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Inflation Dynamics in Mexico: A Characterization Using the New Phillips Curve*

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Abstract

This paper describes the dynamics of inflation in the Mexican economy from 1992 to 2006 using the New Phillips curve framework. The purpose is to identify key structural characteristics of the economy (structural parameters) that define the short-run dynamics of inflation. Results show that despite a previous history of high inflation, a hybrid version of the New Phillips curve fits the data well for the period 1992-2006. The short-run dynamics of inflation in Mexico are best described when both backward and forward looking components are considered. In addition, estimates for the sub-sample 1997-2006 show that as inflation has fallen, on average prices remain fixed for a longer horizon, the fraction of firms that use a backward looking rule of thumb to set their price decreases and the forward looking component of the inflation process gains importance.

Keywords: Inflation dynamics, Phillips Curve.
JEL Classification: E31

Resumen

Este documento describe la dinámica de la inflación en la economía mexicana de 1992 a 2006 utilizando el marco analítico de la Nueva Curva de Phillips. El propósito es identificar características estructurales de la economía (parámetros estructurales) que definen la dinámica de la inflación en el corto plazo. Los resultados muestran que, a pesar de una historia previa de alta inflación, una versión híbrida de la Nueva Curva de Phillips replica los datos razonablemente bien. La dinámica de la inflación en México se puede describir de una forma más adecuada cuando se consideran tanto componentes "backward" como "forward looking". Adicionalmente, estimaciones para la sub-muestra 1997-2006 reflejan que, al disminuir la inflación, en promedio los precios se mantienen fijos por un período más largo, la proporción de empresas que utilizan una regla "backward looking" para determinar su precio ha disminuido y el componente "forward looking" del proceso inflacionario ha ganado importancia.

Palabras Clave: Dinámica inflacionaria, Curva de Phillips.

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1 Introduction

This paper describes the dynamics of inflation in the Mexican economy from 1992 to 2006 using the New Phillips curve framework. Following the literature on the New Phillips curve, the aim is to identify key structural characteristics of the economy (structural parameters) that define the short-run dynamics of inflation. Structural parameters are estimated using standard econometric techniques with a hybrid version of the New Phillips curve.

Ever since the New Phillips curve framework was introduced by Galí and Gertler (1999) (hereafter GG), a considerable amount of research has been done on this topic. In some cases resarch has gone deeper on the theoretical assumptions behind the dynamics of inflation (e.g. mechanisms to introduce price rigidities and the functional form of the production function). Another line of research has gone into the estimation techniques, in particular with respect to the Generalized Method of Moments which is commonly used in this literature. However, in this paper the purpose is to apply some of the standard practices found in this literature to analyze, for the first time, the short-run dynamics of inflation in Mexico using a structural econometric approach.

The Mexican experience with inflation is different from that of most industrialized countries where the dynamics of inflation have been documented using the New Phillips curve framework. Over the last three decades, the dynamics of inflation in Mexico have experienced a major transformation. After the episodes of high chronic inflation that took place in the late seventies and most of the eighties, driven mostly by large public expenditures that led to a fiscal dominance problem, public finances were put in order in the late eighties and early nineties and a gradual disinflation process began. This process was temporarily interrupted during the financial crisis that took place in 1995. However, the economy was stabilized in a relatively short time and inflation resumed its downward trend, reaching levels close to three percent in recent years. Therefore, an important reason for analyzing the dynamics of inflation in Mexico is that it represents an opportunity to compare the structural characteristics of an economy that has experienced high inflation in the past but has been successful in reducing it to low and stable levels, with those of other economies that have experienced price stability for long periods.

A second relevant feature of the New Phillips curve framework is that through its reduced form variant, it is possible to analyze the importance of backward vs. forward looking components in explaining the short-run dynamics of inflation. Thus, in an economy that has experienced episodes of high inflation it is interesting to know whether both types of components are relevant, and if so, their relative importance. Furthermore, the fact that the reduced form parameters are defined in terms of structural ones -in particular, those that describe the degree of price rigidity, on the one hand, and inflation inertia, on the other- enriches the analysis, since the relative importance of backward and forward looking components can be explained in terms of the aforementioned structural parameters.

A third interesting aspect of inflation dynamics in the Mexican economy is related to the disinflation process that has taken place in recent years. This process represents a valuable opportunity to analyze whether certain key structural characteristics of the economy (structural parameters) that influence the short-run dynamics of inflation have changed as inflation has decreased towards low and stable levels.

The paper is organized as follows. Section 2 explains the reasons for which the sample period begins in 1992 and presents estimates of a standard specification of the traditional Phillips curve for the period 1992:01-2006:06. Section 3 presents estimates of the New Phillips curve for the same period, using both a standard forward looking specification, as well as a standard hybrid specification which includes both backward and forward looking components. This section also presents the results of an exercise where the structural parameters of a standard hybrid specification of the New Phillips curve are calibrated using the measure known in this literature as "fundamental inflation". Section 4 analyzes whether over the recent past the dynamics of inflation have changed, by comparing the results of the previous section to the evidence presented in this section for the period 1997:01-2006:06. Section 5 concludes.

2 Traditional Phillips Curve

The traditional Phillips curve defines a relationship between inflation and a cyclical indicator of economic activity, for example, unemployment or the output gap. In addition, to account for the persistence of inflation, some of its lags are usually considered (Fuhrer and Moore, 1995; Rudebusch and Svensson, 1999; Galí, Gertler and López-Salido, 2001 (hereafter GGL); and Orphanides and van Norden, 2005). A common specification of the traditional Phillips curve is:

$$\pi_t = \sum_{i=1}^{n} \varphi_i \pi_{t-i} + \lambda \hat{y}_{t-1} + \varepsilon_t \tag{2.1}$$

where, π_t denotes inflation, $\hat{y}_{t-1}$ is the percent deviation of real GDP from its trend (output gap), ε_t represents a random disturbance with zero mean and constant variance.

