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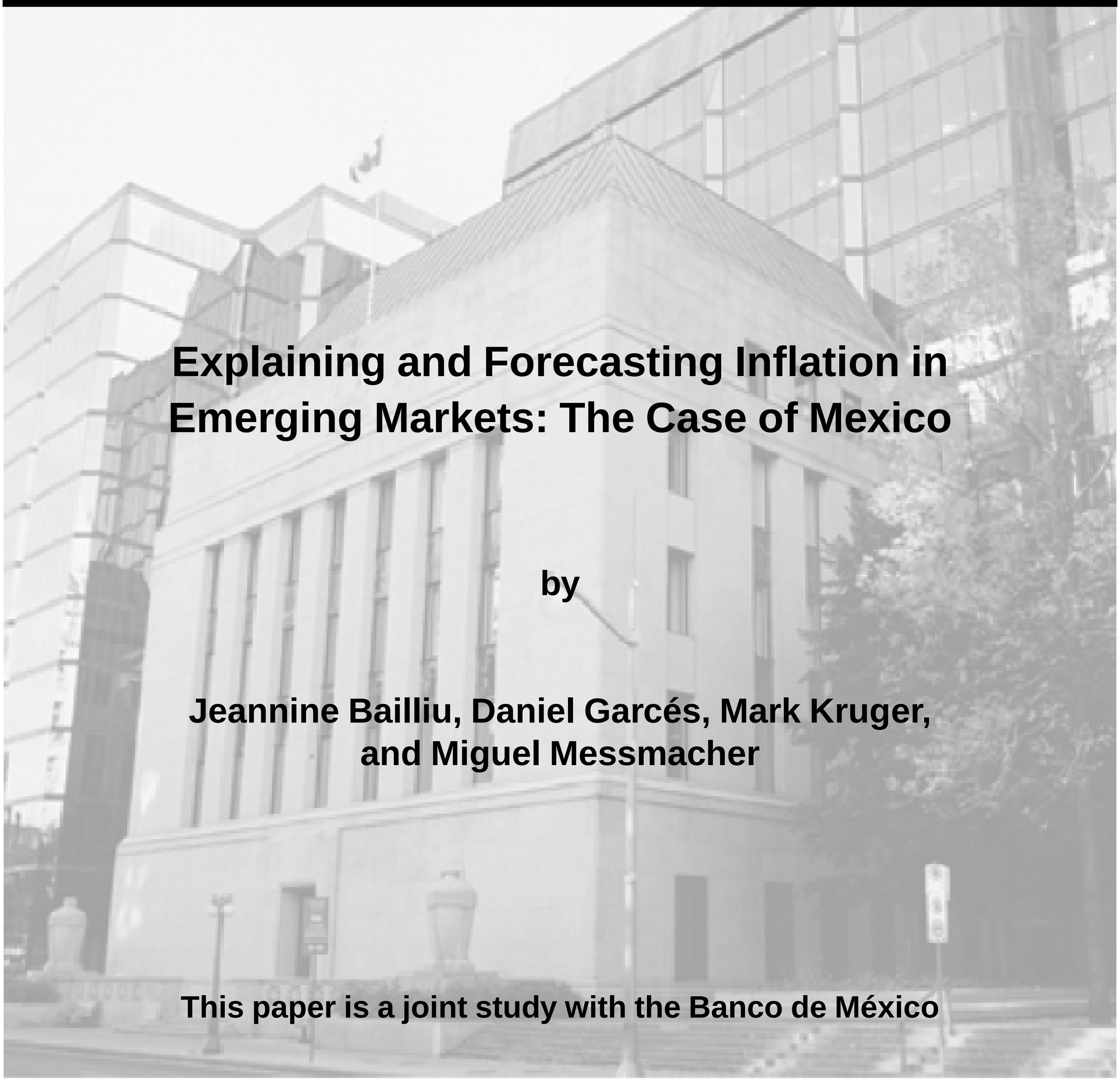

Explaining and Forecasting Inflation in Emerging Markets: The Case of Mexico

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Explaining and Forecasting Inflation in Emerging Markets: The Case of Mexico

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Contents

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Abstract

The authors apply existing inflation models that have worked well in industrialized countries to Mexico, an emerging market that has recently moved to adopt an inflation-targeting framework for monetary policy. They compare the performance of these models with a mark-up model that has been used extensively to analyze inflation in Mexico. The authors focus on three models that have some theoretical foundations and that can therefore help explain the causes of inflation as well as be used for forecasting purposes: a mark-up model, a money-gap model, and a Phillips curve. The authors` empirical results suggest that the evolution of the exchange rate remains a very important factor for forecasting inflation in Mexico. Indeed, in the best-performing model, the mark-up model, the exchange rate plays the most significant role. The Phillips curve explains and forecasts inflation well when using actual values for the explanatory variables, but does not perform well when using forecasted values for the explanatory variables. The money-gap model does not appear to be useful in its current form, because it is unable to beat even a simple AR1.

