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**ESTIMATING THE NEW KEYNESIAN PHILLIPS CURVE FOR SELECTED LATIN AMERICAN COUNTRIES**

**CHRISTIAN EDUARDO LASTIRE OLMEDO**

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ASESORES:

GERRIT KLÜTER & STEPHEN MCKNIGHT

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**Abstract**

In this thesis we estimate several specifications of the New Keynesian Phillips (NKPC) curve for six Latin American countries using the technique of the Generalized Method of Moments. The analysis is conducted using two alternative approaches that introduce open economy considerations into the aggregate supply-side of the economy. In addition, we include lagged inflation as an explanatory variable to study its importance. Our main findings are that the backward-looking inflation is an important determinant in understanding the dynamics of inflation for the Latin American countries in our sample. In addition, we found statistical evidence suggesting that the open economy versions of the NKPC fit better the data for the economies of Chile and Mexico.

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# 1 Introduction

The analysis of what determines inflation and its short-run behavior is one of the most important questions in macroeconomics. For many years the main tool to understand the inflationary process was the Phillips curve. In its moder form, the Phillips curve[1] relates inflation to some cyclical indicator (such as the unemployment rate, the output gap, etc.) plus lagged values of inflation. However, one of the main problems of the Phillips curve is that is subject to the Lucas critique. That is, the stability of this equation across policy regimes is unclear, since the coefficients of the Phillips curve also change with shifts in economic policy (Gali et al., 2001). Consequently, as argued by Galí et al. (2001), structural modeling of inflation is desirable, which gave birth to the New Keynesian Phillips Curve (NKPC).

It is important to stress that there are at least three important differences between the traditional version of the Phillips Curve and the NKPC. First, in the NKPC real marginal cost is the main driving force inflation. Second, the NKPC is the result of a well-defined optimization problem for monopolistically competitive firms. Third, the NKPC implies that the process of inflation is forward looking, with current inflation a function of expected inflation.

There now exists a vast literature with the empirical estimation of the NKPC, considering different assumptions associated with various versions of time-dependent price-setting[2] in a closed economy framework, based on the framework of Taylor (1980) or Calvo (1983) (for further details see Ólafsson (2006)). In this thesis, we are going to focus on a literature that estimates the NKPC, based on the Calvo (1983) price-setting approach, using GMM estimation. However, empirically there are difficulties to reconcile the NKPC with the data. First, since real marginal cost is a non-observable variable, the early literature, like Fuhrer and Moore (1995), used the output gap as a proxy. The reason being that in the absence of rigidities in the labor market, the output gap proportionally varies with real marginal cost (Rotemberg and Woodford, 1997). However, empirically studies typically estimated a negative sign for the output gap coefficient. Second, since current inflation is a function of expected inflation in the NKPC, it has no intrinsic inertia in inflation. This characteristic has been questioned empirically. For example, Fuhrer and Moore (1995) find that the baseline NKPC leads to a poor empirical fit and performs better with an amended specification

[1] By the Phillips curve in its modern form, following Rudd and Whelan (2007), we refer to the Friedman-Phelps expectations augmented Phillips curve.

[2] The time dependent price setting assumes that firms change their prices on an exogenous way that is unaffected by the state of the economy (Ólafsson, 2006).

that includes the lag of inflation (known as hybrid version of the NKPC).

Consequently, in order to overcome these failures, some elements have been added to the standard NKPC in order to improve the empirical results. Galí and Gertler (1999) introduce three main changes. First, they develop a model of inflation that allows for a fraction of firms to use a backward-looking rule to set prices, in order that lagged inflation inertia enters into the NKPC. Second, instead of using the output gap as a proxy for real marginal cost, labor income share is used as a proxy. Finally, they used the technique of the GMM to estimate the parameters of the NKPC for the U.S. for the period 1960:Q1 to 1997:Q4. Their main findings were that the labor income share is positive and significant, and thus, the use of this variable provides a good description of U.S. inflation dynamics. Additionally, Galí and Gertler (1999) found that the coefficient for expected inflation, which takes values between 0.59 and 0.87, dominates the coefficient associated with lag inflation (estimated values are between 0.085 and 0.383). This suggests that the inflation dynamics of the U.S. can be reasonably explained using a pure forward-looking version of the NKPC using the labor share as a proxy of real marginal cost.

Following the methodology of Galí and Gertler (1999), a number of other studies have empirical tested the NKPC for other countries. Galí, Gertler and López-Salido (2001) show evidence for the Euro area for the period 1970-1998. In this article, the authors compare the characteristics of European inflation dynamics with the inflation dynamics of the U.S. They concluded that the NKPC seems to fit the inflation for the Euro are in an acceptable way, and similar to Galí and Gertler (1999), the forward-looking component is estimated to be higher than the backward-looking component. Some other studies for developed countries like Scheufele (2008) for Germany and Masaiko (2009) for Japan found results in line with those of Galí and Gertler (1999). However, despite its apparent empirical success, this representation of the NKPC has been subject to criticism, especially by Rudd and Whelan (2007). First, they criticize the use of the labor share as a proxy for marginal cost, since theoretically real marginal cost and output should be procyclical. Thus, if labor share is a good proxy of real marginal cost, the labor share and output should be also procyclical. However, the empirical evidence for U.S. displays a countercyclical pattern. Second, they prove that the use of instrumental variables that are not part of the model such as the interest rate and commodity price inflation, could bias the estimates for the forward-looking component of the NKPC, and thus, this method will tend to yield a small coefficient on lagged inflation (Rudd and Whelan, 2007). However, despite these criticisms, the Galí and Gertler (1999) framework remains the dominant approach in the empirical literature.

A recent strand of the literature has focused on extending the NKPC framework to an open-economy setting. Examples of this are Batini, Jackson and Nickell (2005) which estimate an open economy version of the NKPC using UK data. They modify the baseline NKPC model by introducing the relative prices of imported inputs and foreign competition pressures in the marginal cost function. They find that these open economy components to be significant. A similar study by Balakrishnan and López Salido (2002), also for the UK, find similar results. Rumler (2005) estimates an open-economy NKPC for 9 Euro Area countries by decomposing the real marginal cost into three different factors of production (real unit labor costs and the price of imported and domestically produced intermediate goods). His results suggest that the degree of structural price rigidity is higher in the open economy case because "the fact that when firms face more variable input costs as they import from volatile international markets they tend to adjust their prices more frequently" (Rumler, 2005). Mihailov, Rumler and Sharler (2011), consider a sample of ten OECD countries, and estimate a NKPC using a modified version of the popular small open economy model of Galí and Monacelli (2005) whereby the NKPC now includes changes in the terms of trade. Their main results show that for many of the sample countries the terms of trade can be considered as a more relevant variable than the output gap, suggesting that external factors are more important in explaining inflation dynamics than internal factors (output gap). Holmberg (2006) also considers the case of an open economy NKPC for Sweden. She proceeds in a similar way to Rumbler (2005) and decomposes real marginal cost into two components: the labor share and the imports of intermediate goods. In this case, however, her results cannot pin down a statistical relationship between the coefficient of the imports of intermediate goods and current inflation.

In respect to the literature related with Latin American countries, for Chile, Céspedes, Ochoa and Soto (2005), following the procedure of Galí and Gertler (1999), estimate the NKPC for the period 1990-2004. Their main findings are that, unlike studies for developed economies, the backward-looking component of the Hybrid NKPC is actually an important variable explaining inflation dynamics. For Mexico, Ramos-Francia and Torres (2006) estimate a closed economy version of the NKPC for the period 1992-2006. Their findings are in line with those of Céspedes, Ochoa and Soto (2005), in the sense that the backward-looking component has a stronger weight compared to the results of Galí and Gertler (1999). These studies indicate important differences in the inflationary process of Latin American countries compared to industrialized economies.

In this thesis, I estimate the NKPC for a set of Latin American countries using quarterly data. I estimate the parameters of the model using GMM, the standard econometric technique of the literature. Because Latin American countries have increased the degree of openness during the last two decades, I consider two open economy specifications of the NKPC. One version is based on the model of Galí and Monacelli (2005) which was employed by Mihailov, Rumler and Sharler (2011). The second version follows the model of Holmberg (2006). In addition, in both frameworks the importance of lagged inflation is also considered.

The main findings of the thesis are as follows. First, it was not possible to find strong statistical evidence between the variables used as proxies for the real marginal cost(i.e., the output gap and the unit labor cost) for all the countries in the sample. However, in the case of Peru, the output gap was found to be an important variable in explaining the inflationary process of this economy. Second, the pure forward-looking model was rejected by the data, since the results for all estimations show that the backward-looking component is high and significant for all the Latin American countries in the sample, which is consistent with the two previous studies mentioned for Latin American countries. Third, the results suggest that the open economy specifications of the NKPC describe in a better way the inflationary process for Mexico and Chile.

The remainder of the thesis is organized as follows. Section 2, outlines the empirical facts for the behavior of inflation in Latin American countries over the sample period. In Section 3, I present the two theoretical frameworks used to derive the NKPCs used in the empirical analysis. Section 4 discusses the data and Section 5 describes the GMM technique which is used to estimate the parameters of each model. The results are reported in Section 6. Finally, Section 7 concludes.

## 2 Motivation

Explaining the evolution of aggregate prices and inflation is one of the most important topics in empirical macroeconomics, and in recent years the New Keynesian Phillips Curve (NKPC) has become a popular tool to analyze the dynamics of inflation. While there exists a number of empirical studies which estimate the NKPC for developed countries as discussed in the introduction, empirical evidence for developing countries is scarce. However, Latin American countries exhibit several characteristics which make them a particularly interesting case to study.

One interesting characteristic of several Latin American countries relates to the evolution of inflation over the last four decades. A number of Latin American economies experienced high and volatile inflation during the 1980's. According to Corbo and Schmidt-Hebel (2001), in many cases this high inflation was due to fiscal dominance (i.e. monetary policy was primarily dictated by fiscal financing needs). However, starting in the early 1990's the region implemented significant fiscal and monetary reforms, the effect of which has resulted in a substantial decrease in inflation rates throughout Latin America. Today, price stabilization has been achieved in the region under various monetary and exchange rate regimes, ranging from exchange-rate-based stabilization and dollarization, to inflation targeting in combination with floating exchange rates (Corbo and Schmidt-Hebbel, 2001).

In order to properly analyze inflation dynamics, it is important to focus not only on its level, but also on its volatility. According to Broto (2008), volatile inflation is costly as it causes more uncertainty about future levels of inflation. Higher uncertainty about future inflation can result in lower credibility of the monetary authority, which in turn, may lead to more persistent inflation (Céspedes et al., 2005)[3]. In Table 1, I present the mean and the standard deviation (as a measure of volatility) of the inflation rates for the sample of Latin American countries that I am going to consider in this thesis: Argentina, Brazil, Chile, Colombia, Mexico and Peru. For comparison, I also include estimates for the U.S., Canada and the Euro area. The inflation rate is measured as the quarterly percentage change of the Consumer Price Index (CPI).

[3] Inflation persistence refers to the impact of past inflation on current inflation.

Table 1: Quarterly CPI inflation statistics (1980-2014)

| Country | Whole sample | | 1980s | | 1990s | | 2000-2014 | |
|---|---|---|---|---|---|---|---|---|
| | **Mean** | **Standard Deviation** | **Mean** | **Standard Deviation** | **Mean** | **Standard Deviation** | **Mean** | **Standard Deviation** |
| Argentina | 22.06 | 62.07 | 57.16 | 92.50 | 15.57 | 55.26 | 2.26 | 2.73 |
| Brazil | 27.31 | 49.75 | 41.11 | 35.75 | 52.46 | 75.19 | 1.58 | 0.92 |
| Chile | 2.45 | 2.39 | 4.76 | 2.50 | 2.60 | 1.91 | 0.83 | 0.84 |
| Colombia | 3.47 | 2.66 | 5.38 | 2.22 | 4.99 | 2.24 | 1.23 | 0.97 |
| Mexico | 5.69 | 7.06 | 13.74 | 8.35 | 4.66 | 3.20 | 1.14 | 0.71 |
| Peru | 21.11 | 71.54 | 39.46 | 49.90 | 33.89 | 120.57 | 0.66 | 0.56 |
| U.S. | 0.79 | 0.62 | 1.20 | 0.75 | 0.73 | 0.33 | 0.57 | 0.56 |
| Canada * | 0.45 | 0.41 | n.a. *** | n.a. *** | 0.38 | 0.33 | 0.48 | 0.45 |
| Euro Area ** | 0.47 | 0.26 | n.a. *** | n.a. *** | 0.42 | 0.19 | 0.49 | 0.28 |

Notes: For Latin American countries all the data comes from the Central Bank of each country. For U.S., Canada and the Euro Area the data comes from OECD. * The period sample for Canada is 1992-2014. ** The period sample for the Euro Area is 1995-2014. *** n.a. means that there is no data available for Canada and the Euro Area for this period.

For the period 1980-2014, Table 1 clearly shows decreasing levels of inflation and inflation volatility for all the Latin American countries of interest. For example, in the case of Mexico a substantial reduction is observed, considering that the average quarterly inflation went from 13.74% in the decade of the 1980's to 1.14% in the period 2000-2014, which represents a remarkable reduction of 1105%, approximately. In respect to volatility, the percentage reduction is similar, since went from 8.35 in the decade of the 1980's to 0.71 for the period 2000-2014, representing an approximate percentage change of 1076%. However, large historical differences exist between inflation levels experienced in Latin American countries and many developed economies, where inflation dynamics have been much more stable. For example, comparing the inflation rates between Chile, the country with the most stable inflation rate in Latin America, and the U.S., is observed that the average quarterly inflation rate has been higher for Chile over the sample, being 4 times larger during the 1980's, 3.5 times higher in the 1990s and 1.5 times in the period 2000-2014. Additionally, it must be noted that these statistics also show that has been a trend toward similarities in the inflation rate for these countries.

Table 1 also shows that significant differences exist in the inflation rates and inflation volatility of the different Latin American countries of interest. In general terms, the region can be divided into two groups: one group consists of Chile, Colombia and Mexico, where quarterly inflation levels have remained below double digits (with the exception of Mexico in the 1980's), and a second group comprised of Argentina, Brazil and Peru, where for much of the sample period (with the exception of 2000-2014) quarterly inflation has been in double digits.

A second interesting characteristic of many Latin American countries is the sizeable increase in trade openness that has taken place in recent years throughout the region. Since the end of the 1980's a number of countries have abandoned protectionism and introduced market-oriented reforms to open-up their economies. Figure 1 depicts the degree of trade openness for each economy of interest over the period 1980-2013, measured as the ratio of the sum of imported and exported goods and services as a share of gross domestic product. While Figure 1 highlights the growing trend of Latin American countries to increase economic openness, there are significant levels of heterogeneity between countries. Table 2, calculates the mean of the degree of trade openness for the period 1980-2013. By inspection, countries such as Mexico and Chile have experienced a much higher degree of trade openness than Brazil and Argentina, for example.

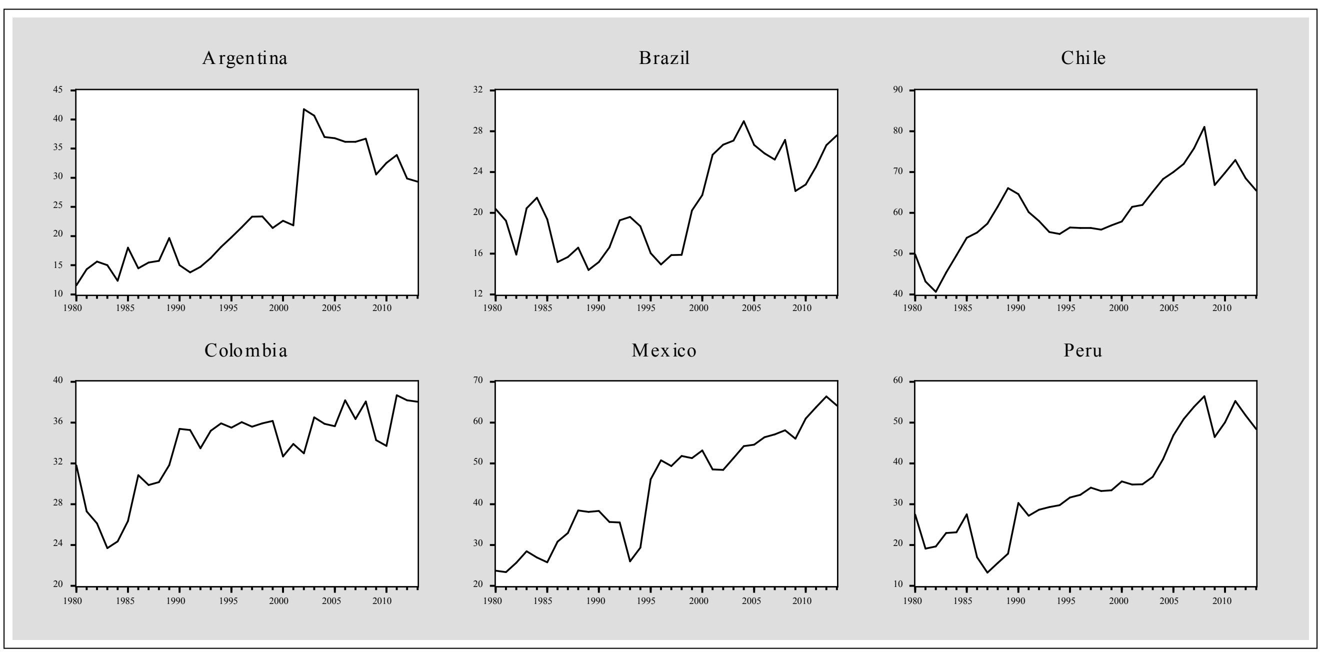


Figure 1: Degree of trade openness for selected Latin American countries (1980-2013). Author estimates using data from the World Bank

Table 2: Average degree of trade openness for selected Latin American countries (1980-2013).

| | Whole Sample | 1980s | 1990s | 2000-2013 |
|---|---|---|---|---|
| **Country** | | | | |
| Argentina | 23.68 | 15.21 | 18.95 | 33.28 |
| Brazil | 20.85 | 17.85 | 17.21 | 25.61 |
| Chile | 60.39 | 52.23 | 57.44 | 68.33 |
| Colombia | 33.51 | 28.22 | 35.44 | 35.92 |
| Mexico | 44.13 | 29.39 | 41.39 | 56.63 |
| Peru | 33.98 | 20.31 | 30.95 | 45.90 |

Notes: Author calculations using data from the World Bank.

While higher degrees of trade openness could have affected the inflation dynamics of each economy via several alternative channels, in this thesis I focus solely on two: the imports of intermediate and capital goods used in the production function, and the terms of trade. Given the heterogeneity found in the data, we would expect that these two channels play a more important role in the inflation dynamics of relatively open economies like Chile and Mexico compared to the relatively closed economies of Brazil or Argentina.

# 3 Theoretical Framework

## 3.1 Models description

This section presents a brief summary of the theoretical New Keynesian models used to derive the different versions of the NKPC which we wish to estimate. For the first approach, I follow Galí and Monacelli (2005) who construct a Dynamic Stochastic General Equilibrium (DSGE) model of the world economy by assuming a continuum of small open economies. As I will show, the supply side of a small economy in this model is represented by the NKPC. The second approach is based on the work of Holmberg (2006) who extends the supply side of Galí and Monacelli (2005) to allow for the effects of international price developments on the inflation rate. She introduces a component which measures the importance of imported goods into the marginal cost function of firms. In addition, Holmberg (2006) derives a hybrid version of the NKPC, which allows the model to capture the impact of inflation inertia.