As mentioned, during the seventies and early eighties, fiscal unbalances led to a fiscal dominance problem and an important increase in inflation took place in Mexico. However, by the end of the eighties and early nineties several actions were undertaken to correct this situation. Among these were a significant fiscal retrenchment and a renegotiation of Mexico's external public debt. These actions allowed for a rapid reduction of inflation. Considering the effects that the said fiscal unbalances had on inflation during the eighties, the sample period in this paper starts in 1992, so that the short-run dynamics of inflation can be analyzed over a period where no fiscal dominance situation was present.[1]

To estimate a traditional Phillips curve using monthly data for the Mexican economy for the period 1992-2006, variables are defined as follows. Inflation is the percent monthly variation of the consumer price index (INPC), whereas the output gap is the percent deviation of a monthly index of economic activity (IGAE) from its trend.[2,3]

The traditional Phillips curve (equation 2.1) is estimated using OLS for the period 1992:01-2006:06. Results reported in Table 2.1 correspond to a specification where 12 lags of inflation are considered.[4] Evidence suggests that inflation is explained mostly by its own lags. The coefficient associated with the output gap (λ) is not statistically different from zero. This result is perhaps explained by the fact that over the sample period the economy was exposed to several strong adverse supply shocks which, in general, led to episodes of rising inflation and to a *reduction* in the output gap (e.g., 1995 and end 1998-early 1999).

[1] Capistrán and Ramos-Francia (2006a) analyze the dynamics of inflation in Latin America and show that in the late eighties and early nineties, inflation experienced an important reduction (structural break) that preceded a long episode of low inflation and low inflation volatility in most economies of the region, part of the so-called "great moderation." In the case of Mexico, their results suggest that inflation experienced a structural break in the form of a reduction in its mean in March of 1988. However, since during the following two years the macroeconomic adjustment that took place allowed the economy to consolidate a sounder fiscal stance and a lower level of inflation, the sample used in this paper to analyze the dynamics of inflation begins in 1992.

[2] The X12-ARIMA procedure is used to remove the seasonal component of inflation.

[3] The output gap measure is computed as follows. First, the seasonal component is removed from the log first difference of the IGAE using the X12-ARIMA procedure. Second, a log IGAE measure without the seasonal component is constructed. Third, the output gap is defined as the difference between this measure and its HP trend (Hodrick and Prescott, 1997).

[4] In order to define the appropriate number of lags for inflation several specifications were considered, in particular, specifications that contained from 1 to up to 14 lags. Although the Akaike criteria suggests 12 lags, in general, results were robust when different number of lags were considered, that is, the coefficient on the output gap is not statistically different from zero and inflation is explained mostly by its own lags.

Table 2.1

Traditional Phillips Curve[1/]

Sample	φ_1	φ_2	φ_3	φ_4	φ_5	φ_6	φ_7
1992:01-2006:06	0.739^{***}	0.016	-0.028	-0.047	0.119^{*}	-0.040	0.015
	(0.059)	(0.062)	(0.062)	(0.064)	(0.067)	(0.065)	(0.065)
	φ_8	φ_9	φ_{10}	φ_{11}	φ_{12}	λ	$Adj.R^2$
	0.096	-0.083	-0.083	-0.009	0.092^{**}	-0.002	0.946
	(0.064)	(0.061)	(0.061)	(0.061)	(0.044)	(0.017)	

[1/] ***, **, * , statistically significant at 1%, 5% and 10%, respectively. Standard deviations in parenthesis. Newey-West and HAC methodology is used to obtain robust errors and to correct for heteroscedasticity.

Results show that when using a standard simple specification of the traditional Phillips curve, the short-run dynamics of inflation are explained to a large extent by its own lags, that is, inflation shows an important level of persistence over the last decade and a half in Mexico ($\sum_{i=1}^{12} \varphi_i = 0.92$). Results also reveal that in this case it is difficult to identify a positive and statistically significant relationship between inflation and a cyclical indicator of economic activity, in particular, a measure of the output gap. To improve upon these results, an alternative would be to introduce additional elements in the specification of the traditional Phillips curve (Fuhrer and Moore, 1995; Rudebusch and Svensson, 1999; and Matheson, 2006). For instance, given that Mexico is a small open economy, including variables that measure relative prices with respect to the rest of the world could help to improve the results (Vela, 2002 and Roldán, 2005). Another alternative, explored below, is to analyze the short-run dynamics of inflation using the theoretical framework of the New Phillips curve.

3 The New-Keynesian Phillips Curve

3.1 The Standard New Phillips Curve

The theoretical framework behind the basic specification of the New Phillips curve assumes an environment of monopolistically competitive firms that set their price on a staggered basis (GG; GGL; Sbordone, 2002; Céspedes, Ochoa and Soto, 2005; and Dib, Gammoudi and Moran, 2006). Following Calvo (1983), the standard specification assumes that in each period there is a fraction θ of firms that keep their price unchanged, and a fraction $(1-\theta)$ that change it by solving an explicit optimization problem.[5] This assumption

[5] As mentioned, alternative methods to introduce price rigidities can be found in the literature. However, given its simplicity, this framework (Calvo, 1983) is commonly used since it allows to track the short-run dynamics of inflation to

implies that on average a firm maintains its price unchanged for $1/(1-\theta)$ periods. Then, after aggregating individual pricing decisions and log-linearizing around the steady state, the short-run dynamics of inflation can be expressed as:

$$\pi_t = \beta E_t\{\pi_{t+1}\} + \lambda mc_t \tag{3.1}$$

where mc_t represents the log deviation of the real marginal cost from its steady state value; β is a subjective discount factor; and, λ is a slope coefficient that depends on the structural parameters θ and β:

$$\lambda = \frac{(1-\theta)(1-\beta\theta)}{\theta}. \tag{3.2}$$

As is well known, it is worth noting three important differences between the New Phillips curve (3.1) and the traditional specification (2.1). First, under the New Phillips curve framework, price setting behavior is the result of an optimization process by monopolistically competitive firms subject to constraints on the frequency with which they can adjust their price. Second, in contrast to the traditional specification, where inflation is defined under the assumption that agents have adaptative expectations (backward looking), in the New Phillips curve inflation is defined under the assumption that agents have rational expectations and thus it is an entirely forward looking phenomenon. Third, as a result of the optimization process of price-setting firms, the relevant indicator of economic activity under the New Phillips curve is represented by real marginal costs.

The standard technique in the literature is to estimate structural parameters β and θ using the Generalized Method of Moments (GMM).[6] Since expected inflation is included on the right hand side of equation (3.1), ex-post observed values of inflation are used to approximate expected inflation. In order to find a set of parameters β and θ that guarantees average zero forecast errors, the GMM technique uses a set of instrument variables z_t, known at time t, that contain useful information to forecast inflation. This strategy imposes a set of orthogonal restrictions, used by GMM to estimate parameters β and θ, given by:

$$E[(\pi_t - \beta\pi_{t+1} - \lambda mc_t)z_t] = 0 \tag{3.3}$$

three structural parameters of the economy. For a recent discussion on state-dependent vs. time dependent pricing see Klenow and Kryvtsov (2005) and Aucremanne and Dhyne (2005).

