SUMMARY

LIST OF TABLES

LIST OF FIGURES

1. Introduction

1.1. Initial Remarks

The debate concerning the conduction of monetary policy is pervasive in economic theory. Such debate necessarily requires a thorough analysis of the mechanisms of operation of markets, which would lead to a better understanding of the transmission channels of monetary policy, thus bringing greater efficacy to it.

Traditionally, the interest rate has been used as instrument of conduction of the monetary policy, due to the fact that there is relative consensus when it comes to its efficacy through the demand transmission channel. Thus, increases in the interest rate would lead, among other effects, to more expensive credit, which would make unaffordable a larger number of consumption and investment plans. This would reduce aggregate demand, and in consequence, the inflationary pressure.

However, the scenario becomes more complex when the operation of a cost-push channel in the economy is considered. The idea is that increases in the interest rate take a toll on firms’ costs, therefore affecting their pricing decisions. This alternative transmission mechanism may have important consequences in the way that an optimal monetary policy is conceived.

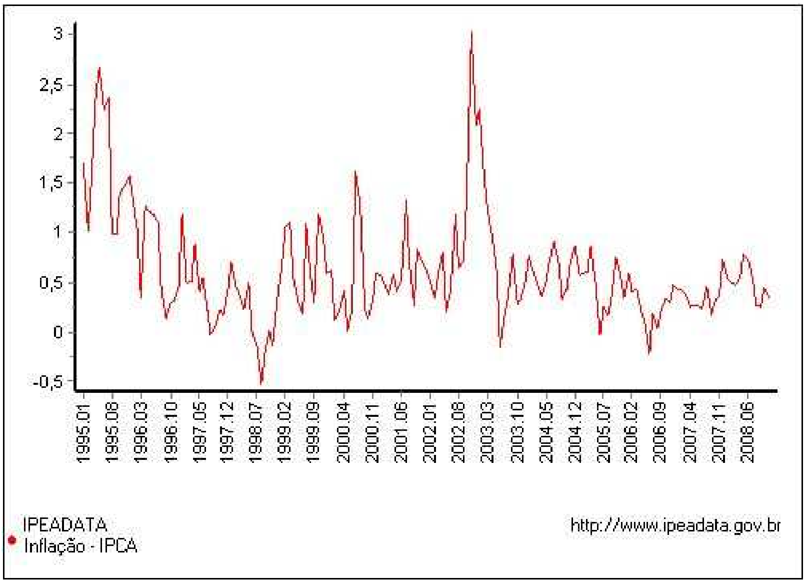
If firms raise their prices in response to these increases in financial costs, the effects of an elevation in the interest rate could go in the opposite direction of that intended by the Central Bank. This has important implications: depending on the magnitude of this effect, a contractionary monetary policy intended to lower inflation would, in fact, increase it.

In this sense, an empirical evaluation of the cost-push channel may change how monetary policy is viewed. If there is enough evidence in favor of the cost-push channel, the counteracting effects of increases in the interest rate on the lowering of inflation, with its negative consequences for income and employment, must be considered. In the Brazilian case, this analysis has perhaps greater importance, since the country has been experiencing high interest rates for many years, which is likely to amplify the cited effects.

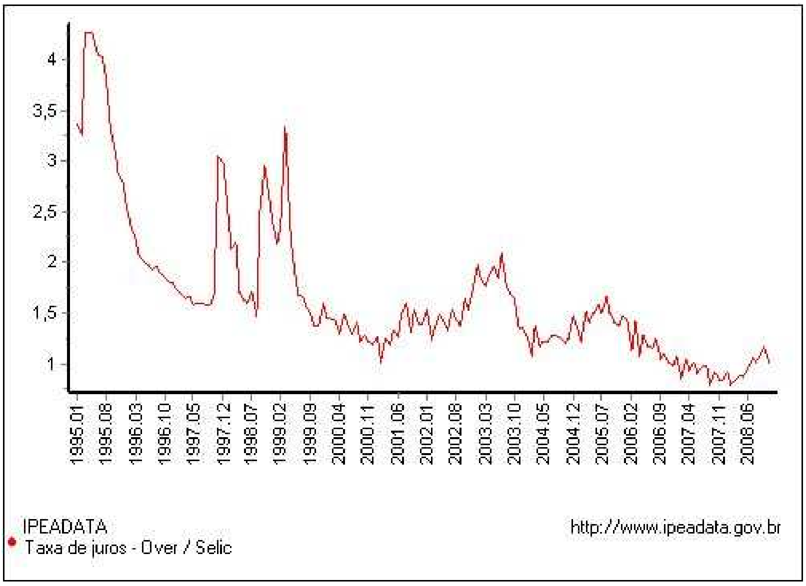
1.2. The Conduction of Monetary Policy in Brazil: 1995 – 2008

Since the introduction of the Real Plan, in 1994, the conduction of monetary policy in Brazil has been marked by high interest rates. Increases in the interest rate are the immediate response of the monetary authority (BACEN) to increases in monthly inflation, measured by the IPCA. This can be observed in the two graphs below:

Graph 1: Inflation rate in Brazil (monthly IPCA) – 1995-2008



Graph 2: Interest rates in Brazil (monthly Selic) – 1995-2008



For instance, large increases in inflation occurred in the second semesters of 1998 and 2002 are coincident with large increases of the interest rate in the same periods. This is not fortuitous: it has been stated by the BACEN in many occasions that the interest rate is the main instrument of monetary policy. This instrument is set by the Committee of Monetary Policy (COPOM), which divulges minutes of its monthly meetings, detailing the factors taken into account in each decision made.

By analyzing the minutes of the COPOM meetings, it can be inferred that the BACEN used increases in the interest rate as a response mechanism against various sources of inflation. This becomes evident in the minute of October of 2002, for example. In it, the COPOM sets out the reasons why it raised the interest rate from 18% to 21% p.a. Firstly, there's the concern with the continued increases of oil prices. There's also concern about the behavior of administered prices, especially electricity. Another cause for concern is the devaluation of the exchange rate. Added with the political scenario, where the upcoming elections caused disturbances in the financial markets, these factors led the COPOM to increase the interest rate in three percentage points. Note, however, that at that time there were hardly any pressures coming from the demand side of the economy: although the COPOM acknowledges the fact that sales had been growing faster than production (which led to lower stocks), capacity utilization remained at a low level.

On the other hand, in June of 2008 the COPOM based its decision basically on imbalances between supply and demand. In the Committee's evaluation, excessive activity in factors markets and in internal demand, coupled with supply restrictions in some sectors, would be reflected in greater pass-through from wholesale to retail prices. For this reason, the COPOM increased the interest rate in 0,5% percentage points.

These are just two examples of a trend that can be observed throughout the meetings: the interest rate is the instrument of monetary policy *par excellence*, and will be used against increases in inflation of all sorts. Only a caveat should be made. In the previously mentioned minute of October of 2002, the COPOM explains how differently it may use the interest rate, depending on the source of inflation.

> It is necessary to distinguish between demand and supply shocks, and temporary and permanent shocks. Demand shocks must be compensated with a policy that has the inverse signal of the shock. In the case of supply shocks (or cost-push shocks), we have followed the traditional guidelines: the direct impact on the level of prices is accommodated (that is, doesn't call for a response from monetary policy), but the secondary (or inertial) effects of the shock are fought. When confronted with shocks of large magnitude, as has been the case in the last 18 months, monetary policy has been calibrated so as to prolong the time of convergence to the inflation target. Such procedure takes into account the costs (in terms of output), associated with the existence of inflationary inertia, of the adjustment process. This policy indicates that, according to the guidelines of inflation targeting, the Central Bank must weigh the volatility of the activity level in its decision, without, however, leaving aside its main goal of reaching the inflation target.

With reference to the specific subject of the dissertation, the cost-push channel of monetary policy, it becomes clear by reading the minutes that such phenomenon was never explicitly considered by the monetary authority as a possible countervailing force in the process of the lowering of inflation rates. This comes as no surprise, since the Central Bank uses New-Keynesian models as its main tool for decision-making, which in general have no place for such a channel of monetary policy transmission.

2. The Literature on the Cost-Push Channel

2.1 Review of literature

Although the debate on the cost-push channel has older references, it reappeared in the literature on the empirical evaluation of monetary policy using VAR's. This literature identifies what has become known as the price puzzle: positive responses of the price level to a shock in the interest rate. It is important to briefly look at the literature that deals with the price puzzle, because the modern literature on the cost-push channel traces back to it. As it will be shown, there are many different explanations put forward in order to account for the price puzzle, at first all of them considering the price puzzle an econometric anomaly that would vanish by better specification of the econometric models. Later on, some authors started to ponder that there could be a theoretical explanation behind the price puzzle, which gave way to a resurgence of the discussion on the cost-push channel.

In this sense, Sims (1992) is groundbreaking because he is the first to identify the appearance of the price puzzle. However, Sims' paper proposes an explanation for the anomaly that doesn't involve the cost-push channel. According to him, the price puzzle would arise due to a problem of econometric misspecification. In the words of Cysne (2004):

> Sims' explanation to the puzzle is primarily based on the bias in the estimation of the coefficients, on account of possibly-missing variables. He argues that the monetary authority often has information regarding inflationary pressures not captured in the history of the variables included in the VAR. For instance, by having knowledge of a supply shock, and that inflationary pressure is about to arrive, the authorities can take the preemptive action of raising interest rates, thereby generating a positive (though spurious) correlation between prices and interest rates. (CYSNE, 2004, p. 2)

In order to be able to capture in the regression this upcoming inflationary pressure, which is the cause of the spurious relation, Sims suggests that a commodity prices index should be incorporated to the model. This procedure has been shown to be effective in his and in other papers.

Nevertheless, other authors that in their works continued to acknowledge the presence of the price puzzle, even making use of Sims' procedure, started to conceive of the cost-push channel as a possible explanation. Among them, one of the first was Barth and Ramey's (2001). The authors put together a partial equilibrium model for an industry. The objective is to build a model that allows them to empirically verify the effects of monetary policy on the demand and cost structures of the companies. Although this approach has the advantage of evaluating different responses of heterogeneous sectors to monetary policy, it is not intended to provide answers about the interaction of monetary policy and the general equilibrium of the economy.

Taking a representative firm, it will maximize profits given by:

$$\pi_{it} = P_{it}Q_{it} - R_{it}W_{it}C(Q_{it}) \qquad [1]$$

where P_{it} is the price level, Q_{it} is the production level, R_{it} is the gross interest rate, W_{it} is the wage level and $C(Q_{it})$ is a convex cost function. The interest rate is included in the cost structure of the firm, since it has to borrow to be able to finance its wage bill.

The inverse demand function of the industry is given by:

$$P_{it} = f(Q_{it}, DS_{it}) \qquad [2]$$

where DS_{it} denotes the impact of exogenous shocks in firms' demand, such as changes in monetary policy, and $f_q < 0$ and $f_d > 0$. Wages are given by:

$$W_{it} = N(Q_{it}, DS_{it}, R_{it}) \qquad [3]$$

with $N_Q \geq 0$, $N_{DS} \geq 0$ and $N_R \leq 0$. The first derivative denotes a positively sloped supply curve, the second reflects that a positive demand shock increases the demand for labor, and the third the fact that increases in costs lower the demand for labor.

From the solution of the profit maximization problem, the price and quantities equilibrium are obtained. By comparative statics, it can be concluded that a negative demand shock (i.e., a decline in DS_{it}) leads to lower equilibrium output level Q_{it} and price/wage ratio, as long as the effect in the industry's inverse demand curve is larger than the effect in the supply curve. Also, a negative supply shock (i.e., an increase in R_{it}) leads to lower output levels, but to a higher price/wage relation, as long as the net effect of this change is an upwards shift in the industry's supply curve. That is, if a monetary shock has its main effect on the industry's cost structure, a decrease in production and an increase in prices will be observed. The authors then proceed to the empirical test, working with the hypothesis that in sectors where there is a fall in production and an increase in the price/wage ratio, the cost-push channel would be in operation. They start from the usual identification strategy used in the literature: first off, they define the reaction function of the monetary authority, which has, generally, indicators of level of activity, consumer prices, commodity price and demand for reserves, from which it is defined the level of the policy instrument that is utilized (in the American case considered by the authors, this corresponds to the target-rate of the Federal Funds Rate (FFR), determined by the FED). Next, the system is put together with the equations of the variables included in the reaction function, ordered in such a way that the FFR is the most endogenous variable, i.e., has no contemporaneous effect on the variables of the reaction function. The advantage of this identification strategy is that the ordering of variables of the reaction function is irrelevant, for it is assumed that the FFR has no contemporaneous effect on them. In other words, it is not necessary to suppose that the output affects the price level contemporaneously, or vice-versa (Barth & Ramey, 2001, p. 13). Lastly, the authors include in the system dummies in order to control for oil shocks.

They estimated VAR's with monthly data from February of 1959 up until December of 1996 for different manufacturing series: two series of three digits; eighteen series of two digits; durables and non-durables; total manufacturing. The variables used were: industrial production (as a proxy for output); a deflator for the index of consumption spending (as a monthly measure of the general price level); difference of the logarithms between total of reserves of the Federal Reserve and non-borrowed reserves (as a measure of the demand for reserves); The end-of-month FFR; the reason between industrial production and price-wage for each sector. For 13 of the 21 sectors analyzed and the three aggregated series, the impulse response functions show that, as a response to a positive shock in the FFR, production falls and prices rise in relation to wages.

Also, tests in which the null hypothesis was that none of the changes in price levels in the last 24 months were larger than zero were rejected at the 10% level for nine sectors. Finally, the sample was split into two periods, February of 1959 until September of 1979 (date associated with the start of Paul Volcker's administration in the FED) and January of 1983 until December of 1996. In the new estimates, the cost-push channel was shown to be much more significant in the first period. According to the authors, this result would be due to differences in the financial system and in how monetary policy was conducted in both periods.

Castelnuovo and Surico (2006) also found evidence that the price puzzle is a phenomenon associated with the pre-Volcker era. They use a microfounded New-Keynesian model, with an IS curve given by:

$$q_t = E_t q_{t+1} - \vartheta(R_t - E_t \pi_{t+1}) + ds_t \qquad [4]$$

where q_t is the output gap, ϑ is the elasticity of intertemporal substitution and ds_t may represent an exogenous demand or preference shock. The Phillips curve is given by:

$$\pi_t = \beta E_t \pi_{t+1} + \kappa(x_t - z_t) \qquad [5]$$

where κ is a parameter that represents the inverse of the sacrifice rate. And the response function of the monetary authority is given by:

$$R_t = \rho_R R_{t-1} + (1 - \rho_R)(\psi_\pi \pi_t + \psi_x x_t) + \varepsilon_{R,t} \qquad [6]$$

where ρ_R denotes the degree of adjustment of the interest rate and $\varepsilon_{R,t}$ denotes monetary policy shocks.

