THE RENAISSANCE OF FRIEDMAN HYPOTHESIS: NATURE OF GLOBAL FINANCIAL CRISIS AND CONSEQUENCES IN A SMALL OPEN AND HIGHLY DOLLARIZED ECONOMY

Pablo Mendieta Ossio*
Banco Central de Bolivia

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Comments and additional suggestions are welcome to: pmendieta@bcb.gob.bo.

Abstract

This paper analyzes the US subprime crisis from a business cycles perspective. For this purpose, it employs a macroeconomic model with endogenous financial imperfections, where central bank's only objectives are output and inflation, using a Small Structural Macroeconometric Model (SSMM). The results show that financial frictions could generate an economic cycle through monetary policy reactions, according to old fashioned Milton Friedman's business cycles origins hypothesis. The model is calibrated according to the American economy recent experience. It also studies the consequences of this crisis in a small open and highly dollarized country, like Bolivia. The paper concludes that in order to achieve global price stability, potential structural problems must be addressed in order to avoid non desired effects; and that policy makers must improve their ability to anticipate future evolution of the economy.

Resumen

El documento analiza la crisis hipotecaria de Estados Unidos desde una perspectiva de ciclos económicos. Para ello, emplea un modelo macroeconómico con imperfecciones financieras endógenas, siendo los principales objetivos de un banco central la estabilización de ciclos del producto e inflación, usando un Modelo Macroeconométrico Estructural Pequeño. Los resultados muestran que las imperfecciones financieras podrían generar ciclos económicos a través de reacciones de la política monetaria, en línea con la tradicional hipótesis de Milton Friedman sobre los orígenes de los ciclos económicos. El modelo está calibrado con la reciente experiencia de la economía americana. También estudia las consecuencias de esta crisis en una economía pequeña, abierta y altamente dolarizada como la boliviana. El documento concluye que para alcanzar la estabilidad global de precios, los problemas potenciales estructurales deben ser direccionados para evitar efectos no deseados; y que los diseñadores de política deben mejorar su habilidad para anticipar la evolución futura de la economía.

Clasificación JEL: *C5, E3, F00*
Keywords: *Financial crisis; Small macroeconometric models*

I. Motivation

> *"There is likely to be a lag between the need for action and government recognition of the need; a further lag between recognition of the need for action and the taking of action; and a still further lag between the action and its effects"* [Friedman, 1962, p.]

Since 2008 the world economy has been affected by a crisis, named by its magnitude "The Great Recession", in remembrance of the Great Depression of 1929. Although initially only developed economies were affected, gradually its effects covered emerging markets. Countries of both regions took measures to mitigate this crisis, especially through interest rate cuts and liquidity facilities, according to the extent of the effect of this deceleration.

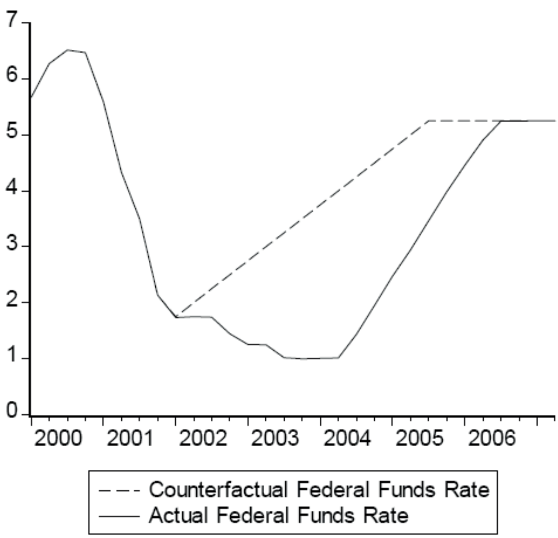
Two questions arise from this phenomenon. One of general characteristics and a particular one related to a special case of emerging markets: i) what is the real importance of financial imperfections in the dynamics of inflation and output in the monetary policy stance?; and, ii) in what extent this phenomenon could affect economic performance of a highly dollarized economy?. The first one will give more insights to analyze an important requisite for price stability and will analyze its relationship with the quotation at the beginning of this document. The second one will show how a small and dollarized country would be affected by external crisis and if it can counteract with its instruments.

Both are addressed in this paper with the use of Small Structural Macroeconometric Models (SSMM). The main benefits of the use of these models are: i) it is a general equilibrium framework which incorporates besides inflation, economic activity, monetary (and sometimes fiscal) policy, exchange rate behavior, among others; ii) it includes expectations about the future evolution of the main variables; and, iii) their relationships can be derived from microeconomic foundations. More details about these models are shown in Appendix A.

According to the precedent questions, this paper has two sections. In the first one, a SSMM is calibrated to the US economy, adding a factor that accounts to a financial friction that explains the financial and real crisis of the US economy, in contrast with a scenario without it. Then, this model is added to another SSMM for the Bolivian economy to study the effects of this kind of crisis in Bolivian economy. Concluding comments finish the document.

The motivation of this paper is the recognition that the main factor that triggered the recent crisis was that, for many years, interest rates in US were extremely low to expand the economic activity caused by an extremely low USA interest rate, lasting many years. With a financial friction, it created the propitious framework to incubate a new cycle. Taylor (2007) pointed out this phenomenon (Graph 1). Then, the denominated "Great recession" could be originated by a well motivated monetary policy, but without considering the possibility of to create a new cycle in the economy caused by collateral effects in some markets.

Graph 1. COUNTERFACTUAL AND ACTUAL FEDERAL FUNDS RATE



Source: Taylor (2007)

II. A simplified model of the effects of the financial crisis of 2007-2009 in the US economy[1]

The actual US crisis is a result of problems in the financial market of this country. The story begins when the extremely low interest rates between 2001 and 2004 lead an important growth of the mortgage market, including loans to potentially insolvent borrowers. When the FED increased interest rates to moderate inflationary pressures, the difficulties in this market arose.

Although only one market was really affected, the development of new financial instruments collateralized by these bad loans, besides its trade in more mature financial markets lead to a global financial crisis. Gradually, economic activity was affected by the consequences of financial collapse in capital markets.