[6] As mentioned, several papers in the literature address the properties of the GMM method, in particular with respect to the robustness of results to different normalization assumptions. For a recent discussion see Fuhrer and Olivei (2004).

Since GMM is based on a nonlinear optimization method, results can be sensitive to the normalization used. For that reason, following the literature on this matter, two alternative sets of orthogonal conditions are considered:

Specification I:

$$E[(\theta\pi_t - \theta\beta\pi_{t+1} - (1-\theta)(1-\beta\theta)mc_t)z_t] = 0 \tag{3.4}$$

Specification II:

$$E[(\pi_t - \beta\pi_{t+1} - (1-\theta)(1-\beta\theta)\theta^{-1}mc_t)z_t] = 0 \tag{3.5}$$

To estimate the New Phillips curve using monthly data of the Mexican economy for the period 1992:01-2006:06, the measure of real marginal cost is defined as follows. For simplicity, a Cobb-Douglas production function is assumed so that the real marginal cost is defined as the unit labor cost, or equivalently, as the labor income share.[7] The measure used to represent unit labor costs is given by an index for the unit labor cost of the manufacturing industry in Mexico. Then, the real marginal cost gap is defined as the percent deviation of the marginal cost from its trend.[8] Inflation is defined as in the previous section (percent monthly variation of the consumer price index).

Results for parameters β, θ and λ using specifications 3.4 and 3.5 are presented in Table 3.1. Estimates for parameter β under specification I show a coefficient of 0.996, which would be consistent with an annual interest rate of 4.76 percent, and under specification II, a coefficient of 0.999, which would be consistent with an annual interest rate of 1.06 percent. Both estimates imply interest rates lower than the realized ex-post real interest rate of 4.96 percent observed on average during the sample period.[9] As for parameter θ, specification I shows a coefficient of 0.919, suggesting that for the sample period, on average, prices remained fixed for approximately 4.1 quarters (12 months). However,

[7] The Cobb-Douglas production function assumption is used in this literature to characterize the dynamics of inflation in its simplest framework and thus results obtained under this assumption are commonly used as a benchmark. This paper is a first characterization of the dynamics of inflation in Mexico using the New Philllips curve framework, therefore, for simplicity in the comparison of results with those reported for other economies, a Cobb-Douglas production function is assumed. An alternative, left for further research, is to assume a CES production function to relax the assumption of a unitary elasticity of substitution between inputs and to impose more structure in the specification of the inputs to be considered, for example, imported vs. domestic inputs.

[8] As in the case of the output gap in the previous section, the marginal cost gap measure is computed as follows. First, the seasonal component is removed from the log first difference of the index for the unit labor cost using the X12-ARIMA procedure. Second, a log index for the unit labor cost measure without the seasonal component is constructed. Third, the marginal cost gap is defined as the difference between this measure and its HP trend (Hodrick and Prescott, 1997).

[9] Ex-post real interest rates are computed using the nominal interest rate from one month government securities (Cetes).

the coefficient of 0.858 on specification II suggests that prices remained fixed for approximately 2.3 quarters (7 months). Finally, results for the reduced form parameter λ (slope coefficient) show that under specification I, the coefficient is not statistically different from zero, while under specification II it is positive and statistically different from zero.[10]

Despite results not being robust to the specification used, in general, they are similar to what has been found for other economies (GGL for the United States and the Euro area and Galí and López-Salido, 2000 for Spain). However, the basic specification of the New Phillips curve is not the best approach to describe the short-run dynamics of inflation, since it does not include a mechanism to incorporate persistence into its dynamics, a "stylized" feature observed in the data (Table 2.1).

Table 3.1

Standard New Phillips Curve[1/]

1992:01-2006:06	β	θ	λ
Spec. I [2/]	0.996***	0.919***	0.007
	(0.011)	(0.032)	(0.005)
Spec. II [3/]	0.999***	0.858***	0.023***
	(0.013)	(0.021)	(0.007)

[1/] ***, **, *, statistically significant at 1%, 5% and 10% respectively. Standard deviations in parenthesis.
[2/] Instruments: marginal cost gap: t-4 to t-9, inflation: t-2 to t-10, exchange rate depreciation: t-5 to t-10 and nominal interest. rate (1 month): t-1 to t-9. J-statistic p value= 0.815.
[3/] Instruments: marginal cost gap: t-4 to t-11, inflation: t-1 to t-7, exchange rate depreciation: t-4 to t-11 and nominal interest rate(1 month): t-1 to t-10. J-statistic p value= 0.73.

3.2 Hybrid Version of the New Phillips Curve

To address the issue of inflation persistence, following GG and GGL, the model is extended by assuming that of the $(1-\theta)$ fraction of firms that each period are able to change their price, a fraction ω use a backward looking rule of thumb to set their prices, and a fraction $(1-\omega)$ set their price by solving an optimization problem that leads them to consider the expected future behavior of marginal costs (i.e. forward looking firms). As a result, it can be shown that the inflation process can be defined as:

[10] Standard errors for the reduced form coefficients are estimated using a Monte Carlo procedure.

$$\pi_t = \gamma_b \pi_{t-1} + \gamma_f E_t\{\pi_{t+1}\} + \lambda mc_t \tag{3.7}$$

where

$$\gamma_b = \frac{\omega}{\phi} \qquad \gamma_f = \frac{\beta\theta}{\phi} \qquad \lambda = \frac{(1-\omega)(1-\theta)(1-\beta\theta)}{\phi} \tag{3.8}$$

and

$$\phi = \theta + \omega(1 - \theta(1-\beta)). \tag{3.9}$$

The hybrid version of the New Phillips curve includes both backward (γ_b) and forward looking (γ_f) components. For example, as implied by (3.8) and (3.9), as the fraction of firms that change their price using a backward looking rule of thumb (ω) is larger, the reduced form coefficient γ_b associated with the first lag of inflation is larger and the coefficient associated with expected inflation γ_f is smaller. This means that as the fraction of backward looking firms is larger, the persistence of inflation increases. Similarly, as ω is larger, the slope coefficient λ on the Phillips curve is smaller. This implies that as a larger fraction of firms set their prices using a backward looking rule, the relationship between real marginal costs and inflation turns weaker.