### 3.1.1 Approach 1: The Galí and Monacelli (2005) Model

**Technology and Marginal Cost of Firms** Galí and Monacelli (2005) assume that firms in each country produce a differentiated good with linear technology represented by the production function[4]

$$Y_t(j) = N_t(j) \tag{3.1}$$

where $N_t(j)$ is the labor force used by firm $j$. Given the production function in equation (3.1) the nominal total costs of the firm, $TC^n$, will be given by

$$TC^n = W_t N_t(j) = W_t Y_t$$

where the nominal marginal cost $MC^n$ of firm $j$ is

$$MC_t^n(j) = W_t$$

In what follows all lower-case letters denote log-deviaions from steady state values. Consequently, the log-linearized expression for real marginal cost (expressed in terms of domestic prices), which is common across domestic firms, is given by:

$$mc_t = w_t - p_{H,t} \tag{3.2}$$

where $p_{H,t}$ is the log-deviation of the domestic price index.

**Firm maximization problem and Calvo price setting behavior** In order to derive an expression for aggregate inflation in this model, it is necessary to derive the price setting behavior of firms. Galí and Monacelli (2005) assume that firms set prices according to Calvo (1983), where each firm can only changes prices infrequently. The frequency of price reoptimization is a stochastic process with a constant probability that a firm sets its prices in an optimal way at each point in time. Thus, each period a measure $1 - \theta$ of randomly selected firms reset their prices, while a fraction $\theta$ keep their prices unchanged. Let $\bar{P}_{H,t}$ denote the price set by a firm $j$ in period $t$ [5]. A firm who reoptimizes in period $t$ will choose the price $\bar{P}_{H,t}$ that maximizes current market value of the profits generated while that price remains effective. Then, in this context, the representative firm´s maximization problem is

[4] In this case, I am using a simplified version of the production function used by Galí and Monacelli (2005), since I set $A_t$, the economy wide technology level, equal to one.

[5] Since all firms resetting prices in any given period will choose the same price, the $j$ can be dropped, and then we can take a representative firm only.

given by:

$$max_{\bar{P}_{H,t}} \sum_{k=0}^{\infty} \theta^k E_t \left\{ Q_{t,t+k} \left[ Y_{t+k} \left( \bar{P}_{H,t} - MC^n_{t+k} \right) \right] \right\} \tag{3.3}$$

where $\beta$ is the time discount factor, $Q_{t,t+k} = \beta^k (C_{t+k}/C_t)^{-\sigma} (P_t/P_{t+k})$ is the stochastic discount factor derived from the optimality condition for the intertemporal problem (the election between present and future consumption) of the household in the economy that we are considering and $MC^n_{t+k}$ is the nominal marginal cost. The firms maximization problem given in (3.3) is subject to its demand function. In this case, given that we are considering an open economy model, the demand for domestic good $j$ is the sum of demand from the small open economy and the world economy. Hence, the demand constraint will be

$$Y_{t+k}(j) = \left( \frac{\bar{P}_{H,t}}{P_{H,t+k}} \right)^{-\varepsilon} \left( C_{H,t+k} + \int_0^1 C^i_{H,t+k} di \right) \equiv Y^d_{t+k}(\bar{P}_{H,t}) \tag{3.4}$$

where $C^i_{H,t}$ denotes country $i$'s demand for good $j$ produced in the home economy, $C_{H,t+k}$ denotes the home household demand for the domestic good $j$, $\varepsilon$ is interpreted as the elasticity of substitution between varieties of goods produced within any given country and $P_{H,t}$ is the domestic price index, which represents an index of prices of domestically produced goods.
To solve this problem we can replace $Y_{t+k}$ in (3.3)

$$max_{\bar{P}_{H,t}} \sum_{k=0}^{\infty} \theta^k E_t \left\{ Q_{t,t+k} \left[ \left( \frac{\bar{P}_{H,t}}{P_{H,t+k}} \right)^{-\varepsilon} \left( C_{H,t+k} + \int_0^1 C^i_{H,t+k} di \right) \left( \bar{P}_{H,t} - MC^n_{t+k} \right) \right] \right\} \tag{3.5}$$

Thus, $\bar{P}_{H,t}$ must satisfy the first order condition:

$$\sum_{k=0}^{\infty} \theta^k E_t \left\{ Q_{t,t+k} \left[ (1-\varepsilon) \left( \frac{\bar{P}_{H,t}}{P_{H,t+k}} \right)^{-\varepsilon} + \varepsilon \left( \frac{\bar{P}_{H,t}}{P_{H,t+k}} \right)^{-\varepsilon-1} \frac{1}{P_{H,t+k}} MC^n_{t+k} \right] \left( C_{H,t+k} + \int_0^1 C^i_{H,t+k} di \right) \right\} = 0$$

$$\implies \quad \sum_{k=0}^{\infty} \theta^k E_t \left\{ Q_{t,t+k} \left[ \bar{P}_{H,t} - \frac{\varepsilon}{(\varepsilon-1)} MC^n_{t+k} \right] \left( \frac{\bar{P}_{H,t}}{P_{H,t+k}} \right)^{-\varepsilon} \left( C_{H,t+k} + \int_0^1 C^i_{H,t+k} di \right) \right\} = 0$$

$$\sum_{k=0}^{\infty} \theta^k E_t \left\{ Q_{t,t+k} Y_{t+k} \left[ \bar{P}_{H,t} - \frac{\varepsilon}{(\varepsilon-1)} MC^n_{t+k} \right] \right\} = 0. \tag{3.6}$$

since $\left(\frac{\bar{P}_{H,t}}{P_{H,t+k}}\right)^{-\varepsilon}\left(C_{H,t+k}+\int_0^1 C^i_{H,t+k}di\right)=Y_{t+k}$. Substituting out the stochastic discount factor and solving for the optimal price $\bar{P}_{H,t}$ yields:

$$\sum_{k=0}^{\infty}\theta^k E_t\left\{\beta^k(C_{t+k}/C_t)^{-\sigma}(P_t/P_{t+k})Y_{t+k}\left[\bar{P}_{H,t}-\frac{\varepsilon}{(\varepsilon-1)}MC^n_{t+k}\right]\right\}=0$$

$$\implies \quad \sum_{k=0}^{\infty}(\beta\theta)^k E_t\left\{(P_{t+k})^{-1}(C_{t+k})^{-\sigma}Y_{t+k}\left(\bar{P}_{H,t}-\frac{\varepsilon}{\varepsilon-1}MC^n_{t+k}\right)\right\}=0$$

$$\bar{P}_{H,t}=\frac{\epsilon}{\epsilon-1}\frac{\sum_{k=0}^{\infty}(\beta\theta)^k E_t\left\{\frac{Y_{t+k}}{P_{t+k}C^\sigma_{t+k}}MC^n_{t+k}\right\}}{\sum_{k=0}^{\infty}(\beta\theta)^k E_t\left\{\frac{Y_{t+k}}{P_{t+k}C^\sigma_{t+k}}\right\}} \tag{3.7}$$

where equation (3.7) it is the optimal price chosen by a firm in period $t$[6]. In order to obtain the log-linearized version of the optimal price setting, equation (3.7) can be rearranged as:

$$\sum_{k=0}^{\infty}(\beta\theta)^k E_t\left\{\frac{\bar{P}_{H,t}Y_{t+k}}{P_{t+k}C^\sigma_{t+k}}\right\}=\frac{\epsilon}{\epsilon-1}\sum_{k=0}^{\infty}(\beta\theta)^k E_t\left\{\frac{Y_{t+k}}{P_{t+k}C^\sigma_{t+k}}MC^n_{t+k}\right\}$$

Log linearizing the above equation around the zero-inflation, flexible price steady state with balanced trade gives:

$$\begin{aligned}&\frac{1}{1-\beta\theta}\frac{Y}{C^\sigma}\sum_{k=0}^{\infty}(\beta\theta)^k E_t\left\{1+y_{t+k}+\bar{p}_{H.t}-p_{t+k}-\sigma c_{t+k}\right\}\\ =&\frac{1}{1-\beta\theta}\frac{Y}{C^\sigma}\sum_{k=0}^{\infty}(\beta\theta)^k E_t\left\{1+y_{t+k}-p_{t+k}-\sigma c_{t+k}+mc^n_{t+k}\right\}\end{aligned}$$

$$\implies \quad \sum_{k=0}^{\infty}(\beta\theta)^k\bar{p}_{H,t}=\sum_{k=0}^{\infty}(\beta\theta)^k E_t\left\{mc^n_{t+k}\right\}$$

$$\bar{p}_{H,t}=(1-\beta\theta)\sum_{k=0}^{\infty}(\beta\theta)^k E_t\left\{mc^n_{t+k}\right\} \tag{3.8}$$

[6]It can be noted that when the flexible price case is considered, i.e., $\theta=0$, (3.7) simplifies to:

$$\bar{P}_{H,t}=\frac{\epsilon}{\epsilon-1}MC^n_t$$

. This equation implies that under flexible prices firms set an optimal price that is constant mark-up over their marginal cost.

where $\bar{p}_{H,t}$ denotes the log of newly set domestic prices in period $t$ and $mc^n_{t+k}$ is the log-deviation of nominal marginal costs around the steady state. It can be seen that the pricing decision in equation (3.11) is forward-looking. The reason for this is that firms that are able to adjust their prices at any given period recognize that the price they set remains unaltered for a random number of periods. As a result, the price they set is a mark-up over a weighted average of expected future marginal costs, instead of just contemporaneous marginal cost only.

**Derivation of the NKPC** We now derive the NKPC for this open economy. In order to do this, we need to consider the dynamics of the domestic price index, which under Calvo (1983) price setting will be a weighted average of a share $(1-\theta)$ of firms which are able to reoptimize in that period and a share $\theta$ of firms who cannot change price. Thus, the structure of the domestic price index is described by the following equation:

$$P_{H,t} = \left[\theta P^{1-\varepsilon}_{H,t-1} + (1-\theta)(\bar{P}_{H,t})^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}} \tag{3.9}$$

The log-linearized version of equation (3.9) around the zero inflation steady state is

$$p_{H,t} = \theta p_{H,t-1} + (1-\theta)\bar{p}_{H,t} \tag{3.10}$$

In order to derive the NKPC, I first use the log-linearized version of the price setting rule of the firms (equation (3.8)) and forward it by one period:

$$\bar{p}_{H,t+1} = (1-\beta\theta)\sum_{k=0}^{\infty}(\beta\theta)^k E_{t+1}\left\{mc^n_{t+k+1}\right\} \tag{3.11}$$

Taking expectations, using the the law of iterated expectations and multiplying by $\beta\theta$ yields:

$$(\beta\theta)E_t\left\{\bar{p}_{H,t+1}\right\} = (1-\beta\theta)\sum_{k=0}^{\infty}(\beta\theta)^{k+1} E_{t+1}\left\{mc^n_{t+k+1}\right\} \tag{3.12}$$

Substracting (3.11) from (3.12) and multiplying by $(1-\theta)$ I get:

$$(1-\theta)\bar{p}_{H,t} = (1-\theta)(1-\beta\theta)mc^n_t + \beta\theta E_t\left\{(1-\theta)\bar{p}_{H,t+1}\right\} \tag{3.13}$$

From the log-linearized equation of the domestic price index (equation (3.10)), I can substitute out $(1-\theta)\bar{p}_{H,t}$ and $(1-\theta)\bar{p}_{H,t+1}$ (after iterating one period forward):

$$\Longrightarrow \quad p_{H,t} - \theta p_{H,t-1} = (1-\theta)(1-\beta\theta)mc^n_t + \beta\theta E_t\left\{p_{H,t+1} - \theta p_{H,t}\right\}$$

Using the fact that the log of the nominal marginal cost can be expressed as $mc_t^n = \widehat{mc}_t + p_{H,t}$, where $\widehat{mc}_t \equiv mc_t - mc$ is the log deviation of real marginal cost from its steady state value[7], and after some algebra I obtain

$$\implies \quad \theta(p_{H,t} - p_{H,t-1}) = (1-\theta)(1-\beta\theta)\widehat{mc}_t + \beta\theta E_t \{p_{H,t+1} - p_{H,t}\}$$

Finally, from the definition of domestic inflation, $\pi_{H,t} = p_{H,t} - p_{H,t-1}$, I arrive at the New Keynesian Phillips Curve (NKPC) for this model:

$$\pi_{H,t} = \lambda \widehat{mc}_t + \beta E_t \pi_{H,t+1} \tag{3.14}$$

where

$$\lambda = \frac{(1-\theta)(1-\beta\theta)}{\theta} > 0$$

Equation (3.14) represents the domestic inflation rate as the sum of two components: the discounted expected inflation and the real marginal cost, with $\lambda$ being the real marginal cost elasticity of inflation. From equation (3.14), it can be observed what are the main differences between the traditional Phillips curve and the NKPC. As discussed in the introduction two main differences can be identified. First, in the NKPC the real marginal cost is the main driving variable for the inflation process. Second, the NKPC implies that the inflation process is forward looking, which means that current inflation is a function of expected future inflation.
In what respect to $\lambda$, it must be noted that it is a decreasing function of $\theta$, the parameter that measures the degree of rigidity in the economy. According to Walsh (2010), the reason of this is that an increase of price rigidity (i.e. an increased of $\theta$) reduces $\lambda$ because with opportunities to adjust arriving less frequently, the firm put less weight on current marginal cost when adjust its price. In addition, an increase of $\beta$, implies that firms gives more weight to future expected profits.

**Consumer Price Index and Terms of Trade** Because we are considering an small open economy, the domestic price index and the consumer price index (CPI) are of course different. In the model of Galí and Monacelli (2005), the CPI index $P_t$ can be defined as a combination of the domestic price index $P_{H,t}$ and the price index of imported goods $P_{F,t}$ for the home economy:

$$P_t = \left[(1-\alpha)(P_{H,t})^{1-\eta} + \alpha\,(P_{F,t})^{1-\eta}\right]^{\frac{1}{1-\eta}} \tag{3.15}$$

where $\eta > 0$ measures the substitutability between domestic and foreign goods, from the point of view of the domestic consumer and $\alpha \in [0,1]$ is a parameter that measures the degree of openness in the economy. The closer $\alpha$ is to one, the more open is the economy. When $\alpha = 0$, we have the case of a closed economy and thus the CPI and the domestic price index are equal. The log-linearized

[7] The steady state value of the real marginal cost is $mc = -log\dfrac{\varepsilon}{\varepsilon - 1} \equiv -\mu$.

version of the CPI around a symmetric steady state satisfying the purchasing parity condition, $P_{H,t} = P_{F,t}$ under assumed full producer currency pricing yields (see Mihailov, Rumler and Sharler (2011) for details)

$$p_t \equiv (1-\alpha)p_{H,t} + \alpha p_{F,t} \tag{3.16}$$

Another important concept in an open economy framework is the terms of trade. In this model, the effective terms of trade are defined as the price of foreign goods in terms of home goods and are represented by

$$S_t = \frac{P_{F,t}}{P_{H,t}} \tag{3.17}$$

where the log-linearized version of equation (3.17) is given by

$$s_t = p_{F,t} - p_{H,t} \tag{3.18}$$

Using the above, it is easy to show that CPI inflation, $\pi_t = p_t - p_{t-1}$, is determined by domestic price inflation and fluctuations in the terms of trade. First, by using the log-linearized version of the terms of trade, where we solve for $p_{F,t}$:

$$p_{F,t} = s_t - p_{H,t} \tag{3.19}$$

to substitute out $p_{F,t}$ from the log-linearized version of the CPI (equation (3.16)) and taking differences yields:

$$\implies \quad p_t = p_{H,t} + \alpha s_t$$

$$\pi_t = \pi_{H,t} + \alpha \Delta s_t \tag{3.20}$$

Now iterate the above equation forward one period and taking expectations yields:

$$E_t\pi_{t+1} = E_t\pi_{H,t+1} + \alpha\Delta E_t s_{t+1} \tag{3.21}$$

and using (3.20) and (3.21) to substitute out $\pi_{H,t}$ and $E_t\pi_{H,t+1}$ from (3.14) the following expression for the NKPC is obtained:

$$\pi_t = \beta E_t\pi_{t+1} + \lambda\widehat{mc}_t + \alpha(\Delta s_t - \beta E_t s_{t+1}) \tag{3.22}$$

In addition, Galí and Monacelli (2005) shown that in their model the output gap and real marginal cost are proportional, thus, the NKPC is also represented as

$$\pi_t = \beta E_t\pi_{t+1} + \kappa_\alpha \hat{y}_t + \alpha(\Delta s_t - \beta E_t s_{t+1}) \tag{3.23}$$

where $\hat{y}$ represents the output gap. Equation (3.22) (or (3.23)) shows that for open economies the CPI inflation rate is not only driven by current-period real marginal cost (or output gap) in addition to expected next-period CPI inflation, as in closed economy, but also by the expected changes in terms of trade. The intuition behind the introduction of the terms of trade in the NKPC is as follows. As pointed out by Mihailov, Rumler and Sharler (2011), an expected improvement in the terms of trade ($\Delta s_t > \beta E_t \Delta s_{t+1}$) would increase current demand for domestic goods (as their price is relatively lower than what is expected in the future) and this increase in demand generates upward pressure on current inflation. Note that if $\alpha = 0$, in equations (3.22) and (3.23) we once again revert to the closed-economy version of the NKPC.