The response to this crisis was a new cut of interest rates and a strong injection of liquidity, particularly in financial entities, in order to avoid the expansion of the financial crisis to other sectors. Previous to Obama´s administration financial regulation proposal of June 2009, this new cut could induce and incursion into a cyclical sequence of expansions and recessions.

To make a formal analysis of previous antecedents, we modify an usual Neo-Keynesian model of the economy proposed by Cho and Moreno (2006) to include the perverse effects of domestic credit accelerated growth, induced by a positive shock in output.

Specifically, Cho and Moreno *op. cit.* analyzes the U.S. economy with a SSMM for a close economy which includes three main equations for inflation, output and nominal interest rate expressed as deviations from steady state. The first one is an aggregate supply curve with a hybrid form, where current inflation (π) depends on lagged and expected inflation and the output gap (y):

1 This part is based mostly on Mendieta and Yañez (2009).

$$\pi_t = \alpha E_t \pi_{t+1} + \left(1-\alpha\right)\pi_{t-1} + \lambda y_t + \varepsilon_t^{AS} \quad (1)$$

The second equation is a new IS curve, similar to the proposed by Moore (2000). Also it has an hybrid form consistent with habit formation and rational expectations. Besides the dynamics described above, it depends on the ex-ante real interest rate, simplified as the difference between the nominal interest rate *(i)* and the expected inflation:

$$y_t = \beta E_t y_{t+1} + \left(1-\beta\right) y_{t-1} - \delta\left(i_t - E_t \pi_{t+1}\right) + \varepsilon_t^{IS} \quad (2)$$

Finally, to close the model a Taylor rule is included, similar to the proposed by Clarida, Gali and Gertler (1999), where monetary authority is concerned about the deviation of expected inflation from its steady state value (the target) and the output's from its potential level. It exhibits inertia to avoid perverse effects of movements of interest rates in the economy:

$$i_t = \rho i_{t-1} + \left(1-\rho\right)\left(r_\pi E_t \pi_{t+1} + r_y y_t\right) + \varepsilon_t^{MP} \quad (3)$$

The authors use the standard technique to find the policy function of these variables. Specifically, the previous model can be expressed as a rational expectations system of infinite difference equations in the following matrix form:

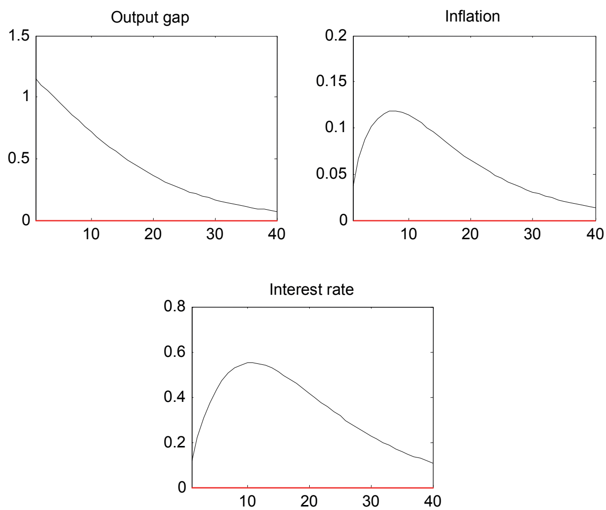
$$\mathbf{B}_{11}\mathbf{X}_t = \boldsymbol{\alpha} + \mathbf{A}_{11} E_t \mathbf{X}_{t+1} + \mathbf{B}_{12}\mathbf{X}_{t-1} + \boldsymbol{\varepsilon}_t,\ \boldsymbol{\varepsilon}_t \sim \left(\mathbf{0},\mathbf{D}\right) \quad (4)$$

Where $\mathbf{X}_t = (\pi_t, y_t, i_t)$ and the system is specified in its structural form. The solution will be a policy function that will only include observable variables:

$$\mathbf{X}_t = \mathbf{c} + \boldsymbol{\Omega} X_{t-1} + \boldsymbol{\Gamma}\,\varepsilon_t \quad (5)$$

In its simple version, the disturbances do not follow an autoregressive form and are only contemporary shocks. The model is calibrated using the parameters of Cho and Moreno *op. cit.* listed in Appendix B. In our case, we are interested in study the effect on the system of a shock in the IS curve, interpreted as an exogenous increase in output. The results are shown in Graph 2, where the smooth transition towards equilibrium is the main characteristic:

Graph 2. IMPULSE RESPONSE ANALYSIS OF AN EXOGENOUS SHOCK TO OUTPUT



Source: Own estimates based on Cho and Moreno *op. cit.*

The next step is to modify this simple model into another one, allowing financial effects of previous exogenous shocks. In previous literature, there were models in which it was possible to include financial frictions, especially in the context of a DSGE model. The most famous effect is the “financial accelerator” developed by Bernanke, Gertler and Gilchrist (2000). They include a risk premium due to problems of asymmetrical information and an agent-principal one. The main conclusion is that financial problems could amplify nominal and real shocks. It is supposed an inverse relationship between the risk premium to external financing to the firm and the net worth of borrowers.

There are other models that include this risk premium in the context of an open economy, some of they are: Céspedes, Chang and Velasco (2000); Gertler, Gilchrist and Natalucci (2007) and Morón and Winkelried (2005). These researches mainly focus on financial restrictions to foreign financing. In these models, the real exchange rate, the net worth of borrowers and the balance sheet effect play important roles determining the risk premium.

In our case, to replicate the financial crisis in US and its real consequences, we will modify the IS curve adding a non-constant risk premium (θ) in line with Morón and Winkelried *op. cit.* Then, this relationship is modeled as follows:

$$y_t = \beta E_t y_{t+1} + (1-\beta) y_{t-1} - \delta\left(i_t - E_t \pi_{t+1} + \theta_t\right) + \varepsilon_t^{IS} \tag{6}$$

The crucial points about this risk premium are:

- It depends on the previous level of the output gap, capturing the fact that an extraordinary level of output will diminish constraints imposed by rationing credit to investors and liquidity restraints to consumers; and will provide enough liquidity to lend to non solvent borrowers due to asymmetrical information.