As in the previous exercise, two alternative sets of orthogonal conditions are used to estimate the hybrid version of the New Phillips curve using GMM:

Specification I:

$$E[\phi\pi_t - (1-\omega)(1-\theta)(1-\beta\theta)mc_t - \beta\theta\pi_{t+1} - \omega\pi_{t-1})z_t] = 0 \tag{3.10}$$

Specification II:

$$E[\pi_t - (1-\omega)(1-\theta)(1-\beta\theta)\phi^{-1}mc_t - \beta\theta\phi^{-1}\pi_{t+1} - \omega\phi^{-1}\pi_{t-1})z_t] = 0. \tag{3.11}$$

Inflation and the real marginal cost gap are defined as in the previous exercise (percent monthly variation of the consumer price index and percent deviation of the unit labor cost of the manufacturing industry from its trend, respectively).[11] Results for parameters β, θ and ω using specifications (3.7) to (3.11) over the sample 1992:01-2006:06 are presented in Table 3.2.

[11] As mentioned, for simplicity a Cobb-Douglas production function is assumed.

Table 3.2

Hybrid version of the New Phillips Curve[1/]

1992:01-2006:06	β	θ	ω	λ	γ_b	γ_f
Spec. I [2/]	0.998***	0.834***	0.600***	0.0077**	0.418***	0.581***
	(0.020)	(0.028)	(0.041)	(0.002)	(0.018)	(0.017)
Spec. II [3/]	0.995***	0.643***	0.888***	0.0094***	0.581***	0.419***
	(0.144)	(0.098)	(0.033)	(0.005)	(0.018)	(0.018)

[1/] ***, **,*, statistically significant at 1%, 5% and 10% respectively. Standard deviations in parenthesis.
[2/] Instruments: marginal cost gap: t-2 to t-12, inflation: t-1 to t-12, nominal interest rate (1 month): t-1 to t-12 and exchange rate depreciation: t-2 to t-10. J-statistic p value= 0.998.
[3/] Instruments: inflation: t-1 to t-6, exchange rate depreciation: t-1 to t-5, marginal cost gap: t-1 to t-7, nominal interest rate (1 month): t-1 to t-6 and change in marginal cost gap: t-1 to t-6.
J-statistic p value= 0.839.
Standard deviation and significance of reduced form parameters were calculated using a Monte Carlo procedure.

As for parameter β, estimates of 0.998 and 0.995 for specifications I and II, would be consistent with annual interest rates of approximately 2.3 percent and 5.9 percent, respectively. Recall that the average ex-post real interest rate observed during the sample period was 4.96 percent.

Results for parameter θ suggest values of 0.83 and 0.64 for specifications I and II, which would imply that prices remain unchanged for approximately 2 quarters (6 months) in the first case, and 0.9 quarters (3 months) in the second. This length is slightly shorter than the evidence reported, among others, in GGL for the United States and the Euro area; Galí and López-Salido (2000) for Spain; Gagnon and Hashmat (2001) for Canada, and Céspedes, Ochoa and Soto (2005) for Chile. Reported estimates of parameter θ for those economies using quarterly data go from 0.80 to 0.90 and suggest that, on average, prices remain fixed for 5 to 10 quarters. Evidently, the difference is consistent with the fact that over the sample periods, average inflation was significantly higher in Mexico than in the aforementioned economies.[12]

With respect to parameter ω, results show that the fraction of firms that set their prices using a backward looking rule of thumb is 0.60 under specification I and 0.88 under specification II. In this case, the evidence for the economies previously mentioned is widespread. In the case of Spain, Canada and Chile, the estimated fraction of backward

[12] Average annual inflation over the estimation sample used in the studies mentioned is approximately: for Mexico (1992-2006) 13 percent; for the United States (1970-1998) 5 percent; for the Euro area (1970-1998) 6 percent; for Spain (1980-1998) 7.5 percent; for Canada (1980-1998) 4.5; and for Chile (1986-2004) 11 percent. In addition, average annual inflation for these economies during the sample period used in this study(1992-2006) is approximately: 2.5 percent for the United States; 2 percent for Euro area; 3 percent for Spain; 2 percent for Canada; and 6 percent for Chile.

looking firms is in the range from 0.65 to 0.80; in the United States, estimates of parameter ω are between 0.40 and 0.45; and, in the Euro area, estimates go from 0.02 to 0.34.

Results for the reduced form coefficients show that, for both specifications, estimates of parameter λ (slope of the Phillips curve) are positive and statistically significant. This result suggests that when using a hybrid version of the New Phillips curve it is possible to identify a positive relationship between inflation and a cyclical indicator of economic activity, in this case the real marginal cost gap.

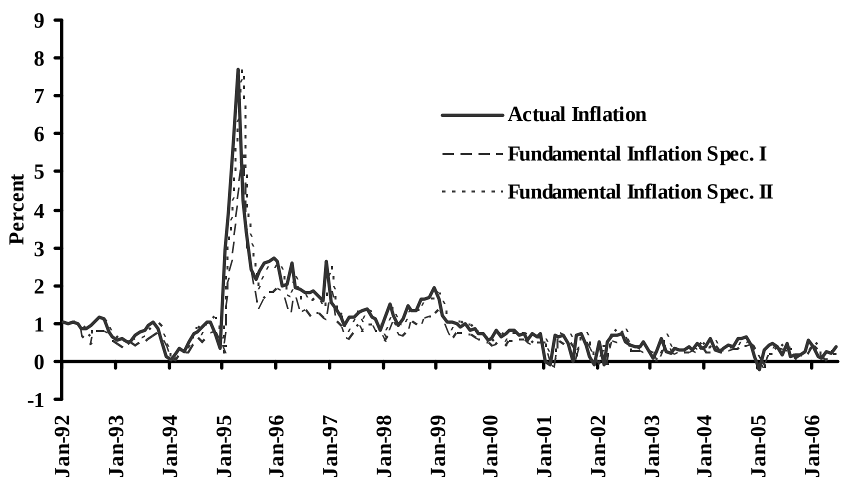
Another interesting result is that both backward (γ_b) and forward looking (γ_f) components are important to describe the dynamics of inflation in Mexico, since both are statistically significant. This result is also found in the economies previously mentioned. In the case of parameter γ_b results for Mexico suggest values of 0.42 and 0.58 for specifications I and II, and, in the case of parameter γ_f, values of 0.58 and 0.42 for specifications I and II, respectively. These results are similar to those reported for the United States, Spain, Canada and Chile, where the parameter γ_b is between 0.4 and 0.6; and slightly different to the evidence reported for the Euro area, where parameter γ_b is reported around 0.02. However, it is important to note that despite these results on reduced form parameters being similar to those reported for other economies, that is, on the relative importance of the backward (inflation persistence) and forward looking (inflation expectations) components, in the case of Mexico they are obtained as a combination of prices remaining unchanged for a shorter period *and* a larger fraction of firms using a backward looking rule of thumb to set their price when they are able to change it. These results could be explained, first, by the fact that, as mentioned, over the sample period average inflation in Mexico was larger than in the aforementioned economies and thus firms revised their price with more frequency; and second, by the fact that prior to the sample period, the economy experienced a prolonged episode of rising inflation (late seventies and eighties) and, thus, past inflation played an important role on the information set considered by firms when setting prices.