### 3.1.2 Approach 2: The Holmberg (2006) model

Holmberg (2006) also assumes that firm price-setting follows Calvo (1983). Consequently, the optimal price set by firm $i$ is:

$$p_{it} = (1-\beta\theta)\sum_{k=0}^{\infty}(\beta\theta)^k E_t\left\{mc^n_{it+k}\right\} \tag{3.24}$$

which is identical to equation (3.8). To introduce inflation persistence into the theoretical framework, Holmberg (2006) follows the Galí and Gertler (1999) and allows for some backwardness to capture the inertia in inflation. Specifically, it is assumed that a share $(1-\theta)$ of firms are able to adjust their price, while the remaining firms keep prices fixed. However, of the firms who are allowed to change their prices, only a fraction $(1-\phi)$ can now set prices optimally (i.e. in a forward looking manner), while a fraction $\phi$ use a simple rule of thumb that is based on the recent history of aggregate price behavior. Galí and Gertler (1999) define these firms as backward-looking firms. Consequently, the index for newly set prices can be expressed in log-linearized form as:

$$p^*_t = (1-\phi)\bar{p}^f_t + \phi p^b_t \tag{3.25}$$

where the superscript $f$ indicates the price of firms that set prices optimally and the superscript $b$ indicates the price of backward looking firms. All forward-looking firms will choose the same optimal price and behave exactly as in equation (3.8)

$$\bar{p}^f_t = (1-\beta\theta)\sum_{k=0}^{\infty}(\beta\theta)^k E_t\left\{mc^n_{t+k}\right\} \tag{3.26}$$

The assumed rule-of-thumb for the backward looking firms can be expressed in log-linearized form as follows[8] is, in log-linearized form, as follows:

$$p^b_t = p^*_{t-1} + \pi_{t-1} \tag{3.27}$$

[8]Galí and Gertler (1999) assume that the rule of thumb has two features: (a) there is no persistent deviations between the rule and optimal behaviour, i.e., in the steady state the rule is consistent with optimal behavior; (b) the price in period $t$ given by the rule depends only in information dated *t-1* or earlier.

where $p^*_{t-1}$ is the price index reset in period $t-1$ and $\pi_{t-1} = p_{t-1} - p_{t-2}$. To derive the NKPC we proceed as follows. First, the aggregate price level in log-linearized form evolves according to

$$p_t = (1-\theta)p^*_t + \theta p_{t-1} \tag{3.28}$$

Second, subtract (3.28) from (3.27) to get

$$p^b_t - p_t = \frac{1}{1-\theta}[\pi_{t-1}] - \pi_t \tag{3.29}$$

Third, solving for $p^*_t$ in (3.28) and plugging the result into equation (3.25) yields

$$\frac{\theta}{1-\theta}\pi_t = (1-\phi)(p^f_t - p_t) + \phi(p^b_t - p_t) \tag{3.30}$$

Solving this equation for $p^f_t$, forwarding this expression one period and taking expectations generates

$$E_t\left\{p^f_{t+1}\right\} = \frac{\theta}{(1-\phi)(1-\theta)}E_t\left\{\pi_{t+1}\right\} - \frac{\phi}{1-\phi}E_t[p^b_{t+1} - p_{t+1}] + E_t\left\{p_{t+1}\right\} \tag{3.31}$$

From (3.29) we can substitute $p^b_{t+1} - p_{t+1}$ in equation (2.31) to get

$$E_t\left\{p^f_{t+1}\right\} = \frac{\theta + \phi(1-\theta)}{(1-\phi)(1-\theta)}E_t\left\{\pi_{t+1}\right\} - \frac{\phi}{(1-\phi)(1-\theta)}\pi_t + E_t\left\{p_{t+1}\right\} \tag{3.32}$$

Fourth, quasi-differentiating (3.26) yields:

$$p^f_t = (1-\beta\theta)mc_t + \beta\theta E_t\left\{p^f_{t+1}\right\} \tag{3.33}$$

which expressed with the log deviation of the real marginal cost becomes:

$$p^f_t = (1-\beta\theta)[mc^r_t + p_t] + \beta\theta E_t\left\{p^f_{t+1}\right\} \tag{3.34}$$

If we subtract $p_t$ from both sides of equation (3.34)

$$p^f_t - p_t = (1-\beta\theta)mc^r_t - \beta\theta p_t + \beta\theta E_t\left\{p^f_{t+1}\right\} \tag{3.35}$$

and substituting (3.32) into (3.35) generates

$$p^f_t - p_t = (1-\beta\theta)mc^r_t + \left[\beta\theta + \beta\theta\left(\frac{\theta + \phi(1-\theta)}{(1-\theta)(1-\phi)}\right)\right]E_t\left\{\pi_{t+1}\right\} - \frac{\beta\theta\phi}{(1-\theta)(1-\phi)}\pi_t \tag{3.36}$$

Finally, substituting (3.36) and (3.29) into (3.30) the hybrid NKPC its obtained

$$\pi_t = \frac{(1-\beta\theta)(1-\theta)(1-\phi)}{\theta + \phi[1-\theta(1-\beta)]}mc^r_t + \frac{\beta\theta}{\theta + \phi[1-\theta(1-\beta)]}E_t\pi_{t+1} + \frac{\phi}{\theta + \phi[1-\theta(1-\beta)]}\pi_{t-1} \tag{3.37}$$

or in a compact version

$$\pi_t = \xi \widehat{mc}_t + \lambda_f E_t \pi_{t+1} + \lambda_b \pi_{t-1} \tag{3.38}$$

where

$$\xi = \frac{(1-\beta\theta)(1-\theta)(1-\phi)}{\theta + \phi[1-\theta(1-\beta)]}$$

$$\lambda_f = \frac{\beta\theta}{\theta + \phi[1-\theta(1-\beta)]}$$

$$\lambda_b = \frac{\phi}{\theta + \phi[1-\theta(1-\beta)]}$$

By inspection of equation (3.38) we see that in the case of $\phi = 0$, i.e., the number of backward-looking firms is zero, $\xi = \dfrac{(1-\theta)(1-\beta\theta)}{\theta}$; $\lambda_f = \beta$, and $\lambda_b = 0$, and then, (3.38) collapses to the baseline representation of the NKPC.

**Real Marginal Cost specification** In order to capture the effects of international price changes, Holmberg (2006) assumes a Cobb-Douglas production function which not only depends on national inputs, but also on imported inputs. The assumption here is that all firms adopt the same production function technology and need three inputs, labor (N), capital (K) and imported goods (IM). In addition, let $A_t$ denotes technology. Thus, the production function of any firm in period $t$ is:

$$Y_t = A_t N_t^{\zeta} (IM_t^{\delta} K_t^{1-\delta})^{1-\zeta} \tag{3.39}$$

where $0 < \zeta < 1$, $0 < \delta < 1$. Note that this production function implies constant return to scale with respect to production factors. To get the cost function, it is necessary to solve the following cost minimization problem (assuming that capital is fixed, where for simplicity I set $A_t$=$K_t$=1)

$$min(W_t N_t + P_t^m IM_t) \tag{3.40}$$

$$\text{s.t. } N_t^{\zeta} IM_t^{\delta(1-\zeta)} = Y_t$$

where $W_t$ is the nominal wage of the workers, $N_t$ is the labor that firms want to hire, $P_t^m$ is the price of imported inputs and $IM_t$ represents the imports of the intermediate inputs. Solving this minimization problem we get the following cost function:

$$C_t = \left[ \left(\frac{\zeta}{\delta(1-\delta)}\right)^{\frac{\delta(1-\zeta)}{\zeta+\delta(1-\zeta)}} + \left(\frac{\zeta}{\delta(1-\zeta)}\right)^{\frac{-\zeta}{\zeta+\delta(1-\zeta)}} \right] W_t^{\frac{\zeta}{\zeta+\delta(1-\zeta)}} (P_t^m)^{\frac{\delta(1-\zeta)}{\zeta+\delta(1-\zeta)}} Y_t^{\frac{1}{\zeta+\delta(1-\delta)}} \tag{3.41}$$

Then, the marginal cost function, which is obtained from the first order condition for $Y_t$ is given by

$$MC_t = \varrho \left(\frac{W_t N_t}{Y_t}\right)^{\frac{\zeta}{\zeta+\delta(1-\zeta)}} \left(\frac{P_t^m IM_t}{Y_t}\right)^{\frac{\delta(1-\zeta)}{\zeta+\delta(1-\zeta)}} \tag{3.42}$$

where to simplify notation we use $\varrho$ to denote the following expression

$$\varrho = \left[ \left( \frac{\zeta}{\delta(1-\delta)} \right)^{\frac{\delta(1-\zeta)}{\zeta+\delta(1-\zeta)}} + \left( \frac{\zeta}{\delta(1-\zeta)} \right)^{\frac{-\zeta}{\zeta+\delta(1-\zeta)}} \right]^{\frac{1}{\zeta+\delta(1-\zeta)}}$$

After dividing by $P_t$ (the aggregate price level), we get an expression for real marginal cost:

$$MC_t^r = \varrho \left( \frac{W_t N_t}{P_t Y_t} \right)^{\frac{\zeta}{\zeta+\delta(1-\zeta)}} \left( \frac{P_t^m IM_t}{P_t Y_t} \right)^{\frac{\delta(1-\zeta)}{\zeta+\delta(1-\zeta)}} \tag{3.43}$$

and its log-linearized version is given by:

$$\widehat{mc}_t^r = \frac{1}{\zeta+\delta-(1-\zeta)} [\zeta(w_t + n_t - p_t - y_t) + \delta(1-\zeta)(p_t^m + im_t - p_t - y_t)] \tag{3.44}$$

where the two components of real marginal cost can be defined as $ls_t = (w_t + n_t - p_t - y_t)$, which is real unit labor costs and $ims_t = (p_t^m + im_t - p_t - y_t)$ is the share of imported intermediate goods to production in current prices.

**NKPC for an open economy** Now, I have all the elements to express the NKPC in the second model as one that takes into account the international environment via the marginal cost of firms. Using equations (3.38) and (3.44), the NKPC can be expressed as

$$\pi_t = \kappa_1 ls_t + \kappa_2 ims_t + \lambda_f E_t \pi_{t+1} + \lambda_b \pi_{t-1} \tag{3.45}$$

where:

$$ls_t = \frac{w_t n_t}{p_t y_t}; \quad ims_t = \frac{p_t^m i_t}{p_t y_t}; \quad \kappa_1 = \xi \frac{\zeta}{\zeta+\delta(1-\zeta)} \quad \kappa_2 = \xi \frac{\delta(1-\zeta)}{\zeta+\delta(1-\zeta)}$$

This representation of the NKPC tell us that current inflation will be driven not only by the expected inflation and the unit labor cost, but also by the share of imported inputs into the economy which has a positive impact on inflation (since the parameter $\kappa_2$ is positive) and by the lag of inflation, which is a measure of inflation inertia. As in the model of Galí and Monacelli (2005), a closed economy representation can be obtained when the share of imported inputs it is equal to zero.

## 3.2 Summarizing

Before proceeding, let's summarize the equations that I am going to empirically estimate. As usual in the literature, I am going to estimate each specification using both, the unit labor cost and the output gap as proxies for marginal cost. Thus, I will specify equations using both variables. As a benchmark, I will first estimate a closed economy version of the NKPC. From equations (3.22) and

(3.23) of the Galí and Monacelli (2005) model, by setting $\alpha = 0$ I get

$$\pi_t = \lambda \widehat{mc}_t + \beta E_t \pi_{t+1} \qquad \pi_t = \kappa \widehat{y}_t + \beta E_t \pi_{t+1} \tag{3.46}$$

By setting the share of imported inputs equal to zero in the hybrid closed-economy version of the NKPC derived from Holmberg (2006) yields

$$\pi_t = \xi \widehat{mc}_t + \lambda_f E_t \pi_{t+1} + \lambda_b \pi_{t-1} \qquad \pi_t = \kappa \widehat{y}_t + \lambda_f E_t \pi_{t+1} + \lambda_b \pi_{t-1} \tag{3.47}$$

After the estimation of the representations above, I am then going to consider the open economy versions of the NKPC. Thus, from the model of Galí and Monacelli (2005) I have the equations

$$\pi_t = \beta E_t \pi_{t+1} + \lambda \widehat{mc}_t + \alpha(\Delta s_t - \beta E_t s_{t+1}) \qquad \pi_t = \beta E_t \pi_{t+1} + \kappa \widehat{y}_t + \alpha(\Delta s_t - \beta E_t s_{t+1}) \tag{3.48}$$

In order to be able to compare both models, I will also consider the special case of the model of Holmberg (2006) when $\phi$, the number of backwardness firms is equal to zero. This gives the expressions

$$\pi_t = \Omega_1 ls_t + \Omega_2 ims_t + \beta E_t \pi_{t+1} \qquad \pi_t = \Omega_1 \hat{y}_t + \Omega_2 ims_t + \beta E_t \pi_{t+1} \tag{3.49}$$

where $\Omega_1 = \left(\frac{(1-\beta\theta)(1-\theta)}{\theta}\right)\left(\frac{\zeta}{\zeta+\delta(1-\zeta)}\right)$ and $\Omega_2 = \left(\frac{(1-\beta\theta)(1-\theta)}{\theta}\right)\left(\frac{\delta(1-\zeta)}{\zeta+\delta(1-\zeta)}\right)$. Finally, I am going to consider the case of a hybrid open economy. Even though for the case of the model of Galí and Monacelli (2005) I have not fully derived a hybrid version of the NKPC, it will be worthwhile to estimate a representation of this model with the lag of the inflation as explanatory variable. This yields

$$\pi_t = \Upsilon_f E_t \pi_{t+1} + \Upsilon_b \pi_{t-1} + \lambda \widehat{mc}_t + \alpha(\Delta s_t - \beta E_t s_{t+1}) \quad \pi_t = \Upsilon_f E_t \pi_{t+1} + \Upsilon_b \pi_{t-1} + \lambda \widehat{y}_t + \alpha(\Delta s_t - \beta E_t s_{t+1}) \tag{3.50}$$

where $\Upsilon_f$ and $\Upsilon_b$ the coefficients associated with forward and backward looking component of inflation. The equivalent derived from the model of Holmberg (2006) is given by

$$\pi_t = \kappa_1 ls_t + \kappa_2 ims_t + \lambda_f E_t \pi_{t+1} + \lambda_b \pi_{t-1} \qquad \pi_t = \kappa_1 ls_t + \kappa_2 \widehat{y}_t + \lambda_f E_t \pi_{t+1} + \lambda_b \pi_{t-1} \tag{3.51}$$

# 4 Data Description

I estimate the equations above for six Latin American countries: Argentina, Brazil, Chile, Colombia, Mexico and Peru. Table 3 summarizes the sample period for each country which differs due to data availability.

Table 3: Period of estimation.

| **Country** | **Period** |
|---|---|
| Argentina* | 1993-2013 |
| Brazil | 1996-2014 |
| Chile | 1996-2014 |
| Colombia | 2000-2014 |
| Mexico | 1993-2914 |
| Peru** | 1996-2014 |

Notes: * For the case of Argentina, the unit labor cost only cover the period 2001-2013.** For the case of Peru, I do not have data of the unit labor cost.

All the data have been obtained from the Central Bank and/or the National Institute of Statistics of each country. In the appendix I detail the source of each variable for each country.For each specification of the NKPC, the inflation rate is expressed as the quarterly percentage change in the Consumer Price Index (CPI).

Figure 2 shows the evolution of the CPI inflation rate for each country. It is important to note that there are some important facts that explain the behavior of inflation during the period that I am considering. For the case of Argentina, the shaded area in the graphic represents the period of the currency board scheme (the Convertibility Regime), which was adopted in April 1991 as an attempt to anchor inflation expectations by fixing the peso to the dollar. This policy, combined with public sector reforms which included the privatization of the main public enterprises and the dollarization of the financial system was succesful in anchoring inflation expectations (D´Amato et al., 2008). By 1993 inflation in Argentina had stabilized at low levels. However, in 2001 a combination of external and financial crises (which was caused in part by the Asian crisis and some internal fiscal disequilibrium), led to the abandonment of the Convertibility regime, to a sharp devaluation of the currency and to the adoption of a managed float. The devaluation of the currency provoked a jump in the inflation rate, which reached a peak in April 2002. After the crisis, the inflation rate returned to lower levels, but still higher than those of the convertibility regime.

For the case of the other countries, one important change happened during the 1990's: all of them adopted the Inflation Targeting (IT) monetary regime. For the case of Brazil, before IT, a pegged exchange rate regime had been adopted from 1994 to 1999, to help stop the country´s hyperinflation crisis. This regime was successful in reducing the inflation rate during those five years, but it turned out to be unsustainable in the medium run, since according to Barbosa (2008), this stabilization strategy was heavily dependent on the inflow of foreign capital and, as a result, the international financial position of Brazil became fragile after the contagion effects of the East Asian currency crises of 1997 and the Russian currency crisis of 1998. This resulted in the adoption of a floating exchange regime in 1999 and the introduction of an explicit inflation targeting framework in the same year, which ended a period when the exchange rate had been the main anchor for monetary policy. In Figure 2, I illustrate with a vertical line the date when Brazil adopted the IT regime, which by inspection, has maintained inflation at a low level, with the exception of a spike in 2002[9]. Chile was the first country in Latin America to adopt an IT monetary regime. According to Céspedes, Ochoa and Soto (2005), there have been two clear phases in the implementation of the inflation targeting regime in Chile. In the first phase, when gaining credibility was a key issue, the Central Bank set short term horizon CPI inflation targets, and actively managed the exchange rate. In the second phase that started in 1999 the Central Bank moved to a fully flexible exchange rate system, and adopted an explicit IT mechanism. Colombia formally implemented an IT strategy after the abandonment of exchange rate bands in 1999. Mexico formally adopted an IT framework in 2001, and from December 2003, a long term inflation target of 3 per cent was adopted with a variability interval of $+/-1$ percentage point. In Figure 2, I illustrate with a red vertical line the period which marks a change in the Mexican monetary regime. Finally, according to Broto (2008) Peru adopted an in 1994, although we follow some other studies which consider 2002 as the year of adoption of an explicit IT framework, as this target coincided with a money growth operational target. In summary, with the exception of Colombia, the period of estimation for each country includes some structural changes in the monetary policy regime.

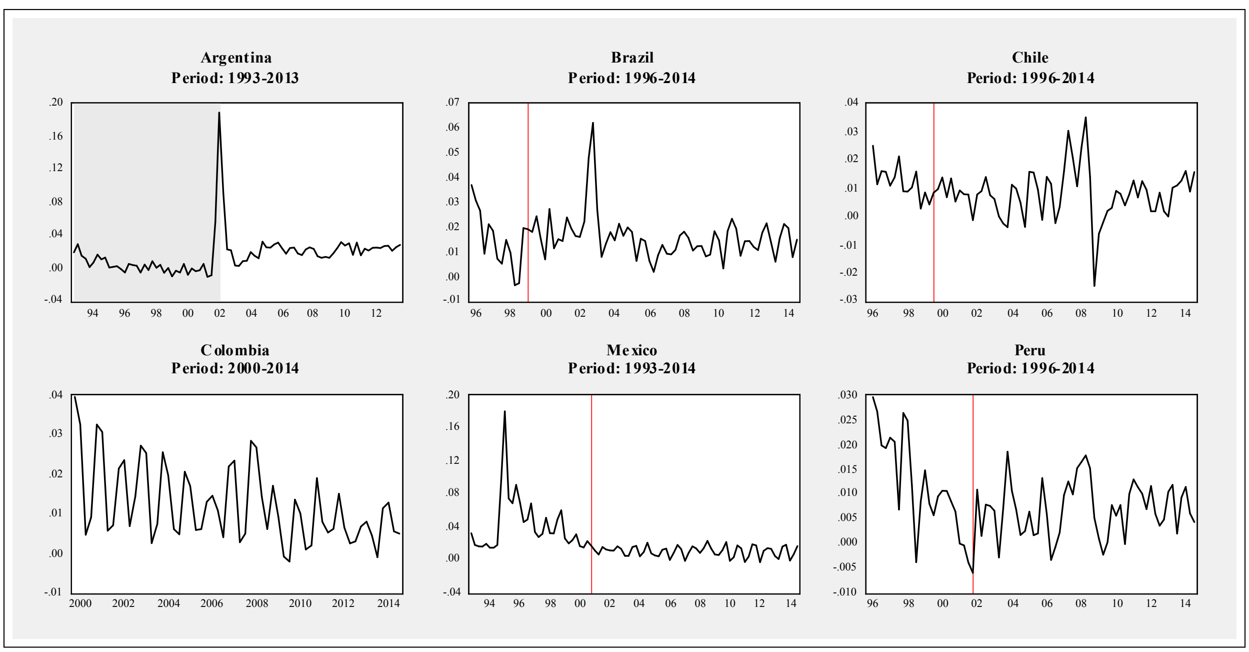


Figure 2: Quarterly Inflation Rate for selected Latin American Countries

[9]According to Minella, Springer, Goldfajn and Kfoury (2003), this was caused by several external and domestic shocks, as a domestic energy crisis, the deceleration of the world economy and the Argentine crisis, which had significant inflationary effects.

Since the real marginal cost is a no observable variable and thus is must be estimated, in this thesis I use two approaches that are frequently used in the empirical work.
First, I consider as a proxy the output gap. The output gap in this case is defined as the deviation of real GDP from a Hodrick-Prescott (HP) trend. Because the HP filter is a smoothing method to obtain a smooth estimate of the long term component of a series (which in our case is the steady state), I need to define a number for the smoothing parameter. I choose as a value of the smoothing parameter 1600, which is the standard value for quarterly data[10]. Additionally, following Mihailov, Rumler and Sharler (2011), this measure is normalized by its standard deviation to ensure comparable magnitudes across the sample countries. Figure 3 depicts the output gap for each country where I also include the inflation rate. In the case of Chile and Peru, inflation and output gap generally move in the same direction, while for Argentina and Brazil inflation and the output gap tend to move in opposite directions.
Theoretically, higher output gaps are associated with an increase in marginal costs.Thus, all else being iqual, one should observe a positive association between the output gap and inflation. For some countries, Figure 3 may indicate some deficiencies of using the output gap as a proxy for real marginal cost. Of course, must be considered that the graphical approach is week, since the inflation rate is influenced by other factors. In addition, in the theoretical perspective of the NKPC, the output gap has a lagged effect on inflation, which may make a visual relationship difficult to detect.