JEL classification: E31, E37
Bank classification: Inflation and prices; International topics

Résumé

Les auteurs ont recours à des modèles d'inflation qui se prêtent bien à l'étude des économies industrialisées pour examiner le cas d'un pays à marché émergent, le Mexique, qui a récemment axé sa politique monétaire sur la poursuite d'une cible d'inflation. Ils comparent l'efficacité de ces modèles à celle d'un modèle souvent utilisé pour l'analyse de l'inflation au Mexique : le modèle dit de « mark-up », dans lequel le niveau des prix s'obtient par addition d'une marge préétablie aux coûts. Ils s'intéressent surtout à trois modèles qui ont des fondements théoriques et qui peuvent donc aider à élucider les causes de l'inflation, mais qui peuvent aussi servir à la prévision : un modèle de mark-up, un modèle fondé sur le déséquilibre monétaire et une courbe de Phillips. Les résultats empiriques des auteurs donnent à penser que l'évolution du taux de change est un facteur déterminant dans la prévision de l'inflation au Mexique. De fait, le modèle produisant les meilleurs résultats, à savoir le modèle de mark-up, est celui où le taux de change joue le rôle le plus important. Le modèle reposant sur la courbe de Phillips permet d'expliquer et de prévoir relativement bien le cours de l'inflation, à condition d'employer les valeurs observées comme variables explicatives; il ne fournit pas de bonnes prévisions si l'on utilise à leur place les valeurs prévues. Le modèle basé sur le déséquilibre monétaire n'est pas très utile dans sa forme actuelle, puisqu'il n'est pas plus efficace qu'un simple processus autorégressif d'ordre 1.

Classification JEL : E31, E37
Classification de la Banque : Inflation et prix; Questions internationales

1. Introduction

In recent years, many emerging-market countries have experienced dramatic declines in inflation as a result of a combination of relatively benign external factors and the adoption of sound domestic policies. In some countries, disinflation stemmed from the use of a pegged exchange rate regime. While pegged exchange rates initially resulted in more stable domestic prices, they often led to balance-of-payments crises. As a result, there has been a movement away from using the exchange rate as a nominal anchor. Many emerging-market countries (such as Brazil, Chile, Israel, and Mexico) have decided to follow the earlier example of several industrialized countries and opted instead to adopt a combination of a floating exchange rate regime and inflation targeting. However, successfully implementing an inflation-targeting framework presupposes that the central bank has a good understanding of domestic inflation dynamics and is relatively successful in predicting the future path of inflation.

There is a large literature on the causes of inflation and there are competing models of the inflation process. The purpose of this paper is to apply existing inflation models that have worked well in industrialized countries to Mexico, an emerging market that has recently moved to adopt an inflation-targeting framework for monetary policy. We compare the performance of these models to a mark-up model that has been used extensively for the analysis of inflation in Mexico. Our approach in this paper is to focus on models that have some theoretical foundations, and thus can be useful in understanding the causes of inflation, but can also be used for forecasting purposes.[1] Moreover, due to the uncertainties inherent in the estimation of any particular model, we are interested in comparing the predictions of several models. This is the approach favoured in many central banks. For instance, as Blinder (1998, p.12) states, when faced with model uncertainty his approach while at the Federal Reserve Board was to "Use a wide variety of models. . . . My usual procedure was to simulate a policy on as many of these models as possible." Then, judgment is used when evaluating the results from the different models. Similarly, Longworth and Freedman (2000) caution that, given model uncertainty and a changing environment, it is important for central banks to rely on a variety of models in conducting policy.

The paper is organized as follows. Section 2 reviews the primary causes of inflation in both industrialized and emerging-market countries, with some emphasis on previous studies conducted for Mexico, and section 3 presents the three classes of models of inflation that we focus on in this paper. In section 4, we present the estimation results of our models, and in section 5 we compare their forecasting performance. In section 6, we explore the potential implications of our results for Mexico in a low-inflation environment. Section 7 offers some concluding remarks.

[1] Our approach can thus be viewed as being partway between an approach that focuses on developing a structural model that is fully specified but not very useful in forecasting, and one that focuses on a structural time-series specification with the sole purpose of finding the optimal forecasting model.