- It is a non linear relationship: an increase of output gap produces higher risk premium with a quadratic relationship, while a negative output gap only reduces partially this risk premium.

- It exhibit high inertia to capture the fact that the financial system remains with problems during a long period of time.[2]

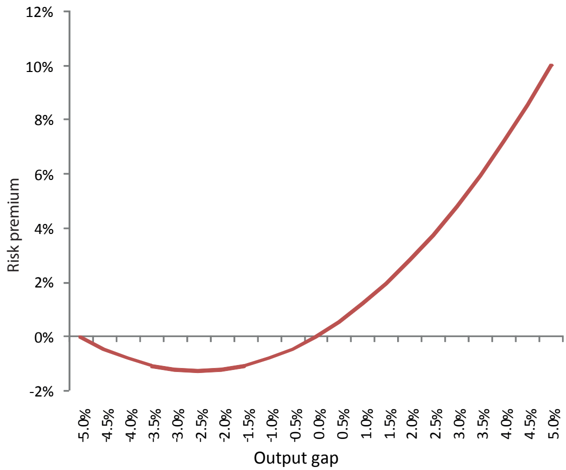
In formal terms:

$$\theta_t = \sigma\theta_{t-1} + (1-\sigma)\left(\gamma y_{t-1} + \eta y_{t-1}^2\right) \tag{7}$$

Graph 3 shows this relationship for a range of 5 percentage points above and below potential output; and the non linearity is clearly pointed out. Then, resolving this system with numerical methods, the dynamics of the main variables is different to the free of risk scenario (Graph 4). There is an additional variable named “Financial cost”, which is defined as the sum of the interest rate plus the risk premium.

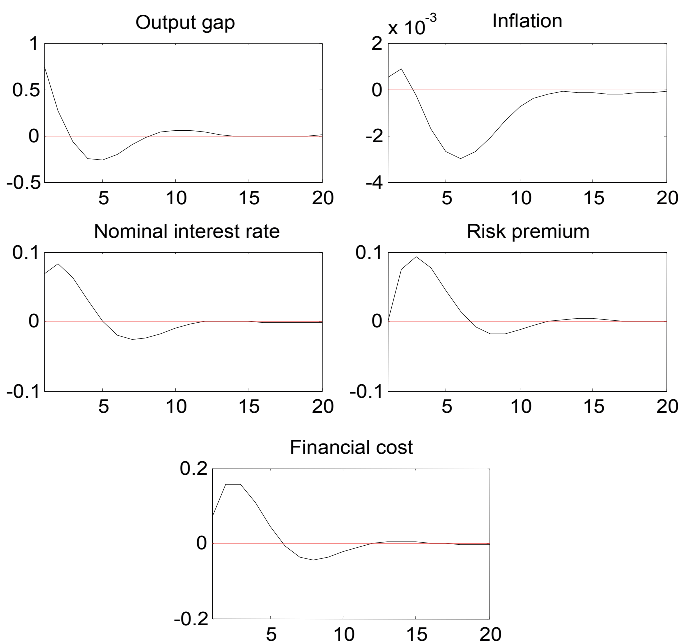
2 It must be noted that this simplified model do not contemplate the possibility of fiscal and monetary measures to reduce this risk premium and improve financial system.

Graph 3. RISK PREMIUM AND OUTPUT GAP



Source: Own estimates

Graph 4. IMPULSE RESPONSE ANALYSIS OF AN EXOGENOUS SHOCK TO OUTPUT WITH THE INCLUSION OF THE RISK PREMIUM



Source: Own estimates based on Cho and Moreno *op. cit.*

Due to the inclusion of this additional variable in the model, a clear cyclical behavior arises, different to the smooth dynamics of free of risk scenario. For example, policy rate increases initially to reduce inflationary pressures and to equalize potential with actual output. But, the additional increase in the risk premium and financial cost induce to a rapid deceleration of the economic activity, which induces to lower interest rates until the equilibrium is restored.[3]

This phenomenon is different from another kind of shocks (exchange rate, current account, etc.), because it is caused by an endogenous problem in the financial system. In the case of other shocks, one conclusion could be to include this argument in the minimization of the inter-temporal loss function of monetary authority. However, in this case the policy prescription is pretty obvious: As non fiscal dominance is a pre-requisite to inflation targeting or implicit price stability, it is also necessary that the financial system will be free of systemic problems to promote output and price stability.

III. Effect of international crisis in a highly dollarized small open economy[4]

The standard SSMM was modified to include main characteristic of Bolivian economy. In the particular case of the Bolivian economy, I estimated an SSMM, which differs from the conventional structure, due to a pair factors: the inclusion of an exchange rate rule consistent with the exchange rate regime (crawling peg) and the exclusion of an interest rate rule, because the BCB has focused in monetary aggregates and the credit channel has been limited. Then, a model with macroeconomic financial linkages, as Beneš, Ötker-Robe and Vávra (2009), seems not appropriated for the Bolivian case. More details about this special SSMM (equation specifications, estimates and limitations) are in Appendix D.

The main feature of this SSMM is the use of an exchange rate rule instead of nominal interest rate, consistent with the degree of dollarization of

3 Appendix C shows the same results but calibrating with the parameters of Alichi *et al* (2009), except for the monetary policy rule. Additionally, it is assumed a negative 5% shock in the interest rate.
4 The analytical framework of this part is based on Mendieta and Palmero (2009).

the Bolivian economy. The rule for determining the nominal exchange rate depends on the gap between the observed and inflation target[5], the real exchange rate misalignment (in levels and growth rates) and the output gap. Besides, this relationship exhibits high inertia due to the high degree of dollarization, especially in the financial system. Dollarization is related to the cost of moving exchange rate; and it explains the high inertia in exchange rate rule as is expected by economic policy theory with adjustment costs. [Turnovsky, 1977].