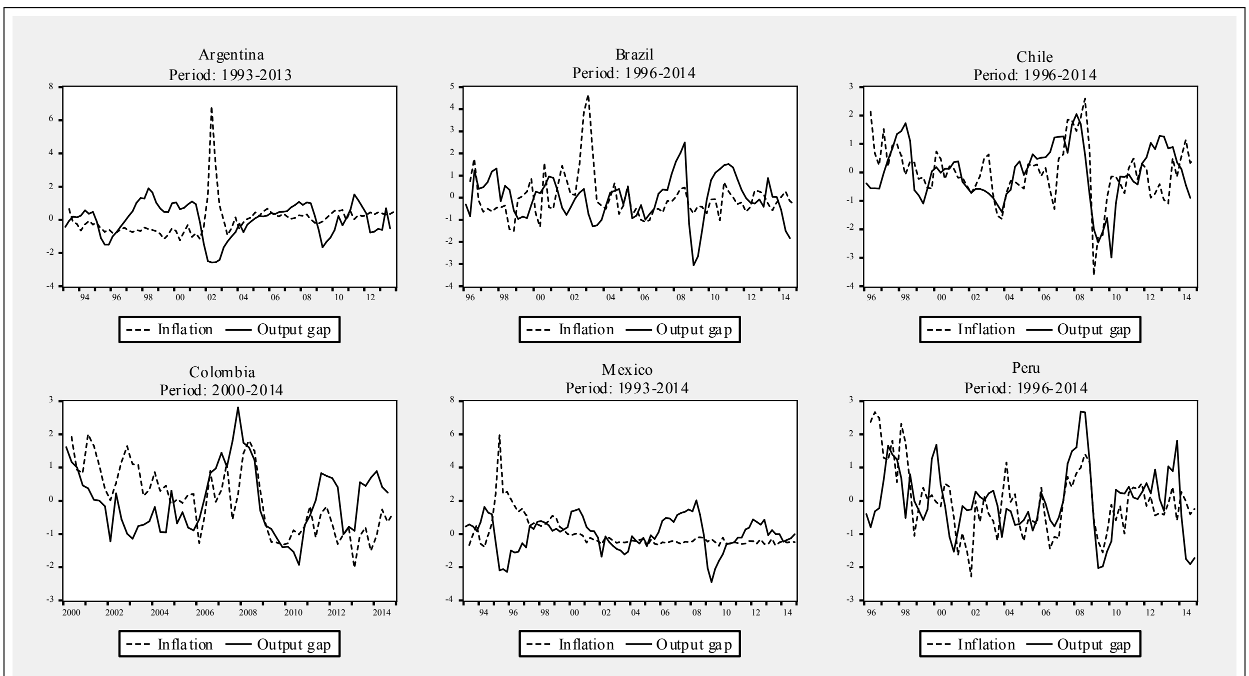


Figure 3: Output gap for selected Latin American countries.

A commonly used alternative to output gaps is to use unit labor costs as a proxy for real

[10]A good explanation of the HP filter can be found in E-views 8 User Guide.

marginal cost. In particular, Galí and Gertler (1999) have proposed the use of the unit labor cost as a measure of the marginal cost, where this concept is defined as $\frac{wL}{PY}$, with $w$ = wage, $L$ = number of workers and $PY$ = nominal GDP. In this case, however, because I use different measures of unit labor cost (depending on data availability), the comparison across countries is limited. For the case of Argentina, Brazil and Colombia this variable was constructed using total compensations of the economy to workers divided by the nominal GDP, consistent with Galí and Gertler (1999). However, for the case of Chile and Mexico this approach was not possible. Instead, for Chile I use an index of real compensations constructed by the Central Bank of Chile, whereas for Mexico, I use the index of the unit labor cost of the manufacturing industry, which is published by the Instituto Nacional de Estadística y Geografía (INEGI) [11].

In order to avoid estimating relations between non-stationary variables that could be subject to the problem of spurious correlation, the trend for the unit labor cost measures is removed, using as detrending method the H-P filter.

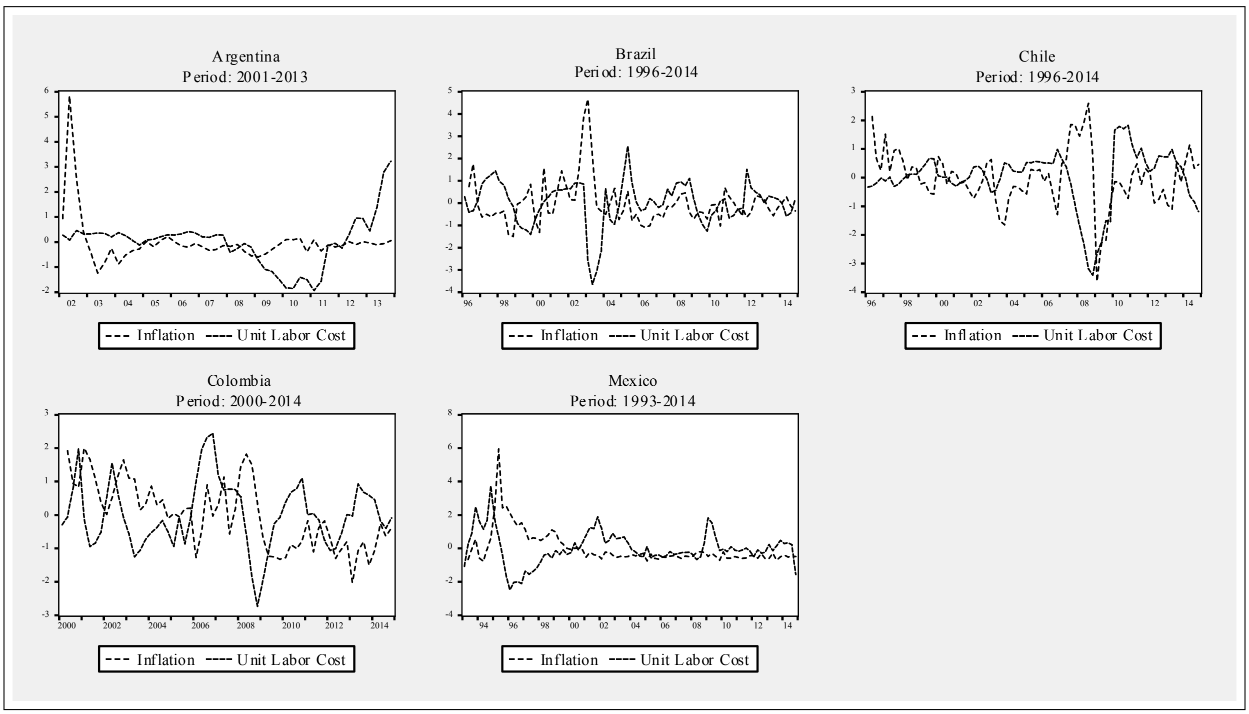


Figure 4: Unit Labor Cost for selected Latin American countries.

In respect to the effective terms of trade which is required for the open economy specification of the NKPC, recall that it is defined as the price of foreign goods in terms of home goods. I calculate the log difference of the import prices and the export prices for each country, which as discussed

[11]The main difference between the index of real compensations of Chile and the index of unit labor cost of Mexico is that the index of real compensations includes all the economic activities in Chile, while the index of Mexico includes only the manufacturing industry. As it noted above, for that reason the comparison is limited.

by Mihailov, Rumler and Sharler (2011) implicitly gives the effective terms of trade because the importance of the trading partners is automatically reflected in the deflators. The evolution of this variable it is shown in Figure 5. Because of the way in which the terms of trade are defined, a decrease in this variable implies an improvement of the terms of trade. Hence, by inspection of Figure 5, the terms of trade have shown an improvement in Argentina, Brazil, Chile and Colombia (countries that are mainly exporters of primary goods), especially since 2008, when prices of raw materials and commodities increased. For Mexico, which exports are mainly manufactured goods, the terms of trade deteriorated in 2008, due to the impact generated by the increase in the price of raw materials.

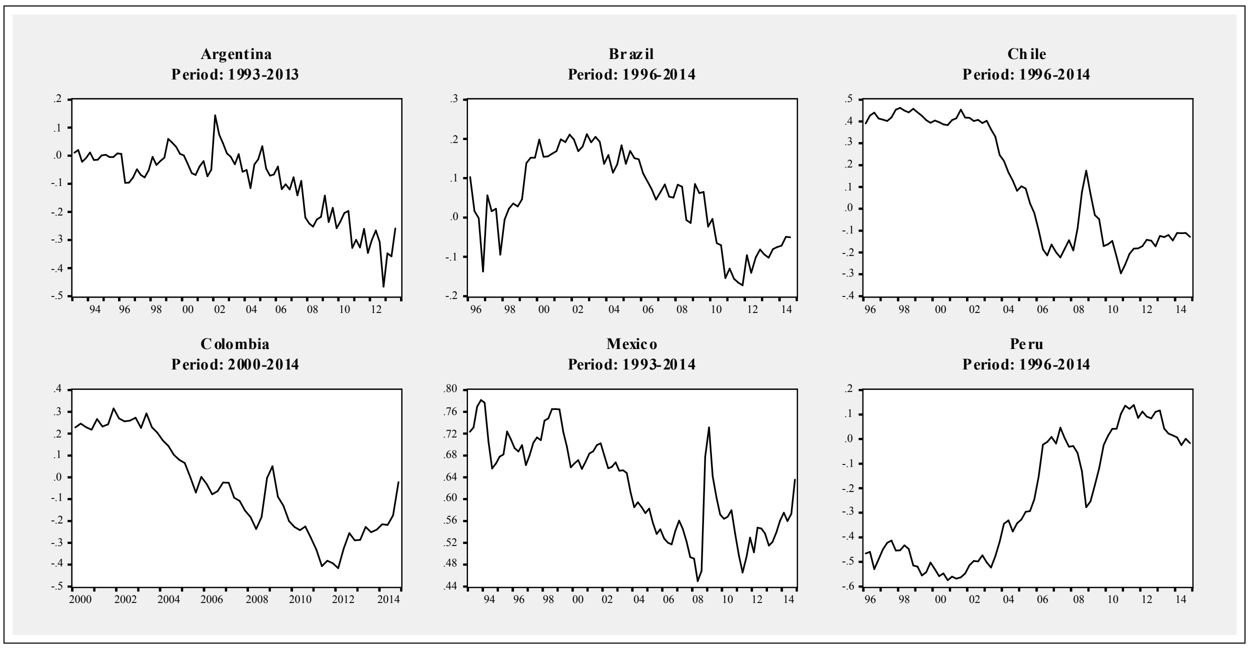


Figure 5: Terms of trade for selected Latin American countries.

Finally, to estimate the model specification based on Holmberg (2006), for the cost measure of imported goods I use the imports of capital and intermediate goods as a share of the nominal GDP as a proxy of the imported goods used into the production. Following Holmberg (2006), this variable will be expressed as the percentage deviation from the mean. By inspection of Figure 6, for all the countries, with the exception of Chile, there is a growing trend in the imports of intermediate and capital goods as a proportion of nominal GDP.


Figure 6: Import share as deviation from mean.

# 5 Estimation Technique

The usual technique to estimate the parameters of the New Keynesian Phillips curve is to employ the Generalized Method of Moments (GMM). In this section, I will briefly summarize this method and discuss the reasons for using it. Before proceeding, I want to remark that by a moment I refer here to the moments of a distribution, which are a set of numerical descriptive measures that define a probability distribution (Gujarati, 2003). Following Wackerly, Mendenhall and Scheaffer (2007), a formal definition of moments can be established

**Definition 5.1.** The $k$th moment of a random variable $w$ taken about the origin is defined to be $E(w^k)$.

Using an example to clarify this concept, consider the first moment (which implies $k = 1$) of the random variable $w$. In this case, what we have is the expected value of the random variable, or, as Davidson and Mackinnon (2004) point out, the population mean of the random variable $w$, $E(w) = \mu$, where $\mu$ is the common notation for the population mean. In general, the moments of the random variables are known as the population moments.

Returning to GMM, this is an estimator originally proposed by Hansen (1982), and is a generalization of the classical Method of Moments (MM). At this point, in order to facilitate the procedure of GMM, I am going to briefly discuss the MM technique. The MM procedure makes use of the fact that a natural way to estimate parameters is to replace population moments by sample moments (Davidson and MacKinnon, 2004). Again, I can use the previous example to clarify this.

Suppose that I want to estimate $E(w) = \mu$ using MM. Then, according to this method, what I should do is to form an equation called the population moment condition, which in this example is $E[w - \mu] = 0$[12]. Solving this equation would give the value of $\mu$ that satisfy the population moment condition (2004). However, this population moment condition cannot be observed. Thus, based on the MM technique, the way to proceed is to replace the population moment condition with the sample moment condition, where the sample moment condition is

$$\frac{1}{T}\sum_{i=1}^{T}(w_i - \hat{\mu}) = 0$$

where T is the size of the available sample and $\hat{\mu}$ is the estimator that solves the sample moment condition, i.e., is the estimator that makes that the expression of the left side of the equation be equal to zero.

Now I can consider the general case of the MM technique. Following Greene (2008), it can be assumed that there are a set of $L$ population moment conditions and $K$ parameters of interest that should satisfy these moment conditions . Then, we can consider a model which involves $K$ parameters, $\theta = (\theta_1, \theta_2, ..., \theta_K)$. Let $\mathbf{w_t}$ be a vector of random variables, $\theta$ be a $K$ by 1 vector of parameters, and $\mathbf{g}$ be a $L$ by 1 vector valued function whose expected value is zero in the population. Then, for the general case, the population moment condition can be defined as:

$$E\left[\mathbf{g}(\mathbf{w_t}, \theta)\right] = \mathbf{0} \tag{5.1}$$

where $\mathbf{0}$ is a vector of zeros. From equation (5.1) it can be noted that by population moment condition we make reference to a function $\mathbf{g}$ (for the general case), that evaluated at the true value of the parameters $\theta$, the expectation of that function is equal to zero. In equation (5.1), when the number of moment conditions are equal to the number of parameters, $L = K$, we have a system with the same number of equations as parameters. In this case, we can say that the system is identified.

Solving these equations would give the value of $\theta$ that satisfies the moment conditions and this will be the true value of the parameters. However, $E\left[\mathbf{g}(\mathbf{w_t}, \theta)\right] = \mathbf{0}$ cannot be observed. Then, the population moment conditions in (5.1) are replaced with the sample moment condition which is

$$\mathbf{g}_t(\mathbf{w}, \theta) = \frac{1}{T}\sum_{t=1}^{T}\mathbf{g}(\mathbf{w_t}, \theta) = \mathbf{0} \tag{5.2}$$

where $T$ is again the size of the available sample. The parameter vector $\theta$ that solves equation (5.2) is the traditional MM estimator.

Nevertheless, there are cases when the number of moment conditions are greater than the number

[12]In this case I am using the fact that the expected value of a constant is equal to the same constant, which implies $E[\mu] = \mu$

of parameters, $L > K$, and then, the system of equations given in (5.2) may not have an exact solution, and then, it is not possible to use the MM technique. In cases like these, when $L > K$, it is said that the system of equations is algebraically overidentified. In such cases, to use all the information in the sample it is necessary to devise a way to reconcile the conflicting estimates that may emerge from the overidentified system. It is in situations like these, when the GMM estimator can be used. According to Green (2008), though it is generally not possible to find an exact solution for an overidentified system, the problem can be reformulated as one of choosing $\theta$ so that the sample moment $\mathbf{g}_t(\mathbf{w}, \theta)$ is as close to zero as possible, where close is defined using the quadratic form:

$$Q_T(\theta) = \mathbf{g}_t(\mathbf{w}, \theta)' \mathbf{W}_t \mathbf{g}_t(\mathbf{w}, \theta) \tag{5.3}$$

where $\mathbf{W}_t$ is a positive definite matrix $L \times L$ which will be discussed below. The GMM estimate is defined as the $\theta$ that minimizes equation (5.3):

$$\hat{\theta} = argminQ_T(\theta) \tag{5.4}$$

One important aspect of specifying a GMM estimator is the choice of $\mathbf{W}_t$, which is called the weighting matrix. While it can be shown that any symmetric positive definite matrix $\mathbf{W}_t$ will yield a consistent estimate of the vector of interest, the choice of the weighting matrix affects the asymptotic variance of the GMM estimator (Greene, 2008). Hansen (1982) show that a necessary condition to obtain an asymptotically efficient estimate of $\theta$ is to set $\mathbf{W}_t$ equal to the inverse of the covariance matrix of the sample moments, i.e., if the covariance matrix is defined as $S_0$, then the smallest asymptotic covariance matrix for an estimator $\theta$ that minimizes (5.5) is obtained by letting $\mathbf{W}_t = S_0^{-1}$:

$$Q_T(\theta) = \mathbf{g}_t(\mathbf{w}, \theta)' S_0^{-1} \mathbf{g}_t(\mathbf{w}, \theta) \tag{5.5}$$

Under suitable regularity conditions, it can be shown that the GMM estimator which minimizes (5.5) is consistent, asymptotically normally distributed and asymptotically efficient (Mátyás, 1999). There are three main reasons to use GMM to estimate the parameters of the NKPC. First, because it is an estimation procedure that allows economic models to be specified while avoiding often unwanted or unnecessary assumptions, such as specifying a particular distribution of the error term. Second, I have a non-linear equation when I estimate the model of Mihailov, Rumler and Sharler (2011), and then traditional econometrics methods cannot be applied. Third, because the GMM solves the problem of endogeneity that arises in the estimation, since the residuals are correlated with some of the variables of the model. This can be shown from the empirical equations of the models that I am going to estimate:

$$\pi_t = \lambda \widehat{mc}_t + \beta \pi_{t+1} + u_{t1} \tag{5.6}$$

$$\text{where } u_{t1} = \nu_{t1} - \beta(\pi_{t+1} - E_t \pi_{t+1})$$

$$\pi_t = \xi \widehat{mc}_t + \lambda_f E_t \pi_{t+1} + \lambda_b \pi_{t-1} + u_{t2} \tag{5.7}$$

$$\text{where } u_{t2} = \nu_{t2} - \lambda_f(\pi_{t+1} - E_t\pi_{t+1})$$

$$\pi_t = \beta\pi_{t+1} + \lambda\widehat{mc}_t + \alpha(\Delta s_t - \beta\Delta s_{t+1}) + u_{t3} \tag{5.8}$$

$$\text{where } u_{t3} = \nu_{t3} - \beta(\pi_{t+1} - E_t\pi_{t+1}) + \beta\alpha(\Delta s_{t+1} - \Delta E_t s_{t+1})$$

$$\pi_t = \Omega_1\widehat{ls}_t + \Omega_2 ims_t + \beta\pi_{t+1} + u_{t4} \tag{5.9}$$

$$u_{t4} = \nu_{t4} - \beta(\pi_{t+1} - E_t\pi_{t+1})$$

$$\pi_t = \Upsilon_f\pi_{t+1} + \Upsilon_b\pi_{t-1} + \lambda\widehat{mc}_t + \alpha(\Delta s_t - \beta s_{t+1}) + u_{t5} \tag{5.10}$$

$$\text{where } u_{t5} = \nu_{t5} - \beta(\pi_{t+1} - E_t\pi_{t+1}) + \beta\alpha(\Delta s_{t+1} - \Delta E_t s_{t+1})$$

$$\pi_t = \kappa_1 ls_t + \kappa_2 ims_t + \lambda_f\pi_{t+1} + \lambda_b\pi_{t-1} + u_{t6} \tag{5.11}$$

$$\text{where } u_{t6} = \nu_{t6} - \lambda_f(\pi_{t+1} - E_t\pi_{t+1})$$

It must be noted that the expected terms in all the equations have been replaced by their realization $\pi_{t+1}$, whereas the expectational error is part of the residual in all the equations. For example, in the empirical equation (5.6) I use the value of the realization of $\pi_{t+1}$ instead of the expectational term. Then, the forecast error ($\pi_{t+1} - E_t\pi_{t+1}$) is now part of the residual, $u_{t1}$. The same explanation applies for all the equations, but in the case of equations (5.8) and (5.10), the forecast error associated with the change in the terms of trade is also included in the residual term. Now, given that the residual in each equation is correlated with $\pi_{t+1}$ in all the equations (and with $\Delta s_{t+1}$ in equations (5.8) and (5.10)) an instrumental variable estimator is needed in order to guarantee unbiased results. In this case, I can use the structure of the GMM and the theoretical economic model to generate moment conditions that can be written as an orthogonality condition between the residuals of equations (4.6)-(4.11) and a vector of instruments $\mathbf{Z}_t$[13] such that:

$$E_t[u_{ti}\mathbf{Z}_t] = \mathbf{0} \tag{5.12}$$

for all $i$=1,2,3,4,5 and 6. One thing must be made clear about equation (5.12). Under the assumption of rational expectations, the vector of instruments will include instruments dated t or earlier to rule out simultaneity issues. As will be seen in the next section, I will choose instruments dated $t-1$ or earlier, because this guarantees that the information is already available at time $t$ due to the potential publication lag.