Initially, the authors estimated a VAR with U.S. quarterly data from 1966 to 2002, which included real GDP, changes in the GDP deflator as a measure of inflation and the FFR, in this order (i.e., they use an identification strategy similar to that of Barth and Ramey, 2001). In the estimation with aggregated data, the price puzzle shows up, although the results are not statistically significant. In the estimates with sub-samples, in the pre-Volcker era the price puzzle becomes significant, being larger in the aggregated case. In the post-Volcker era, the coefficient of inflation has the correct signal, besides being insignificant. Following Giordani (2004), who emphasizes the utilization of some measure of output gap instead of output level, the authors run new estimations replacing real GDP by three measures of output gap, each corresponding to different estimates of potential output: HP filter, quadratic trend and estimates of the Congressional Budget Office. The result of these estimations by sub-samples reveals to be robust under the new specification. Another robustness analysis carried out by the authors was to expand the VAR to four variables, having as an additional variables the real unit labor costs, an index of commodity prices, FFR, real output, growth of M2 and inflation. Once again, results were not significantly altered.

Finally, Castelnuovo and Surico identify not only monetary policy shocks, but also supply and demand shocks, using the identification strategy known as sign restrictions. Instead of identifying the system by making use of a triangular decomposition of the matrix containing the contemporaneous parameters, they impose restrictions on the direction of some impulse response functions, such restrictions being imposed according to basic relations given by economic theory. According to Peersman (2005), not only do restrictions on the contemporaneous impact of variables tend to be too restrictive, but they also are not based on economic theory. When it comes to long-run restrictions, such as the ones made by Blanchard and Quah (1989), although based on theoretical models, they are contradicted by some growth models, an example being some overlapping generation models. Therefore, sign restrictions would be more adequate.

Castelnuovo and Surico impose that monetary shocks have non-negative effects on the interest rate and non-positive effects on GDP, while supply (demand) shocks have non-negative (non-positive) on interest rate and inflation, and non-positive (non-negative) on output gap. Unlike previous papers which used this identification strategy, no restriction on the response of inflation to the interest rate was imposed, since the objective was to investigate the price puzzle. The hypothesis that the interest rate has no contemporaneous effect on other variables was maintained. Once again, the price puzzle is observed only in the pre-Volcker era.

The authors' explanation for the price puzzle does not involve the cost-push channel but, as in Sims' work, it involves omitted variables. The pre-Volcker era would be associated with weak responses of the monetary authority to increases in inflation (that is, the interest rate was increased proportionately less than the observed increase in inflation). Such lack of rigor by the monetary policy would lead to inertia in inflation expectations, which would generate perverse dynamics such as the price puzzle. This theory is corroborated by the fact that estimates of VARs, using data simulated from a New-Keynesian model, only generates the puzzle when the interest rate is not sufficiently raised when inflation increases. The conclusion is that the puzzle is solved by the inclusion of inflation expectations in the VAR.

Even if it is considered that, in general, the inclusion of a variable that captures inflation expectations or information about future inflation is the solution to the price puzzle, such results are not always observed. The investigation carried out by Hanson (2004) attempts to show that the common practice of including an index of commodity prices in the VAR, despite its intuitive appeal, needs more solid theoretical (since there is no room for such a variable in business cycle models) and empirical foundations. Hanson argues that the inclusion of an index of commodity prices would only eliminate the puzzle if this variable improves the predictive power of the model, that is, if its omission truly generates an estimation bias. Next, he shows that if this is the case, the observed magnitude of the puzzle must bear a direct relation to the omitted variable's predictive power and to how strongly the monetary authority responds to inflationary pressures.

However, estimation of monthly VARs for the U.S., from January of 1959 until December of 1998, and robust to different choices of inflation index, do not stand by these implications. In order to test these hypotheses, Hanson initially estimates a VAR containing only real GDP, aggregate price level and a monetary policy instrument. This VAR replicates the puzzle and will serve as a basis for comparison. Subsequently, different VARs are estimated, with different indicators of future inflation and expected inflation, such as labor costs, capacity utilization, commodities index, the spread between short-run and long-run interest rates, oil prices, among others. The author computes the root mean squared error (RMSE) of the prediction of the price level in each VAR, as well as the mean squared error (MSE), which are compared with the RMSE and the MSE of the standard model. The difference between them represents the improvement in terms of prediction gained with the inclusion of the new variable. Furthermore, it is computed how much the inclusion of each specific variable mitigated the anomalous behavior of the impulse response functions by observing the magnitude of the decrease in percentage points of the increase in inflation response in the initial periods. Through graphical analysis, Hanson comes to the conclusion that it is not possible to capture a direct relation between the variable’s predictive power and how much it was capable of reducing the puzzle.

Finally, Hanson splits the sample in pre-Volcker and post-Volcker periods, observing the price puzzle only in the first period, as in Castelnuovo and Surico (2006). However, this fact invalidates the second implication of the rationalization of the use of Sims-like variables, since the post-Volcker era is recognized in the literature as a period of active monetary policy, unlike the pre-Volcker period. Therefore, despite making only a slight reference to the eventual existence of the cost-push channel, Hanson questions the traditional interpretation of the price puzzle.

For Brazil, Luporini (2008) estimates a VAR and finds evidence that the price puzzle is relevant, which does not disappear with the implementation of the procedure proposed by Sims. Although Cysne (2004) also makes use of a VAR, he also constructs confidence intervals for impulse response functions using a bias-correcting bootstrap, finding a small effect that lasts only a quarter.

Most of the previously cited papers discuss the price puzzle using the VAR methodology, and few of them consider the cost-push as a possible explanation. A different approach takes as a starting point the possible existence of the cost-push channel, and seeks to evaluate it by the estimation of a Phillips Curve, where there would be a positive relation between inflation and the interest rate due to a liquidity constraint faced by the firms.

In Chowdhury *et al* (2006), firms need to borrow not only to finance their wage bill, but also to pay for production inputs. That leads to:

$$L_{dit} \geq P_t w_t l_{it} + P_t ip_t x_{it} \qquad [7]$$

where L_{dit} is the nominal value borrowed by firm i in period t, w_t is the value of the real wage in the economy, ip_t is the real price of production inputs and P_t is the aggregate price level. By the end of the period, firms pay back the loan with interest given by i_t^l. From the solution of a cost minimization problem subject to technological and liquidity constraints, the expression for the marginal cost of firm i is derived:

$$mc_{it} = (1-\alpha)^{-1} R_t^l s_{it} \qquad [8]$$

where $R_t^l = 1 + i_t^l$, α is the technological coefficient of capital and $s_{it} = w_t l_{it} / y_{it}$ denotes unit real labor cost of firm i.

The existence of a degree of price rigidity, the so-called price staggering, is assumed. The probability that firms change their pricing rule is given by $1-\phi$, independently of the last price change. Of these firms, a fraction ω change their prices according to the rule of thumb $P_{it} = \pi_{t-1} P_{t-1}$, where $\pi_t = P_t / P_{t-1}$ denotes the inflation rate. The fraction of firms $1-\omega$ set their prices in an optimal way, maximizing their market value, which is given by the profit flow discounted by a stochastic factor. The other ϕ firms set their prices according to average, or steady-state inflation $\bar{\pi}$.

Financial intermediaries take deposits D_t from households and give loans L_t. The basic rate paid by the intermediaries is given by $R_t = 1 + i_t$, where i_t is determined by the monetary authority. An imperfection in the financial market is introduced, in which the risk of default by firms increases with an increase in the interest rates. The impact of this imperfection is reflected in the following relation, derived from the profit maximization of the financial intermediaries:

$$\hat{R}_t^l = (1+\psi_r)\hat{R}_t \qquad [9]$$

where, for any variable k_t, $\hat{k}_t = \log(k_t) - \log(\bar{k}_t)$ denotes the percentage deviation from the steady-state value $\bar{k}_t$. The larger the value of ψ_r, which is a variable that represents the size of the market imperfection, the larger is the response of the deviation of the interest rate paid by firms in relation to the steady-state to a deviation in the rate set by the monetary authority.

After some manipulations, the Phillips Curve is:

$$\hat{\pi}_t = \gamma_f E_t \hat{\pi}_{t+1} + \gamma_b \hat{\pi}_{t-1} + \chi \hat{s}_t + \chi(1+\psi_r)\hat{R}_t \qquad [10]$$

that is, percentage deviations of the inflation rate depend on percentage deviations of the expectations of future inflation, of past inflation, of unit labor costs and of the basic rate. It is possible to show that the variable that represents deviations from labor unit costs is equivalent to percentage deviations of output from its steady-state. This is the specification estimated by the authors, which differs from the traditional Phillips Curve because of the positive coefficient associated with the interest rate. This positive effect on inflation will depend positively on the degree of imperfection of the financial markets.

The authors estimated a Phillips curve for each country in their sample which contained inflation expectations for the following period, inflation of the previous period, real unit labor costs and the interest rate. Inflation was measured by the GDP deflator, and alternatively by a consumer prices index. The interest rate used was the 3-month Treasury bill rate, and labor costs were approximated by the ratio between total compensation and GDP.

The authors used a quarterly sample, from 1980 to 1997, for Canada, France, Germany, Italy, Japan, United Kingdom and United States. The method used for estimation was GMM, using as instruments lags of inflation and commodity prices, real unit labor costs and T-bill rates. The results show a significant direct relation between interest rates and inflation for Canada, France, Italy, United Kingdom and United States. On the other hand, the coefficient was not significant for Germany and Japan. When the consumer prices index is used, the cost-push channel becomes significant for Germany, being no longer significant for Italy. For France and the United Kingdom, the cost-push channel is stronger in the estimation that uses the consumer prices index. That would be explained by the fact that consumption goods have in their composition components with more cyclical cost behavior, which then makes the marginal cost of production of these goods more susceptible to changes in the nominal interest rate in the short run.

However, it is possible to argue that the positive coefficient associated with the interest rate would simply reflect a feedback from inflation to the interest rate, such feedback being due to reactions of monetary policy to inflation. This argument led the authors to estimate a Phillips Curve and a Taylor Rule using simultaneous GMM. Two specifications of the Taylor Rule were used: in the first, inflation responded to contemporaneous inflation; in the second, to inflation expectation. In all countries but France the cost-push channel was present, independent of the type of Taylor Rule that was used. Finally, the authors include in the estimation a commodities index. The conclusion is that the cost-push channel is still valid, for even in countries where the coefficient associated with the commodities index, as in Italy, Canada and the United Kingdom, the coefficients associated with the interest rate were still positive and significant.

In Ravenna and Walsh (2006), the economy is composed by households, firms, government and financial intermediaries, which interact in the goods, financial and labor markets. The representative consumer maximizes the expected present value of a utility function which is increasing in consumption and decreasing in labor. The function also has exogenous preference shocks. Consumption is given by a composite good, which consists of differentiated products produced by firms operating in monopolistic competition markets.

Households start each period with cash holdings given by M_t. At the beginning of the period, they receive wage income $W_t N_t$ and make deposits M_t at the financial intermediaries. Therefore consumption is given by a cash-in-advance restriction:

$$P_t C_t \leq H_t + W_t N_t - M_t \qquad [11]$$

At the end of the period, households receive profit income f_t, plus the interest and the principal of the previously made deposits $R_t M_t$. Therefore, cash holdings of the next period are given by:

$$H_{t+1} = H_t + W_t N_t - M_t - P_t C_t + R_t M_t + F_t - T_t \qquad [12]$$

where R_t is the gross nominal interest rate, F_t are firms and financial intermediaries' profits and T_t are lump-sum taxes.

Goods market equilibrium requires $Y_t = C_t + G_t$. It is assumed that government spending is proportional to output: $G_t = (1-\gamma_t)Y_t$, where γ_t is stochastic and has values between zero and one. Therefore, $C_t = \gamma_t Y_t$.

Firms change their prices according to a Calvo rule, in which the number of firms that set prices optimally is given by $1-\omega$. Such firms maximize profits subject to the demand curve and production technology given by $y_{jt} = pr_t N_{jt}$, where pr_t is a stochastic aggregate productivity factor with expected value of 1. The other ω firms set their prices by the steady-state rate of inflation.

Firms borrow $W_t N_t$, with interest rate R_t. Once again, real marginal costs are given by:

$$\varphi_t = R_t \frac{WL}{y}_t \qquad [13]$$

where $\frac{WL}{y}_t$ is the labor share in income.

The usual result of this New-Keynesian model is the Phillips Curve with the following specification:

$$\pi_t = \beta E_t \pi_{t+1} + \kappa\hat{\varphi} \qquad [14]$$

where $\kappa = \frac{(1-\omega)(1-\omega\beta)}{\omega}$.

Financial intermediaries receive from the monetary authority cash balances H_t, these balances are lent at the rate R_t. These intermediaries operate with no cost, so their profits are given by $R_t(D_t + H_t) - R_t D_t = R_t H_t$. Being $\hat{H}_{t+1}$ the growth rate of cash balances from t to t+1, $H_t = M_{t+1} - M_t = (\hat{H}_{t+1} - 1)M_t$ and equilibrium in the loan market implies $W_t N_t^d = D_t + X_t$, where X_t^d is aggregate demand for labor by firms.

With sticky prices $(\omega > 0)$, real marginal costs are given by $\hat{\varphi} \approx \hat{R}_t + \hat{s}_t$. Therefore, in the presence of the cost-push channel:

$$\pi_t = \beta E_t \pi_{t+1} + \kappa(\hat{R}_t + \hat{s}_t) \quad [15]$$

Solving the model for flexible prices and linearizing, the expressions for output gap and Philips Curve are obtained:

$$\begin{aligned} \hat{Y}_t - \hat{Y}_t^f &= E_t(\hat{Y}_{t+1} - \hat{Y}_{t+1}^f) - (\frac{1}{\sigma})[(\hat{R}_t - E_t\pi_{t+1}) - \hat{r}_t^f] \\ \pi_t &= \beta E_t \pi_{t+1} + \kappa(\sigma + \eta)(\hat{Y}_t - \hat{Y}_t^f) + \kappa(\hat{R}_t - \hat{R}_t^f) \end{aligned} \quad [16]$$

where σ and η are the elasticities of substitution of consumption and labor, respectively.

The authors estimate a Phillips Curve for the U.S. containing inflation expectations, real unit labor costs and the interest rate. They use quarterly data, from 1960 to 2001. The estimation procedure utilized is GMM, having initially as instruments four lags of unit labor costs, GDP deflator, a commodities index, the interest rate spread, wage inflation, nominal interest rate and a measure of output gap. Then, another estimation was carried out, with a different set of instruments: two lags of real unit labor costs, wage inflation, a measure of output gap, four lags of the GDP deflator and the nominal interest rate. The cost-push channel was significant and robust to different sets of instruments and specifications of the normality condition.