This feature has some earlier empirical evidence. The estimation of a exchange rate rule has three main precedent studies: one specifically applied to Bolivia [Parrado, Maino and Leiderman, 2006], one applied to Singapore [Parrado, 2004] and one applied to Central America countries [Jacome and Parrado, 2007]. It is convenient to point out that in most of central banks, monetary policy decisions do not use specifically a strict rule; but, central bankers act as if they have one in mind.

The exchange rate has an important role in the economy. This is given through two ways: its effect in the interest rate (a weighted rate of US and local credits, expressed in Bolivianos) and the real exchange rate misalignment. Both imply a negative relationship between exchange rate and the output gap, specially the first one. It is rationalized by an income effect and “balance sheet” effects. Then abrupt movements in exchange rate could have perverse effects in the economy. This fact explains that, according to Parrado, Maino and Leiderman *op.cit.*, Bolivia followed a “Fear of floating competitiveness targeting” scheme, where the primary target is competitiveness and the secondary one is inflation; the operational target is the rate of crawl; and the primary shock absorber is foreign assets and the secondary one is the interest rate. As it is shown in Appendix B, the estimated rule shows more evidence in the same way.

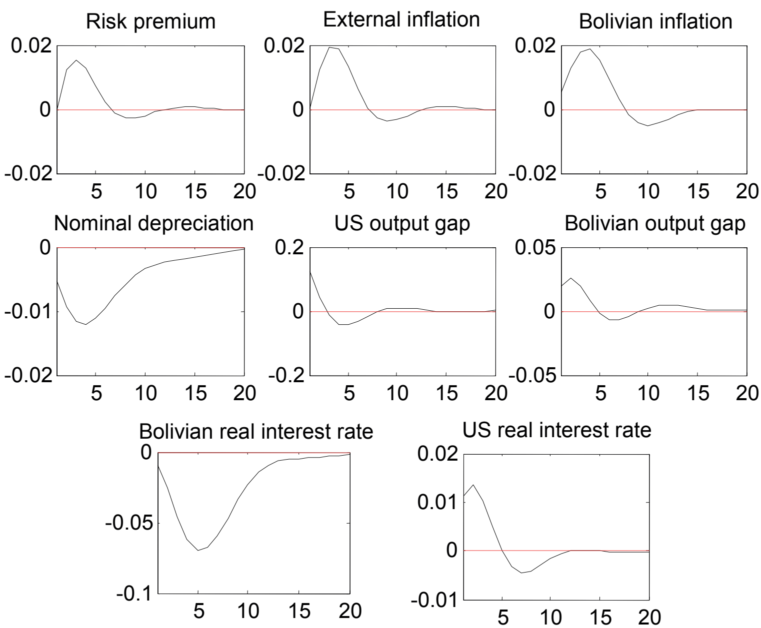
The SSMM can capture the effect of two external variables: global output and international inflation. Due to the low degree of capital mobility and

5 Although BCB has not adopted a Full-Fledged Inflation Targeting Regime, since 1995 it announces a target for the annual inflation and in the last years has been concentrated in a medium term target.

a small financial system, it seems not relevant to include movements in international interest rates.

Empirical results show that a shock of the nature depicted in the previous section affects Bolivian output, inflation and exchange rate policy. The impulse response analysis of one shock of 10% exogenous increase of US output increases the US risk premium, which is related with external inflation relevant for Bolivia (higher risk means US dollar depreciation, then inflation in US dollar increases). The impulse of US activity in Bolivian output leads an increase of Bolivian inflation. The policy response is a nominal appreciation to mitigate domestic inflationary pressures. Finally, the Bolivian real interest rate (exogenously determined in this model) decreases as result of higher inflation, while US interest rates increases to diminish US inflation. These results are shown in Graph 5.

Graph 5. IMPULSE RESPONSE ANALYSIS TO A RISE IN US OUTPUT WITH RISK PREMIUM



Source: Own estimates based on a modified SSMM

The main differences of Bolivian economy with other economies with different monetary and exchange rate regimes are i) domestic inflation is primarily determined by external inflation due the crawling peg regime; ii) the main policy instrument to restore the equilibrium is the rate of crawl, which is limited by the high degree of dollarization; and iii) domestic interest rates follows an opposite movement relative to US one, because in the first case is exogenously determined and only affected by inflation and nominal depreciation.

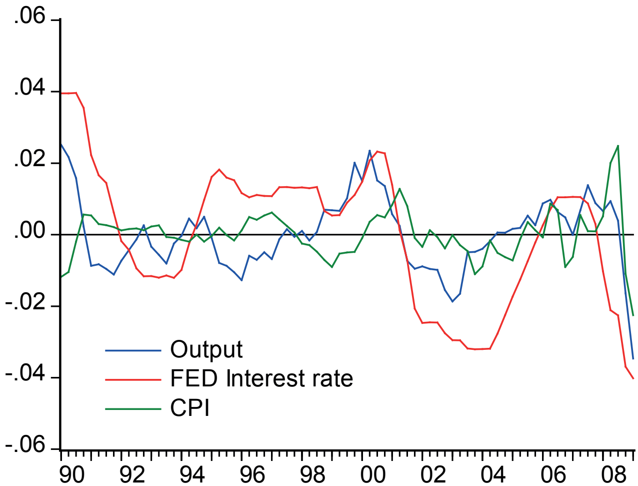
IV. Concluding Remarks

Based on the results obtained in this paper, the following conclusions and final thoughts can be inferred.

A final reflection: It is convenient to remember the quotation at the beginning of this paper, related to “long and variable lags” [Friedman, 1961] of monetary policy. In a new era of price stability around the world and with central banks more focused on mitigating inflation and output cycles, it is important to address that in order to avoid “monetary induced” cycles, policy makers must realize two points to improve monetary administration

The first one is that the solution of structural and potential troubles in the economy (financial markets, fiscal accounts, external accounts, among others) is essential to achieve the goals of monetary policy. And the second one is that there is a special need to focus more accurately in the forecast of the more probable future scenario, including quantitative analysis and “educated guess”, because the recent events show a pro-cyclical stance of monetary policy. Graph 6 illustrates the second point with US data and shows that the monetary policy stance does not follow a counter cyclical stance. By the contrary, in recent years, it was expansive (contractive) in recessions (expansions) with a limited anticipation of future events. Then, the celebrated “long and variable” lags must be considered with major emphasis.

