a 1% shock on IS curve (%)



6. Final Remarks

The development and implementation of the SEM, whatever its versions, provides the Central Bank of Argentina (BCRA) with a simple analytical tool, capable of evaluating the macroeconomic implications of different policy options and forecasting the relevant variables. The SEM's forecasts feed auxiliary econometric models which are most useful to project monetary and macroeconomic variables, such as output gap,[39] monetary aggregates,[40] and aggregate demand components such as consumption and investment. Therefore, this type of tool plays a major role as an aid to monetary policy decision making in a consistent and informed manner. In addition, the model appropriately incorporates past performance of key macroeconomic variables, and at the same time allows to forecast them into the future on a consistent basis.

Nevertheless, due to its minimal complexity this model has limitations, especially at the time of evaluating and analyzing monetary policies which operate through more sophisticated transmission channels. For such reason, progress continues in the development of supplementary and alternative models, mainly with dynamic and stochastic general equilibrium (DSGE) models, consistently with the latest developments in economic literature and the research agendas of most central banks. This will allow to supplement and strengthen the capacity to make forecasts and analyze the economic impact of different monetary policy measures.

It should be noted that one of the restrictions faced at the time of forecasting and adjusting (microfounded or non-microfounded) models against the local economy, is directly related to the availability of data and the presence of major shocks and structural changes. For such reason, a substantial effort is made to make a proper econometric implementation of these models. Finally, the adjustment and implementation of the forecasts arising from the models require the use of forecasting techniques that are executed on various platforms, such as WinSolve and MATLAB. This shows that the development of projection models is a major challenge for the economic research area, since it implies theory-based research efforts, econometric estimation, and quantitative methods. Such effects have their counterpart in the development of useful analytical tools for monetary policy decision making.

[39] Elosegui et al. (2006).

[40] Aguirre et al. (2006).

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Appendix

A.1 Definition of MRER

The SEM uses a Multilateral Real Exchange Rate (MRER) which incorporates three trading partners, the U.S.A., the Euro area, and Brazil, who hold participations α_{US}, α_{EU} and α_{BR} (which add one). The MRER (e_t) is defined below in two alternative and identical ways: (1) as a geometric average of the bilateral RER with trading partners, and (2) as the ratio between the product of the Multilateral Nominal Exchange Rate (MNER) and the Consumer Price Index (CPI) of Argentina:

$$e_t = \left(\frac{S_t P_t^{US}}{P_t}\right)^{\alpha_{US}} \left(\frac{(S_t/\rho_t^{EU})P_t^{EU}}{P_t}\right)^{\alpha_{EU}} \left(\frac{(S_t/\rho_t^{BR})P_t^{BR}}{P_t}\right)^{\alpha_{BR}} = \frac{P_t^* S_t/\rho_t}{P_t}, \qquad (59)$$

where P_t^j is the partner j's CPI (j=US, EU, BR), P_t is Argentina's CPI, S_t is the peso/dollar exchange rate and ρ_t^k is the exchange rate of k against the dollar (currency of k/dollars; k=EU, BR).

$$\rho_t \equiv (\rho_t^{EU})^{\alpha_{EU}} (\rho_t^{BR})^{\alpha_{BR}} = (1)^{\alpha_{US}} (\rho_t^{EU})^{\alpha_{EU}} (\rho_t^{BR})^{\alpha_{BR}}$$

is the exchange rate of a trade-weighted currency basket against the dollar (basket units per dollar),

$$S_t/\rho_t = (S_t)^{\alpha_{US}} (S_t/\rho_t^{EU})^{\alpha_{EU}} (S_t/\rho_t^{BR})^{\alpha_{BR}}$$

is the multilateral nominal exchange rate (MNER), and

$$P_t^* \equiv (P_t^{US})^{\alpha_{US}} (P_t^{EU})^{\alpha_{EU}} (P_t^{BR})^{\alpha_{BR}}$$

is the price index of trading partners, weighted by the participations in Argentina's foreign trade.

Notice that (59) can also be written as:

$$e_t = (e_t^{US})^{\alpha_{US}} (e_t^{EU})^{\alpha_{EU}} (e_t^{BR})^{\alpha_{BR}} \qquad (60)$$

If we define bilateral real exchange rates:

$$e_t^{US} = \frac{S_t P_t^{US}}{P_t} \qquad (61)$$

$$e_t^{EU} = \frac{(S_t/\rho_t^{EU})P_t^{EU}}{P_t} \qquad (62)$$

$$e_t^{BR} = \frac{(S_t/\rho_t^{BR})P_t^{BR}}{P_t}. \qquad (63)$$

As can be seen in (59), changes in the prices of trading partners and also in the cross exchange rates among their currencies directly affect the MRER of Argentina. In the SEM, the variables which determine a P_t^* and ρ_t (i.e., ρ_t^{EU}, ρ_t^{BR} and P_t^k $(k = US, EU, BR)$) are exogenous, that is to say, variables whose values are not determined within the model. The movements of P_t^* and ρ_t show what happens with the prices of trading partners and their currencies against the dollar. Therefore, we can use the nominal exchange rate with the dollar S_t to define Argentina's exchange-rate policy. As the SEM is a medium-term model, it is assumed that in the model's long term time is not enough to change trading partners' participations in the foreign trade of Argentina. Consequently, coefficients α_{US}, α_{EU} and α_{BR} are constant.