In Tillmann (2008), given the liquidity constraint faced by the firms, their total costs are given by:

$$TC_t = R_t^l W_t L_t \quad [17]$$

where R_t^l denotes the gross interest rate. Production technology is given by:

$$Y_t = pr_t L_t \quad [18]$$

Nominal marginal costs are given by $\frac{R_t^l W_t}{pr_t}$. Dividing by P_t, the expression for real marginal costs is obtained:

$$\phi_t = R_t^l S_t \quad [19]$$

where $S_t = \frac{W_t L_t}{P_t pr_t}$. Linearizing this expression, the components of the real marginal costs expressed in terms of deviations from steady-state values are obtained:

$$\hat{\phi}_t = \hat{R}^l_t + \hat{S}_t \quad [20]$$

Assuming that the interest rate bears a direct relation to the rate set by the monetary authority, R_t, the New-Keynesian Phillips Curve which incorporates the cost-push channel is derived:

$$\pi_t = \varphi E_t \pi_{t+1} + \gamma(\hat{s}_t + \psi_t R_t) \quad [21]$$

where ψ_t denotes the spread.

The empirical test consists in checking the significance and the sign of the coefficient associated with the interest rate. The author uses quarterly data from the U.S., from 1960 to 2004. The variables used are: GDP deflator for inflation; three-month Treasury bill rate for the interest rate, having as alternatives the borrowing rate and the FFR; and income labor share as proxy for unit labor costs. The instruments used were six lags of inflation, of income labor share and output gap, obtained by the application of HP filter to the real GDP series, the nominal interest rate and the spread. The estimation was carried out for the U.S., with quarterly data from 1960 to 2004.

The cost-push channel was significant in the full sample estimates, as well as in the estimates using sub-samples. It was larger in the periods of 1960-1982 and 1992-2004, losing importance in the 1983-2004 period. The results are not significantly altered by removing two lags of output gap from the set of instruments. This second set of instruments was used in the rolling-window estimation. Each window has 60 quarters, which is modified step by step over the entire period. In this manner, it is possible to observe the entire cost-push channel dynamics through the whole period. The conclusion is that the cost-push channel followed a U-shaped trajectory through the entire period, this conclusion being independent of the measure of interest rate used.

In Rabanal (2007), a slight change is introduced: only a fraction γ of firms must borrow in order to pay for the wage bill. Firms in the intermediate goods sector operate in an environment of monopolistic competition, using labor and capital, which has a utilization rate that is decided by the households. Each household supplies differentiated labor, which is an imperfect substitute of all other types of labor. Firms choose the aggregate demand for labor taking wages as given. Firms in the final goods sector operate in competitive markets, using as inputs intermediate goods.

Households have a utility function which is increasing in consumption and decreasing in labor. Also, they own the stock of capital, deciding with regard to investment and utilization. Consumption decisions carry inertia from previous periods. The utility function is maximized subject to a budget constraint that includes risk-free bonds and *lump-sum* transfers by the government. Households rent capital at a rate R_t^k and adjust the utilization rate with a cost given by the function $\psi(u_t)$, which is increasing and convex. Adjustment of the capital level also has a cost which depends on the growth rate of investment, $S(\frac{I_t}{I_{t-1}})$, this function also being increasing and convex. In steady-state, both functions are at their minimum value.

As in the previous models, prices are sticky, possessing a Calvo-type structure. Monetary policy follows an interest-based rule, and fiscal policy is Ricardian, following an intertemporal budget constraint. *Lump-sum* transfers are made not only to households, but also to firms that face liquidity constraints. In steady-state the marginal costs and, consequently, output of all firms are the same.

In the log-linearized version of the model, as usual, a Phillips Curve that depends on past inflation, on expectations of future inflation and real marginal costs is derived. These are expressed as:

$$mc_t = \alpha r_t^k + (1-\alpha)(\omega_t + \gamma r_t) - pr_t \qquad [22]$$

where pr_t is a productivity factor for all of the economy α is income capital share and ω_t is the fraction of firms that, when not allowed to set prices optimally, set prices according to past inflation (all variables expressed as deviations from the steady-state).

In these models, the variable that drives inflation is real marginal costs. Traditionally, the effect operates through a demand channel, since, when the interest rate is raised, marginal costs fall for two reasons: because of the fall in real wages due to the fall in the demand for labor; and because of the fall in the return of capital, due to lower demand for investments. When the cost-push channel is operating ($\gamma > 0$), increases in the interest rate will affect inflation, operating also through a supply channel, because increases in the interest rate will raise marginal costs due to an increase in the cost of financing. In order for the cost-push channel to prevail over the demand channel and, therefore, for the model to reproduce the price puzzle, the effects of increases in the interest rate on real wages and return of capital must be smoothed. In the first case, real wage stickiness is increased, which implies in a lower probability that a firm is allowed to set prices optimally and a larger fraction of firms set prices according to past inflation. In the second case, it is assumed that the utilization rates are highly unstable, which implies in a stable trajectory for capital return.

Since the model is a dynamic stochastic general equilibrium one (DSGE), the evaluation of the cost-push channel is done by simulations. The author reaches the conclusion that the cost-push channel is not relevant, since, when imposing parameter values compatible with it, the model's fit worsens significantly, particularly with respect to nominal variables.

Up until now, only Gaiotti and Secchi (2006) used panel data in order to investigate the cost-push channel. They look for evidence of the existence of cost-push channel using micro-data for 14 years of prices and individual interest rates for 2000 Italian firms. They find evidence in favor of the cost-push channel, and its relevance would be proportional to the stock of capital held by each firm.

For Brazil, although many papers deal with the price puzzle, from what we could gather only Rabi Junior (2008) considers specifically the cost-push channel as an explanation for it. Initially, the author estimates a VAR with GDP, exchange rate, administered and free prices and M1, in order to check for the existence of the price puzzle for Brazil. The impulse response function shows that there is no significant effect of monetary shocks on the trajectory of the IPCA's free prices. The conclusion is that there is either a specification problem in the VAR, or there is the operation of the cost-push channel.

To check the validity of the second hypothesis, the author estimates a New Keynesian Phillips Curve containing the cost-push channel, derived from a general equilibrium model. The data is monthly, from August of 1994 to June of 2008. It is found that there is no evidence of the cost-push channel, independently of the parameterization utilized, or whether the estimation is done for an open or a closed economy. Reaching the conclusion that the insignificance of monetary policy in the VAR is attributable to a specification problem, the author substitutes industrial production for an estimated series of monthly GDP and includes three exogenous variables: a measure of country-risk, inflation target and inflation expectations. In the augmented VAR, the response of prices to a monetary policy shock becomes significant and has the correct sign.

After reviewing the literature, it becomes clearer in what way this dissertation contributes to the literature. It sees the cost-push channel as a plausible explanation for phenomena such as the price puzzle; therefore it proceeds to verify its empirical relevance. It does so initially by using econometric methods (some of them used sparsely or not at all in this literature) to estimate four different specifications of the Phillips Curve. The idea is that the lack of consensus in the empirical literature concerning the cost-push channel may be due to the fact that estimations take into account only one specification, namely: the level of the interest rate affecting inflation. When taking into account specifications that consider other measures of the interest rate, evidence in favor of the cost-push channel might turn out to be more robust. Besides this empirical exercise, we also adapt and simulate a stock-flow model in order to look into theoretical chains of causation and mechanisms that might lead to the emergence of a perverse effect of monetary policy on inflation.

2.2 Modeling the Cost-Push Channel of Monetary Policy

Having scanned the theoretical and empirical literature on the cost-push channel, we now follow Lima and Setterfield (2010)[1], who explore different models of the cost-push channel that are consistent with the canonical model of pricing behavior in heterodox economics. Throughout this section, it is assumed that firms set prices as:

$$P = \varphi Wa \qquad [23]$$

[1] In order to somewhat uniformize the notation used throughout the dissertation, some changes were made to the original notation

where P is the price level, φ is the gross mark up (one plus the percentage margin for gross profits), W is the nominal wage and a is the labor--output ratio (which is assumed fixed). The purpose is to consider how debt-servicing costs (and hence the rate of interest) affect the pricing decision and ultimately aggregate price dynamics, as summarized by the short-run Phillips curve (SRPC).

2.2.1 Debt servicing as an overhead cost

An intuitive initial hypothesis is that:

$$\varphi = \delta \iota D \qquad [24]$$

where δ is a constant coefficient, D is firms' outstanding stock of debt (taken as given in the short run) and ι denotes the nominal rate of interest. In equation [24], the gross mark up varies with firms' debt-servicing costs, the idea being that debt servicing is an overhead cost, thus the mark up being sensitive to overheads.

Assuming also that wages depend on inflation expectations and the level of output:

$$w = \beta p^e + \gamma y \qquad [25]$$

and expressing this equation in growth rates, the following Phillips Curve is obtained:

$$p = \hat{\iota} + \beta p^e + \gamma y \qquad [26]$$

In this formulation the *rate of growth* of the interest rate is a determinant of inflation in the SRPC.

2.2.2 Debt servicing and the target rate of return

A second approach to modeling the cost-push channel is based on a special case of mark-up pricing – namely, target-return pricing – in conjunction with insights from the conflicting claims theory of inflation. The authors begin by hypothesizing that:

$$\hat{\varphi} = \varphi(\omega - \omega_F^T) \qquad [27]$$

where ω and ω_F^T are the wage share and firms' target wage share, respectively. The idea here is that the mark up grows in response to any disparity between the actual wage share and firms' target wage share, an idea that comes from the conflicting-claims literature. The same idea can be used for wage-setting, where we can write:

$$w = \eta y(\omega_W^T - \omega) + \beta p^e \quad [28]$$

where ω_W^T is the target wage share of workers.

In order to derive an expression for the SRPC that is consistent with the equilibrium conditions of the conflicting claims process, we therefore need to consider the situation where the wage share is constant (at its equilibrium value) in order to further our analysis. From the definition of the wage share, a constant wage share implies that p = w (recalling that a is a constant). Given the pricing equation [23], it follows that:

$$p = \eta y(\omega_W^T - \omega_F^T) + \beta p^e \quad [29]$$

In order to introduce a relation between the price level and the rate of interest, the authors resort to the idea of target-return pricing.[2] They suppose that what is really driving the equilibrium value of k established by firms is a target rate of return on their capital, r^T. By definition:

$$r = \frac{(1-\omega)u}{v} \quad [30]$$

where r is the rate of profit, u is the rate of capacity utilization, and v is the capital: output ratio (assumed fixed). It therefore follows that:

$$r^T = \frac{(1-\omega_F^T)u_n}{v} \quad [31]$$

or:

$$\omega_F = 1 - \frac{r^T v}{u_n} \quad [32]$$

where u_n denotes the normal rate of capacity utilization at which the target rate of return, r^T, is calculated. In other words, firms' target wage share (the inverse of the equilibrium mark up) is ultimately explained by a target rate of return (given the values of v and u_n).

Now suppose further that firms carry debt, on which they must pay interest, so that:

[2] See Lavoie (1992, pp. 131-2) and Lee (1998, pp. 204-06) on target-return pricing.

$$F_E = F - \iota D \qquad [33]$$

where F_E denotes enterprise profits and F denotes gross profits (with ιD being rental income that is earned by creditors). After normalizing by capital:

$$r = r_E + \iota\lambda \qquad [34]$$

therefore:

$$r^T = r_E^T + \iota\lambda \qquad [35]$$

where $\lambda = D/PK$ is the ratio of corporate debt to the stock of capital, which (following Lavoie, 1995) is assumed to be constant in the short run.

In other words, the target rate of return which determines firms' target wage share depends, *inter alia*, on the nominal interest rate. After the appropriate substitutions and linearizations for the sake of simplicity, the inflation process can be approximated by:

$$p = \theta_1 \iota + \theta_2 p^e + \theta_3 y \qquad [36]$$

In this formulation of the SRPC, then, it is the level of the interest rate that is a determinant of inflation.

2.2.3 Debt servicing as a component of prime costs

In the next approach to modeling the cost-push channel, it is supposed that the interest rate impacts prices via prime or direct costs, instead of via the mark-up, as was done previously. This is achieved by hypothesizing that firms borrow working capital to finance the wage bill. The price level can therefore be described as:

$$P = \varphi(1+\iota)Wa \qquad [37]$$

from which it follows that:

$$\ln P = \ln\varphi + \ln(1+\iota) + \ln W + \ln a$$

[38]

Appealing to the approximation $\ln(1 + \iota) = \iota$ for small values of ι, differentiating this last expression with respect to time, bearing in mind that both *k* and *a* are now being treated as constant, and using the wage-setting equation, it follows that:

$$p = i + \beta p^e + \gamma y \qquad [39]$$

In this formulation of the SRPC, the *rate of change* of the nominal interest rate affects the rate of inflation.

2.2.4 Inventory accumulation, debt and the pricing decision

A final model of the cost-push channel appears when firms borrow to finance inventory accumulation. To derive the implications of this behavior for pricing and price dynamics, we begin with the expression:

$$WaY + \pi PY + \iota D = P(C + I + G) + P\dot{IN} + \dot{P}IN \qquad [40]$$

where Y denotes real output, π is the profit share of income, $D = PIN$ is the debt undertaken by firms to finance inventories (Z), C, I, and G denote (respectively) aggregate consumption, investment and public expenditures (all in real terms), and all other variables are as previously defined. $P\dot{IN}$ and $\dot{P}IN$ denote additions to inventories and capital gains on existing inventories, respectively. Real output is given by:

$$Y = C + I + G + \dot{IN} \qquad [41]$$

and it is assumed that:

$$IN = \xi Y \qquad [42]$$

where the ratio of inventories to total output, ξ, is fixed. Substituting [41] and [42] into [40], recalling that $D = PIN$, and solving for P, we arrive at an expression identical to equation [1] with:

$$\varphi = \frac{1}{1 - \pi - (\iota - p)\xi} \qquad [43]$$

Intuitively, firms adjust the mark up in response to the negative impact of the nominal interest rate on profits (which arises from the effect of the nominal interest rate on the costs of servicing the debt that finances inventory accumulation), and the positive impact of inflation on profits (which arises from the realization of capital gains on inventories). Of course, this amounts to the claim that the mark up is sensitive to the *real* rate of interest – as in equation [43].