Graph 6. CYCLICAL COMPONENT OF GDP, CPI AND FED FUNDS RATE



Source: Federal Reserve Bank of St. Louis
Note: The cyclical component of GDP and CPI is the difference between the original series and the H-P filtered ones. In the case of FED rate is the difference between the observed one and the average of whole period.

In the case of emerging markets, they also must improve their monetary policy and to solve structural problems to avoid perverse effects of external shocks. The development of the financial system must be followed by a prudent regulation framework for the financial system. What's more it is necessary a major coordination with economic authorities of developed economies, to know in advance their most probable evolution, in order to take the appropriate measures.

Finally, the recent crisis showed that monetary policy has yet some limitations, besides the advances in econometric modeling, monetary theory and specific events acknowledgement. It is only an appeal for humility for policy makers and economists related to monetary and financial economics.

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APPENDIX A
SSMM in the context of economic modeling and its main characteristics

Monetary policy generally affects the economy with lags and there are different transmission mechanisms (credit channel, expectations, exchange rate, among other) and they are specific for each country. For this reason, central banks have emphasized the use of economic and econometric models that can replicate the main empiric regularities of the economic cycle to take the pertinent actions.

Previous to the eighties, this interest was focused in the estimation of econometric models including many static relationships or with a very simple dynamic structure for an important group of variables [Favero, 2001]. However, these models failed in policy analysis and forecasting.

Alternatively, accounting models were used, like Financial Programming, based primarily in the monetary approach to the balance of payments [Polak, 1957] and [Robichek, 1967 and 1971] and static models based on this initial approach as 1-2-3 or RMSX models, among others [Agenor, 2004]. However, their use has been questioned too [Edwards, 1989] and [Easterly, 2004], since they only guarantee accounting consistency and main relationships, as the stability of the velocity of money, the effective control of liquidity by central banks, among others, seem implausible empirically.

In contrast, econometric models improved gradually their capacity to replicate dynamic characteristics of economic series, with the use of new techniques, especially the estimation of co-integration models (long run relationships) and error correction models (short run relationships but consistent with long run ones). Nevertheless, the critic to conventional econometrics from the Prize Nobel Robert Lucas in 1976 pointed out the limitations of the use of these tools for macroeconomic analysis. In synthesis, Lucas argued that changes in economic policy affect the estimated parameters of equations, invalidating forecasting and even the analysis.

Then, econometric relationships without economic structure, as VAR were more popular among central banks, since they were able to replicate the dynamics of economic variables and they were not based in particular theories. However, the last one was its main weakness.

Due to these theoretical and empiric limitations, the development of new models called Real Business Cycles (RBC) was a landmark for economic modeling, because they tried to combine micro-economic foundations of macroeconomics with the dynamic properties of variables. From them, Dynamic Stochastic General Equilibrium (DSGE) models were developed, which consist in tools consistent with conventional economic theory, but with the capacity to replicate empirical regularities of the economic cycle. For this reason, they are immune to previously mentioned Lucas's Critique.

A special cases of these models are the Small Structural Macro-econometric Models [Berg, Karam and Laxton, 2006a and 2006b], because they use a basic structure to construct a general equilibrium model. They are broadly used across the world, including developing countries. In its basic form, they include:

- The neo-keynesian Phillips curve, which determines the price formation. This relationship comes from a sticky-wage model of prices *a la* Calvo (1983) and Rotemberg (1984). It relates actual inflation (π) with expected inflation and marginal costs. Then, the main assumption behind this curve is the existence of a relationship between marginal cost and the output gap through the labor supply equation.[6] Another assumption to include lagged inflation goes in line with Clarida, Gali and Gertler (1999), to form an hybrid version (forward and backward looking behavior):

$$\pi_t = \alpha_1 \pi_{t-1} + \left(1 - \alpha_1\right) E_t \pi_{t+1} + \alpha_2 y_{t-1} + \varepsilon_t^{\pi^c} \qquad \text{(A1)}$$

6 This analysis could be refined using a proxy of marginal cost and it is in the BCB further research agenda.

- The evolution of output gap is described by a new IS curve. Its microeconomic foundation is obtained from the dynamic optimization of consumption (the log-linearized version of the Euler equation, that relates actual and future consumption with the behavior of real interest rate) and an investment function (usually with adjustment costs, also related to interest rate). In formal terms, it relates actual output gap *(y)* with expected and lagged gap, real interest rate *(R)* gap and real exchange rate *(z)* miss-alignment:[7]

$$y_t = \beta_1 E_t y_{t+1} + \beta_2 y_{t-1} + \beta_3 (R_{t-1} - R^*_{t-1}) + \beta_4 (z_{t-1} - z^*_{t-1}) + \varepsilon^y_t \quad \text{(A2)}$$

- A monetary policy rule (called Taylor rule), which describes the response of the authority against deviations from the target variables (usually inflation and output). Svensson (1997) and further studies show that it can be derived from a minimization of a central bank loss function, given the previous two equations.

$$i_t = R_t + \pi_t = \gamma_1 + \gamma_2 \left(\pi_t - \overline{\pi}_t \right) + \gamma_3 y_t + \varepsilon^i_t \quad \text{(A3)}$$

- In the case of open economies, Uncovered Interest Parity (UIP) for the determination of exchange rate is added, which can be adjusted for risk premium.

As Table A.1 shows, they are used in many central banks and international organizations for economic analysis and forecasting purposes.

7 The gap of variable x is the difference or log-difference between actual and potential (steady-states) values. It is denoted with an asterisk.

Table A.1. USE OF SSMM AND DSGE IN SELECTED COUNTRIES OR REGIONS

Country	SSMM	DSGE	Country	SSMM	DSGE
Argentina	U	D (ARGEM)	Italy	U	D
Australia	U		Japan	U	
Belgium	U		Namibia	U	
Bolivia	U (MEP)	D	New Zealand	U (QPM)	
Canada	U (QPM)	D (TOTEM)	Norway		D (NEMO)
Chile	U (MEP)	MAS	Peru	U (MPT)	
Colombia	U	D (PATACON)	South Africa	U	
Czech Republic	U (QPM)	D	Sweden		U
European Union	U	D	Switzerland	U	D
IMF	U	U (GEM)	U.S.A.	U (FRBUS)	SIGMA
Israel	U		United Kingdom	U	U

Source: Adapted from Vega (2007)
Notes: U=Used by CB. D=Developing. Between brackets are the models' names.