3.3 Fundamental Inflation

To assess the performance of the New Phillips curve, it is common to use a measure known in the literature as "fundamental inflation." This methodology was initially proposed by Campbell and Shiller (1987), and then applied to the issues at hand by GG. A hybrid version of the New Phillips curve (3.7) implies that inflation depends on lagged inflation and on the discounted stream of expected future marginal costs. Since future marginal costs are not observable, the first step is to estimate a VAR for a group of observable variables that could be used by economic agents to assess the performance of future marginal costs. Typically, this VAR is defined in its most simple specification in terms of the real marginal cost gap and inflation. The VAR is used to estimate future real marginal cost gaps and, then, a measure of "fundamental inflation" is computed using the estimated hybrid version of the New Phillips curve (details are presented in the Appendix).

For this exercise, the VAR is defined with four lags of the real marginal cost gap and inflation.[13] Two measures of "fundamental inflation" are computed using the estimates reported in Table 3.2 for specifications I and II and are presented in Figure 3.1. Results show that despite the previous episodes of high inflation, in general, the estimated measures of "fundamental inflation" are able to replicate reasonably well the dynamics of inflation in Mexico over the last fifteen years.[14] It therefore appears that a hybrid version of the New Phillips curve is able to capture most features of the short-run dynamics of inflation in Mexico.

Figure 3.1
Monthly Inflation



[13] The lag length was defined according to the Akaike criteria. However, results are robust to VAR specifications using different number of lags.

[14] The RMSE with respect to actual inflation is 0.586 for Specification I and 0.4770 for Specification II. As will be shown in the next section, the performance of fundamental inflation using the coefficients estimated under Specifications I and II is not too different from that of the meassure of fundamental inflation that is obtained when parameters θ and ω are calibrated to minimize the RMSE statistic, given a β consistent with the observed interest rate over the sample period.

3.4 Calibration of a Hybrid Version of the New Phillips Curve

An alternative method to evaluate the performance of the hybrid version of the New Phillips curve estimated in the previous section is to calibrate the structural parameters θ and ω given a β consistent with the observed interest rate. The exercise consists of finding a set of parameters θ and ω for the hybrid version of the New Phillips curve (equations 3.7 to 3.9) that minimizes the difference between the measure of "fundamental inflation" obtained with the calibrated coefficients θ and ω and actual inflation, conditioned on the choice of β mentioned above. Thus, the first step is to set parameter β equal to 0.9962, the discount factor associated with a real interest rate of 4.96 percent (average ex-post real interest rate over the sample period). Then, a measure of "fundamental inflation" (using the VAR described in the previous section) is computed for each combination of parameters θ and ω and the RMSE statistic with respect to actual inflation is computed. The grid search for parameters θ and ω is performed across 9,801 combinations, where values for both parameters go from 0.01 to 0.99 with increments of 0.01. To illustrate the results of the exercise, RMSE statistics for some combinations of parameters θ and ω are reported in Table 4.1.

Table 4.1

RMSE: "Fundamental Inflation" vs. Actual Inflation

	ω →	**0.40**	**0.60**	**0.80**	**0.81**	**0.82**	**0.83**	**0.90**
	0.40	3.5604	1.4300	0.6564	0.6354	0.6158	0.5976	0.5083
	0.60	1.0303	0.7101	0.5096	0.5041	0.4991	0.4947	0.4780
	0.80	0.8168	0.5763	0.4762	0.4762	0.4764	0.4766	0.4786
θ	**0.84**	0.8228	0.5881	0.4761	0.5011	0.4758	0.4762	0.4799
	0.85	0.8253	0.5919	0.4765	0.4759	**0.4757**	0.4760	0.4801
	0.86	0.8280	0.5958	0.4771	0.4762	0.5012	0.4758	0.4803
	0.90	0.8412	0.6137	0.4824	0.4801	0.4783	0.4770	0.4793

Results show that smaller values of both parameters are associated with larger values for the RMSE. This implies that specifications where the fraction of firms that are not able to change their price at a given period (θ) is small and where the fraction of firms that use a backward looking rule of thumb to set their price (ω) is small do not provide a good approximation of the short-run dynamics of inflation in the Mexican economy over the last fifteen years. On the contrary, results show that the measure of "fundamental inflation" that minimizes the RMSE statistic is obtained when the hybrid version of the

New Phillips curve (equations 3.7 to 3.9) is defined with θ equal to 0.85 and ω equal to 0.82, given a parameter β equal to 0.9962.

The first important issue to consider when comparing the results from this calibration exercise to the ones obtained in the previous section (GMM estimation), is the difference in the parameter β. To analyze if differences between both exercises (GMM estimation and calibration) are related to the value of that parameter, specifications I and II from the previous section (equations 3.10 to 3.11) are estimated imposing the restriction that parameter β be equal to 0.9962, as in the calibration exercise. Results reported in Table 4.2 show that the restriction on β has, in general, no important effects on the other parameters. Point estimates and their level of significance have almost negligible changes when the restriction on β is imposed. Once having done this, the comparison of results across the two exercises (GMM estimation vs. calibration) shows that the calibrated parameters are similar to the higher values obtained under GMM for specifications I and II. In the case of parameter θ, the calibration exercise suggests a value of 0.85, similar to the GMM estimate of 0.83 for specification I and slightly above the estimated 0.64 for specification II. With respect to parameter ω, the calibration exercise suggests a value of 0.82, which is above the GMM estimate of 0.60 for specification I and similar to the estimate of 0.88 for specification II.