Using the second arithmetical equality of (59) it derives that:

$$\frac{e_t}{e_{t-1}} = \frac{(P_t^*/P_{t-1}^*)(S_t/S_{t-1})/(\rho_t/\rho_{t-1})}{P_t/P_{t-1}} = \frac{\pi_t^* \delta_t/\delta_t^*}{\pi_t}, \qquad (64)$$

where the second arithmetical equality includes a definition of nominal depreciation rate of the peso against the dollar, domestic inflation rate, appreciation rate of the dollar against a trade-weighted currency basket, and trade-weighted inflation rate of trading partners:

$$\delta_t \equiv S_t/S_{t-1},$$
$$\pi_t \equiv P_t/P_{t-1},$$
$$\delta_t^* \equiv \rho_t/\rho_{t-1},$$
$$\pi_t^* \equiv P_t^*/P_{t-1}^*.$$

Therefore, the log-linear version of (64) is:

$$\hat{e}_t - \hat{e}_{t-1} = \hat{\delta}_t - \hat{\pi}_t + \hat{\pi}_t^* - \hat{\delta}_t^*. \qquad (65)$$

Then (65) says that the peso multilateral real depreciation is necessarily equal to the nominal depreciation rate with the dollar, less domestic inflation rate, plus foreign inflation rate and less appreciation rate of the dollar against the currency basket of Argentina's trading partners, weighted by the participations in foreign trade, where all these variables are also expressed as percentage deviations from their long-term values. In order to familiarize with the methodology to calculate the multilateral real exchange rate, see «*Índice del Tipo de Cambio Real Multilateral*» [Multilateral Real Exchange Rate Index], at *www.bcra.gov.ar*, Economic Research Division, BCRA, May 2005.

A.2 Treatment of Exogenous Variables

A.2.1 Consumer Prices in Brazil, the Euro Area, and the U.S.A.

For the U.S.A. and the Euro area, we use the projections of inter-annual consumer price inflation supplied by *Bloomberg* in their monthly *Consensus Forecast Survey*, a summary report with the forecasts made by different market institutions. Information covers the current quarter and the following four/five quarters. In the case of Brazil, we use market expectations relative to CPI inflation for the next twelve/thirteen months weekly surveyed by the Central Bank of Brazil.

Beyond such forecast horizon and up until completing the period of twenty-five years that the SEM needs as data input, we proceed differently in the cases of the Euro area and the U.S.A., on the one hand, and Brazil on the other hand. For the first two instances, it is assumed that both cases reach a steady-state inflation of 2% until completing the relevant period. In the case of Brazil, it is assumed that this country complies with the inflation targets fixed by their Central Bank and, as from the year for which inflation targeting has not been announced, it is assumed that this economy may reach a steady-state inflation of 3% p.a.

A.2.2 Real-Dollar and Euro-Dollar Bilateral Exchange Rates

Exchange rate forecasts for the medium and long term are taken from consensus projections surveyed by *Bloomberg* for the euro and the real vis-à-vis the dollar.

For the euro/dollar exchange rate, they are also taken from short and medium term projections provided by the IMF, which cover more than five years ahead and are the basis for their *World Economic Outlook* semiannual report. The values taken by the SEM for each exchange rate correspond to the standard average of the values projected for each quarter by the two sources mentioned above.

In order to project the long-term euro/dollar cross exchange rate as from the time at which there are no available forecasts (more than five years ahead), we use the values traded in forward contracts on this currency, at several available terms (with a maximum period of ten years.) There are no reference values for the Brazilian currency beyond five years' sight.

Finally, for the remaining period up until completing twenty-five years ahead, it is assumed that the respective bilateral real exchange rates versus the dollar remain constant in the real parities given by the last projected value stemming from the above-mentioned data.

A.2.3 International Interest Rate

The international interest rate used by the SEM is dollar denominated 3-month LIBOR. The forecasts for this variable derive from two sources. The first one is *JPMorgan*, through its *US Weekly Prospects*. This report provides forecasts for the current as well as the subsequent four/five quarters.

The second source is the IMF, which procures information from the data base mentioned in the section addressing cross exchange rates. This source provides quarterly forecasts of 6-month LIBOR for the next five years, which is carried to an annual nominal 3-month rate by making the necessary conversion.

Beyond such horizon and up until completing the relevant period (twenty-five years) it is assumed that the nominal rate (softly) converges, in one year, into the compatible value with a real interest rate of 2.5% p.a., given the inflationary forecast for the U.S.A. in each period. This value for the real rate is deemed to be steady state, and it was calculated as the average of the 3-month real LIBOR observed throughout the period.

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This document partly reflects the task associated with the development and implementation of economic forecasting models used by the BCRA for monetary policy decision-making. This paper introduces the Small Economic Model (SEM) which, in a stylized manner, addresses the dynamics of a small and open economy. It contains a description of a standard SEM version, with a structure similar to that of the models commonly used at central banks, including some variants which allow to simulate different monetary and exchange rate regimes in accordance with the reality in a developing country. One of these variants considers a regime based on managed float or simultaneous central bank intervention in the money and foreign exchange markets. Despite the simplicity of the SEM, this paper shows how the model can be used to analyze the relative importance of the various transmission channels and the time-lags which characterize the operation of monetary policy.



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