APPENDIX B

Table B.1 PARAMETER FOR THE CALIBRATION OF A SSMM FOR THE US ECONOMY

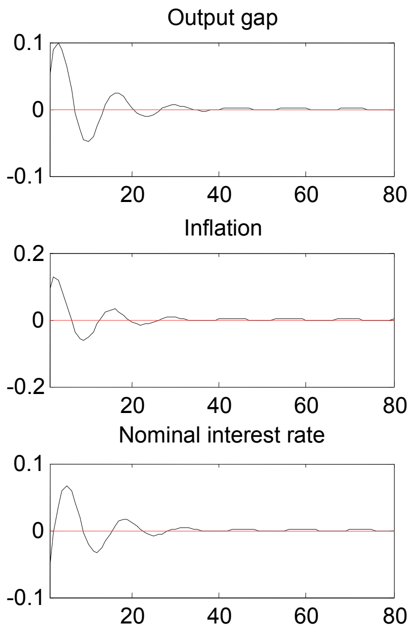
i) Phillips Curve: $\pi_t = \alpha E_t \pi_{t+1} + (1-\alpha)\pi_{t-1} + \lambda y_t + \varepsilon_t^{AS}$	
α	**0.5586**
λ	**0.0011**
σ_{AS}^2	**0.4585**
ii) IS Curve: $y_t = \beta E_t y_{t+1} + (1-\beta) y_{t-1} - \delta(i_t - E_t \pi_{t+1}) + \varepsilon_t^{IS}$	
β	**0.4859**
δ	**0.0045**
σ_{IS}^2	**0.3734**
iii) Interest rate rule: $i_t = \rho i_{t-1} + (1-\rho)(r_\pi E_t \pi_{t+1} + r_y y_t) + \varepsilon_t^{MP}$	
ρ	**0.8458**
r_π	**1.6409**
r_y	**0.6038**
σ_{MP}^2	**0.7327**
iv) Risk premium: $\theta_t = \sigma\theta_{t-1} + (1-\sigma)(\gamma y_{t-1} + \eta y_{t-1}^2)$	
σ	**0.9**
γ	**1.0**
η	**20.0**

Source: Cho and Moreno op. cit. and own estimates for iv)

APPENDIX C

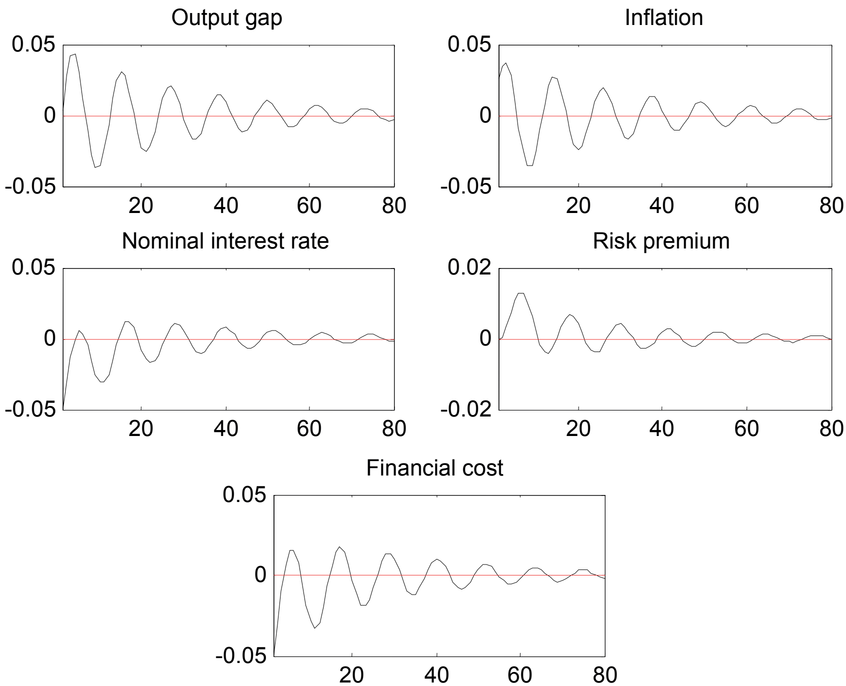
Graph C.1. AN ALTERNATIVE CALIBRATION OF A SSMM FOR THE US ECONOMY

a) Without risk premium



Graph C.1.: AN ALTERNATIVE CALIBRATION OF A SSMM FOR THE US ECONOMY (Cont).

b) With risk Premium



APPENDIX D
The SSMM estimated for Bolivian Economy

The SSMM was modified to take into account main particularities of the Bolivian Economy. The SSMM estimated has 3 of 4 equations included in a standard model, one of them modified: A New Keynesian Hybrid Phillips Curve for the core inflation, an IS equation modified to include competitiveness, external output and fiscal expenditure and a policy rule for the exchange rate. Then, it does not include a monetary policy rule for the interest rate and the Uncovered Interest Parity for the exchange rate. Table D.1, at the end of this section, explains the definitions and notation employed below.

The Phillips curve captures the dynamic of core inflation, including expectations. This equation comes from a variation of estimates of Mendieta and Rodriguez (2007 and 2008), whom rationalizing the approach of D'Amato and Garegnani (2006) for Argentina, indicating that at the time of forming a price, one part of the firms instead of just taking the past information, they use a set of information, which in this case also includes foreign inflation and exchange rate movements. The equation has been used to model core inflation:

$$\pi_t^c = \alpha_1 \pi_{t-1}^c + (1-\alpha_1) E_t \pi_{t+1}^c + \alpha_2 y_{t-1} + \alpha_3 \Delta e_{t-1} + \alpha_4 \pi_{t-1}^* + \varepsilon_t^{\pi^c} \qquad \text{(D1)}$$

A priori it is expected that all parameters will be positive. Furthermore, although not restricted in the estimation, it implies that inflation is a weighted average of the public expectations plus the own inflation inertia. In economies where the central bank has more credibility, it is expected that α_1 to be large. More advanced models assume that instead of a relationship with the gap, there is a relationship with the marginal costs. Unfortunately, in the case of Bolivia, it is impossible to construct this variable because of the low regularity of labor statistics.