What does this pricing behavior imply for price dynamics? Defining $\imath_R = (\imath - p)$ as the real rate of interest, note that it follows from [43] that:

$$\dot{\varphi} = \frac{\xi i_R}{(1-\pi-\imath_R\xi)^2} = \varphi^2 \xi i_R \qquad [44]$$

which implies that:

$$\hat{\varphi} = \varphi \xi i_R \qquad [45]$$

Substituting this last expression together with equation [25] now gives us a SRPC of the form:

$$p = k\xi i_R + \beta p^e + \gamma y \qquad [46]$$

In other words, price dynamics now operate in such a way that it is the rate of change of the *real* interest rate that affects the rate of inflation.

3. Empirical Testing for Brazil

3.1 Methodology and Data

For the empirical analysis we used monthly data from August of 2001 to November of 2008. All time series come from IPEADATA: the IPCA index of inflation; an index of industrial production measured by IBGE; monthly SELIC rate; an index of inflation (IPCA) expectations. The month of August of 2001 was chosen as the initial point of analysis due to the fact that it is the month in which the inflation expectations survey started being published by the Central Bank.

As a proxy for economic activity, we initially used an index of industrial production. However, in all estimations its coefficient was too small. Additionally, in many cases they were insignificant and/or had the wrong sign. Attempts to solve this problem were made by using other variables, such as capacity utilization, deviations of the industrial production index from its trend (measured by HP filtering, as well as regressions against trend and quadratic trend), among others. Still, results were not substantially altered. This is a recurring problem in estimations of the Phillips Curve for other countries (Galí and Gertler 2000) and for Brazil (Schwartzman 2006).

As in Clarída, Galí and Gertler (2000), we considered that inflation and nominal interest are stationary, even though some unit root tests do not reject the null hypothesis. As for inflation expectations and industrial production, the ADF, Philips-Perron and KPSS tests indicate that these series are also stationary. Even if there are lingering doubts concerning the stationarity of the industrial production series, results are not altered when capacity utilization is used as the proxy variable.

Estimations were carried out by three different methods: GMM, System GMM and Kalman Filter. Each method has its own particular advantage. Estimations by GMM are usually performed on grounds that estimations of macroeconomic relations such as the Phillips Curve or the Taylor Rule involve some sort of endogeneity, which implies biased estimations. According to Bueno (2006), prior estimations by OLS of the Taylor

Rule for Brazil find coefficients which are substantially different than those reported in GMM estimations, which is a signal of endogeneity.

Estimations by System GMM, besides having the advantage associated with single equation GMM, also allow the simultaneous estimation of the Phillips Curve and some kind of simplified Taylor Rule. This procedure is recommended by Chowdhury, Hoffmann and Schabert (2006) as a robustness test, since estimatives may be biased due to the fact that monetary policy reacts to changes in inflation. And finally, the utilization of the Kalman Filter not only allows for simultaneous estimations as in the case of System GMM, but also renders irrelevant the problem of the eventual existence of unit roots. Besides, the decomposition of the series in the components of classical econometrics (trend, cycle and seasonality) allows for a clearer economic interpretation (Souza 1989).

In order to run the Kalman Filter, the variables are decomposed in structural models:

$$\begin{aligned} y_t &= \mu_t + \psi_t + \gamma_t + \varepsilon_t \\ \mu_t &= \mu_{t-1} + \beta_{t-1} + \eta_t \\ \beta_t &= \beta_{t-1} + \varsigma_t \end{aligned} \qquad [47]$$

where y_t is a Nx1 vector, μ_t denotes the variable's trend and β_t its slope, ψ_t stands for the cycle term, γ_t for the seasonality term, and ε_t, η_t and ς are white noise error terms, which are non-correlated. The cycle takes a trigonometric form, while seasonality may be modeled by fixed dummies or by taking a trigonometric form as well. Each component of the model may be modeled deterministically or stochastically: all that is needed is to set the variance of its error term to zero, or not. In the model may be included exogenous variables and autoregressive terms.

For estimation, it is needed to write the system in state space form:

$$\begin{aligned} y_t &= z_t \alpha_t + \varepsilon_t \\ \alpha_t &= T_t \alpha_{t-1} + \eta_t \end{aligned} \qquad [48]$$

where α_t is called state vector and T_t transition vector. The first equation is called measurement equation and the second transition equation, with non-correlated error terms.

To run the filter, it is guessed an initial value for the estimator of the state vector and for the hiperparameters, which is how the unknown parameters are called. Using a prediction equation, an estimative is obtained for the state vector in the next period. With the incorporation of new information, the state vector and the hiperparameters correspondent to that period are obtained, which will be used for prediction in the next period. This prediction will be updated with the incorporation of a new element of the sample, and the process keeps going until the last element of the sample, thus arriving at the final state vector, along with the vector of hiperparameters. With these elements, a likelihood function of the prediction errors is minimized with respect to the hiperparameters. The solution to this problem is used in running the filter once again. Running the filter, another vector of hiperparameters is found, which will be used in another likelihood maximization. The process is repeated until there is convergence to a final vector of hiperparameters, which is the vector used to find the final state vector.

Using a common factors model, it is possible to impose that some components of a variable are affected by components of other variables. For instance, it is possible to suppose that the slope of the trend of some variable is a linear combination of the other slopes. Consider a simplified version of this model:

$$\begin{aligned} y_t &= \Theta \mu_t^{\dagger} + \mu_\theta + \varepsilon_t \\ \mu_t^{\dagger} &= \mu_{t-1}^{\dagger} + \eta_t \end{aligned} \qquad [49]$$

where Θ is a NxK matrix of standardized factor loadings with the elements in the diagonal equaling 1 and elements above it equaling zero, μ_θ is a Nx1 vector whose N-K first elements equal zero and the other elements are contained in a vector $\bar{\mu}$, and the variance matrix of η_t has rank K.

3.2 Results

Next, the results of the estimations for the four specifications of the Phillips Curve are presented. All specifications had the same standard format:

$$\pi_t = \alpha + \beta r_t + \delta p^e{}_t + \phi y_t \qquad [50]$$

where only the measure of the interest rate was altered in each specification, and α is a vector which includes a constant and dummies for the last three months of 2002 which eliminated autocorrelation in the residuals, all three of them being significant at 1% in all estimations.

For simultaneous estimations, the specification of the simplified Taylor Rule was:

$$r_t = \alpha + \beta\pi_t + \delta p^e{}_t + \phi y_t \qquad [51]$$

All estimations by GMM had as instruments four lags of the exogenous variables. The over identifying restrictions were not rejected by the J test. The estimations by System GMM had as instruments five lags of each variable, with all of them also respecting the over identifying restrictions. For the estimations by Kalman Filter, lags of the exogenous variables were included in the equations of inflation and interest rate, as well as level and outliers dummies, in order to account for problems of non-normality and autocorrelation. To test the existence of the cost-push channel, a relation of dependence of the trend of the inflation rate to the trend of the interest rate was imposed by means of a common factors model (Harvey 1989). The statistic LR was used to test the hypothesis that the coefficient associated to the trend equals zero. Occasional discrepancies between the estimatives generated by GMM and by the Kalman Filter are probably due to sample size, since estimation by Kalman Filter has high computational requirements.

3.2.1 Impact of the level of the nominal interest rate on the rate of inflation

Below are presented the results for the regression for the first specification, which is given by equation [36]:

Table 1: Estimates with the level of the interest rate

	i	p^e	y
GMM *J = 0,0855*	**-0,0402****** (0,0131)	0,0792** (0,0353)	-0,0106*** (0,0037)
System GMM *J = 0,2489*	**-0,0414****** (0,0036)	0,1868*** (0,0101)	-0,0085*** (0,0013)
Kalman Filter	**-0,0140****** (0,0009)	0.3198*** (0,0462)	0.0135*** (0,0067)

***, ** e * indicate significance at 1%, 5% e 10%, respectively. GMM estimatives were made with HAC (Newey-West) covariance matrices

It can be shown that, independently of the estimation method, the coefficient of the nominal interest rate is significant and has the correct signal, at least according to conventional monetary policy theory. Therefore, there would be no evidence of the existence of a cost-push channel in this specification which is the one typically used in the New Keynesian literature. A marginal increase in the interest rate would lead to a decrease of approximately 0,04 percentage points in monthly inflation.

Results are robust to the introduction of capacity utilization as a proxy of economic activity:

Table 2: Capacity utilization as proxy

	i	p^e	y
GMM *J = 0,1004*	**-0,0290****** (0,029)	0,1143*** (0,0303)	-0,0500*** (0,0146)
System GMM *J = 0,2432*	**-0,0305****** (0,0051)	0,1795*** (0,0159)	-0.0311 (0,0064)

3.2.2. Impact of the rate of change of the nominal interest rate on the rate of inflation

In this subsection, as well as in the next one, we will verify whether the mixed evidence found in the literature concerning the cost-push channel is sensitive to the specification of the Phillips Curve. Or, more precisely, if changes in the interest rate, instead of its level, are the cause of perverse inflation responses to monetary policy. Below are the results associated to the specification that uses its rate of change as a measure of the interest rate:

Table 3: Estimates with the rate of change of the interest rate (eq. [39])

	i	p^e	y
GMM *J = 0,0684*	**0,1661***** (0,0407)	0,1100*** (0,0161)	-0,0059** (0,0025)
System GMM *J = 0,2497*	**0,2246***** (0,0127)	0,0869*** (0,0087)	-0,0042*** (0,0012)
Kalman Filter	**0,1371***** (0,0234)	**0,1605***** (0,0159)	**0,0157***** (0,0075)

Thus, there is evidence that the cost-push channel is significant, appearing as a response to changes in the basic interest rate.

Following the literature, we include in the regression an index of commodity prices, so as to make sure that the result is not due to a specification problem. The results of this regression, as well as the regression using capacity utilization as proxy, show the robustness of the cost-push channel:

Table 4: Inclusion of an index of commodity prices

	i	comm	p^e	y
GMM *J = 0,0416*	**0,1156***** (0,0603)	**0,0020***** (0,0006)	0,0577** (0,027)	-0,0153*** (0,0038)
System GMM *J = 0,2563*	**0,2000***** (0,0099)	**0,0008***** (0,0001)	0,1000*** (0,0044)	-0,0070*** (0,0007)

Table 5: Capacity utilization as proxy

	i	p^e	y
GMM *J = 0,0426*	**0,1852***** (0,0461)	0,1011*** (0,018)	-0,0434** (0,0165)
System GMM *J = 0,2578*	**0,2355***** (0,0175)	0,0971*** (0,0071)	-0,0208*** (0,0072)

3.2.3. Impact of the growth rate of the nominal interest rate on inflation

Given the results of the last subsection, it would be expected that the coefficients of the interest rate in the specification that uses its rate of growth would also be positive, since both specifications reflect some sort of change in the instrument of monetary policy. In other words, the evidence in favor of the cost-push channel of that specification would have to be confirmed by the following results:

Table 6: Estimates using the growth rate of the interest rate (eq. [26])

	i	p^e	y
GMM *J = 0,0735*	**0,0280***** (0,0101)	0,1130*** (0,0164)	-0,0064** (0,0026)
System GMM *J = 0,2524*	**0,0441***** (0,0035)	0,0841*** (0,0093)	-0,0047*** (0,0013)
Kalman Filter	**0,1273***** (0,0358)	0,2674*** (0,0299)	-0.0044 (0,0062)

The results confirm the initial intuition. These are robust to the change of proxy and the inclusion of commodity prices.

Table 7: Inclusion of an index of commodity prices

	i	comm	p^e	y
GMM *J = 0,0424*	**0,0207*** -0,0125	**0,0020***** -0,0006	0,0378 -0,333	-0,0151*** -0,0037
System GMM *J = 0,2568*	**0,0371***** -0,0026	**0,0009***** -0,0002	0,0998*** -0,0048	-0,0080*** -0,0011

Table 8: Capacity utilization as proxy

	i	p^e	y
GMM *J = 0,0635*	**0,0299***** (0,0086)	0,0838*** (0,0154)	-0,0460*** (0,0167)
System GMM *J = 0,2565*	**0,0444***** (0,0045)	0,0947*** (0,0095)	-0,0241*** (0,0081)

3.2.4. Impact of the rate of change of the real rate of interest on inflation

In this specification, the cost-push channel can also be observed, robust to the use of capacity utilization as proxy and the inclusion of the index of commodities.

Table 9: Estimates with the rate of rate of the real rate of interest (eq [46])

	i	p^e	y
GMM *J = 0,1024*	**0,1270***** (0,028)	0,1039*** (0,0112)	0,0001 (0,0005)
System GMM *J = 0,2468*	**0,1123***** (0,0140)	0,0992*** (0,0070)	-0,0035*** (0,0013)

Table 10: Inclusion of an index of commodity prices

	i	comm	p^e	y
GMM *J = 0,0625*	**0,1313**** (0,0557)	**0,0015*** (0,0008)	0.0923*** (0,0256)	-0,0151*** (0,0039)
System GMM *J = 0,2524*	**0,0694***** (0,0128)	**0,0018***** (0,0002)	0,1144*** (0,0063)	-0,0101*** (0,0011)

Table 11: Capacity utilization as proxy

	i	p^e	y
GMM *J = 0,0569*	**0,1232***** (0,0437)	0,0964*** (0,0236)	-0,0340** (0,0156)
System GMM *J = 0,2467*	**0,1090***** (0,0159)	0,1064*** (0,0103)	-0,0091 (0,0113)

Therefore, the results show, in a robust manner, the significant presence of the cost-push channel in specifications in which the rate of inflation depends on the rate of change or the rate of growth of the monetary instrument, instead of depending on its level. Evidence was found that the real rate of interest affects inflation in a positive way in the short-run. In this respect, the broader literature summarized in chapter 2, by estimating only specifications in which the inflation rate depends on the level of the interest rate, may have underestimated the importance of the cost-push channel of monetary policy.

3.3 Some Considerations

The main conclusion so far is that there is strong evidence that the cost-push channel of monetary policy had empirical relevance for Brazil. This conclusion was arrived at by estimating of a broader set of microfounded specifications than those typically used in the literature. It is important to note, however, that these estimations only capture the immediate effect of a marginal change in the interest rate on inflation, hence the use of Short Run Phillips Curves. An analysis of the trajectory of the inflation rate over time in response to a shock in the interest rate would require the utilization of a different methodology, such as VARs. As for possibilities of extensions, one of them would be the estimation of non-linear forms, as suggested in Lima and Setterfield (2010). Another possibility is the estimation using longer time series, which would require some sort of procedure for imputation of data for expected inflation. And last, but not less (and eventually more) relevant, is the appraisal of the cost-push channel in an open economy, in which other forms of influence of the interest rate on prices would be present.