Solving for the error term in equations (5.6)-(5.11) and substituting in equation (5.12), I get the moment conditions that form the basis for estimating the model via GMM:

$$E_t[(\pi_t - \lambda\widehat{mc}_t - \beta\pi_{t+1})\,\mathbf{Z}_t] = \mathbf{0} \tag{5.13}$$

[13]This can be done because one of the important characteristics to be a valid instrument it´s that the variable we are considering has to be uncorrelated with the error term.

$$E_t[(\pi_t - \xi\widehat{mc}_t - \lambda_f\pi_{t+1} - \lambda_b\pi_{t-1})\,\mathbf{Z}_t] = \mathbf{0} \tag{5.14}$$

$$E_t[(\pi_t - \beta\pi_{t+1} - \lambda\widehat{mc}_t - \alpha(\Delta s_t - \beta\Delta s_{t+1}))\,\mathbf{Z}_t] = \mathbf{0} \tag{5.15}$$

$$E_t[(\pi_t - \Omega_1 ls_t - \Omega_2 ims_t - \beta\pi_{t+1})\,\mathbf{Z}_t] = \mathbf{0} \tag{5.16}$$

$$E_t[(\pi_t - \Upsilon_f\pi_{t+1} - \Upsilon_b\pi_{t-1} - \lambda\widehat{mc}_t - \alpha(\Delta s_t - \beta s_{t+1}))\,\mathbf{Z}_t] = \mathbf{0} \tag{5.17}$$

$$E_t[(\pi_t - \kappa_1 ls_t - \kappa_2 ims_t - \lambda_f\pi_{t+1} - \lambda_b\pi_{t-1}))\,\mathbf{Z}_t] = \mathbf{0} \tag{5.18}$$

One final note about GMM. When there are more moments conditions than parameters to be estimated, which will be the case when I estimate the parameters of the model, a chi-square test can be used to test overidentifying restrictions. This statistic is called the J-statistic. The $J$ statistic is used to test the validity of additional restrictions when the number of instruments is larger than the number of parameters to be estimated. The null hypothesis for this test is that additional restrictions are satisfied. If we reject the null hypothesis, then we must include different instruments, since additional restrictions are not satisfied. (Davidson and MacKinnon, 2004)

# 6 Results

In this Section I discuss the empirical results of the various versions of the NKPC. The structure of this section is as follows. First, I present the results for the closed economy specifications of the NKPC, which include the baseline case and the hybrid representation. Then, I present the results for the open economy NKPC specifications. Finally, I compare my results with those of Mihailov, Rumler and Sharler (2011) and Holmberg (2006).

As was mentioned in Section 4 (data description), I use the output gap and the unit labor cost as proxies for real marginal cost for all the countries with the exception of Peru, because data of the unit labor cost were not available. In each table I report the p-values for all the parameters. Recall that the p-value is defined as the lowest significance level at which a null hypothesis can be rejected (Gujarati, 2004). If the p-value is smaller than a traditional level of significance, for example, 10%, 5% or 1%, the null hypothesis must be rejected.

In relation to the instrumental variables used in each specification of the NKPC, it is necessary to discuss the issues related with the instruments used. First, as Eichenbaum and Fisher (2003) point out, GMM estimations are sensitive to the size of the instrument set. To explore this possibility, I expand the instrument set to include more lags of each variable. Although these results are not reported, I found no meaningfully change in the parameters. Second, the literature has questioned inference using GMM methods in the presence of weak instruments (Stock and Yogo, 2002). In order to check the relevance of the instruments set used in the regressions, I follow the approach made by Galí and Gertler (1999) and for Céspedes, Ochoa and Soto (2005), and test the null hypothesis that the coefficients on all the instruments are jointly zero in the first stage of the

estimation using the F-*statistic*. This is, I make a regression taking as dependent the endogenous variable ($\pi_{t+1}$ and $s_{t+1}$ in the equations of Mihailov, Rumler and Sharler (2011)) with respect to the instruments used in each specification. If the null hypothesis that the instruments are jointly irrelevant is rejected, then the instruments used in the estimation could be considered as valid. These results are shown in tables (17) to (28) of the appendix, where I report the F-*statistic*, the associated p-value and the adjusted $R^2$ from the first stage regression for each specification. For all the cases, the null hypothesis is rejected.
Third, in each specification I also report the $J - statistics$, which, as it was explained in the previous section, has a null hypothesis that additional restrictions are satisfied. Fourth, the instrumental variables used for each specification are reported in appendix. Finally, since is a time series model, it is known that the presence of autocorrelation is highly probable. Because of this, I proceed to do the Ljung-Box test in each specification, which cannot reject the null hypothesis that errors are not autocorrelated. To overcome this problem, we need to get robust standard errors. In order to do that, I choose the Heteroskedasticity and Autocorrelation (HAC) consistent estimator, because according to Gujarati (2003), this is the common way to proceed when we are working with time series.

## 6.1 Closed economy specification

Table 4 reports the results for the baseline NKPC using the output gap, which is denoted with parameter $\kappa$, as a proxy for real marginal cost. The discount factor $\beta$ is statistically significant for all the countries in the sample, as it can be seen from the p-values, which in all the cases reject the null hypothesis that the coefficients are statistically equal to zero. Additionally, the discount factor is positive and below one for each country, which is consistent with the theory. For this specification of the NKPC, the highest discount factor is estimated for Argentina, while the lowest discount factor is for Chile. The economic implication of this will be explained below.

With respect to the parameter $\kappa$, there are some theoretical elements that could give us some intuition about the results that we should expect. Intuitively, higher output gaps are associated with an increase in marginal costs, which translate into higher prices, implying that the expected value of $\kappa$ would be positive. Second, from a theoretical point of view, a higher discount factor, all else being equal, implies that firms gives more weight to future expected profits (Walsh, 2010). The consequences of this, is that inflation is less sensitive to current marginal cost, i.e., the value of the parameter associated to output gap, $\kappa$, must be lower. Then, what should be expected is that in Chile, for example, the country with the lowest discount factor estimate, the impact of the parameter associated to the real variable should be greater, while the country with the highest discount factor estimate, which for this specification is Argentina, the impact should be lower. However, what is observed from Table 4, is that in some cases, the outcomes are not what was expected. In the case of Chile, where we should expect that the coefficient associated to the output gap to have a greater value, even when the coefficient has the expected sign (i.e. is positive), the coefficient is not significant. While the parameter $\kappa$ is statistically significant only for Brazil, Mexico and Peru, for the first two countries the parameter is negative. In the case of Peru, this evidence suggest that output gap is an important determinant of inflation dynamics, and in fact, as will be shown below, this result is robust throughout different specifications.

It is important to stress however that this is a common result in many empirical works. Actually, some of these problems were pointed out in the data description section, where I depicted the output gap and the inflation rate (see Figure 3 of Section 4). In Section 4 I remarked that in the case of Argentina and Brazil, the inflation rate and the output gap move in opposite directions. As we can see in Table 4, for both these countries the sign of $\kappa$ is indeed negative. Also, it was shown in Section 4 that for the case of Peru and Chile, inflation rand the output gap moved in same direction. This is also reflected in Table 4, where for both countries the sign of $\kappa$ is positive (but for Chile the coefficient is not significant).

Galí and Gertler (1999), have argued that a possible explanation of this negative sign for the output gap parameter is because conventional measures of the output gap are likely to be ridden with error, primarily due to the unobservability of the natural rate of output. In order to overcome this problem, several studies have proposed using the unit labor cost as a measure of real marginal cost in place of the output gap. The results of the estimation using unit labor costs are shown in Table 5. Finally, must be noted that the null hypothesis of the $J - statistic$ that additional restrictions are satisfied, cannot be rejected for all the countries in Table 4. Actually, this will be the case for all the specifications estimated in the thesis.

Table 4: Estimates of equation $\pi_t = \kappa \widehat{y_t} + \beta \pi_{t+1} + u_{t1}$ using the output gap.

| **Country** | $\beta$ | **p-value** | $\kappa$ | **p-value** | **P(J-statistic)** |
|---|---|---|---|---|---|
| Argentina | 0.9915*** | 0.0000 | −0.0002 | 0.7934 | 0.2806 |
| Brazil | 0.9783*** | 0.0000 | −0.002* | 0.0580 | 0.2498 |
| Chile | 0.8845*** | 0.0000 | 0.0020 | 0.1139 | 0.2059 |
| Colombia | 0.9462*** | 0.0000 | 0.0008 | 0.4209 | 0.1528 |
| Mexico | 0.9888*** | 0.0000 | −0.0046*** | 0.0015 | 0.2096 |
| Peru | 0.9423*** | 0.0000 | 0.0021** | 0.0126 | 0.1827 |

Notes: Standard errors are robust to heteroskedasticity and autocorrelation. The stars attached to the coefficient estimates show significance levels, where * denotes significance at the 10%, ** at the 5% and *** at the 1% level. In all the cases, the null hypothesis of the validity of the overidentifying restrictions cannot be rejected.

Table 5: Estimates of equation $\pi_t = \lambda \widehat{mc}_t + \beta \pi_{t+1} + v_{t1}$ using the unit labor cost.

| **Country** | $\beta$ | **p-value** | $\lambda$ | **p-value** | **P(J-statistic)** |
|---|---|---|---|---|---|
| Argentina | 0.9681*** | 0.0000 | −0.0006 | 0.1598 | 0.2806 |
| Brazil | 0.9416*** | 0.0000 | 0.0026* | 0.0991 | 0.1681 |
| Chile | 0.8675*** | 0.0000 | 0.0025** | 0.042 | 0.3906 |
| Colombia | 0.9749*** | 0.0000 | 0.0049*** | 0.0000 | 0.2122 |
| Mexico | 0.9590*** | 0.0000 | −0.0064*** | 0.0000 | 0.1464 |

Notes: Standard errors are robust to heteroskedasticity and autocorrelation. The stars attached to the coefficient estimates show significance levels, where * denotes significance at the 10%, ** at the 5% and *** at the 1% level. In all the cases, the null hypothesis of the validity of the overidentifying restrictions cannot be rejected.

As in Table 4, the results of the discount factor are significant and consistent with the theory (below 1 and positive). Again, the country with the lowest discount factor estimate is Chile. But now, the country with the highest discount factor estimate is Colombia. From Table 5 we see that replacing the output gap with unit labor cost as the proxy for real marginal cost tends to improve the results, since now $\lambda$, the parameter associated with the unit labor cost, is statistically significant for Brazil, Chile, Colombia and Mexico. However, the problem of a negative sign is present again for Argentina and Mexico. Recalling that $\lambda = \frac{(1-\theta)(1-\beta\theta)}{\theta}$, then a negative sign in the parameter $\lambda$ would imply that the parameter that measure the degree of price rigidity, $\theta$, will have values that are not possible from the economic point of view[14]. A possible explanation of these outcomes is that probably the real unit labor cost is a poor proxy for firms true marginal cost, as Rotemberg and Woodford (1999) point out. They discuss some reasons why firms real marginal cost may vary more with resource utilization in the economy than real unit labor cost (such as adjustment cost of labor, the existence of overhead labor and other fixed costs in production). This suggest that it would seem important to develop alternative measures of real marginal cost in order to improve the empirical fit in the estimations for Latin American countries. However, this is beyond the scope of this thesis, but it could represent an interesting direction for future research.

**Hybrid specification of the NKPC in a closed economy** The results of the estimation of the Hybrid NKPC are shown in Tables 6 and 7, where I present the specifications with the output gap and the unit labor cost, respectively. In Table 6 we see that for Argentina, Brazil, Colombia and Mexico, the coefficient associated with the output gap it is not significant and for Argentina, Brazil and Colombia the estimated parameter is of the wrong sign. The parameter $\kappa$ is only significant for Peru and Chile, and in both cases, has a positive value. It must be noted that in the case of

[14]This analysis is also true for parameter $\kappa$, since $\kappa$ and $\lambda$ are the same thing: the real marginal cost elasticity of inflation.

Peru, the parameter associated with the output gap was also significant in the baseline specification (Table 4). As discussed in Table 4, the results let to argue that the output gap is a determinant variable in the explanation of the inflation dynamics for Peru.
In respect to the coefficient associated with the backward looking component, we can see that it is significant in all the cases[15]. Additionally, if we compare the coefficients associated with the backward looking component against the coefficient associated with the forward looking component (which is also significant), it can be seen that, with the exception of Argentina and Chile, the backward looking parameter is higher than the forward looking parameter for the countries of the sample.

Table 6: Estimates of equation $\pi_t = \kappa \hat{y}_t + \lambda_f \pi_{t+1} + \lambda_b \pi_{t-1} + u_{t1}$ using the output gap.

| **Country** | $\lambda_\mathbf{f}$ | **p-value** | $\lambda_\mathbf{b}$ | **p-value** | $\kappa$ | **p-value** | **P(J-statistic)** |
|---|---|---|---|---|---|---|---|
| Argentina | 0.6441*** | 0.0000 | 0.3068*** | 0.0000 | −0.0004 | 0.5291 | 0.7043 |
| Brazil | 0.3957*** | 0.0000 | 0.5995*** | 0.0000 | −0.0011 | 0.1880 | 0.3682 |
| Chile | 0.6919*** | 0.0000 | 0.2299** | 0.0255 | 0.0024*** | 0.0021 | 0.2805 |
| Colombia | 0.4922*** | 0.0000 | 0.4928*** | 0.0000 | −0.0002 | 0.6795 | 0.2526 |
| Mexico | 0.4468*** | 0.0000 | 0.5046*** | 0.0000 | 0.0007 | 0.5502 | 0.1301 |
| Peru | 0.5416*** | 0.0000 | 0.4548*** | 0.0000 | 0.0013** | 0.0235 | 0.5073 |

Notes: Standard errors are robust to heteroskedasticity and autocorrelation. The stars attached to the coefficient estimates show significance levels, where * denotes significance at the 10%, ** at the 5% and *** at the 1% level. In all the cases, the null hypothesis of the validity of the overidentifying restrictions cannot be rejected.

Turning to the hybrid closed-economy specification of the NKPC using the unit labor cost, the results are reported in Table 7. We can observe that the coefficient associated with the unit labor cost presents similar problems to those previously discussed in Table 5, since for three of the five countries in the sample the coefficient has a negative value (Argentina, Chile and Colombia). Additionally, it is only significant for Brazil and Colombia. Until this point, it can be seen that for the case of Brazil, the coefficient associated with the unit labor cost has been significant in both the baseline and hybrid NKPC specifications. This suggests that there evidence that the unit labor cost plays a significant role in the inflation dynamics for the Brazilian economy.
Now, if we turn our attention to the coefficients associated to the backward looking we can see that the results are consistent with those presented in Table 6, where a specification of the output gap was used. As in Table 6, with the exception of Argentina and Chile, the coefficient associated with the backward-looking component is greater than the coefficient associated with the forward-looking component. In both tables, Chile is the country with the lowest backward looking coefficient. Recall

[15]For Chile and Mexico, the results are consistent with the previous studies of Céspedes, Ochoa and Soto (2005) and Ramos-Francia and Torres (2006), respectively.

that according to Céspedes, Ochoa and Soto (2005), inflationary inertia could be associated with low credibility levels of the central bank. Thus, in this case, a possible explanation for the values of the backward looking coefficient in Chile, it could be associated with the idea that the monetary authorities in Chile have higher levels of credibility that other countries in the sample. The result obtained in the case of Chile, actually, it makes sense, since Chile was the first country of the sample to implement IT. The opposite can be said about Brazil, since also in both tables, the backward looking component is the highest of the countries considered in the sample.

Table 7: Estimates of equation $\pi_t = \lambda \widehat{mc}_t + \lambda_f \pi_{t+1} + \lambda_b \pi_{t-1} + v_{t2}$ using the the unit labor cost.

| **Country** | $\lambda_\mathbf{f}$ | **p-value** | $\lambda_\mathbf{b}$ | **p-value** | $\lambda$ | **p-value** | **P(J-statistic)** |
|---|---|---|---|---|---|---|---|
| Argentina | 0.5346*** | 0.0000 | 0.4735*** | 0.0000 | −0.0004 | 0.2630 | 0.7223 |
| Brazil | 0.3176*** | 0.0001 | 0.6606*** | 0.0000 | 0.0042*** | 0.0000 | 0.3928 |
| Chile | 0.6366*** | 0.0000 | 0.3334** | 0.0000 | −0.0006 | 0.3700 | 0.2729 |
| Colombia | 0.3983*** | 0.0000 | 0.5564*** | 0.0000 | −0.0002*** | 0.0072 | 0.1330 |
| Mexico | 0.4416*** | 0.0000 | 0.5191*** | 0.0000 | 0.0008 | 0.6042 | 0.2795 |

Notes: Standard errors are robust to heteroskedasticity and autocorrelation. The stars attached to the coefficient estimates show significance levels, where * denotes significance at the 10%, ** at the 5% and *** at the 1% level. In all the cases, the null hypothesis of the validity of the overidentifying restrictions cannot be rejected.

From the results presented in table 6 and 7, it can be concluded that, at least statistically, we can say that inflation inertia still has a key role in explaining the dynamics of inflation in Latin American countries.

This section has analyzed the case of a closed economy specification of the NKPC. We identified at least two results. First, neither the output gap nor the unit labor cost, seem to be good proxies for real marginal cost, since with both specifications we found contradictory results. However, in the case of Peru it was observed that statistically speaking the output gap is an important determinant of inflation. And in the case of Brazil, it seems that the unit labor cost is an important factor in explaining Brazilian inflation dynamics.
Another important result is the fact that the coefficient associated with the backward-looking component in the hybrid specification of the NKPC plays a key role in understanding inflation dynamics.

## 6.2 Open economy specification

**Small Open Economy model: The approach of Galí and Monacelli** In Table 8, I report the results for the basic open-economy specification of the NKPC derived using the model of Galí and Monacelli (2005). As in the closed economy specification, the discount factor is significant for all the countries in the sample. For this coefficient, the results are quite similar with those of the closed economy case, except for Chile, the discount factor is now above 0.90.