Consistent with studies on the Phillips curve, the most direct channel to affect inflation is the exchange rate. The indirect channel, which is more usual in other economies, occurs through the output gap, which is affected by the interest rate, the main instrument of macroeconomic policy in other countries.

The output gap is related to other four gaps: interest rate, real exchange rate, external output and fiscal expenditures. The IS equation is:

$$y_t = \beta_1 E_t y_{t+1} + \beta_2 y_{t-1} + \beta_3 (R_{t-1} - R^*_{t-1}) + \beta_4 (z_{t-1} - z^*_{t-1}) + \beta_5 (yext_t - yext^*_t) + \beta_6 \left(g_t - g^*_t\right) + \varepsilon^y_t \quad \text{(D2)}$$

It is expected that the parameters would have a positive sign, except for β_3. In the last case, according to the theory, an increase of interest rate would discourage demand by its contractionary effect on consumption and investment. Because of low financial market development, particularly investment might be expected that β_3 is small in absolute terms In this regard, currency depreciation has a contractionary effect due to the increase in the real interest rate.

Although in most cases it is expected that the effect of real depreciation is positive, for its effects on exports, for dollarized economies like Bolivia could be negative because of the effects on real incomes (if it is assumed transactions' dollarization) and the effect on the balance sheet of firms and financial institutions, was constructed in such a way that an increase shows a depreciation and a fall a currency appreciation.

The rule of monetary policy is an exchange rate rule. One of the key roles of monetary policy is to provide the public with a nominal anchor that allows identifying the stance of monetary policy (contractionary or expansionary). The monetary rule is the variable that fulfills this role. Usually, the central bank determines monetary policy by using some kind of interest rate on short-term, or, each time less, through monetary aggregates. However, as was demonstrated by Parrado (2004) and Leiderman *et al.* (2006) for Singapore and Bolivia, the conduct of monetary policy can be performed by an exchange rate rule.[8]

Although Bolivia does not have an anchor inflation formally defined, the monetary policy stance has been based on the position regarding the movement of the nominal exchange rate, based on a crawling peg regime that consists of un-announced and gradual movement of

8 In the case of Singapore the motivation is different, since the country uses the exchange rate because of its high capital mobility environment where the interest rates are similar to international ones.

parity. Under these assumptions and in the direction of Mendieta and Rodriguez (2008), the rule for the nominal exchange rate is:

$$\Delta e_t = \delta_0 + \delta_1 \Delta e_{t-1} + \delta_2 y_{t-1} + \delta_3 (\pi_{t-1} - \overline{\pi}_{t-1}) + \delta_4 (\pi_t - \pi_t^*) + \delta_5 (z_t - z_t^*) + \varepsilon_t^{\Delta e} \quad \text{(D3)}$$

It is expected that all coefficients will be negative, except δ_4.

These main equations were estimated with a method to avoid endogeneity bias and use actual variables to approximate expected ones. Equations were estimated with the Generalized Method of Moments (GMM). Next, they were calibrated in suitable programs designed for this task.[9] Results are shown in Table D.2, below this Appendix.

To include the effect of international food inflation were added other equations. International food inflation has effects in two ways: i) Expressed in local currency, it is a determinant of Bolivian food inflation, which is related to non-core inflation; and ii) It affects external inflation, and by this way, core inflation. In formal terms:

$$\pi_t^{nc} = \kappa_0 + A(L)\pi_{t-1}^{nc} + \kappa_1 \pi_t^{Bfi} + \varepsilon_t^{\pi^{nc}} \quad \text{(D4)}$$

$$\pi_t^{Bfi} = \mu_0 + B(L)\pi_{t-1}^{Bfi} + \mu_1 \left(\Delta \ln(e_t) + \pi_t^{Wfi}\right) + \varepsilon_t^{\pi^{Bfi}} \quad \text{(D5)}$$

$$\pi_t^* = \zeta_0 + \zeta_1 \pi_{t-1}^* + \zeta_2 \pi_t^{Wfi} + \zeta_3 \pi_t^{Oil} + \varepsilon_t^{\pi^*} \quad \text{(D6)}$$

Where *A(L)* and *B(L)* are polynomials of the lag operator *(L)*.[10] Because there are not endogeneity problems these equations were estimated with the usual Ordinary Least Squares (OLS) technique.

Mostly, the results of estimation were consistent with the expected signs and magnitudes. They are shown in Table D.2. The main difference with standard results is the contractionary effect of a real depreciation, but explained by the high degree of dollarization of the Bolivian economy.

9 The estimation was made in E-Views, while the analysis of impulse response was made in Matlab's toolboxes: Dynare and Iris.
10 Lag operator is defined as follows: $L^j x_t = x_{t-j}$.

This SSMM has some limitations to be taken into account. The first is the scope of the data used, especially in the measurement of economic activity, because Bolivia has a large informal sector. However, the GDP reported by INE is the unique proxy for this variable and the estimates of equations that include this series seems plausible. An additional argument comes from the Central Bank of Peru, a country with wide informal sector as Bolivia, which has used this model successfully in the last years to analyze and forecast inflation [Luque and Vega, 2003]. Colombia is other useful example.