With respect to other results found in the literature, the most immediate comparison can be made to the works of Chowdhury *et al* (2006), Tillmann (2008) and Rabi Junior (2008). Both use quarterly data, with the level of the interest rate being used in the econometric specification. In the former, the parameters associated with the interest rate vary between 0,015 (Italy) and 0,076 (UK). In the latter, estimates for the U.S. give rise to coefficients between 0,047 and 0,146. In Rabi Junior (2008), the reduced form parameter has a positive signal, but the structural form parameter takes values from -0,0146 to -0,1962 (this discrepancy would be due to sensitivity to the parameterization of the model). Our estimates using the level of the interest rate found values between -0,014 and -0,04. Therefore, it could be argued that the result found so far, of significance of the cost-push channel in other specifications, would be due to the fact that these positive coefficients do not come from a structural estimation. However, it should be noted that models with structural estimations also found evidence in favor of the cost-push channel.

Looking closer at the way firms finance their production, the idea of a cost-push channel of monetary policy has its merits. For instance, in the U.S., most of working capital for big businesses is acquired via the market for commercial papers, which is a short-term debt instrument issued by large corporations. In this market, companies are able to raise capital cheaply at short-term interest rates and investors are able to obtain yields that are a bit higher than those offered by Treasury bills without incurring in risks. Before the financial crisis that began in 2007, commercial paper was the largest U.S. short-term instrument with more than $1.97 trillion outstanding (Kacperczyk and Schnabl, 2010, p.29).

Usually commercial papers are held by investors until maturity, therefore secondary markets for these instruments are not very important. Most investors roll over maturing commercial papers, so basic movements in prices (hence interest rates) are given at issuance. There are three categories of commercial papers: asset-backed, financial and corporate financial paper. The asset-backed category refers to debt that is issued by off-balance-sheet conduits of large financial corporations, in many cases these corporations providing credit guarantees to outside investors. Financial commercial paper is issued by large financial institutions, with the differences being that it is issued directly by the institution and there are no pledges of assets as collateral. The main issuers are captive finance companies and bank-related finance companies. The former are subsidiaries of automobile and manufacturing companies that issue debt in order to finance their parent companies. In January 2007, captive finance companies held as liabilities $165 billion dollars in commercial paper. Some of the largest captive finance companies issuing financial commercial paper are those owned by General Motors, General Electric and Toyota (Kacperczyk and Schnabl, 2010, p. 31-34).

Lastly, corporate commercial paper is issued by non-financial businesses. In January 2007, outstanding debt in the form of corporate commercial paper was valued at $145 billion. Most issuers are in the largest size quintile of publicly traded corporations, General Electric and Coca-Cola being examples. Historically, these issuers use the proceeds from issuance to cover their short-term financing needs for working capital and inventory. For these firms, it is an important source of financing, representing about 30 percent of their current liabilities and 36 percent of their investment outlays (Kacperczyk and Schnabl, 2010, p.35).

Thus, having demonstrated the importance of this source of financing in the U.S., in order to be able to understand the movements in the costs of productions of firms, one must look into how the interest rates in the markets for commercial papers are determined. In the finance literature, there are two main theories that account for how the term structure of interest rates is defined by the market. The first is the market expectations hypothesis, which states that the shape of the yield curve depends on market participants' expectations of future interest rates. Short-term and long-term instruments are basically substitutes, so their interest rates are tied together. This is done compounding this year's interest rates with future expected rates in other to determine the yield in instruments of longer maturity. This, along with a liquidity preference theory, will give the yield curve its usual upward slope. The other theory is the segmented market hypothesis. It states that short and long term rates are determined independently, and since there is higher demand for short-term instruments, its yields will be lower.

There is a vast literature that tests for these hypotheses in different market segments. In the case of the market for commercial paper, Downing and Oliner (2007) test as the null hypothesis what they call generalized expectations hypothesis (GEH), which encompasses the traditional expectation hypothesis and takes account of interest risk, credit risk and limited liquidity, imposing the restriction that the compensation for the combined effects of these risks must remain constant over time. The authors used a database that consists of daily indexes constructed from the markets yields on nearly all commercial paper issued by non-financial US firms, beginning in January 1998 up until January 2005. Initially they conclude that GEH doesn't hold for the US market.

However, it is noticed that term premiums often jump up at year-end, and when these effects are accounted for, the null hypothesis is not rejected. A few explanations are offered, such as year-end window dressing by financial institutions and preference for liquidity during this time of the year. This result leads us to conclude that changes in the effective and the expected interest rates are passed on to market rates in a robust manner. Are these changes passed on to prices? Given that the companies that are being dealt with here are large companies that possess large market shares (therefore they are companies that would set prices in a way that is laid out in Kaleckian models such as the ones being used for this analysis of the cost-push channel), we would find this result to be an indication (anecdotal, at least) of the possible operation of this transmission mechanism.

4. Using a Stock-Flow Model for Further Inquiry

In the previous estimations, it can be pointed out that they do not take into account exchange rate pass-through effects, since the estimations are based on reduced forms taken from models of closed economies. To deal with this issue, we use a stock-flow model put forward in Godley and Lavoie (2007)[3], introducing additional equations to it in order to analyze the cost-push channel in light of an open economy. The importance of adding an external sector lies in the need to include the dynamics of the impacts of changes in the exchange rate on inflation due to increases in the interest rate.

According to Dos Santos (2006), stock-flow models are "ones in which the balance sheet dynamics of all assumed institutional sectors (given by sectoral saving flows, portfolio shifts, and capital gains) are explicitly and rigorously modeled (p. 542). These types of models have two advantages. Firstly, "the double entry bookkeeping in a transaction-flow matrix or SAM imposes numerous restrictions on the variables included in a model based upon it" (Taylor, 2008, 641). In other words, variables that otherwise would be treated in a particular model as exogenous can be found to actually be endogenous, for example[4].

Secondly, these models enable analysis in terms of stock-flow norms, or "magic ratios", as Taylor (2008) puts it. To realize the importance of this, consider the consumption function put forward by Godley and Lavoie (2007, p. 66):

$$C = \alpha_1 . YD + \alpha_2 H_{h-1} \qquad [52]$$

where C is consumption, YD is disposable income and H_{h-1} is wealth accumulated over the past. Change in wealth is given by:

$$\Delta H_h = H_h - H_{h-1} = YD - C \qquad [53]$$

this can be rewritten as:

$$C = YD - \Delta H_h \qquad [54]$$

[3] In order to somewhat uniformize the notation used throughout the dissertation, some changes were made to the original notation

[4] An instance of this can be found in Taylor (2004).

Equating (52) and (54), we have:

$$\Delta H_h = (1-\alpha_1).YD - \alpha_2.H_{h-1} \qquad [55]$$

from which we obtain:

$$\Delta H_h = \alpha_2(\alpha_3.YD - H_{h-1}) \qquad [56]$$

where $\alpha_3 = \dfrac{(1-\alpha_1)}{\alpha_2}$.

According to Godley and Lavoie (2007, p. 75), equation (56):

> is a partial adjustment function. It says that wealth is being accumulated at a certain rate, determined by the partial adjustment parameter α_2, towards some desired proportion α_3 of disposable income. Thus households are saving, wishing, we may suppose, to end the period with some well defined quantity of accumulated wealth. (…) The α_3 coefficient is the *stock-flow norm* of households. It is the assumed wealth to income target ratio which is implicitly embedded into the so-called Modigliani consumption function proposed above. Thus whenever the target level of wealth is higher than the realized level, households save, in an attempt to reach their target.

The importance of this lies in the fact that it is an answer to a criticism made by authors such as Friedman and Lucas to Keynesian models. These models portrayed consumption as depending only on current income, without taking into account possible future changes in its flows. In Friedman's permanent income model, an attempt was made to introduce "the idea that people are actually concerned with their income over several periods when making a decision about current-period consumption" (Hartley, 1997, p.5). A stock-flow norm is a device that incorporates this idea in a satisfactory way, without the need to make use of representative agents or rational expectations. This is possible by the fact that these models keep track of stocks, and therefore are able to gauge the effect changes in these stocks have in the decisions of agents. As Davis, quoted by Dos Santos (2006), puts it, "the movements of these stocks through time may change (considerably) the short run equilibrium itself, and the associated prices and flows. Omission of these stocks from a model may therefore lead to false predictions of the consequences of policy changes or of exogenous shocks to the system" (Dos Santos, 2006, p. 542). The gist of the Lucas critique consists exactly of these false predictions.

Conclusions taken from these models, however, should be taken with a grain of salt. They often contain many behavioral equations, which can make the interpretation of its results somewhat difficult. Besides, the simulation of the model using strictly imputed data and parameter values is not the best way to evaluate empirically how economy A or B works, since in order to pursue this goal the use of real data is imperative. And finally, they do not have the intention of proposing innovations in terms of theory, since the behavioral equations used are well known in the Keynesian literature. Nevertheless, these models can be very useful in the sense that they can unveil new possible theoretical relations, many times due to the fact that they keep track of stocks and the effect they might have on the overall results. Not to mention the fact that they attempt to realistically model a monetary production economy, a long sought-after goal in the Keynesian tradition.

4.1 A model of an open economy with banks and government

The model to be developed is closely based on the INSOUT model that can be found in Godley and Lavoie (2007). Concerning the object of study of this dissertation, in this model banks grant loans to firms that wish to keep inventories; therefore the cost of keeping inventories (consequently the cost of production) is directly related to the interest rate. Households accumulate wealth, which they can allocate in different assets. This means that the interest rate will also have an effect on that part of consumption which is a function of wealth. The main difference to the original model is that an external sector is added, in order to account for the effects of the exchange rate on unit costs, since it is assumed that imported inputs are needed for production. Variables denoted by capital letters represent nominal values.

4.1.1 Producing firms

Real production is given by:

$$y = s^e + (in^e - in_{-1}) \qquad [57]$$

where s^e is expected sales, in^e is expected inventories and in_{-1} is inventories in the prior period.

Expected sales will be a weighted average of expected and realized sales in the previous period:

$$s^e = \beta.s_{-1} + (1-\beta).s^e{}_{-1} \qquad [58]$$

Employment is given by:

$$N = \frac{y}{pr} \qquad [59]$$

where pr denotes productivity.

The wage bill is given by:

$$WB = N.W \qquad [60]$$

with W being the wage rate.

Unit costs are given by:

$$UC = \frac{WB + IM}{y} \qquad [61]$$

where IM being nominal imports. The amount to be imported will be shown later on.

Given that realized sales will diverge from production, inventories in will play an important role. Firms will have a target level of inventories, in^T which will depend on expected sales and the interest rate on loans, σ^T ,charged by the banks in order to finance the holding of stocks of production:

$$in^T = \sigma^T.s^e \qquad [62]$$

$$\sigma^T = \sigma_0 - \sigma_1.r_l \qquad [63]$$

The short-run planned level of inventories is:

$$in^e = in_{-1} + \gamma.(in^T - in_{-1}) \qquad [64]$$

The price level is given by a mark-up over what is called normal historic unit costs and a sales tax:

$$p = (1+\tau).(1+\varphi).NHUC \qquad [65]$$

with NHUC being:

$$NHUC = (1-\sigma^T).UC + \sigma^T.(1+r_l).UC_{-1} \qquad [66]$$

Now on to definitions related to the firm. Actual sales are given by:

$$s = c + g + x \qquad [67]$$

with g being actual government expenditures and x being actual exports. Nominal sales therefore are:

$$S = p.(c+g) + p_x.x \qquad [68]$$

Realized changes in inventories are given by the discrepancy between sales and production:

$$in - in_{-1} = y - s \qquad [69]$$

Realized inventories are valued at current unit cost:

$$IN = in.UC \qquad [70]$$

Banks grant loans as demanded by firms:

$$L_d = IN \qquad [71]$$

Profits are given by (inventories are included for accounting purposes):

$$F_f = S - T - WB + \Delta IN - r_l.IN_{-1} \qquad [72]$$

Finally, inflation is determined as usual:

$$\pi = \frac{(p - p_{-1})}{p_{-1}} \qquad [73]$$

4.1.2 Households

Household income depends on wages, profits and interest receipts from different assets (more will be said about these later on):

$$YD_r = F + WB + r_{m-1}.M2_{h-1} + r_{b-1}.B_{hh-1} + BL_{h-1} \qquad [74]$$

with YD_r being regular nominal income, r_{m-1} the interest rate being accrued on time deposits $M2_{h-1}$, r_{b-1} the interest rate on government bills held by households B_{hh-1} and

BL_{h-1} stands for long-term bonds held by households, with these bonds being perpetuities that pay a dollar to its owner each period. As a simplification, we assume that only households hold bonds. We assume that bills have the price of one unit, and their prices do not change during each period. Bonds do incur in price changes, and capital gains derived from them are given by:

$$CG = \Delta p_{bl}.BL_{h-1} \quad [75]$$

The Haig-Simons definition of nominal income is given by the sum of regular nominal income and capital gains:

$$YD_{hs} = YD_r + CG \quad [76]$$

Total profits are given by the sum of firm and bank profits:

$$F = F_f + F_b \quad [77]$$

The change in realized nominal wealth is given by the income that is not spent on consumption:

$$\Delta V = YD_{hs} - C \quad [78]$$

Realized wealth net of cash is:

$$V_{nc} = V - H_{hh} \quad [79]$$

with realized actual wealth being:

$$v = \frac{V}{p} \quad [80]$$

Realized actual regular real disposable income is:

$$yd_r = \frac{YD_r}{p} - \pi.\frac{V_{-1}}{p} \quad [81]$$

with realized actual Haig-Simons income being:

$$y_{hs} = \frac{YD_r}{p} - \pi.\frac{V_{-1}}{p} + \Delta p_{bL}.\frac{BL_{h-1}}{p} \quad [82]$$