2. Causes of Inflation

There is general agreement that, in the long run, inflation is a monetary phenomenon. However, in the horizon relevant for monetary policy, inflation can be affected by other variables. Shocks which increase aggregate demand relative to aggregate supply are inflationary. Shocks to domestic nominal variables, such as wages, or those to imported prices can raise production costs and also increase inflation. Moreover, movements in the exchange rate can affect inflation through the price of imports as well as by influencing expectations and the price-setting behaviour of domestic agents.[2] This section reviews the theoretical and empirical work done to identify the causes of inflation that would be most important in both emerging markets and industrialized countries.

The Phillips curve predicts that inflation will be related to real factors—shocks to aggregate supply and aggregate demand. Indeed, in reviewing the experience of both industrial and developing countries between 1960 and 1995, the IMF (1996) found that the output gap accounted for a substantial portion of the medium- and long-term movements in inflation for industrial countries. However, monetary accommodation of adverse supply shocks (like increases in the price of oil) explained a large part of the increase in inflation in industrial countries in the 1970s as an initial rise in the price level fed into inflation expectations, raising the cost of subsequent disinflation. This episode emphasizes why it is important for monetary authorities to be able to distinguish between demand and supply shocks.

While real factors are pointed to as the main determinants of inflation in industrialized countries, the primary focus of the literature on inflation in emerging markets has been on nominal factors. For example, the IMF (1996) found that the output gap explained little of the movement in inflation for developing countries. Inflation in these countries was better explained by changes in money growth and nominal exchange rates. This is not to say that inflation is not a function of excess demand in these countries. However, it appears that the contribution of excess demand is dominated by those of nominal shocks; in particular, inflation in the medium term is seen as the result of the government financing its deficit through the creation of money or through time-inconsistent monetary policy.[3]

The government`s use of seigniorage to finance its deficit is one of the key strands in this literature.[4] Seigniorage is the revenue that accrues to the government from increases in the public's real money balances and the loss of the purchasing power of these cash holdings (the “inflation tax”). Simply put, the government prints money to pay its bills and this increase in the money supply translates into inflation when there is no corresponding rise in the output of goods and services.

[2] The IMF (1996) notes that shocks to the exchange rate and imported prices can be thought of as real shocks, since they increase the cost of production by increasing the price of imported inputs.
[3] The episodes of sharp exchange rate depreciations that have translated into higher inflation in many emerging markets are frequently a reflection of these two channels. If the government finances its deficit through foreign indebtedness, leading to an increase in the current account deficit, the country is more vulnerable to external shocks and the probability of a balance-of-payments crisis increases. A time-inconsistent monetary policy in the context of a fixed exchange rate will lead to a run on international reserves and, eventually, a devaluation.
[4] For a survey of this literature, see Fischer (1994).

In many emerging-market countries, especially those with underdeveloped tax systems, seigniorage is an attractive source of government finance. It is easier to collect than most other taxes and it does not require the approval of a legislative body to implement. However, the ability of the government to collect seigniorage will be reduced where the “tax-base” is smaller; i.e., the public's holding of domestic currency is lower (for example, in dollarized economies). In addition, in those countries in which the public has a low tolerance for inflation, the government will face disapproval if it finances its deficit through seigniorage.

Notwithstanding the theoretic links, the empirical evidence of the connection between deficits, seigniorage, and inflation has been rather elusive. Fischer, Sahay, and Vegh (2002) find that the relationship between the fiscal deficit and inflation is strong only in high-inflation countries (or during high-inflation episodes), but they find there is no obvious relationship between deficits and inflation during low-inflation episodes or for low-inflation countries. The lack of a tight relationship for low-inflation countries could be due to the government's ability to borrow domestically in these countries.[5, 6] In this case, the transfer of resources from the private to the public sector would not lead to inflation.

In more recent work, however, Catão and Terrones (2001) successfully relate long-run inflation to the permanent component of the fiscal deficit scaled by the inflation “tax base,” measured as the ratio of narrow money to GDP. They find that a 1 per cent reduction in the ratio of the fiscal deficit to GDP typically lowers inflation by 1.5 to 6 percentage points, depending on the size of the money supply.