Reduced form parameters do not show important differences either. The backward looking component (γ_b) and the forward looking component of inflation (γ_f) are very similar in both exercises. For the backward looking component, the calibration excercise suggests a value of 0.49, while GMM estimations suggest values of 0.42 and 0.58 for specifications I and II, respectively; the calibrated parameters resulted in a forward looking component of inflation of 0.51, whereas estimated parameters suggest values of 0.58 for specification I and 0.42 for specification II. Finally, the slope coefficient of the Phillips curve (parameter λ) suggested by calibrated parameters (0.0025) is slightly below the slope coefficients obtained with GMM estimations (0.0077 and 0.0094 for each specification).[15]

[15] In general, the comparison of the calibrated coefficients with the GMM estimates of each specification suggest that differences are statistically significant. However, in most cases, the calibrated coefficients are in the range between the GMM estimates for specification I and II. The only exception is parameter λ for which the calibration exercise suggests a smaller value.

Table 4.2
Hybrid version of the New Phillips Curve:
Calibrated versus Estimated Parameters[1/]

1992:01-2006:06	β	θ	ω	λ	γ_b	γ_f
Calibration	0.996	0.850	0.820	0.0025	0.492	0.508
Estimation						
Spec. I [2/]	0.9981***	0.8341***	0.6003***	0.00774**	0.4187***	0.5808***
	(0.020)	(0.028)	(0.041)	(0.002)	(0.018)	(0.017)
Spec. II [3/]	0.9954***	0.6428***	0.8877***	0.00944***	0.5809***	0.4187***
	(0.144)	(0.098)	(0.033)	(0.005)	(0.018)	(0.018)
Estimation ($\beta = 0.996$)						
Spec. I [2/]	**0.996**	0.8361***	0.5988***	0.00776**	0.4178***	0.5812***
		(0.018)	(0.041)	(0.002)	(0.017)	(0.017)
Spec. II [3/]	**0.996**	0.6424***	0.8878***	0.00945***	0.5809***	0.4188***
		(0.043)	(0.031)	(0.004)	(0.016)	(0.016)

[1/] ***, **,*, statistically significant at 1%, 5% and 10% respectively. Standard deviations in parenthesis.
[2/] Instruments: marginal cost gap: t-2 to t-12, inflation: t-1 to t-12, nominal interest rate (1 month): t-1 to t-12 and exchange rate depreciation: t-2 to t-10. J-statistic p value= 0.998.
[3/] Instruments: inflation: t-1 to t-6, exchange rate depreciation: t-1 to t-5, marginal cost gap: t-1 to t-7, nominal interest rate (1 month): t-1 to t-6 and change in marginal cost gap: t-1 to t-6. J-statistic p value= 0.839. Standard deviation and significance of reduced form parameters were calculated using a Monte Carlo procedure.

4 Recent Changes in the Short-Run Dynamics of Inflation

From 1992 to 2006 the Mexican economy experienced an important disinflation process, although there were some episodes when inflation presented temporary bursts. In particular, during 1995 the economy underwent a financial crisis, refered to as the "Tequila" crisis. To address this situation, a comprehensive stabilization package was put in place (Ramos-Francia and Torres, 2005 and Capistrán and Ramos-Francia, 2006a). As it happened, although GDP contracted sharply during that year, the economic program implemented was able to stabilize the economy in a relatively short period of time. In this section, the New Phillips curve framework is used to analyze whether, in the more recent past, whence the economy has been converging towards a low inflation environment, the short-run dynamics of inflation have experienced significant changes. In effect, in order to exclude from the analysis the effects of the "Tequila" crisis and its aftermath that took place during 1995 and 1996, and to concentrate on the more recent disinflation episode, the sub-sample is defined from 1997:01 to 2006:06.[16]. An additional reason for this is that after the crisis, important changes were made to monetary and fiscal policies. In particular, a floating exchange rate regime was put in place, a considerable fiscal retrenchment effort was made and important reforms to the financial system were undertaken. The average performance of inflation across the sub-samples 1992:01-1996:12 and 1997:01-2006:06 is remarkably different. Average monthly inflation decreased from 1.56 to 0.66 percent and its standard deviation from 1.45 to 0.55.[17] Therefore, it is likely that the short-run dynamics of inflation might have changed.

The exercise consists of estimating a hybrid version of the New Phillips curve (equations 3.7 to 3.9) for the sub-sample 1997:01-2006:01. It is important to mention that results from these exercises should be interpreted carefully, since the sub-sample 1997:01-2006:06 is relatively small. For comparison purposes, results are reported in Table 5.1 along with the evidence discussed in the previous section for the sample 1992-2005 (Table 3.2).

Estimates for β suggest a value of 0.994 in specification I and a value of 0.996 in specification II. These results would be consistent to an annual interest rates of 7.87 and 5.57 percent, respectively and are similar to the observed ex-post annual real interest rate of 5.05 percent on average over the sub-sample 1997:01-2006:06.[18]

In general, results for the sub-sample 1997:01-2006:06 suggest that the fraction θ of firms that keep their price fixed each period increases when compared to the 1992:01-2006:06 sample. For specification I parameter θ increases from 0.83 to 0.89, implying that the average number of periods for which firms keep their price fixed increased from 2 to 3 quarters. For specification II this parameter increases from 0.64 to 0.78, implying also that the average number of periods prices remain unchanged increased from 0.9 to

[16] The evidence presented by Capistrán and Ramos-Francia (2006a) shows that inflation experienced an additional reduction (structural break) in most countries in the Latin American region in the late nineties. In the case of Mexico, the methodology of Bai and Perron (2003) suggests that when considering the 1992-2006 sample, average monthly inflation in Mexico experienced a structural break in the form of a reduction in its mean in January of 1997 and then in September of 1999. However, if the test is performed considering only the 1997-2006 sub-sample, results suggest that the last statistically significant reduction on average monthly inflation takes place in January of 2001. Considering that the the 1997-2006 sub-sample is already relatively small, estimates for sub-samples starting either in 1999 or 2001 are left for further research once additional data is available.

[17] Average monthly inflation for the sample 1992:01-2006:06 is 0.97 percent and its standard deviation is 1.05.

[18] As mentioned, the average ex-post real interest rate over the 1992:01-1996:06 period was 4.96 percent. This average is slightly below the average reported for the sub-sample 1997:01-2006:06 of 5.05 percent. This could be explained by the fact that during the first months of 1995, inflation increased sharply and consequently ex-post real interest rates were negative during those months.