The consumption function will include actual expected regular income (defined below) and past wealth, which will enable consumers to follow the stock-flow norm shown in the beginning of this chapter:

$$c = \alpha_0 + \alpha_1.yd_r^e + \alpha_2.v_{-1} \quad [83]$$

$$yd_r^e = \varepsilon.yd_{r-1} + (1-\varepsilon)yd_{r-1}^e$$

The money value of consumption is:

$$C = p.c \quad [84]$$

And expected nominal regular disposable income is given by:

$$YD_r^e = p.yd_r^e + \pi.\frac{V_{-1}}{p} \qquad [85]$$

Household's demand for cash depends on a fraction of their consumption:

$$H_{hd} = \lambda_c.C \qquad [86]$$

Expected nominal wealth will be important in the household's decision concerning the allocation of its wealth. It will be defined as the wealth carried over from the previous period plus expected savings in this period:

$$V^e = V_{-1} + (YD_r^e - C) \qquad [87]$$

Expected nominal wealth net of cash is defined as:

$$V_{nc}^e = V^e - H_{hd} \qquad [88]$$

Households will allocate their expected nominal wealth net of cash on different assets: checking deposit accounts (which do not pay any interest), time deposit accounts, government bills and government bonds. The share of wealth allocated among these assets will depend on the interest rates associated to them, and also on the regular income to net wealth ratio:

$$\frac{M1_d}{V_{nc}^e} = \lambda_{10} + \lambda_{12}.r_m + \lambda_{13}.r_b + \lambda_{14}.ERr_{bL} + \lambda_{15}.\frac{YD_r^e}{V_{nc}^e} \qquad [89]$$

$$\frac{M2_d}{V_{nc}^e} = \lambda_{20} + \lambda_{22}.r_m + \lambda_{23}.r_b + \lambda_{24}.ERr_{bL} + \lambda_{25}.\frac{YD_r^e}{V_{nc}^e} \qquad [90]$$

$$\frac{B_{hd}}{V_{nc}^e} = \lambda_{30} + \lambda_{32}.r_m + \lambda_{33}.r_b + \lambda_{34}.ERr_{bL} + \lambda_{35}.\frac{YD_r^e}{V_{nc}^e} \qquad [91]$$

$$\frac{p_{bL}.BL_d}{V_{nc}^e} = \lambda_{40} + \lambda_{42}.r_m + \lambda_{43}.r_b + \lambda_{44}.ERr_{bL} + \lambda_{45}.\frac{YD_r^e}{V_{nc}^e} \qquad [92]$$

with ERr_{bL} being the expected rate of return on bonds, defined as:

$$ERr_{bL} = r_{bL} + \frac{p_{bL}^e - p_{bL}}{p_{bL}} \qquad [93]$$

Restrictions on the parameters of the portfolio equations must be put in place so that the sum of levels held of each asset, and the sum of changes in portfolio, will assume consistent values: these restrictions are what are called adding-up constraints. The first restriction is related to the constant shares of assets in net wealth:

$$\lambda_{10} + \lambda_{20} + \lambda_{30} + \lambda_{40} = 1 \quad [94]$$

The next restrictions imply that any changes in the share of some asset in net wealth due to changes on a particular interest rate (or changes in the nominal regular income to net wealth ratio) must be balanced out by changes in the shares of other assets:

$$\lambda_{15} + \lambda_{25} + \lambda_{35} + \lambda_{45} = 0 \quad [95]$$

$$\lambda_{11} + \lambda_{21} + \lambda_{31} + \lambda_{41} = 0 \quad [96]$$

$$\lambda_{12} + \lambda_{22} + \lambda_{32} + \lambda_{42} = 0 \quad [97]$$

$$\lambda_{13} + \lambda_{23} + \lambda_{33} + \lambda_{43} = 0 \quad [98]$$

$$\lambda_{14} + \lambda_{24} + \lambda_{34} + \lambda_{44} = 0 \quad [99]$$

$$\lambda_{11} = -(\lambda_{12} + \lambda_{13} + \lambda_{14}) \quad [100]$$

$$\lambda_{22} = -(\lambda_{21} + \lambda_{23} + \lambda_{24}) \quad [101]$$

$$\lambda_{33} = -(\lambda_{31} + \lambda_{32} + \lambda_{34}) \quad [102]$$

$$\lambda_{44} = -(\lambda_{41} + \lambda_{42} + \lambda_{43}) \quad [103]$$

4.1.3 The government sector and the central bank

Total taxes are determined by an indirect tax that is levied on the ex-tax value of sales at a proportional rate τ :

$$T = \tau.(S - T) = S.\frac{\tau}{(1+\tau)} \quad [104]$$

The government's deficit, which here is called public sector borrowing requirement, is the difference between all outlays (included interest payments) and all revenue, included the profits of the central bank:

$$PSBR = G + r_{b-1}.B_{s-1} + BL_{s-1} - (T + F_{cb}) \quad [105]$$

Nominal government spending, set exogenously, is defined as:

$$G = p.g \quad [106]$$

Bonds are supplied on demand:

$$BL_s = BL_d \quad [107]$$

this means that the government pegs the long-term interest rate:

$$r_{bL} = \bar{r}_{bL} \quad [108]$$

and that part of the public deficit that is not financed by the issue of bonds is financed by the issue of bills:

$$B_s = B_{s-1} + PSBR - \Delta(BL_s).p_{bL} \qquad [109]$$

Since bonds are perpetuities that pay a dollar as interest each period, then:

$$p_{bL} = \frac{1}{r_{bL}} \qquad [110]$$

Moving on to the central bank's equations, there is balance between its assets and liabilities if the total amount of high-powered money it supplies is equal to the sum of its advances to banks plus the amount of government bills it holds:

$$H_s = B_{cb} + A_s \qquad [111]$$

The total of supply of cash has two components, the supply to banks and the supply to households:

$$H_{bs} = H_s - H_{hs} \qquad [112]$$

The central bank is the residual purchaser of bills, that is, it buys any bill that is not demanded by the banks or the households:

$$B_{cb} = B_s - B_{hh} - B_{bd} \qquad [113]$$

this again means that the central bank is able to enforce the short-term interest rate it sees fit:

$$r_b = \bar{r}_b \qquad [114]$$

Advances to banks are supplied on demand:

$$A_s = A_d \qquad [115]$$

and the rate of interest on these advances is the same as the rate on bills:

$$r_a = r_b \qquad [116]$$

The central bank does not incur in any costs, so its profits are the sum of its interest incomes:

$$F_{cb} = r_{b-1}.B_{cb-1} + r_{a-1}.A_{s-1} \qquad [117]$$

4.1.4 Commercial Banks

In this model, banks hold households' deposits and grant loans to firms. Cash, deposits and loans are all supplied on demand:

$$H_{hs} = H_{hd} \quad [118]$$

$$M1_s = M1_d \quad [119]$$

$$M2_s = M2_d \quad [120]$$

$$L_s = L_d \quad [121]$$

Banks are required to hold an amount of reserves that is a proportion of its liabilities (checking and time deposits):

$$H_{bd} = \rho_1.M1_s + \rho_2.M2_s \quad [122]$$

The amount of bills held by banks will be used as an adjustment variable to absorb any fluctuation in money deposits or in loans. Banks will have a minimum target for the amount of bills they hold. This target is called net bank liquidity ratio. There will be times when the fluctuations in the assets and liabilities of banks are such that bills will fall below the minimum level targeted by banks. When this happens, banks will make use of advances granted by the central bank.

Since all other elements in the banks' balance sheet are determined, we can define the amount of bills held as a function of these elements. However, at first we will define what is called the notional stock of bills held by banks, which does not include the amount of bills acquired via central bank advances:

$$B_{bdN} = M1_s + M2_s - L_s - H_{bd} \quad [123]$$

The target for bills mentioned above is called net bank liquidity ratio, and is defined as:

$$BLR_N = \frac{B_{bdN}}{M1_s + M2_s} \quad [124]$$

When the notional stock of bills falls below the net bank liquidity ratio, this triggers the demand for advances from the central bank in the value of:

$$A_d = \{bot.(M1_s + M2_s) - B_{bdN}\}.z_4 \quad [125]$$

$$z_4 = 1 \text{ if } BLR_N < bot \quad [126]$$

Given the advances taken by banks, the actual amount of bills they hold is:

$$B_{bd} = A_d + M1_s + M2_s - L_s - H_{bd} \quad [127]$$

and the actual bank liquidity ratio is:

$$BLR = \frac{B_{bd}}{M1_s + M2_s} \quad [128]$$

Deposit rates move with bill rates, and also depend on whether the net bank liquidity ratio is within its target range:

$$r_m = r_{m-1} + \Delta r_m + \xi.\Delta r_b \qquad [129]$$

$$\Delta r_m = \xi_m (z_4 - z_5) \qquad [130]$$

$$z_4 = 1 \text{ if } BLR_{N-1} < bot \qquad [131]$$

$$z_5 = 1 \text{ if } BLR_{N-1} > top \qquad [132]$$

This mechanism can be described as follows: whenever BLR falls below its target range, banks will increase their deposit rates, in order to lower their indebtedness towards the central bank. They will achieve this by attracting more deposits (since households will give up their bills in order to earn higher rates), with which they can purchase more bills or pay back their debts. Likewise, if BLR is above its target range, banks will lower deposit rates and get rid of bills. This will be done because banks will not want to hold more bills than necessary, since it is more profitable to lend to the private sector.

Profits of banks are defined as:

$$F_b = r_{l-1}.L_{s-1} + r_{b-1}.B_{bd-1} - r_{m-1}.M2_{s-1} - r_{a-1}.A_{d-1} \qquad [133]$$

Movements of loan rates are given by:

$$r_l = r_{l-1} + \Delta r_l + \Delta r_b \qquad [134]$$

$$\Delta r_l = \xi_l (z_6 - z_7) \qquad [135]$$

$$z_6 = 1 \text{ if } BPM < botpm \qquad [136]$$

$$z_7 = 1 \text{ if } BPM > toppm \qquad [137]$$

$$BPM = \frac{(F_b + F_{b-1})}{\{M1_{s-1} + M1_{s-2} + M2_{s-1} + M2_{s-2}\}} \qquad [138]$$

Loan rates move along with the Treasury bill rate. Also, they move relative to the bill rate depending on the value taken by the bank profit margin, which is a mean index over two periods of the ratio of banks' profits relative to the stock of deposits of the previous period. This mean over two periods is used in order to prevent excessive fluctuations in the lending rate. Whenever BPM is below a certain threshold, banks raise lending rates in order to assure a certain level of profitability. They will lower lending rates when profits are excessive for fear of government legislation or public outrage.

4.1.5 External sector

As a simplification, the demand for imports comes only from firms. This depends directly on their level of production:

$$im = \eta . y \qquad [139]$$

Real exports are related to the level of world income and the actual exchange rate:

$$x = \mu_1 . y_f + \mu_2 . xr . \frac{p_f}{p} \qquad [140]$$

with p_f being the price level abroad. As a simplification, prices of imports and exports in local currency depend on the real exchange rate:

$$p_{im} = v_{0im} + v_{1im} . xr . \frac{p_f}{p} \qquad [141]$$

$$p_x = v_{0x} + v_{1x} . xr . \frac{p_f}{p} \qquad [142]$$

Thus nominal imports and nominal exports can be defined as:

$$IM = p_{im} . im \qquad [143]$$

$$X = p_x . x \qquad [144]$$

The capital account balance is determined by the interest rate differential:

$$kab = \kappa (r_b - r_{bf}) \qquad [145]$$

and changes in the exchange rate depend on the flow of hard currency in and out of the country:

$$xr = xr_{-1} - psi.(X - IM + kab) \qquad [146]$$

4.1.6 Wage bargaining and the hidden equation

Workers have an actual wage target in mind, which will depend on productivity and as well as on the employment rate:

$$\omega^T = (\frac{W}{p})^T = \Omega_0 + \Omega_1 + \Omega_2 .(\frac{N}{N_{fe}}) \qquad [147]$$

Wage inflation will depend on how wide is the discrepancy between the target actual wage and actual wage of the previous period:

$$W = W_{-1}(1+\Omega_3.(\omega^T_{-1} - \frac{W_{-1}}{p_{-1}}) \quad [148]$$

The definition of gross domestic product is as follows:

$$Y = p.s + UC.\Delta in \quad [149]$$

And finally, even though there are separate and unrelated equations for supply (equation 112) and demand for reserves (122), the model's consistency assures that there is balance in the reserves market:

$$H_{bs} = H_{bd} \quad [150]$$

4.2 Interest rate effects on inflation

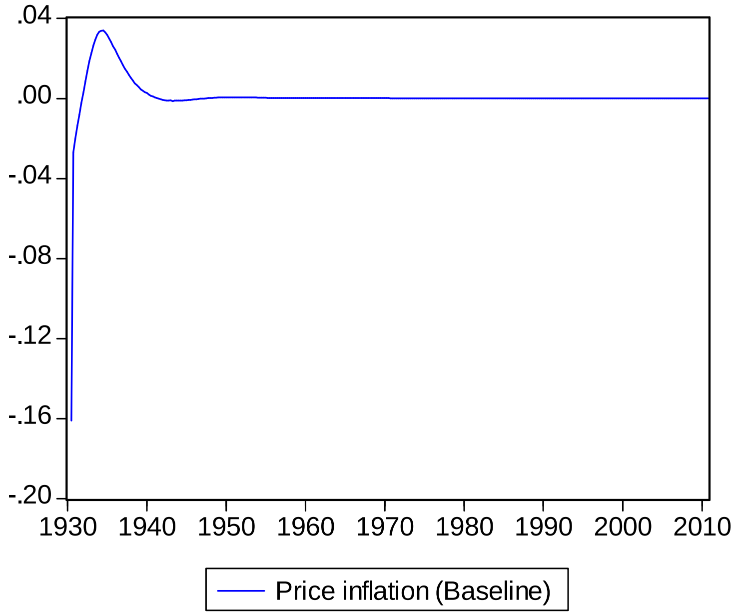
The parameter values used are listed below:

Table 12: Parameter Values

$\alpha_1 = 0.95$	$\lambda_{30} = 0.47311$	$\varphi = 0.1$	$\omega_2 = 1.5$
$\alpha_2 = 0.05$	$\lambda_{31} = 40$	$\rho_1 = 0.1$	$\omega_3 = 0.1$
$\beta = 0.5$	$\lambda_{32} = -20$	$\rho_2 = 0.1$	$\eta = 0.05$
bot=0.02	$\lambda_{33} = 40$	$\sigma_0 = 0.3612$	$\mu_1 = 1$
botpm=0.02	$\lambda_{34} = -20$	$\sigma_1 = 3$	$\mu_2 = 0.7$
$\varepsilon = 0.5$	$\lambda_{35} = -0.06$	$\tau = 0.3$	$\psi = 0.00125$
$\gamma = 0.5$	$\lambda_{40} = 0.17515$	top=0.04	$\kappa = 300$
$\lambda_{20} = 0.52245$	$\lambda_{41} = 20$	toppm=0.05	$\nu_{0m} = 5$
$\lambda_{21} = 20$	$\lambda_{42} = -20$	$\xi_b = 0.9$	$\nu_{0x} = 5$
$\lambda_{22} = 40$	$\lambda_{43} = -20$	$\xi_l = 0.002$	$\nu_{1m} = 0.01$
$\lambda_{23} = -20$	$\lambda_{44} = 40$	$\xi_m = 0.002$	$\nu_{1x} - 0.5$
$\lambda_{24} = -20$	$\lambda_{45} = -0.06$	$\omega_0 = -0.32549$	
$\lambda_{25} = -0.06$	$\lambda_c = 0.1$	$\omega_1 = 1$	