The literature has also examined the proposition that a lack of central bank independence can give way to political considerations that may cause monetary policy to be looser than optimal. For example, if it is believed that output can be raised by expansionary monetary policy, politicians could put pressure on the central bank, say during an election, to trade off a boost to growth against higher inflation. Indeed, the IMF (1996) shows that inflation performance between 1970 and 1995 in industrial countries is negatively correlated with an index of central bank independence. However, this study concluded that the same relationship did not hold over the same period for developing countries. This may be due to imprecision in the measurement of central bank independence, since there could be a divergence between *de jure* and *de facto* central bank independence in these countries.[7]

In a more recent study, however, Jácome (2001) uncovered a negative correlation between increased central bank independence and inflation during 1999-2001 in Latin America. He constructed an index of central bank independence for 14 Latin American countries that expanded on previous work by including criteria for central bank responsibility for lender-of-last-resort activities in addition to other *de jure* measures of independence. In this index, discretionary policy

[5] Low-inflation countries typically have better-developed local capital markets. The government financing itself through *external* borrowing could also be inflationary, if net exports are not crowded out by an appreciation of the nominal exchange rate.
[6] However, if fiscal deficits have been large and persistent, the possibility of a solvency crisis will eventually arise when the private sector is no longer willing to finance the deficit.
[7] Independence is typically assessed by evaluating the central bank’s founding legislation and its institutional structure.

for emergency loans could prejudice achievement of inflation control, while a more limited role for central bank lending to commercial banks would enhance it.[8]

Changes in the exchange rate can affect inflation directly by raising the price of imports, and indirectly by altering inflation expectations. Thus, the pass-through of a depreciation into domestic prices could be much larger than the share of imported goods in the consumption basket would suggest. Moreover, inflation expectations can also affect the exchange rate. An increase in inflation expectations would tend to depreciate the exchange rate as agents purchase foreign currency in an effort to preserve purchasing power. Because of the feedback between the exchange rate and domestic prices, a country can fall victim to a vicious circle of depreciation and inflation. In such situations, many countries have opted to fix their exchange rates in an effort to break this cycle. While this strategy is often successful in the short run, it can lead to a balance-of-payments crisis if macroeconomic policies are not consistent with the exchange rate regime.

The evolution of inflation expectations is an important part of the inflation process. It is likely that these are strongly influenced by past inflation, which can also lead to institutional changes that increase inflation persistence. For example, indexing wages and prices to past inflation increases the staying power of inflation. In addition, if nominal interest rates on government debt are high because they embody forecasts of high future inflation, the government has an incentive to validate them, maintaining the real value of the debt.[9]

A number of empirical studies have tried to identify the most important sources of inflation in emerging-market countries. Lougani and Swagel (2001) examine the experience of 53 developing countries between 1964 and 1998. They estimate six variable vector autoregressions (VARs), which include the price of oil, non-oil commodity prices, an estimate of the output gap, money growth, exchange rate changes, and inflation. They find that either money growth or exchange rate movements (depending on the ordering) account for two-thirds of the variance of inflation at both short and long horizons. The authors show that inflation expectations also play an important role in inflation determination, with past realizations of inflation accounting for between 10 and 20 per cent of inflation movements.[10] In aggregate, cost shocks or the output gap are not found to be significant factors. In disaggregating their sample, the authors find that in countries with fixed exchange rate regimes inflation tends to have a substantial inertial component, while money and the exchange rate play a larger role in countries that float.

In contrast, from their examination of the experience of 14 emerging-market countries in the 1980s and 1990s, Mohanty and Klau (2001) find that exogenous supply shocks, in particular those to food prices, are an important determinant of the variability of inflation. Food prices typically account for a larger percentage of the CPI in emerging-market countries than in industrial countries. Moreover, they are highly volatile, due to the influence of weather and the presence of trade restrictions. Demand factors, as proxied by the output gap and excess money, were not found to have played a large role. However, wage growth and exchange rate changes were seen as making

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[8] Argentina, Peru, and Uruguay were the most contained in this regard.

[9] A reduction in inflation would increase the value of the debt in real terms.

[10] An alternative explanation for the importance of past inflation is that it indicates that there are important rigidities or indexation of prices and contracts. Ideally, to capture expectations, one should include an explicit value for this variable. However, these data are not readily available for many emerging markets.