With respect to $\kappa$, the parameter that measures the impact of the output gap on the inflation rate, we see that, even though it is significant for five out of the six countries in the sample, in the cases of Brazil and Mexico, the sign associated with $\kappa$ is negative, a problem that was also found and discussed in the closed economy specification of the NKPC. An important point to remark about this parameter is that, for Peru, the result of $\kappa$ is significant and with the expected sign, which seems to support the idea that the output gap is a determinant variable to explain the dynamic of inflation in Peru.

Table 8: Estimates of equation $\pi_t = \beta\pi_{t+1} + \kappa\widehat{y_t} + \alpha(\Delta s_t - \beta\Delta s_{t+1}) + u_{t3}$ using the output gap.

| **Country** | $\beta$ | **p-value** | $\kappa$ | **p-value** | $\alpha$ | **p-value** | **P(J-statistic)** |
|---|---|---|---|---|---|---|---|
| Argentina | 0.9227*** | 0.0000 | 0.0011 | 0.1189 | 0.0001 | 0.2176 | 0.6898 |
| Brazil | 0.9242*** | 0.0000 | −0.002*** | 0.0000 | 0.0031*** | 0.0009 | 0.6477 |
| Chile | 0.9074*** | 0.0000 | 0.0037*** | 0.0037 | −0.0055*** | 0.0032 | 0.5020 |
| Colombia | 0.9563*** | 0.0000 | 0.0017* | 0.0544 | −0.0001 | 0.1983 | 0.3807 |
| Mexico | 0.9031*** | 0.0000 | −0.0036*** | 0.0012 | 0.0297* | 0.0700 | 0.5050 |
| Peru | 0.9300*** | 0.0000 | 0.0021*** | 0.0056 | 0.0011 | 0.3711 | 0.5073 |

Notes: Standard errors are robust to heteroskedasticity and autocorrelation. The stars attached to the coefficient estimates show significance levels, where * denotes significance at the 10%, ** at the 5% and *** at the 1% level. In all the cases, the null hypothesis of the validity of the overidentifying restrictions cannot be rejected.

For the estimates of $\alpha$, the parameter I am most interested in this specification of the NKPC which measures the degree of trade openness in the economy (and for that reason a negative estimate for $\alpha$ is inconsistent with this interpretation) it is significant for Brazil, Chile and Mexico, but in the case of Chile the estimated parameter is negative.

It is important to stress that Mihailov, Rumler and Sharler (2011) also get negative values for $\alpha$ in their results. They argue that the model of Galí and Monacelli (2005) does not fully capture all factors influencing the impact of the terms of trade fluctuations on inflation dynamics, thereby explaining why negative estimates can arise. In particular, the assumption that exporting firms engage in full producer currency pricing may not be appropriate if firms implement local currency pricing. This argument also seems to be appropriate for the countries of Latin America. One way the empirical literature can test the presence of local currency pricing is by analyzing the degree of exchange rate pass-through. When the degree of exchange rate pass-through is equal to one, the full currency pricing assumptions is satisfied. However, when the degree of exchange rate pass-through is less than 1, then the local currency pricing exists. Bussiére, Delle Chaie and Peltonen (2014) in a study about the exchange rate pass-through find that, even when the pass-through effect is higher for emerging markets than for developed economies, the pass through effect it is not complete for emerging markets (including Latin American countries). They estimate the following values for the degree of exchange rate pass-through: 0.464 for Argentina, 0.362 for Brazil, 0.476 for Chile and 0.577 for Mexico. This could explain not only the negative sign for Chile and Colombia in both tables, but also the low values of $\alpha$ that I get for all the countries with the exception of Mexico[16].

The results when I use the unit labor cost as a proxy to the real marginal cost are reported in Table 9. As in previous specifications, the results of the discount factor are significant for all the levels of significance.

For the parameter $\lambda$, we see that it is significant for Argentina, Chile and Colombia. And as in previous results, for some countries, the sign associated with this parameter is negative. In this case, however, unlike the results for the closed-economy specification, the parameter of the unit labor cost for Brazil, even though it has the correct sign, it is not significant.

For the case of the degree of trade openness parameter, $\alpha$, we see that similar to Table 8, it is significant for Brazil, Chile and Mexico, with Mexico being the country with the highest coefficient in the sample (and this is true also in Table 8).

These results can be interpreted as evidence that for these three countries, the terms of trade, appears to be a relevant factor in explaining inflation dynamics. This result seem to be sensible for the case of Chile and Mexico, since as was discussed in Section 2, these countries have the highest level of openness to trade. But the results for Brazil are not so intuitive, since the degree of openness for Brazil is the lowest of the countries in the sample (see Table 2).

[16]This could be an evidence of the explanation made by Mihailov, Rumler and Sharler (2011), since according to the study of Bussiére, Delle Chaie and Peltonen (2014), Mexico is the country with the highest coefficient of pass-through, and then, is probably that the model fits better with the Mexican case.

Table 9: Estimates of equation $\pi_t = \beta\pi_{t+1} + \lambda\widehat{mc}_t + \alpha(\Delta s_t - \beta\Delta s_{t+1}) + v_{t3}$ using the unit labor cost.

| **Country** | $\beta$ | **p-value** | $\lambda$ | **p-value** | $\alpha$ | **p-value** | **P(J-statistic)** |
|---|---|---|---|---|---|---|---|
| Argentina | 0.9977*** | 0.0000 | −0.0012** | 0.0154 | 0.0003*** | 0.0672 | 0.9290 |
| Brazil | 0.9597*** | 0.0000 | 0.0006 | 0.8858 | 0.0007* | 0.0684 | 0.4178 |
| Chile | 0.9906*** | 0.0000 | −0.0027*** | 0.0027 | −0.0056*** | 0.0000 | 0.6769 |
| Colombia | 0.9546*** | 0.0000 | 0.0014** | 0.0191 | −0.0001 | 0.1764 | 0.2425 |
| Mexico | 0.9374*** | 0.0000 | −0.0061 | 0.0000 | 0.0670*** | 0.0022 | 0.2714 |

Notes: Standard errors are robust to heteroskedasticity and autocorrelation. The stars attached to the coefficient estimates show significance levels, where * denotes significance at the 10%, ** at the 5% and *** at the 1% level. In all the cases, the null hypothesis of the validity of the overidentifying restrictions cannot be rejected.

**The Holmberg's approach** Now, I present the results of the model of Holmberg (2006). In order to compare the results of this model with the previous results obtained for the model of Galíand Monacelli (2005), I first consider a special case of this model when the number of backward looking firms is equal to zero. As it has been done in previous examples, I first report place the results using the output gap as a proxy for real marginal cost.

In Table 10 we see that for all countries the discount factor is statistically significant, which has been the case in the previous NKPC specifications. Additionally, it seems to be the case that for the open economy NKPC specifications, the discount factor of Chile is greater than the estimate obtained using the closed economy specification, since once again the value of the discount factor is above 0.90.

With respect to the parameter associated to output gap, it is significant for four countries: Argentina, Brazil, Chile and Peru. It must be noted again that in the case of Peru, the parameter associated to the output gap has been significant for all the estimations that I have considered. Actually, Chile, with the exception of the first table, this parameter has been also significant for all the estimations. In addition, an element that is also important, is the fact that in both countries the sign associated with the output gap has been positive.

The parameter $\Omega_2$ measures the impact of the change of capital and intermediate imports as a proportion of the nominal GDP. In this sense, the parameter $\Omega_2$ represent a measure of the impact of international elements on the dynamic of inflation. The results for this parameter show that it is significant for Brazil, Chile, Mexico and Peru. Comparing these results with those of the model of Galí and Monacelli (2005), it can be seen that for the cases of Brazil, Chile and Mexico, open-economy NKPC models seems to be more appropriate than those of the closed -economy case.

Table 10: Estimates of equation $\pi_t = \Omega_1 \hat{y}_t + \Omega_2 ims_t + \beta\pi_{t+1} + u_{t4}$ using the output gap.

| **Country** | $\beta$ | **p-value** | $\mathbf{\Omega_1}$ | **p-value** | $\mathbf{\Omega_2}$ | **p-value** | **P(J-statistic)** |
|---|---|---|---|---|---|---|---|
| Argentina | 0.9963*** | 0.0000 | −0.0028*** | 0.0007 | 0.0058 | 0.2280 | 0.3455 |
| Brazil | 0.9978*** | 0.0000 | −0.0031*** | 0.0002 | −0.0194** | 0.0177 | 0.4183 |
| Chile | 0.9300*** | 0.0000 | 0.0043*** | 0.0001 | 0.0181** | 0.0130 | 0.2991 |
| Colombia | 0.8053*** | 0.0000 | −0.0001 | 0.9014 | −0.0059 | 0.6466 | 0.2278 |
| Mexico | 0.9777*** | 0.0000 | −0.0018 | 0.1029 | 0.0229*** | 0.0052 | 0.1344 |
| Peru | 0.9265*** | 0.0000 | 0.0018*** | 0.0058 | 0.0033* | 0.0921 | 0.4089 |

Notes: Standard errors are robust to heteroskedasticity and autocorrelation. The stars attached to the coefficient estimates show significance levels, where * denotes significance at the 10%, ** at the 5% and *** at the 1% level. In all the cases, the null hypothesis of the validity of the overidentifying restrictions cannot be rejected.

In Table 11, we show the results of the same model but using the unit labor cost proxy. The results are similar to those found in the Table 10. The discount factor is significant for all the countries, and again for the case of Chile the discount factor is above 0.90. With respect to values of the parameter associated to the unit labor cost, we see that it is significant for three countries, Argentina, Chile and Mexico. But for all these cases in which the coefficient is significant, the value of the parameter is negative.

Finally, for the parameter $\Omega_2$, we see that is significant only for Mexico and Chile, which is consistent with the previous results found for the open economy NKPC specification. However, now this parameter is not significant for Brazil, which could generate some doubts about the validity of the above results using output gaps.

Table 11: Estimates of equation $\pi_t = \Omega_1 ls_t + \Omega_2 ims_t + \beta\pi_{t+1} + v_{t4}$ using the unit labor cost.

| **Country** | $\beta$ | **p-value** | $\mathbf{\Omega_1}$ | **p-value** | $\mathbf{\Omega_2}$ | **p-value** | **P(J-statistic)** |
|---|---|---|---|---|---|---|---|
| Argentina | 0.9700*** | 0.0000 | −0.0015** | 0.0168 | 0.0033 | 0.1643 | 0.4819 |
| Brazil | 0.9677*** | 0.0000 | 0.0019 | 0.1023 | −0.0094 | 0.1707 | 0.3370 |
| Chile | 0.9190*** | 0.0000 | −0.0015* | 0.0620 | 0.0195*** | 0.0010 | 0.1918 |
| Colombia | 0.8261*** | 0.0000 | 0.0014 | 0.1162 | −0.0091 | 0.4296 | 0.2165 |
| Mexico | 0.9691*** | 0.0000 | −0.0069*** | 0.0000 | 0.0191** | 0.0341 | 0.1654 |

Notes: Standard errors are robust to heteroskedasticity and autocorrelation. The stars attached to the coefficient estimates show significance levels, where * denotes significance at the 10%, ** at the 5% and *** at the 1% level. In all the cases, the null hypothesis of the validity of the overidentifying restrictions cannot be rejected.

### Hybrid specification of the open economy models

**The approach of Galí and Monacelli** In Table 12, I report the results of the hybrid version of the NKPC derived from the model of Galí and Monacelli (2005) using the output gap as the proxy for the real marginal cost. We see that in this case, there is a significant change with respect to the values of the parameters associated to the forward and backward-looking components obtained in the closed-economy version. Even though for all the countries these coefficients are significant (as was the case in Tables 6 and 7), the results show that now, with the exception of Argentina, the value of the parameter of the forward-looking component is higher than the coefficient of the backward-looking component. However, given the high values of the coefficient of the backward looking component the statement about the key role that the inertia plays for Latin American countries still remain.

For the case of the parameter $\kappa$, we see that it is positive and significant again for Chile and Peru, which is in line with the previous specifications. In addition, the coefficient is also significant for Argentina and Brazil, but in these cases, the value of the parameter is negative.

Finally, for $\alpha$ we can see that for this specification, it is significant for all the countries. Of course these results do not let us to conclude anything, since it seems to be the case that the values of the coefficients are sensitive to different specifications, it is not possible to conclude that for all the countries international factors are an important determinant of the inflation rate. Actually, given the results that have been obtained, such an asseveration could be only possible for the cases of Chile and Mexico.

Table 12: Estimates of equation $\pi_t = \Upsilon_f \pi_{t+1} + \Upsilon_b \pi_{t-1} + \kappa \widehat{y}_t + \alpha(\Delta s_t - \beta \Delta s_{t+1}) + u_{t5}$ using the output gap.

| **Country** | $\Upsilon_\mathbf{f}$ | **p-value** | $\Upsilon_\mathbf{b}$ | **p-value** | $\kappa$ | **p-value** | $\alpha$ | **p-value** | **P(J-statistic)** |
|---|---|---|---|---|---|---|---|---|---|
| Argentina | 0.4009*** | 0.0000 | 0.5923*** | 0.0000 | −0.0016*** | 0.0001 | −0.0007*** | 0.0000 | 0.8255 |
| Brazil | 0.7427*** | 0.0000 | 0.2730*** | 0.0000 | −0.0036*** | 0.0000 | 0.0012*** | 0.0037 | 0.6648 |
| Chile | 0.7208*** | 0.0000 | 0.2110** | 0.0171 | 0.0033*** | 0.0001 | −0.0071*** | 0.0000 | 0.6627 |
| Colombia | 0.5073*** | 0.0000 | 0.4683** | 0.0000 | 0.0001 | 0.8297 | −0.0001* | 0.0519 | 0.6627 |
| Mexico | 0.5021*** | 0.0000 | 0.4860*** | 0.0000 | 0.0012 | 0.1637 | 0.0312* | 0.0536 | 0.3819 |
| Peru | 0.6291*** | 0.0000 | 0.3993*** | 0.0000 | 0.0017*** | 0.0050 | 0.0019* | 0.0603 | 0.8596 |

Notes: Standard errors are robust to heteroskedasticity and autocorrelation. The stars attached to the coefficient estimates show significance levels, where * denotes significance at the 10%, ** at the 5% and *** at the 1% level. In all the cases, the null hypothesis of the validity of the overidentifying restrictions cannot be rejected.

The results of the hybrid version of the model of Galí and Monacelli (2005) using the unit labor cost as a proxy for the real marginal cost are presented in Table 13. It can be seen that the coefficient of the backward and forward-looking components are significant for all countries. Also the

forward-looking coefficient is greater than the backward looking coefficient for Argentina, Chile and Mexico. With respect to the coefficient $\lambda$, we see that is significant for Brazil, Colombia and Mexico. It must be noted that until now, it has not been possible to find a strong association between the unit labor cost and the inflation rate for any country using the open economy specification of the NKPC. We must to remember that in the closed economy version of the NKPC, I found that for the case of Brazil the unit labor cost was a determinant variable to explain the dynamics of the inflation rate. However, in the open economy case the evidence does not seem conclusive, since it has been significant only for this specification.
For $\alpha$, the results suggest that it is significant as usual, for Brazil, Chile and Mexico. In addition, for this specification it is also significant for Argentina.

Table 13: Estimates of equation $\pi_t = \Upsilon_f \pi_{t+1} + \Upsilon_b \pi_{t-1} + \lambda \widehat{mc}_t + \alpha(\Delta s_t - \beta \Delta s_{t+1}) + v_{t5}$ using the unit labor cost.

| Country | $\Upsilon_f$ | p-value | $\Upsilon_b$ | p-value | $\lambda$ | p-value | $\alpha$ | p-value | P(J-statistic) |
|---|---|---|---|---|---|---|---|---|---|
| Argentina | 0.5307*** | 0.0000 | 0.4625*** | 0.0000 | −0.0003 | 0.2778 | −0.0003* | 0.0880 | 0.8715 |
| Brazil | 0.3457*** | 0.0000 | 0.6309*** | 0.0000 | 0.0042*** | 0.0000 | 0.0011* | 0.0694 | 0.7368 |
| Chile | 0.5609*** | 0.0000 | 0.3997*** | 0.0000 | −0.0006 | 0.2589 | −0.0110*** | 0.0003 | 0.5307 |
| Colombia | 0.3573*** | 0.0000 | 0.6417*** | 0.0000 | −0.0003*** | 0.0002 | 0.0003 | 0.2056 | 0.6413 |
| Mexico | 0.4738*** | 0.0000 | 0.3549*** | 0.0000 | 0.0020* | 0.0602 | 0.0609** | 0.0195 | 0.3147 |

Notes: Standard errors are robust to heteroskedasticity and autocorrelation. The stars attached to the coefficient estimates show significance levels, where * denotes significance at the 10%, ** at the 5% and *** at the 1% level. In all the cases, the null hypothesis of the validity of the overidentifying restrictions cannot be rejected.

**Holmberg's approach: An hybrid specification** In Table 14, I report the results using the output gap as the proxy for the real marginal cost. In the case of the parameters associated with the forward and backward-looking components are significant for all the countries in the sample. Here, the forward-looking component is greater than the backward-looking component only for Argentina and Chile, similar to the results found in the closed economy specification. In the case of $\kappa_1$, the coefficient associated with the output gap, it can be seen that it is significant for Argentina, Brazil, Chile and Peru. The results found for Chile and Peru is consistent with the results found under alternative NKPC specifications, which could be seen as evidence of the importance of the output gap for inflation dynamics in these countries. Finally, the coefficient associated with the share of imports of intermediate and capital goods, $\kappa_2$, it is significant for Chile, Colombia and Mexico. Again, the results suggest that in the case of Chile and Mexico, international factors, in this case the imports of inputs used in the process of production, seems to be an important determinant of the inflation rate.

Finally, the results with the unit labor cost as proxy for real marginal cost are presented in Table 15. We can see that in this case, the coefficient of the unit labor cost is significant for Brazil, Colombia and Mexico, but in the case of Colombia, the problem of the wrong sign is present again.
With respect to the coefficient associated with the forward-looking and the backward-looking components, we can see that are high and significant for all countries.
For the last coefficient, the coefficient associated to the share of the imports of capital and intermediate, the results shown that it is significant for three countries of the sample, Colombia, Chile and Mexico. This result confirms that an open economy model explains better the dynamics of inflation in the economies of Chile and Mexico.

Table 14: Estimates of equation $\pi_t = \kappa_1 \hat{y}_t + \kappa_2 ims_t + \lambda_f \pi_{t+1} + \lambda_b \pi_{t-1} + u_{t6}$ using output gap.

| **Country** | $\kappa_1$ | **p-value** | $\kappa_2$ | **p-value** | $\lambda_f$ | **p-value** | $\lambda_b$ | **p-value** | **P(J-statistic)** |
|---|---|---|---|---|---|---|---|---|---|
| Argentina | $-0.0012^{*}$ | 0.0725 | 0.0008 | 0.7263 | $0.5485^{***}$ | 0.0000 | $0.4657^{***}$ | 0.0000 | 0.6179 |
| Brazil | $-0.0013^{*}$ | 0.0964 | $-0.0027$ | 0.6199 | $0.3604^{***}$ | 0.0000 | $0.6538^{***}$ | 0.0000 | 0.6070 |
| Chile | $0.0020^{***}$ | 0.0094 | $0.0083^{*}$ | 0.0782 | $0.5988^{***}$ | 0.0000 | $0.3282^{***}$ | 0.0000 | 0.3733 |
| Colombia | 0.0012 | 0.1230 | $-0.0296^{***}$ | 0.0040 | $0.4916^{***}$ | 0.0000 | $0.5490^{***}$ | 0.0000 | 0.4455 |
| Mexico | 0.0002 | 0.7034 | $0.0219^{***}$ | 0.0003 | $0.3929^{***}$ | 0.0000 | $0.5488^{***}$ | 0.0000 | 0.2491 |
| Peru | $0.0012^{***}$ | 0.0078 | 0.0033 | 0.0.0216 | $0.3696^{***}$ | 0.0000 | $0.5337^{***}$ | 0.0000 | 0.4310 |

Notes: Standard errors are robust to heteroskedasticity and autocorrelation. The stars attached to the coefficient estimates show significance levels, where * denotes significance at the 10%, ** at the 5% and *** at the 1% level. In all the cases, the null hypothesis of the validity of the overidentifying restrictions cannot be rejected.