Table D.1: DEFINITION OF MAIN VARIABLES USED IN THE BOLIVIAN SSMM

Variable	Definition	Observations
$\pi_t^c = \frac{\Delta p_t^c}{p_{t-1}^c}$	Core inflation	Quarterly percentage change of Core CPI (p_t^c), which is defined as total CPI less perishable food and regulated prices.
$y_t = \log\left(\frac{PIB_t^{SA}}{PIB_t^*}\right)$	Output gap	Log-difference between the seasonal adjusted GDP not including mining and hydrocarbons (PIB_t^{SA}) and potential GDP (PIB_t^*). The last one was obtained using a Hodrick – Prescott (HP) filter with a factor specific for Bolivia (λ=7185), according Rodriguez (2007).
e_t	Nominal exchange rate	Official exchange rate fixed by the BCB in daily auctions in the *Bolsín* (sell exchange rate).
π_t^*	External inflation in U.S. dollars	Quarterly percentage change of an index of Bolivia's 13 main partner countries inflation, expressed in U.S. dollars.
R_t	Real interest rate	It corresponds to ($R_t = i_t - \pi_t$).[11] Furthermore, to include financial dollarization, the nominal interest rate is a weighted average of rates on domestic and foreign currency expressed in domestic currency.[12] R_t^* denotes the natural interest rate, estimated in a similar way as the potential output. Therefore, the difference measures the gap between the real interest rate with respect to its natural or potential level.
z_t	Real exchange rate	Correspond to the multilateral real exchange rate index calculated by the BCB, taking into account the main trade partners of Bolivia. Then, $z_t - z_t^*$ is the exchange rate misalignment.
$yext_t$	External output relevant for Bolivian economy	It is measured as an average of the GDP of the most of the 13 major trading partners of the country, weighted by their share in foreign trade. With an asterisk denotes the potential external output.
g_t	Growth of fiscal expenditures	It measures the quarterly growth of seasonally adjusted expenditures of central government. With an asterisk denotes the trend growth.
π_t^{nc}	Non-core inflation	Quarterly percentage change of Non Core CPI (perishable food and regulated prices).

11 Unlike other models that use the expression $R_t = i_t - E_t\pi_{t+1}$, in the case of Bolivia the rate of inflation is directly used, because according to the results of the Economic Expectations Survey of the BCB was noted that expected inflation has co-movements respect to the observed one.

12 This variable is the average weighted active interest rate of banking system, according to the following formula:

$$i_t = Bol_t \times i_t^{Bol} + Dol_t \times i_t^{Dol} \qquad / \qquad i_t^{Dol} = \frac{1+i_t^{\$us}}{1+\hat{e}_t} - 1$$

Where *Bol (Dol)* is Bolivianization (dollarization) of portfolio, i^{Bol} (i^{Dol}) is the average nominal interest rate of credits in national currency (foreign currency) of the banking system.

Table D.1: DEFINITION OF MAIN VARIABLES USED IN THE SSMM (Cont.)

Variable	Definition	Observations
π_t	Total inflation	Is defined as $\chi\pi_t^c + (1-\chi)\pi_t^{nc}$, a weighted average of core and non core inflation according their share in total CPI
π_t^{Bfi}	Bolivian food inflation	Quarterly percentage change of Bolivian food CPI (p_t^{Bfi}), which includes food and beverages.
π_t^{Wfi}	International food inflation	Quarterly percentage change of international food prices index, calculated by The World Bank.
π_t^{Oil}	Oil inflation	Quarterly percentage change of West Texas Intermediate (WTI) oil price.

Table D.2: ESTIMATION RESULTS OF A SSMM FOR BOLIVIA

i) Phillips Curve: $\pi_t^c = \alpha_1 \pi_{t-1}^c + (1-\alpha_1) E_t \pi_{t+1}^c + \alpha_2 y_{t-1} + \alpha_3 \Delta e_{t-1} + \alpha_4 \pi_{t-1}^* + \varepsilon_t^{\pi^c}$	
α_1	**0.578** (0.048)
α_2	**0.242** (0.078)
α_3	**0.193** (0.046)
α_4	**0.068** (0.031)
ii) IS Curve: $y_t = \beta_1 E_t y_{t+1} + \beta_2 y_{t-1} + \beta_3 (R_{t-1} - R_{t-1}^*) + \beta_4 (z_{t-1} - z_{t-1}^*) + \beta_5 (yext_t - yext_t^*) + \beta_6 (g_t - g_t^*) + \varepsilon_t^y$	
β_1	**0.617** (0.086)
β_2	**0.180** (0.047)
β_3	**-0.033** (0.020)
β_4	**-0.045** (0.014)
β_5	**0.214** (0.075)
β_6	**0.050** (0.010)
iii) Exchange rate rule: $\Delta e_t = \delta_0 + \delta_1 \Delta e_{t-1} + \delta_2 y_{t-1} + \delta_3 (\pi_{t-1} - \overline{\pi}_{t-1}) + \delta_4 (\pi_t - \pi_t^*) + \delta_5 (z_t - z_t^*) + \varepsilon_t^{\Delta e}$	
δ_1	**0.740** (0.023)
δ_2	**-0.051** (0.013)
δ_3	**-0.023** (0.008)
δ_4	**0.006** (0.001)
δ_5	**-0.051** (0.004)
iv) Non core inflation: $\pi_t^{nc} = \kappa_0 + A(L) \pi_{t-1}^{nc} + \kappa_1 \pi_t^{Bfi} + \varepsilon_t^{\pi^{nc}}$	
κ_1	**S.R.: 0.197** (0.022) **L.R.: 0.459**
iv) Bolivian food inflation: $\pi_t^{Bfi} = \mu_0 + B(L) \pi_{t-1}^{Bfi} + \mu_1 (\Delta \ln(e_t) + \pi_t^{Wfi}) + \varepsilon_t^{\pi^{Bfi}}$	
μ_1	**S.R.: 0.124** (0.030) **L.R.: 0.574**

Table D.2: ESTIMATION RESULTS OF A SSMM FOR BOLIVIA (Cont.)

iv) External inflation in U.S. dollars: $\pi_t^* = \zeta_0 + \zeta_1 \pi_{t-1}^* + \zeta_2 \pi_t^{Wfi} + \zeta_3 \pi_t^{Oil} + \varepsilon_t^{\pi^*}$	
ζ_2	**S.R.: 0.155** (0.082) **L.R.: 0.194**
ζ_3	**S.R.: 0.075** (0.026) **L.R.: 0.093**