1.5 quarters. This result could be consistent with a menu costs type story. In effect, in an environment of lower and more stable inflation, firms are more likely to absorb small shocks to their costs and wait until the difference between their current and desired (optimal) price is large enough to compensate the costs in which they have to incur when changing their price.

Table 5.1

Hybrid version of the New Phillips Curve[1/]

1992:01-2006:06	β	θ	ω	λ	γ_b	γ_f
Spec. I [2/]	0.998***	0.834***	0.600***	0.007**	0.418***	0.581***
	(0.020)	(0.028)	(0.041)	(0.002)	(0.018)	(0.017)
Spec. II [3/]	0.995***	0.643***	0.888***	0.009***	0.581***	0.419***
	(0.144)	(0.098)	(0.033)	(0.005)	(0.018)	(0.018)
1997:01-2006:06						
Spec. I [4/]	0.994***	0.892***	0.129***	0.010**	0.127***	0.869***
	(0.010)	(0.022)	(0.035)	(0.004)	(0.030)	(0.032)
Spec. II [5/]	0.996***	0.783***	0.350**	0.027*	0.310***	0.688***
	(0.048)	(0.069)	(0.171)	(0.016)	(0.126)	(0.140)

[1/] ***, **,*, statistically significant at 1%, 5% and 10% respectively. Standard deviations in parenthesis.
[2/] Instruments: marginal cost gap: t-2 to t-12, inflation: t-1 to t-12, nominal interest rate: t-1 to t-12 and exchange rate depreciation: t-2 to t-10. J-statistic p value= 0.998.
[3/] Instruments: inflation: t-1 to t-6, exchange rate depreciation: t-1 to t-5, marginal cost gap: t-1 to t-7, nominal interest rate: t-1 to t-6 and change in marginal cost gap: t-1 to t-6. J-statistic p value= 0.839.
[4/] Instruments: marginal cost gap, inflation, nominal interest rate, exchange rate depreciation and change in in marginal cost gap: t-2 to t-10. J-statistic p value= 0.997.
[5/] Instruments: inflation, exchange rate depreciation, marginal cost gap, nominal interest rate and change in marginal cost gap: t-3 to t-4. J-statistic p value= 0.504.
Standard deviation and significance of reduced form parameters were calculated using a Monte Carlo procedure.

Another important change observed within both specifications is that the fraction of firms that use a backward looking rule of thumb (ω) decreased over the last few years. For specification I, the estimated ω decreased from 0.600 to 0.129. In the case of specification II, it decreased from 0.888 to 0.350.

With respect to the reduced form parameters γ_b and γ_f, results show changes over time for both specifications. In general, the relative importance of the backward looking component decreased sharply. For the sample period 1992:01-2006:06, estimates for γ_b suggest values of 0.42 and 0.58 for specification I and II, while estimations for the sub-sample period 1997:01-2006:06 suggested values of 0.12 and 0.31, respectively. Estimates for the forward looking component γ_b for the sample period of 1992:01-2006:06 suggest values of 0.58 and 0.42 for specification I and II while, for the sub-sample 1997:01-2006:06, values of 0.87 and 0.68, respectively.

Finally, results show that parameter λ is statistically different from zero for both samples, but larger for the 1997:01-2006:06 sub-sample. This increase in the slope of the Phillips curve is consistent with the fact that the fraction of firms that use a backward looking rule of thumb to set their price (ω) decreases, that is, the relationship between real marginal costs and inflation is stronger. However, the increase in the fraction θ of firms that keep their price fixed each period for the 1997:01:2006:06 sub-sample operates in the opposite direction, that is, reducing the slope of the Phillips curve. As it is, the combined effect of changes in parameters ω and θ suggests that the effect of the first one more than compensates the effect of the second. As a result, the relationship between marginal costs and inflation is stronger for the 1997:01:2006:06 sub-sample.

5 Conclusions

This paper describes the short-run dynamics of inflation in the Mexican economy over the last two and a half decades using the New-Keynesian Phillips curve framework. Evidence suggests that the short-run dynamics of inflation can be described fairly well using this approach. In effect, despite being an economy that has experienced in its past episodes of high inflation, the New Phillips curve framework provides a good characterization of inflation in Mexico. In particular, short-run inflation dynamics are described in terms of three key structural parameters: a subjective discount factor (β), the fraction of firms that are not able to change their price on a given period (θ), and the fraction of firms that use a backward looking rule of thumb to set their prices (ω).

The New Phillips curve framework stresses the importance of real marginal costs to describe the short-run dynamics of inflation. The evidence presented reveals that through this framework it is possible to identify (slope coefficient λ) a positive relationship between inflation and cyclical indicator of economic activity, in this case the real marginal cost gap. This result implies that marginal costs contain information that is relevant in explaining inflation dynamics. Therefore, as is known, a better understanding of the determinants of marginal costs should be an important part of the research agenda on the short-run dynamics of inflation.

The results presented in this paper show that the short-run dynamics of inflation in Mexico can be best described using a hybrid version of the New Phillips curve. This specification includes backward and forward looking components. Evidence suggests that from 1992 to 2006, both the backward (γ_b) and forward looking (γ_f) components are important in explaining the short-run dynamics of inflation. The relative importance of the backward looking component is between 0.4 and 0.6. This result implies that although inflation expectations are an important determinant of inflation, lagged inflation (inflation persistence) also plays a key role. This result is in line with evidence found for the United States, the Euro area, Spain, Canada and Chile. However, it is important to stress that despite results on reduced form coefficientes being similar to the evidence from the aforementioned economies, there are important diferences in terms of key structural characteristics of the economies.

The evidence for the structural parameters of the economy suggest that the degree of price rigidity (parameter θ) is between 0.83 and 0.64 for monthly data. On average prices remain fixed for approximately 1 to 2 quarters. As explained, this length is slightly shorter than in other economies that have experienced lower levels of inflation. Results for parameter ω suggest that the fraction of firms that use a backward rule of thumb to set their price is between 0.6 and 0.8. As mentioned, this fraction is larger then what has been reported for other economies. Furthermore, the fact that from 1992 to 2006 the dynamics of inflation in Mexico exhibit a considerable degree of persistence is consistent with the finding that an important fraction of firms use a backward rule of thumb to set their prices.