Table 15: Estimates of equation $\pi_t = \kappa_1 ls_t + \kappa_2 ims_t + \lambda_f \pi_{t+1} + \lambda_b \pi_{t-1} + v_{t6}$ using the unit labor cost.

| **Country** | $\kappa_1$ | **p-value** | $\kappa_2$ | **p-value** | $\lambda_f$ | **p-value** | $\lambda_b$ | **p-value** | **P(J-statistic)** |
|---|---|---|---|---|---|---|---|---|---|
| Argentina | $-0.0004$ | 0.2420 | 0.0031 | 0.1080 | $0.5015^{***}$ | 0.0000 | $0.4455^{***}$ | 0.0000 | 0.8426 |
| Brazil | $0.0031^{***}$ | 0.0000 | $-0.0108$ | 0.3210 | $0.2154^{***}$ | 0.0000 | $0.8099^{***}$ | 0.0000 | 0.6694 |
| Chile | 0.0002 | 0.4700 | $0.0075^{**}$ | 0.0398 | $0.5507^{***}$ | 0.0000 | $0.4082^{***}$ | 0.0000 | 0.3513 |
| Colombia | $-0.0030^{***}$ | 0.0000 | $-0.0208^{***}$ | 0.0008 | $0.3667^{***}$ | 0.0000 | $0.6526^{***}$ | 0.0000 | 0.4992 |
| Mexico | $0.0040^{***}$ | 0.0000 | $0.03152^{***}$ | 0.0001 | $0.3163^{***}$ | 0.0000 | $0.4228^{***}$ | 0.0000 | 0.2591 |

Notes: Standard errors are robust to heteroskedasticity and autocorrelation. The stars attached to the coefficient estimates show significance levels, where * denotes significance at the 10%, ** at the 5% and *** at the 1% level. In all the cases, the null hypothesis of the validity of the overidentifying restrictions cannot be rejected.

## 6.3 Conclusions of the section

As final point of analysis, the results that were obtained in this section are compared with those of the works of Mihailov, Rumler and Sharler (2011) (MRS henceforth) and Holmberg (2006).

MRS (2011) make several estimates of the model of Galí and Monacelli (2005) that was developed above. They use three proxies for the real marginal cost: the deviation of the real Gross Domestic Product (GDP) from a quadratic polynomial trend, the deviation of real GDP from a Hodrick-Prescott (HP) trend and the real unit labor cost. To compare results, I only consider the deviation of real GDP from the HP trend, since it was the procedure used in this thesis to obtain the output gap. Additionally, the results obtained when the unit labor cost is used are similar, and then the qualitatyve analysis will be the same. Thus, the equation under analysis is:

$$\pi_t = \beta\pi_{t+1} + \kappa\widehat{y}_t + \alpha(\Delta s_t - \beta\Delta s_{t+1}) + u_{t3}$$

The results of this thesis and the results of MRS (2011) are similar in three aspects: the parameter $\beta$ is significant and above 0.85 for both results; the parameter associated to output gap is significant for a few countries and in some cases, negative; and the parameter $\alpha$ is significant only for half of the sample. However, a significant difference between the results that I get and the results of MRS (2011) is related with the size of parameter $\alpha$. Since the differences are considerable, it is worthwhile to show both results. In Table 16, I report the results for the countries with a significant $\alpha$ for both, the results of this section and the results of the article of MRS (2011).

Table 16: Comparison of results for coefficient $\alpha$. Output gap specification.

| Results MRS (2011)* | | | Results Section 6** | | |
|---|---|---|---|---|---|
| **Country** | $\alpha$ | **p-value** | **Country** | $\alpha$ | **p-value** |
| Germany | 0.17*** | 0.00 | Brazil | 0.031*** | 0.00 |
| Netherlands | 0.48*** | 0.00 | Chile | −0.0055*** | 0.00 |
| UK | 0.48*** | 0.00 | Mexico | 0.0297* | 0.07 |
| Canada | 0.14* | 0.07 | | | |
| Switzerland | 0.24* | 0.07 | | | |

Notes: *The estimation period is 1970:1-2007:4. ** The estimation period is different for each country. See Table 3 in Section 4 for the period estimated for each country. The stars attached to the coefficient estimates show significance levels, where * denotes significance at the 10%, ** at the 5% and *** at the 1% level.

Differences in values of the coefficients are substantial. In addition, all the significant results for the model of MRS (2011) are positive. A possible explanation for these results is the significant difference in the size of the sample, which in the case of MRS (2011) could generate more precise estimates.

With respect to Holmberg (2006), she estimates several specifications of equation

$$\pi_t = \kappa_1 ls_t + \kappa_2 ims_t + \lambda_f \pi_{t+1} + \lambda_b \pi_{t-1} + v_{t6}$$

for Sweden for the period 1986:01- 2004:4. In each specification, she uses different index to measure the quarterly inflation rate: the GDP deflator, the Consumer Price Index (CPI) and an index of the core inflation. Since in this work we are considering as a measure of inflation the quarterly percentage change of the CPI, I am going to consider only the specification of the CPI in order to be able to compare. In addition, she uses as proxies for real marginal cost, the output gap and the unit labor cost, in the same spirit of the present work. But for the specification that uses the CPI as dependent variable, she only estimates the above equation using the unit labor cost. For that reason, the results are compared only for this specification.
Her results shown that it was not possible to find evidence of the impact of the labor share and the imports of intermediate goods (parameters $\kappa_1$ and $\kappa_2$, respectively.) in current inflation. Comparing with our results, a similar conclusion can be done only for the case of Argentina, since for other countries at least one coefficient is significant.
For the coefficients that measure the impact of future and lag inflation, she establishes a restriction: that the sum of both be equal to one, this is:

$$\lambda_1 + \lambda_2 = 1$$

Their results suggest that, in line with Galí and Gertler (1999), the expectations about future inflation are more important for explaining inflation than past inflation for Sweden, since the coefficient $\lambda_f$ is equal to 0.746, implying that given the restriction she imposes, the coefficient $\lambda_b$ be equal to 0.254. Of course, this results are significantly different to our findings, since for any country of our sample, the value of $\lambda_f$ was greater than 0.6, as can be observed in Table 15. Thus, in this case the main difference is related with the size of the forward-looking component, $\lambda_f$ which is higher than those of the values in Table 15.

# 7 Conclusions

In this thesis I have estimated several specifications of the New Keynesian Phillips Curve (NKPC) using the technique of the Generalized Method of Moments (GMM) to analyze what are the main drivers of inflation dynamics for six Latin American countries: Argentina, Brazil, Chile, Colombia, Mexico and Peru.
The relevance of this it is twofold. First, given the scarce literature for the analysis of inflation dy-

namics for developing economies using the NKPC, we contribute here estimating different versions of the NKPC for a set of Latin American countries.
Second, considering the characteristics of these economies and their changes during the last two decades, it is important to analyze how this changes are reflected in the evolution of aggregate prices.
In order to analyze this, I first estimated versions of the NKPC under a closed economy specification. The main findings for the closed economy specifications are as follows. First, it could not be established a strong statistical relationship between the inflation rate and the variables used as proxies to real marginal cost for many Latin American countries. One remarkable exception has been Peru, since for the specifications estimated in the closed economy case, it was possible to pin down a statistical relationship between output gap and the inflation rate. This evidence suggests that output gap is an important determinant of the inflationary process in this country.
Second, we found that both, the forward looking component and the backward looking component of the hybrid version of the NKPC are important components to explain the inflation dynamics for the Latin American countries considered in this thesis. This results also suggest that even when inflation expectations are an important variable to describe the inflation dynamics for these countries, inertia also play a key role, which is in difference with the findings for developed countries.

When we extend the analytical framework of the NKPC to an open economy specification based on the models of Galí and Monacelli (2005) and Holmberg (2006), the main results of the closed economy specifications remain. This is, for most of the countries of the sample neither the output gap nor the unit labor cost seems to properly describe the inflation dynamics for the countries considered in the sample, with the exception of Peru.
However, we found strong statistical evidence relating to the impact that the terms of trade and the imports of intermediate and capital goods have in the inflationary processes for Chile and Mexico. This results show that for these two countries, Chile and Mexico, an open economy version of the NKPC describes better the inflationary process.

As a final consideration, we think that to overcome some of the problems that arise in the present work, as the sign of the proxies for the real marginal cost, it is necessary a deepest research into the study of the NKPC, in order to properly characterize such a fundamental variable, as is in fact, the level of aggregate prices in the economy.

# Bibliography

Balakrishnan, R. and Lopez-Salido, J. D. (2002). Understanding UK inflation: the role of openness. Bank of England working papers 164, Bank of England.

Barbosa-Filho, N. (2008). Inflation targeting in Brazil: 1999-2006. *International Review of Applied Economics*, 22(2):187–200.

Batini, N., Jackson, B., and Nickell, S. (2005). An open-economy new keynesian phillips curve for the u.k. *Journal of Monetary Economics*, 52(6):1061–1071.

Broto, C. (2008). Inflation targeting in Latin America: Empirical analysis using GARCH models. Banco de España Working Papers 0826, Banco de España.

Bussiére, M., Chiaie, S. D., and Peltonen, T. A. (2014). Exchange Rate Pass-Through in the Global Economy: The Role of Emerging Market Economies. *IMF Economic Review*, 62(1):146–178.

Calvo, G. A. (1983). Staggered prices in a utility-maximizing framework. *Journal of Monetary Economics*, 12(3):383–398.

Céspedes, L. F., Ochoa, M., and Soto, C. (2005). The New Keynesian Phillips Curve in an Emerging Market Economy: The Case of Chile. Working papers central bank of chile, Central Bank of Chile.

Corbo, V. and Schmidt-Hebbel, K. (2001). Inflation Targeting in Latin America. Working Papers Central Bank of Chile 105, Central Bank of Chile.

D´Amato, L., Garegnani, L., and Sotes, J. M. (2008). Inflation Persistence and Changes in the Monetary Regime: The Argentine Case. *Ensayos Económicos*, 1(50):127–167.

Davidson, R. and MacKinnon, J. (2004). *Econometric Theory and Methods*. Oxford University Press.

Eichenbaum, M. and Fisher, J. D. (2003). Testing the Calvo model of sticky prices. *Economic Perspectives*, (Q II):40–53.

Francia, M. R. and García, A. T. (2006). Inflation Dynamics in Mexico: A Characterization Using the New Phillips Curve. Working Papers 2006-15, Banco de México.

Fuhrer, J. and Moore, G. (1995). Inflation Persistence. *The Quarterly Journal of Economics*, 110(1):127–59.

Gali, J. and Gertler, M. (1999). Inflation dynamics: A structural econometric analysis. *Journal of Monetary Economics*, 44(2):195–222.

Gali, J., Gertler, M., and Lopez-Salido, J. D. (2001). European inflation dynamics. *European Economic Review*, 45(7):1237–1270.

Galí, J. and Monacelli, T. (2005). Monetary policy and exchange rate volatility in a small open economy. *The Review of Economic Studies*, 72(3):707–734.

Greene, W. (2008). *Econometric Analysis:*. Pearson/Prentice Hall.

Gujarati, D. (2003). *Basic econometrics*. Economic series. McGraw Hill.

Hansen, L. P. (1982). Large Sample Properties of Generalized Method of Moments Estimators. *Econometrica*, 50(4):1029–54.

Holmberg, K. (2006). Derivation and Estimation of a New Keynesian Phillips Curve in a Small Open Economy. Working Paper Series 197, Sveriges Riksbank (Central Bank of Sweden).

Mihailov, A., Rumler, F., and Scharler, J. (2011). The Small Open-Economy New Keynesian Phillips Curve: Empirical Evidence and Implied Inflation Dynamics. *Open Economies Review*, 22(2):317–337.

Minella, A., de Freitas, P. S., Goldfajn, I., and Muinhos, M. K. (2003). Inflation Targeting in Brazil: Constructing Credibility under Exchange Rate Volatility. Working Papers Series 77, Central Bank of Brazil, Research Department.

Ólafsson, T. T. (2006). The New Keynesian Phillips Curve: In Search of Improvements and Adaptation to the Open Economy. Economics, Department of Economics, Central Bank of Iceland.

Rotemberg, J. and Woodford, M. (1997). An Optimization-Based Econometric Framework for the Evaluation of Monetary Policy. In *NBER Macroeconomics Annual 1997, Volume 12*, NBER Chapters, pages 297–361. National Bureau of Economic Research, Inc.

Rotemberg, J. J. and Woodford, M. (1999). The cyclical behavior of prices and costs. Working Paper 6909, National Bureau of Economic Research.

Rudd, J. and Whelan, K. (2007). Modeling Inflation Dynamics: A Critical Review of Recent Research. *Journal of Money, Credit and Banking*, 39(s1):155–170.

Rumler, F. (2005). Estimates of the open economy New Keynesian Phillips curve for euro area countries. Working Paper Series 0496, European Central Bank.

Scheufele, R. (2008). Evaluating the German (New Keynesian) Phillips Curve. IWH Discussion Papers 10, Halle Institute for Economic Research.

Shibamoto, M. (2009). The Estimation of the New Keynesian Phillips Curve in Japan and Its Implication for the Inflation Response to a Monetary Policy Shock. Discussion Paper Series 235, Research Institute for Economics & Business Administration, Kobe University.

Stock, J. H. and Yogo, M. (2002). Testing for Weak Instruments in Linear IV Regression. NBER Technical Working Papers 0284, National Bureau of Economic Research, Inc.

Taylor, J. B. (1980). Aggregate Dynamics and Staggered Contracts. *Journal of Political Economy*, 88(1):1–23.

Wackerly, D., Mendenhall, W., and Scheaffer, R. (2007). *Mathematical Statistics with Applications*. International student edition / [Brooks-Cole]. Cengage Learning.

Walsh, C. E. (2010). *Monetary Theory and Policy, Third Edition*, volume 1 of *MIT Press Books*. The MIT Press.

# Appendices

## A Instrumental Variables

- **Instrumental variables used in table 4 to estimate the parameters of equation $\pi_t = \kappa\widehat{y}_t + \beta\pi_{t+1} + u_{t1}$ using the output gap**
  **Argentina**: CPI inflation lags 1 to 5, H-P filtered output gap lags 1 to 5.
  **Brazil**: CPI inflation lags 1 to 4, H-P filtered output gap lags 1 to 4.
  **Chile**: CPI inflation lags 1 to 4, H-P filtered output gap lags 1 to 4.
  **Colombia**: CPI inflation lags 1 to 4, H-P filtered output gap lags 1 to 4.
  **Mexico**: CPI inflation lags 1 to 6, H-P filtered output gap lags 1 to 6.
  **Peru**: CPI inflation lags 1 to 4, H-P filtered output gap lags 1 to 4.

- **Instrumental variables used in table 5 to estimate the parameters of equation $\pi_t = \lambda\widehat{mc}_t + \beta\pi_{t+1} + v_{t1}$ using the unit labor cost**
  **Argentina**: CPI inflation lags 1 to 5, unit labor cost gap lags 1 to 5.
  **Brazil**: CPI inflation lags 1 to 4, unit labor cost gap lags 1 to 4.
  **Chile**: CPI inflation lags 1 to 4, unit labor cost gap lags 1 to 4.
  **Colombia**: CPI inflation lags 1 to 5, unit labor cost gap lags 1 to 5.
  **Mexico**: CPI inflation lags 1 to 6, unit labor cost gap lags 1 to 6, rate of growth exchange rate lags 1 and 2.

- **Instrumental Variables used in table 6 to estimate the parameters of equation $\pi_t = \kappa\hat{y}_t + \lambda_f\pi_{t+1} + \lambda_b\pi_{t-1} + u_{t2}$ using the output gap**
  **Argentina**: CPI inflation lags 2 to 6, H-P filtered output gap lags 1 to 6.
  **Brazil**: CPI inflation lags 2 to 6, H-P filtered output gap lags 1 to 6.
  **Chile**: CPI inflation lags 2 to 6, H-P filtered output gap lags 1 to 6.
  **Colombia**: CPI inflation lags 2 to 6, H-P filtered output gap lags 1 to 6.
  **Mexico**: CPI inflation lags 2 to 6, H-P filtered output gap lags 1 to 6.
  **Peru**: CPI inflation lags 2 to 6, H-P filtered output gap lags 1 to 6.

- **Instrumental variables used in table 7 to estimate the parameters of equation $\pi_t = \lambda\hat{mc}_t + \lambda_f\pi_{t+1} + \lambda_b\pi_{t-1} + v_t2$ using the unit labor cost**
  **Argentina**: CPI inflation lags 2 to 6, unit labor cost gap lags 1 to 6.
  **Brazil**: CPI inflation lags 2 to 6, unit labor cost gap lags 1 to 6.
  **Chile**: CPI inflation lags 2 to 6, unit labor cost gap lags 1 to 6.
  **Colombia**: CPI inflation lags 2 to 5, unit labor cost gap lags 1 to 5.
  **Mexico**: CPI inflation lags 2 to 6, unit labor cost gap lags 1 to 6.

- **Instrumental variables used in table 8 to estimate the parameters of equation**

$\pi_t = \beta\pi_{t+1} + \kappa\widehat{y}_t + \alpha(\Delta s_t - \beta\Delta s_{t+1}) + u_{t3}$

**Argentina**: CPI inflation lags 1 to 6, H-P filtered output gap lags 1 to 6, change in terms of trade lags 1 to 5.

**Brazil**: CPI inflation lags 1 to 4, H-P filtered output gap lags 1 to 4, change in terms of trade lags 1 to 4.

**Chile**: CPI inflation lags 1 to 5, H-P filtered output gap lags 1 to 5, change in terms of trade 1 to 4.

**Colombia**: CPI inflation lags 1 to 4, H-P filtered output gap lags 1 to 4, change in terms of trade 1 to 4.

**Mexico**: CPI inflation lags 1 to 6, H-P filtered output gap lags 1 to 6, change in terms of trade lags 1 to 4.

**Peru**: CPI inflation lags 1 to 4, H-P filtered output gap lags 1 to 4. change in terms of trade.

- **Instrumental variables used in table 9 to estimate the parameters of equation** $\pi_t = \beta\pi_{t+1} + \lambda\widehat{mc}_t + \alpha(\Delta s_t - \beta\Delta s_{t+1}) + v_{t3}$

  **Argentina**: CPI inflation lags 1 to 6, unit labor cost gap lags 1 to 6, change in terms of trade lags 1 to 6.

  **Brazil**: CPI inflation lags 1 to 5, unit labor cost gap lags 1 to 4, change in terms of trade lags 1 to 4.

  **Chile**: CPI inflation lags 1 to 6, unit labor cost gap lags 1 to 6, change in terms of trade lags 1 to 4.

  **Colombia**: CPI inflation lags 1 to 4, unit labor cost gap lags 1 to 4, change in terms of trade 1 to 4.

  **Mexico**: CPI inflation lags 1 to 6, unit labor cost gap lags 1 to 6, change in terms of trade 1 to 4.

- **Instrumental variables used in table 10 to estimate the parameters of equation** $\pi_t = \Omega_1\hat{y}_t + \Omega_2 ims_t + \beta\pi_{t+1} + u_{t4}$

  **Argentina**: CPI inflation lags 1 to 4, H-P filtered output gap lags 1 to 4, imports of intermediate inputs as percentage deviation from the mean lags 1 to 4.