The simulations are performed supposing that each period of production is equivalent to a quarter of the year. As we are not using actual data, the time frame of the simulations is not crucial. We start simulations on year 1930, in order to allow the model to reach something similar to a steady-state around year 1970. This can be seen in the behavior of price inflation, for instance:

Graph 3: Price inflation in the baseline scenario



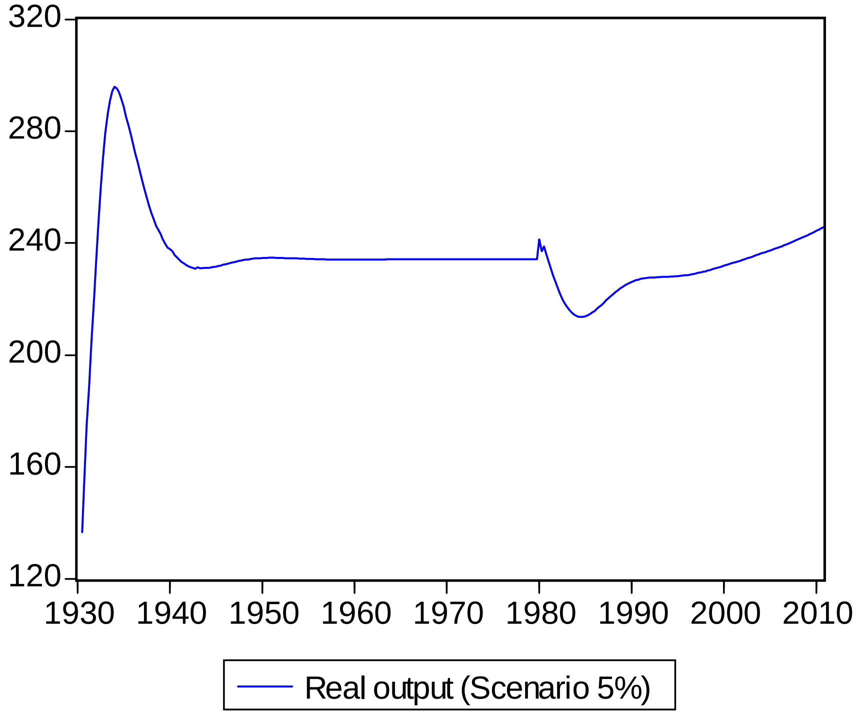
In this baseline case, the interest rate is at 4%. We will perform experiments where we will increase the interest rate in different magnitudes, all of them happening in the first quarter of 1980. First off, we impose a 1% increase, to 5%:

Graph 4: Price inflation in Scenario 5%

As stated by traditional monetary theory, the increase in the interest rate leads to a decrease in inflation until the model reaches its steady-state again.

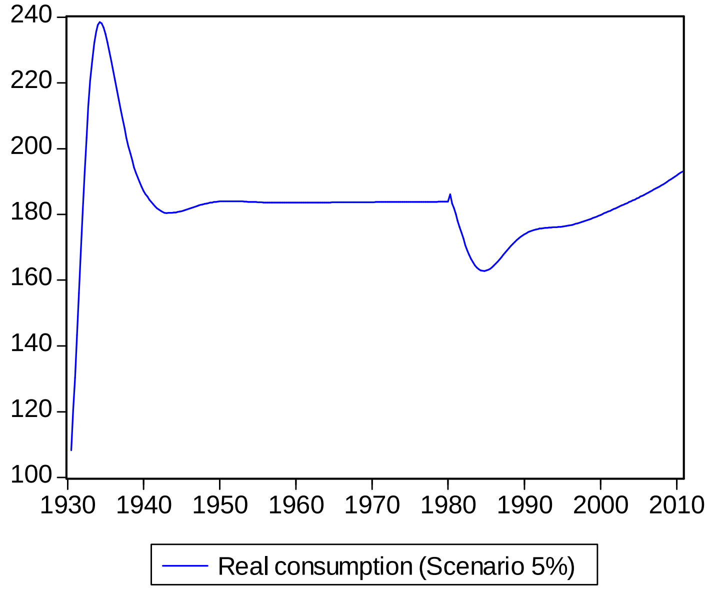
Real output suffers a sharp decrease, followed by a slow recovery until it returns to its steady-state level:

Graph 5: Real output in Scenario 5%

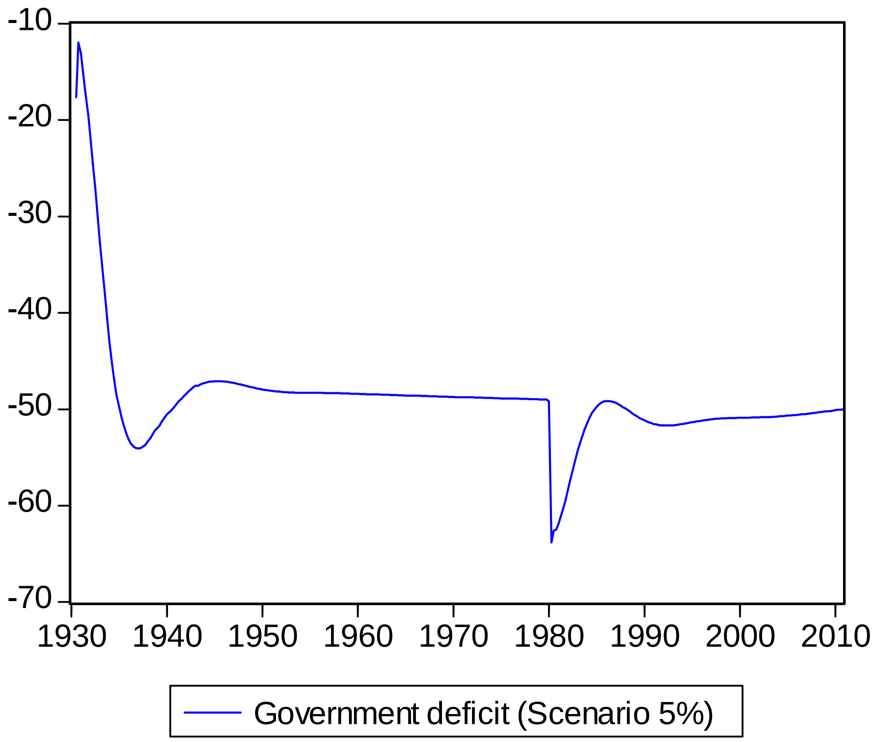


This decrease is related to a fall in consumption and an increase in the government's surplus:

Graph 6: Real Consumption in Scenario 5%



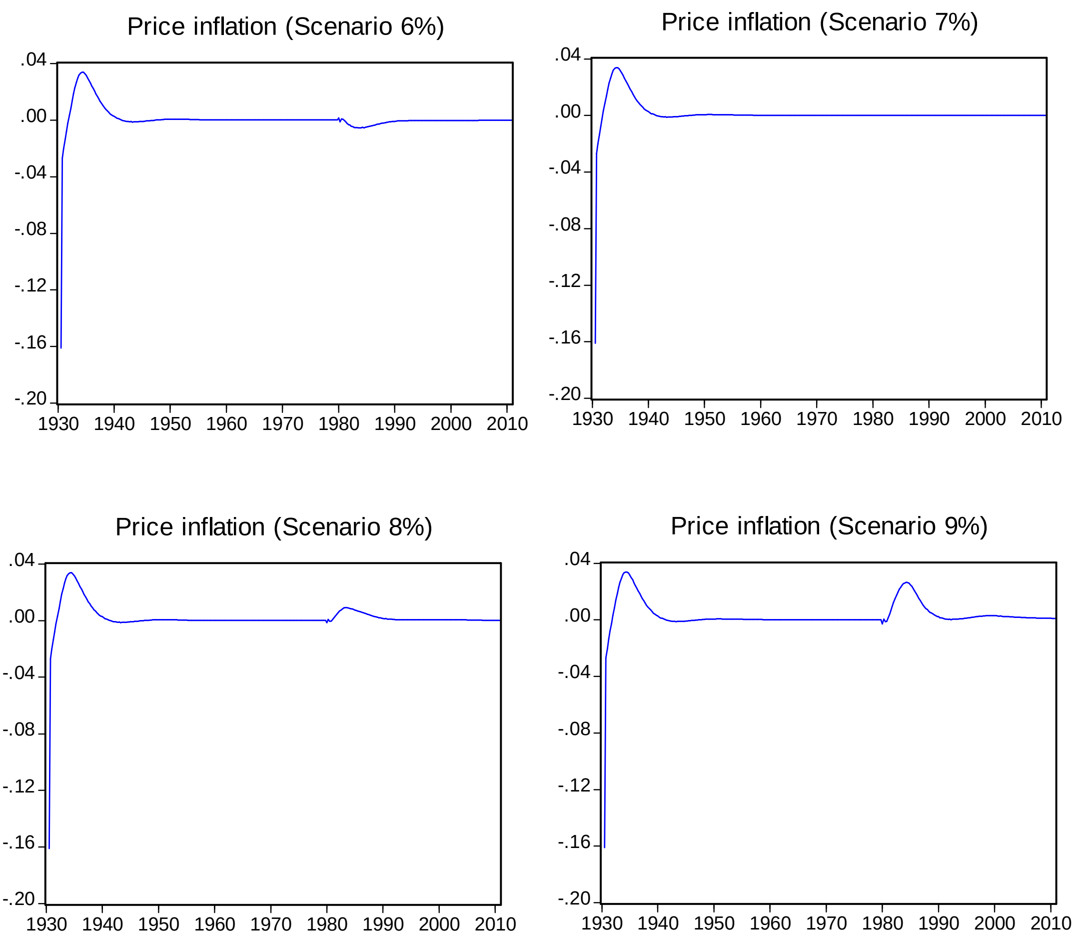
Graph 7: Government deficit in Scenario 5%



It is interesting to note that so far price inflation and real output follow the same trends after an increase in interest rates as documented in the VAR literature, with Christiano, Eichenbaum and Evans (1999) being a representative example: price inflation falls slightly, with real output decreasing further than price inflation and exhibiting a hump-shaped trajectory.

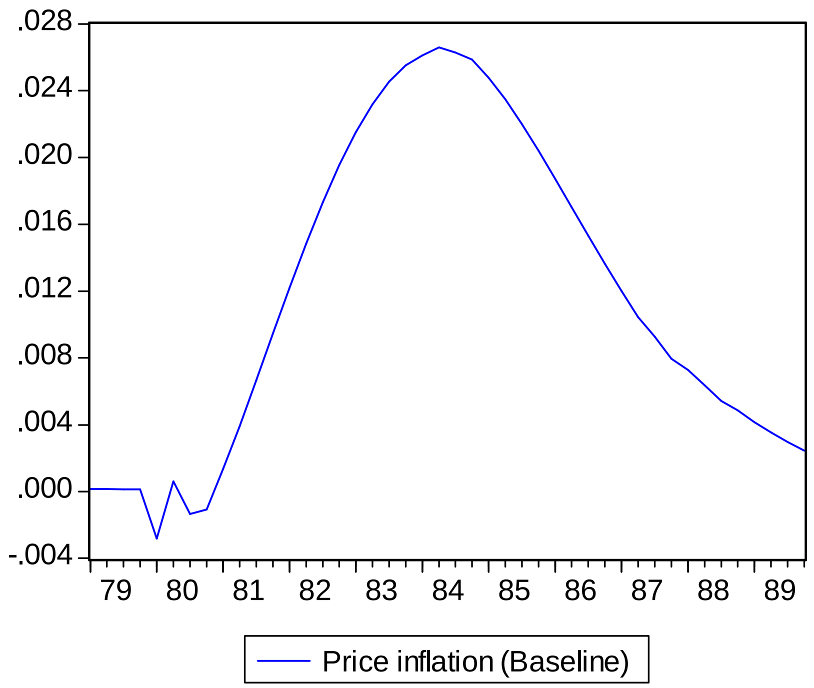
However, the fall in price inflation is very small. This could be explained by the operation of a cost-push channel of monetary policy. Indeed, as we raise the interest rate to higher levels, we can observe a reversal in the behavior of price inflation. As the interest rate increase to 6%, then 7%, decreases in price inflation become smaller. When the interest rate reaches 8% and 9%, price inflation assumes the behavior associated with the cost-push channel in the VAR literature: a hump-shaped trajectory, with an increase followed by a decrease.

Graph 8: Price inflation in different scenarios



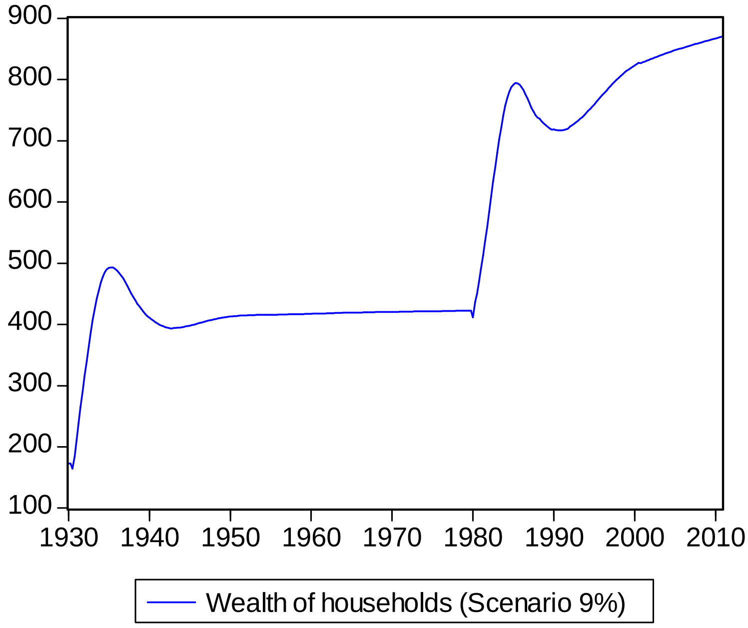
As in the regression results, the rates of inflation associated with these increases are not that high. The highest rate of inflation observed in the Scenario 9% is 2,7% in a quarter (second quarter of 1984), which is not that high when considering that we are analyzing a 5% spike in the interest rate. Since we are not using real data, analysis of the time dynamics of changes in the inflation rate are not easily done. What can be said is that this peak in inflation occurs after 18 periods of production.