Inflation in Mexico has experienced a disinflationary process and has been gradually converging towards a low and stable level in recent years. To identify whether the key structural characteristics underlying inflation dynamics have changed recently, the New Phillips curve framework is used to analyze inflation for the sub-sample from 1997 to 2006. Results suggest that the average number of quarters for which prices remain fixed has increased in the last years and that the fraction of firms that use a backward looking rule of thumb to set their prices has decreased. Estimates for the reduced form coefficients show an increase (reduction) in the relative importance of the forward (backward) looking component of inflation and a stronger relationship between marginal costs and inflation for the 1997-2006 sub-sample. Nevertheless, these results should be interpreted only as preliminary, since the analysis is performed for a relatively small sample (1997-2006).

The results found in this paper are in line with several stylized facts that have been documented recently for inflation in Mexico. For example, the reduction in the relative importance of the backward looking component of inflation is in line with the reduction in inflation persistence that has been documented by Capistrán and Ramos-Francia (2006a) and Noriega (2006). Similarly, the smaller fraction of firms that use a backward looking rule to set their price is consistent with the finding of Capistrán and Ramos-Francia (2006b) that, as inflation decreases, inflation credibility in the inflation target is improved.

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Appendix

Fundamental Inflation: Hybrid version of the New Phillips Curve

The specification of the hybrid version of the New Phillips curve, given by equations (3.7) to (3.9) constitutes a difference equation of second order. The measure of "fundamental inflation", π^*, is defined as the standard closed solution of this equation, given by the following expression (Galí and Gertler, 1999; Galí, Gertler and López-Salido, 2001):

$$\pi_t = \delta_1 \pi_{t-1} + \left(\frac{\lambda}{\delta_2 \gamma_f}\right) \sum_{k=0}^{\infty} \left(\frac{1}{\delta_2}\right)^k E_t\{mc_{t+k}\} \equiv \pi^*. \tag{A.1}$$

where $\delta_1 \leq 1$ and $\delta_2 \geq 1$ stands for the stable and the unstable roots, respectively, which are defined by:

$$\delta_1 = \frac{1 - \sqrt{1 - 4\gamma_b \gamma_f}}{2\gamma_f} \quad , \qquad \delta_2 = \frac{1 + \sqrt{1 - 4\gamma_b \gamma_f}}{2\gamma_f}. \tag{A.2}$$

As can be seen in (A.1), the "fundamental inflation" is determined by the discounted stream of expected future real marginal costs as well as lagged inflation, which arises from the presence of firms that change their price using a backward looking rule of thumb. The measure of "fundamental inflation" represents a useful tool to assess the extent to which the estimates of expression (3.7) to (3.9) are able to reproduce inflation dynamics. However, since future marginal costs are not observable, π^* cannot be directly calculated. Following the methodology of Campbell and Schiller (1987), it is possible to obtain an estimate of this term in (A.1) using a VAR.

Let $X_t = [mc_t, mc_{t-1}, ..., mc_{t-q}, \pi_t, \pi_{t-1}, ...\pi_{t-q}]'$ be a vector of observable variables that represents a set of available information for private agents at time t, defined for any finite q. The conditional expectation on X_t of expression (A.1) is:

$$\pi_t = \delta_1 \pi_{t-1} + \left(\frac{\lambda}{\delta_2 \gamma_f}\right) \sum_{k=0}^{\infty} \left(\frac{1}{\delta_2}\right)^k E_t\{mc_{t+k} \mid X_t\} \equiv \pi^*. \tag{A.3}$$

According to Campbell and Schiller (1987), a VAR formed by the variables contained in X_t can be represented as follows:

$$\begin{bmatrix} mc_t \\ \vdots \\ \vdots \\ mc_{t-q+1} \\ \pi_t \\ \vdots \\ \vdots \\ \pi_{t-q+1} \end{bmatrix} = \begin{bmatrix} \vartheta_1 & \dots & \dots & \vartheta_q & \zeta_1 & \dots & \dots & \zeta_q \\ 1 & & & & & & & \\ & \ddots & & & & & & \\ & & 1 & & & & & \\ \varphi_1 & \dots & \dots & \varphi_q & \varkappa_1 & \dots & \dots & \varkappa_q \\ & & & & 1 & & & \\ & & & & & \ddots & & \\ & & & & & & 1 & \end{bmatrix} \begin{bmatrix} mc_{t-1} \\ \vdots \\ \vdots \\ mc_{t-q} \\ \pi_{t-1} \\ \vdots \\ \vdots \\ \pi_{t-q} \end{bmatrix} + \begin{bmatrix} v_{1t} \\ 0 \\ \vdots \\ 0 \\ v_{2t} \\ 0 \\ \vdots \\ 0 \end{bmatrix}. \tag{A.4}$$

The system represented by (A.4) can be expressed in a compact form as:

$$X_t = AX_{t-1} + v_t \tag{A.5}$$

where A is the companion matrix of the VAR(q) representation for X_t and v_t is a vector of white noise disturbances.

Thus, an estimate of the stream of expected future real marginal costs can be calculated assuming that agents use the available information at time t to take their decisions. This is, assuming that agents' expectations are approximated by the conditional forecast derived from the VAR(q).

From (A.5) it is possible to obtain an expression for $E_t\{mc_{t+k} \mid X_t\}$. If $E\{X_{t+i} \mid H_t\}$ represents a linear projection under a set of information given by H_t, it follows that:

$$\begin{aligned} &E\{X_{t+1} \mid H_t\} = E\{AX_t + v_{t+1} \mid H_t\} = AX_t \\ &E\{X_{t+2} \mid H_t\} = E\{AX_{t+1} + v_{t+2} \mid H_t\} = A^2X_t \\ &\vdots \\ &E\{X_{t+k} \mid H_t\} = A^kX_t \end{aligned}$$

which, after being substituted in (A.3), allows to define "fundamental inflation" π^*, as:

$$\pi^* = \delta_1\pi_{t-1} + \left(\frac{\lambda}{\delta_2\gamma_f}\right)\sum_{k=0}^{\infty}\left(\frac{1}{\delta_2}\right)^k h'A^kX_t \tag{A.6}$$

where h' is a vector of dimension $2q$ with a 1 in its first position and zeros elsewhere. Simplifying the infinite sum on the right hand side of expression (A.6), and assuming A is invertible, "fundamental inflation" can be expressed as follows:

$$\pi^* = \delta_1\pi_{t-1} + \left(\frac{\lambda}{\delta_2\gamma_f}\right)h'(\mathbf{I} - \left(\frac{1}{\delta_2}\right)A)^{-1}X_t. \tag{A.7}$$