  **Brazil**: CPI inflation lags 1 to 4, H-P filtered output gap lags 1 to 4, imports of intermediate inputs as percentage deviation from the mean lags 1 to 4.

  **Chile**: CPI inflation lags 1 to 4, H-P filtered output gap lags 1 to 4, imports of intermediate inputs as percentage deviation from the mean lags 1 to 4.

  **Colombia**: CPI inflation lags 1 to 4, H-P filtered output gap lags 1 to 4, imports of intermediate inputs as percentage deviation from the mean lags 1 to 4.

  **Mexico**: CPI inflation lags 1 to 4, H-P filtered output gap lags 1 to 4, imports of intermediate inputs as percentage deviation from the mean lags 1 to 4.

**Peru**:CPI inflation lags 1 to 4, H-P filtered output gap lags 1 to 4, imports of intermediate inputs as percentage deviation from the mean lags 1 to 4.

- **Instrumental variables used in table 11 to estimate the parameters of equation** $\pi_t = \Omega_1 ls_t + \Omega_2 ims_t + \beta\pi_{t+1} + v_{t4}$

  **Argentina**: CPI inflation lags 1 to 4, unit labor cost gap lags 1 to 4, imports of intermediate inputs as percentage deviation from the mean lags 1 to 4.

  **Brazil**: CPI inflation lags 1 to 4, unit labor cost gap lags 1 to 4, imports of intermediate inputs as percentage deviation from the mean lags 1 to 4.

  **Chile**:CPI inflation lags 1 to 4, unit labor cost gap lags 1 to 4, imports of intermediate inputs as percentage deviation from the mean lags 1 to 4.

  **Colombia**: CPI inflation lags 1 to 4, unit labor cost gap lags 1 to 4, imports of intermediate inputs as percentage deviation from the mean lags 1 to 4.

  **Mexico**: CPI inflation lags 1 to 5, unit labor cost gap lags 1 to 5, imports of intermediate inputs as percentage deviation from the mean lags 1 to 5.

- **Instrumental variables used in table 12 to estimate the parameters of equation** $\pi_t = \Upsilon_f \pi_{t+1} + \Upsilon_b \pi_{t-1} + \kappa\widehat{y_t} + \alpha(\Delta s_t - \beta\Delta s_{t+1}) + u_{t5}$

  **Argentina**: CPI inflation lags 2 to 6, H-P filtered output gap lags 1 to 6,change in terms of trade lags 1 to 6.

  **Brazil**: CPI inflation lags 2 to 6, H-P filtered output gap lags 1 to 6, change in terms of trade lags 1 to 6.

  **Chile**: CPI inflation lags 2 to 6, H-P filtered output gap lags 1 to 6, change in terms of trade lags 1 to 6.

  **Colombia**: CPI inflation lags 2 to 6, H-P filtered output gap lags 1 to 6, change in terms of trade lags 1 to 6.

  **Mexico**: CPI inflation lags 2 to 6, H-P filtered output gap lags 1 to 6, change in terms of trade lags 1 to 6.

  **Peru**: CPI inflation lags 2 to 6, H-P filtered output gap lags 1 to 6, change in terms of trade lags 1 to 6.

- **Instrumental variables used in table 13 to estimate the parameters of equation** $\pi_t = \Upsilon_f \pi_{t+1} + \Upsilon_b \pi_{t-1} + \lambda\widehat{mc}_t + \alpha(\Delta s_t - \beta\Delta s_{t+1}) + v_{t5}$

  **Argentina**: CPI inflation lags 2 to 6, unit labor cost lags 1 to 6, change in terms of trade lags 1 to 6.

  **Brazil**: CPI inflation lags 2 to 6, unit labor cost lags 1 to 6,change in terms of trade lags 1 to 6.

  **Chile**: CPI inflation lags 2 to 6, unit labor cost lags 1 to 6,change in terms of trade lags 1 to 6.

  **Colombia**: CPI inflation lags 2 to 6, unit labor cost lags 1 to 6,change in terms of trade lags

1 to 6.

**Mexico**: CPI inflation lags 2 to 6, unit labor cost lags 1 to 6,change in terms of trade lags 1 to 6.

- **Instrumental variables used in table 14 to estimate the parameters of equation** $\pi_t = \kappa_1 \hat{y} + \kappa_2 ims_t + \lambda_f \pi_{t+1} + \lambda_b \pi_{t-1} + u_{t6}$

  **Argentina**: CPI inflation lags 2 to 6, H-P filtered output gap lags 1 to 6, imports of intermediate inputs as percentage deviation from the mean lags 1 to 5.

  **Brazil**: CPI inflation lags 2 to 6, H-P filtered output gap lags 1 to 6, imports of intermediate inputs as percentage deviation from the mean lags 1 to 4.

  **Chile**: CPI inflation lags 2 to 6, H-P filtered output gap lags 1 to 6, imports of intermediate inputs as percentage deviation from the mean lags 1 to 4.

  **Colombia**: CPI inflation lags 2 to 6, H-P filtered output gap lags 1 to 6, imports of intermediate inputs as percentage deviation from the mean lags 1 to 4.

  **Mexico**: CPI inflation lags 2 to 6, H-P filtered output gap lags 1 to 6, imports of intermediate inputs as percentage deviation from the mean lags 1 to 4.

  **Peru**:CPI inflation lags 2 to 6, H-P filtered output gap lags 1 to 6, imports of intermediate inputs as percentage deviation from the mean lags 1 to 4.

- **Instrumental variables used in table 15 to estimate the parameters of equation** $\pi_t = \kappa_1 ls_t + \kappa_2 ims_t + \lambda_f \pi_{t+1} + \lambda_b \pi_{t-1} + v_{t6}$

  **Argentina**: CPI inflation lags 1 to 6, unit labor cost gap lags 1 to 6, imports of intermediate inputs as percentage deviation from the mean lags 1 to 4.

  **Brazil**: CPI inflation lags 1 to 6, unit labor cost gap lags 1 to 6, imports of intermediate inputs as percentage deviation from the mean lags 1 to 4.

  **Chile**:CPI inflation lags 1 to 6, unit labor cost gap lags 1 to 6, imports of intermediate inputs as percentage deviation from the mean lags 1 to 4.

  **Colombia**: CPI inflation lags 1 to 6, unit labor cost gap lags 1 to 6, imports of intermediate inputs as percentage deviation from the mean lags 1 to 4.

  **Mexico**: CPI inflation lags 1 to 6, unit labor cost gap lags 1 to 6, imports of intermediate inputs as percentage deviation from the mean lags 1 to 4.

# B Results from F-test from first stage regressions

Table 17: Results from F-test from first stage regressions. Specification $\pi_t = \kappa\widehat{y}_t + \beta\pi_{t+1} + u_{t1}$

| Country | $\pi_{t+1}$ | | |
|---|---|---|---|
| | $F-stat$ | $p-value$ | Adj $R^2$ |
| **Argentina** | 6.0814 | 0.0000 | 0.3975 |
| **Brazil** | 1.9598 | 0.0670 | 0.1001 |
| **Chile** | 2.7862 | 0.0107 | 0.1715 |
| **Colombia** | 13.6154 | 0.0000 | 0.6556 |
| **Mexico** | 3.9254 | 0.0001 | 0.3076 |
| **Peru** | 2.5327 | 0.0189 | 0.1508 |

Table 18: Results from F-test from first stage regressions. Specification $\pi_t = \lambda\widehat{mc}_t + \beta\pi_{t+1} + \upsilon_{t2}$

| Country | $\pi_{t+1}$ | | |
|---|---|---|---|
| | $F-stat$ | $p-value$ | Adj $R^2$ |
| **Argentina** | 2.5098 | 0.0242 | 0.2691 |
| **Brazil** | 5.5887 | 0.0000 | 0.3440 |
| **Chile** | 2.1391 | 0.0453 | 0.1166 |
| **Colombia** | 19.0344 | 0.0000 | 0.7761 |
| **Mexico** | 5.9903 | 0.0000 | 0.4693 |

Table 19: Results from F-test from first stage regressions. $\pi_t = \kappa \hat{y}_t + \lambda_f \pi_{t+1} + \lambda_b \pi_{t-1}$

| Country | $\pi_{t+1}$ | | |
|---|---|---|---|
| | $F-stat$ | $p-value$ | Adj $R^2$ |
| **Argentina** | 1.8576 | 0.0619 | 0.1104 |
| **Brazil** | 4.3201 | 0.0000 | 0.3694 |
| **Chile** | 3.2839 | 0.0015 | 0.2727 |
| **Colombia** | 9.1681 | 0.0000 | 0.6379 |
| **Mexico** | 3.5119 | 0.0006 | 0.2591 |
| **Peru** | 2.7778 | 0.0059 | 0.2259 |

Table 20: Results from F-test from first stage regressions. Specification $\pi_t = \lambda \hat{mc}_t + \lambda_f \pi_{t+1} + \lambda_b \pi_{t-1}$

| Country | $\pi_{t+1}$ | | |
|---|---|---|---|
| | $F-stat$ | $p-value$ | Adj $R^2$ |
| **Argentina** | 2.2095 | 0.0419 | 0.2450 |
| **Brazil** | 3.8549 | 0.0002 | 0.3350 |
| **Chile** | 1.8478 | 0.0667 | 0.1206 |
| **Colombia** | 20.1960 | 0.0000 | 0.7686 |
| **Mexico** | 6.7985 | 0.0000 | 0.4467 |

Table 21: Results from F-test from first stage regressions. Specification $\pi_t = \beta \pi_{t+1} + \kappa \widehat{y_t} + \alpha(\Delta s_t - \beta \Delta s_{t+1}) + u_{t3}$

| Country | $\pi_{t+1}$ | | | $s_{t+1}$ | | |
|---|---|---|---|---|---|---|
| | $F-stat$ | $p-value$ | Adj $R^2$ | $F-stat$ | $p-value$ | Adj $R^2$ |
| **Argentina** | 1.8901 | 0.0752 | 0.2809 | 17.321 | 0.0000 | 0.8697 |
| **Brazil** | 4.5705 | 0.0000 | 0.4021 | 2.0286 | 0.0330 | 0.1534 |
| **Chile** | 1.6599 | 0.0813 | 0.1506 | 2.2584 | 0.07195 | 0.0662 |
| **Colombia** | 14.9012 | 0.0000 | 0.7588 | 6.4526 | 0.0139 | 0.0887 |
| **Mexico** | 6.0386 | 0.0000 | 0.5050 | 1.9628 | 0.0410 | 0.1235 |

Table 22: Results from F-test from first stage regressions. Specification $\pi_t = \beta\pi_{t+1} + \lambda\widehat{mc}_t + \alpha(\Delta s_t - \beta\Delta s_{t+1}) + u_{t3}$

| Country | $\pi_{t+1}$ | | | $s_{t+1}$ | | |
|---|---|---|---|---|---|---|
| | $F-stat$ | $p-value$ | Adj $R^2$ | $F-stat$ | $p-value$ | Adj $R^2$ |
| **Argentina** | 3.6086 | 0.0001 | 0.3684 | 4.6916 | 0.0004 | 0.6023 |
| **Brazil** | 4.7071 | 0.0000 | 0.3885 | 2.0286 | 0.0383 | 0.1536 |
| **Chile** | 2.3274 | 0.0167 | 0.1875 | 1.9904 | 0.0915 | 0.0652 |
| **Colombia** | 9.3417 | 0.0000 | 0.6538 | 3.1710 | 0.0498 | 0.0719 |
| **Mexico** | 2.9379 | 0.0008 | 0.3063 | 1.9959 | 0.0516 | 0.0974 |
| **Peru** | 2.7821 | 0.0047 | 0.2366 | 1.7969 | 0.0705 | 0.1217 |

Table 23: Results from F-test from first stage regressions. Specification $\pi_t = \Omega_1\hat{y}_t + \Omega_2 ims_t + \beta\pi_{t+1} + u_{t4}$

| Country | $\pi_{t+1}$ | | |
|---|---|---|---|
| | $F-stat$ | $p-value$ | Adj $R^2$ |
| **Argentina** | 6.5989 | 0.0000 | 0.4725 |
| **Brazil** | 3.1891 | 0.0015 | 0.2757 |
| **Chile** | 3.4710 | 0.0007 | 0.3005 |
| **Colombia** | 13.1044 | 0.0000 | 0.7326 |
| **Mexico** | 7.9479 | 0.0000 | 0.5072 |
| **Peru** | 2.8715 | 0.0037 | 0.2455 |

Table 24: Results from F-test from first stage regressions. Specification $\pi_t = \Omega_1 ls_t + \Omega_2 ims_t + \beta\pi_{t+1} + v_{t4}$

| Country | $\pi_{t+1}$ | | |
|---|---|---|---|
| | $F-stat$ | $p-value$ | Adj $R^2$ |
| **Argentina** | 4.9642 | 0.0001 | 0.5310 |
| **Brazil** | 3.0883 | 0.0020 | 0.2664 |
| **Chile** | 2.5125 | 0.0100 | 0.2082 |
| **Colombia** | 15.3122 | 0.0000 | 0.7641 |
| **Mexico** | 9.2698 | 0.0000 | 0.6079 |

Table 25: Results from F-test from first stage regressions. Specification $\pi_t = \Upsilon_f \pi_{t+1} + \Upsilon_b \pi_{t-1} + \kappa \widehat{y_t} + \alpha(\Delta s_t - \beta \Delta s_{t+1}) + u_{t5}$

| Country | $\pi_{t+1}$ | | | $s_{t+1}$ | | |
|---|---|---|---|---|---|---|
| | $F-stat$ | $p-value$ | Adj $R^2$ | $F-stat$ | $p-value$ | Adj $R^2$ |
| **Argentina** | 1.5833 | 0.0984 | 0.1154 | 8.8094 | 0.0000 | 0.7684 |
| **Brazil** | 3.9773 | 0.0001 | 0.3999 | 1.8589 | 0.0465 | 0.1811 |
| **Chile** | 4.3695 | 0.0000 | 0.3917 | 2.0580 | 0.0959 | 0.0555 |
| **Colombia** | 6.5808 | 0.0000 | 0.6214 | 3.3127 | 0.0439 | 0.0762 |
| **Mexico** | 2.8999 | 0.0013 | 0.5050 | 2.7056 | 0.0009 | 0.1593 |
| **Peru** | 3.7300 | 0.0001 | 0.3946 | 2.6309 | 0.0150 | 0.1571 |

Table 26: Results from F-test from first stage regressions. Specification $\pi_t = \Upsilon_f \pi_{t+1} + \Upsilon_b \pi_{t-1} + \lambda \widehat{mc}_t + \alpha(\Delta s_t - \beta \Delta s_{t+1}) + v_{t5}$

| Country | $\pi_{t+1}$ | | | $s_{t+1}$ | | |
|---|---|---|---|---|---|---|
| | $F-stat$ | $p-value$ | Adj $R^2$ | $F-stat$ | $p-value$ | Adj $R^2$ |
| **Argentina** | 1.8845 | 0.0755 | 0.2683 | 9.6960 | 0.0000 | 0.7912 |
| **Brazil** | 4.2799 | 0.0000 | 0.3666 | 2.3245 | 0.0220 | 0.1610 |
| **Chile** | 1.7193 | 0.0701 | 0.1543 | 2.5243 | 0.0490 | 0.0801 |
| **Colombia** | 11.7348 | 0.0000 | 0.7815 | 3.1694 | 0.0499 | 0.0719 |
| **Mexico** | 5.4260 | 0.0000 | 0.4878 | 2.2442 | 0.0280 | 0.1188 |

Table 27: Results from F-test from first stage regressions. Specification $\pi_t = \kappa_1 \hat{y}_t + \kappa_2 ims_t + \lambda_f \pi_{t+1} + \lambda_b \pi_{t-1} + u_{t6}$

| Country | $\pi_{t+1}$ | | |
|---|---|---|---|
| | $F-stat$ | $p-value$ | Adj $R^2$ |
| **Argentina** | 2.8741 | 0.0019 | 0.2753 |
| **Brazil** | 2.4491 | 0.0087 | 0.2449 |
| **Chile** | 3.7504 | 0.0001 | 0.3811 |
| **Colombia** | 8.6315 | 0.0000 | 0.6917 |
| **Mexico** | 9.5359 | 0.0000 | 0.6184 |
| **Peru** | 2.9046 | 0.0022 | 0.2989 |

Table 28: Results from F-test from first stage regressions. Specification $\pi_t = \kappa_1 ls_t + \kappa_2 ims_t + \lambda_f \pi_{t+1} + \lambda_b \pi_{t-1} + v_{t6}$

| Country | $\pi_{t+1}$ | | |
|---|---|---|---|
| | $F-stat$ | $p-value$ | Adj $R^2$ |
| **Argentina** | 2.2673 | 0.0339 | 0.3221 |
| **Brazil** | 2.4414 | 0.0089 | 0.2439 |
| **Chile** | 1.9990 | 0.0335 | 0.1827 |
| **Colombia** | 14.1952 | 0.0000 | 0.7951 |
| **Mexico** | 9.7312 | 0.0000 | 0.6237 |

# C Data Source

Table 29: Argentina. Source of each variable

| **Country** | **Variable** | **Source** |
|---|---|---|
| **Argentina** | Consumer Price Index | Banco Central de la República de Argentina |
| | Output gap | Instituto Nacional de Estadística y Censos |
| | Unit Labor Cost | Instituto Nacional de Estadística y Censos |
| | Terms of Trade | Instituto Nacional de Estadística y Censos |
| | Imported inputs | Instituto Nacional de Estadística y Censos |

Table 30: Brazil. Source of each variable

| **Country** | **Variable** | **Source** |
|---|---|---|
| **Brazil** | Consumer Price Index | Instituto de Pesquisa Econômica Aplicada |
| | Output gap | Instituto Brasileiro de Geografia e Estatística |
| | Unit Labor Cost | Instituto de Pesquisa Econômica Aplicada |
| | Terms of Trade | Instituto Brasileiro de Geografia e Estatística |
| | Imported inputs | Instituto de Pesquisa Econômica Aplicada |

Table 31: Chile. Source of each variable

| **Country** | **Variable** | **Source** |
|---|---|---|
| **Chile** | Consumer Price Index | Banco Central de Chile |
| | Output gap | Banco Central de Chile |
| | Unit Labor Cost | Banco Central de Chile |
| | Terms of Trade | Banco Central de Chile |
| | Imported inputs | Banco Central de Chile |

Table 32: Colombia. Source of each variable

| **Country** | **Variable** | **Source** |
|---|---|---|
| **Colombia** | Consumer Price Index | Banco Central de Colombia |
| | Output gap | Departamento Administrativo Nacional de Estadística |
| | Unit Labor Cost | Departamento Administrativo Nacional de Estadística |
| | Terms of Trade | Banco Central de Colombia |
| | Imported inputs | Banco Central de Colombia |

Table 33: Mexico. Source of each variable

| **Country** | **Variable** | **Source** |
|---|---|---|
| **Mexico** | Consumer Price Index | Banco de México |
| | Output gap | Instituto Nacional de Estadística y Geografía |
| | Unit Labor Cost | Instituto Nacional de Estadística y Geografía |
| | Terms of Trade | Banco de México |
| | Imported inputs | Banco de México |

Table 34: Peru. Source of each variable

| Country | Variable | Source |
|---|---|---|
| **Peru** | Consumer Price Index | Banco Central de Reserva del Perú |
| | Output gap | Banco Central de Reserva del Perú |
| | Unit Labor Cost | No data available |
| | Terms of Trade | Banco Central de Reserva del Perú |
| | Imported inputs | Banco Central de Reserva del Perú |

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