Graph 9: Price inflation in Scenario 9% in the period 79-89



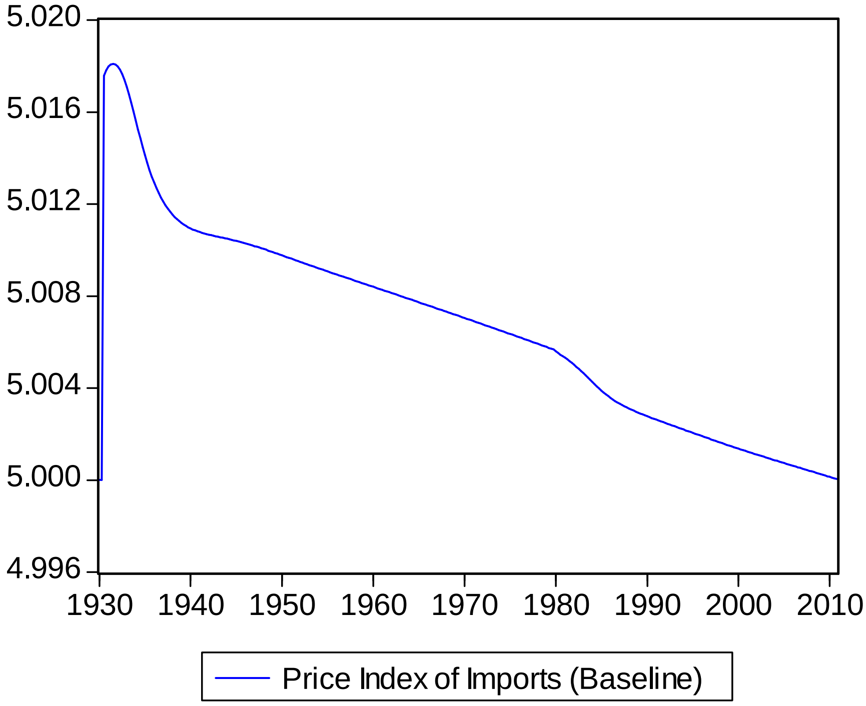
Taking Scenario 9% for analysis, it can be seen that this spike in the inflation rate has two sources. One is the increase in household's wealth, due to an increase in interest payments:

Graph 10: Wealth of households in Scenario 9%

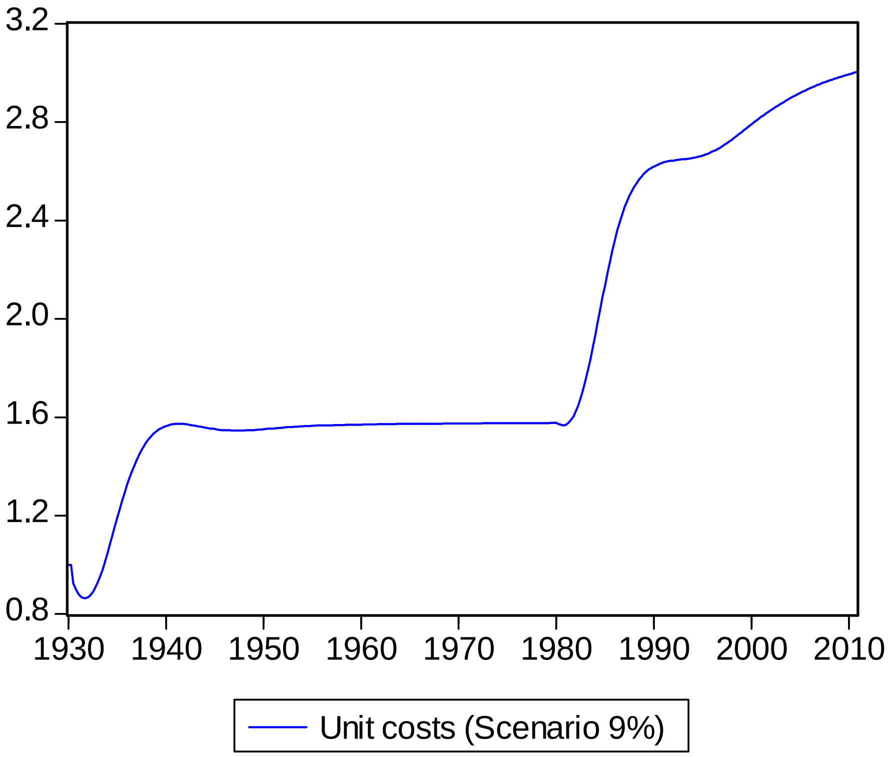


The other source is the increase in unit costs (even though imports are cheaper):

Graph 11: Price index of imports in Scenario 9%



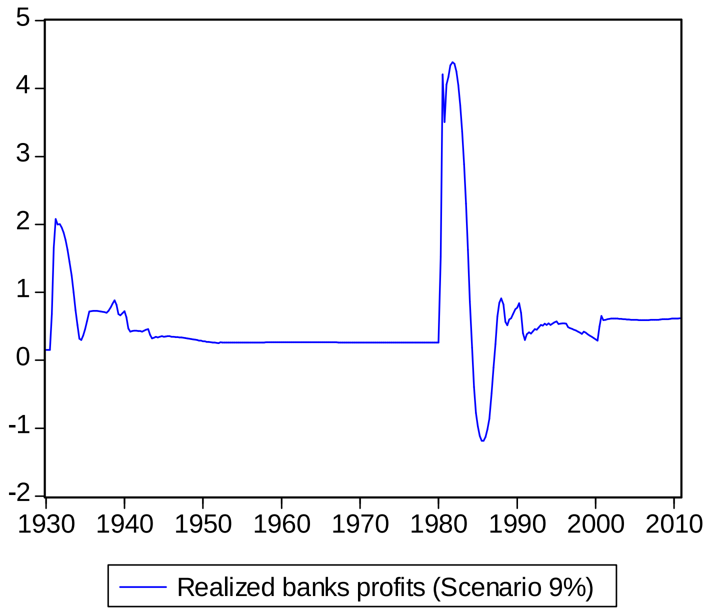
Graph 12: Unit costs in Scenario 9%



As the interest rate increases, it becomes more expensive for firms to hold inventories, since in order to do that they have to borrow from banks. Since pricing is a mark-up over unit costs that include the cost of inventories, this will result in higher prices. From the banks point of view, this feature of the model can be seen by the spikes in the interest rate on loan and bank profits:

Graph 13: Interest rate on loans in Scenario 9%

Graph 14: Realized banks profits in Scenario 9%



4.3 Interpreting the results

The conclusions arrived at by these simulations should be framed in a proper perspective. The fact that neither calibrated parameters nor actual data are used prevents us from making empirical assertions about the economy. Nevertheless, the goal of this exercise was to look into theoretical chains of causation and mechanisms that might lead to the emergence of a perverse effect of monetary policy on inflation, if these chains of causation and mechanisms are sufficiently strong. This last condition is an empirical matter, which should be dealt with the use of econometrics, and this attempt was made in chapter 4. Having said that, we believe the goal was achieved. Evidently, this goal is the same the models presented in chapter 3 had, but chapter 4 brings two new elements. The use of a model of an open economy brings into light the dynamics of changes in inflation due to changes in the exchange rate when the interest rate is increased. Besides that, the model was able to unveil two channels through which the interest rate might affect inflation positively. Firstly, increases in the interest rate increase the inventory- keeping cost for firms. This channel was already within the model presented in section 3.4. And secondly, increases in the interest rate might lead to a perverse demand effect, where higher interest payments to households might lead to greater spending, nullifying the intended contractionary effects of the policy. Even though this channel may not be qualified as cost-push *per se* but as a wealth effect, it could play an important role.

Two objections to this channel might be raised. Firstly, the recipients of these interest payments would be households (or even firms) with a much lower propensity to consume than households that, by nature of their low earnings, save very little. This is one of the main ideas found in part of the literature that is based on the concept of “financialization”. The other objection is that this model assumes away capital. This means that the negative effect of increases of the interest rate on investment, which would lower aggregate demand, is also assumed away. Nevertheless, this a discussion that presents itself when looking at the results generated by the simulations.

5. Concluding Remarks

This dissertation attempted to shed light on a concept known in the literature as the cost-push channel of monetary, whereby increases in the interest rate might lead to effects opposite to that intended by the policy-maker (at least temporarily). After reviewing the literature, estimation of four different specifications using Brazilian data were innovatively performed. These estimations found that, while there was no evidence of the cost-push channel when the usual specification in the literature was used (the one which included the level of the interest rate), the other three specifications found evidence in favor of the cost-push channel. Thus, in our understanding, the existing empirical literature may have underestimated the relevance of the cost-push channel of monetary transmission.

Additionally, a stock-flow model of an open economy with banks and government was simulated. There we found that increases in the interest rate might affect inflation positively through two channels: increases in the cost to firms of keeping inventories; higher interest payments that would lead to greater spending by households. Even though how these results translate to real economies is an empirical matter, these results are consistent with the idea of a cost-push channel.

In conclusion, the idea that there might be a cost-push channel operating in economies should give food for thought for policy-makers. It is a reasonably well-established fact that increases in the interest rate will bring down inflation (of course, when inflation does not involve issues of indexation or the like, as was the case in Brazil in the last decades of the past century). However , how effective this policy is, in the sense of how much production and employment is lost in order to achieve a certain rate of disinflation, and how long it takes to be successful are still up for debate. In this sense, the existence of a cost-push channel could represent an obstacle to the idea that the best way to bring down inflation is via the use of the interest rate, at least by itself. However, it should be clear that this dissertation did not intend to discuss implications at the level of monetary policy, at least *a priori*.

References

BARTH, Marvin; RAMEY, Valerie. *"The cost channel of monetary transmission"*, *in*: BERNANKE, Ben e*t* al (Org.). **NBER Macroeconomics Annual 2001**, Cambridge, MIT Press, 2001

BUENO, Rodrigo. L. S. *Did the Taylor Rule stabilize inflation in Brazil? In*: **2008 Annual Meeting of the Latin American and Caribbean Economics Association (LACEA)**, 2008, Rio de Janeiro.

CLARÍDA, Richard; GALÍ, Jordí; GERTLER, Mark. *Monetary policy rules and macroeconomic stability: Evidence and some theory.* **Quarterly Journal of Economics,** v**.** 115, n. 1, p. 147-80, 2000.

CYSNE, Rubens. P. "*Is there a price puzzle in Brazil? An application of bias-corrected bootstrap,* **Ensaios Econômicos 577, Fundação Getúlio Vargas**, Rio de Janeiro, 2004

CASTELNUOVO, Efrem; SURICO, Paolo. *The price puzzle: fact or artefact?*, **Working Paper no. 288, Bank of England**, January, 2006

CHOWDHURY, Ibrahim; HOFFMANN, Mathias; SCHABERT, Andreas. *Inflation dynamics and the cost channel of monetary transmission*, **European Economic Review**, v. 50, p. 995-1016, 2006

CHRISTIANO, Lawrence; EICHENBAUM, Martin; EVANS, Charles. *Monetary policy shocks: what have we learned and to what end?* in: TAYLOR, J.B.; WOODFORD. Michael, **Handbook of Macroeconomics,** vol. 1**,** Elsevier, 1999

DOS SANTOS, Claudio H. *Keynesian theorizing during hard times: stock-flow consistent models as an unexplored frontier of Keynesian macroeconomics*, **Cambridge Journal of Economics**, v. 30, p. 541-565, 2006

DOWNING, Chris; OLINER, Stephen. *The term structure of commercial paper rates*, **Journal of Financial Economics**, v. 83, p. 59-86, 2007

GAIOTTI, Eugenio; SECCHI, Alessandro. *Is there a cost channel of monetary policy transmission? An investigation into the pricing behavior of 2,000 firms*, **Journal of Money, Credit and Banking**, v. 38, p. 2013-2037, 2006.

GIORDANI, Paolo. *An Alternative Explanation of the Price Puzzle*. **Journal of Monetary Economics**, v. 51, p. 1271-1296, 2004

GODLEY, Wynne; LAVOIE, Marc. *Monetary Economics – An Integrated Approach to Credit, Money, Income, Production and Wealth*. Palgrave MacMillan, 2007

HANSON, Michael S. *The price puzzle reconsidered*, **Journal of Monetary Economics**, v. 51, p. 1385-1413, 2004

HARTLEY, James E. **The Representative Agent in Macroeconomics**. Routledge, 1997

HARVEY, Andrew. C. **Forecasting, structural time series and the Kalman filter**. Cambridge: Cambridge University Press, 1989.

KACPERCZYK, Marcin; SCHNABL, Phillip. *When safe proved risky: commercial paper during the financial crisis of 2007-2009*, **Journal of Economic Perspectives**, v. 24, p. 29-50, 2010

LAVOIE, Marc. **Foundations of Post-Keynesian Economic Analysis**. Aldershot: Edward Elgar, 1992.

LEE, Frederic. **Post-Keynesian Pricing Theory**. Cambridge: Cambridge University Press, 1998.

LIMA, Gilberto Tadeu; SETTERFIELD, Mark. *Pricing Behavior and the Cost-Push Channel of Monetary Policy*, **Review of Political Economy**, v.22, p. 19-40, 2010

LUPORINI, Viviane. *The monetary transmission mechanism in Brazil: evidence from a VAR analysis*, **Estudos Econômicos**, v. 38, n. 1, p. 7-30, 2008

PEERSMAN, Gert. *What caused the early millennium slowdown? Evidence based on vector autoregressions*, **Journal of Applied Econometrics**, v. 20, p. 185-207, 2005

RABANAL, Pau. *Does inflation increase after a monetary policy tightening? Answers based on an estimated DSGE model*, **Journal of Economic Dynamics & Control**, v. 31, p. 906-37, 2007

RABI JUNIOR, Luís Alberto. **Três ensaios sobre macroeconomia aplicada,** São Paulo, 2008. Tese (Doutorado em Teoria Econômica) - Programa de Pós-Graduação em Economia, Faculdade de Economia, Administração e Contabilidade da Universidade de São Paulo.

RAVENNA, Federico; WALSH, Carl. E. *Optimal monetary policy with the cost channel*, **Journal of Monetary Economics**, v. 53, p. 199—216, 2006

SCHWARTZMAN, Felipe F. *Estimativa de Curva de Phillips para o Brasil com preços desagregados*. **Economia Aplicada**, 10, n. 1, 137-155, 2006.

SIMS, Christopher A. *Interpreting the macroeconomic time series facts: the effects of monetary policy*, **European Economic Review**, v. 36, p. 975-1000, 1992

TAYLOR, Lance. *Exchange rate indeterminacy in portfolio balance, Mundell-Fleming and uncovered interest rate parity models*, **Cambridge Journal of Economics**, v. 28, 205-227, 2004

TAYLOR, Lance. *A foxy hedgehog: Wynne Godley and macroeconomic modelling*, **Cambridge Journal of Economics**, v. 32, p. 639-663, 2008

TILLMANN, Peter. *The time-varying cost channel of monetary transmission*, **Journal of International Money and Finance**, v. 28, p. 941-953, 2009