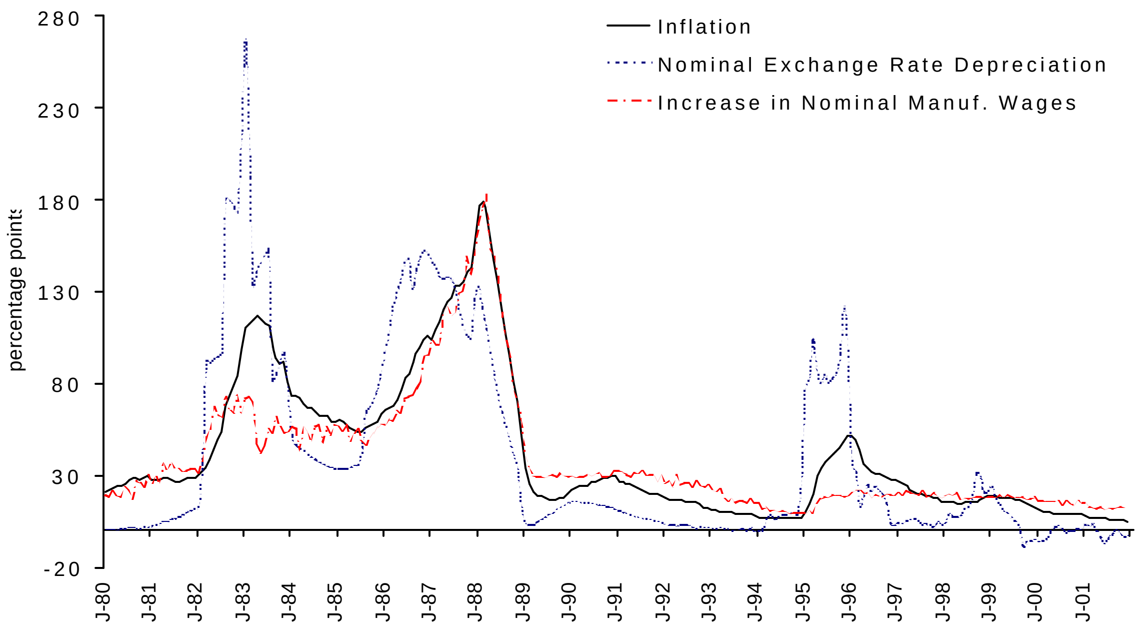
important contributions to inflation volatility in many countries. The authors also find that inflation persistence plays a large role in explaining both the average level of inflation and its variation.

2.1 Inflation in Mexico

During the period 1980–2001, average inflation was high in Mexico, 41.8 per cent, and quite volatile, with a standard deviation of 38.9 per cent. As can be seen in Graph 1, inflation is positively related to changes in the exchange rate. Indeed, inflation generally declined in periods of exchange rate stability and rose sharply in response to the large exchange rate movements associated with the balance-of-payments crises of 1982 and 1994 as well as the sharp drop in the price of oil in 1986.

Graph 1. Annual nominal rates of change in the CPI, the exchange rate, and average wages in manufacturing

Period 1980-2001



While the rate of depreciation is positively related to inflation, the inflation rate has typically been smaller than the depreciation rate when exchange rate movements have been large, but have remained above the rate of depreciation when exchange rate movements were small. The reason for the asymmetric behaviour of inflation with respect to the rate of depreciation lies in the behaviour of nominal wages. Graph 1 also shows the evolution of nominal wage increases in manufacturing. They increased in nominal terms during the periods of balance-of-payments crises, but they fell in real terms, probably limiting the increase in inflation. In periods of exchange rate stability and falling inflation, nominal wage increases decelerated but by a smaller amount than the fall in inflation, translating into increases in real wages that may also explain why inflation has remained above the rate of depreciation in these episodes. It is likely that the evolution of wages is strongly determined by the output gap, an issue that we discuss below.

The pattern observed in Graph 1 has motivated much of the work on inflation in Mexico, which has focused primarily on estimating the effects on inflation of movements in the exchange rate or of wages (we discuss mark-up models in section 3.1). A recent study by Santaella (2001) also analyzes the relationship between prices and the exchange rate in Mexico during the period 1969-2000. He excludes wages from his model, arguing that, in the end, wages are endogenous and would adjust until purchasing-power parity (PPP) held. This implies that the final pass-through from exchange rate changes to prices has to be one, and he finds evidence of this employing a cointegrating relationship.

3. Models of Inflation

The foregoing evidence has led policy-makers to focus on three classes of models for inflation determination. The first views inflation as a cost-push phenomenon in the context of a long-term constant mark-up over costs. The second treats inflation primarily as a monetary phenomenon and attempts to link changes in monetary aggregates to those in prices. The third class views inflation as arising from real factors, in particular imbalances between aggregate demand and aggregate supply.[11] The first type of model has been applied mainly in emerging markets, whereas the other two have been typically (but not exclusively) applied to industrialized countries. We elaborate on these three classes of models below.

3.1 Mark-up models

Mark-up models are usually based, either explicitly or implicitly, on a mark-up model for the determination of inflation, such as that developed by de Brouwer and Ericsson (1998) for the Australian economy.[12] In these types of models, the price level is determined by costs and a given mark-up in the following form:

$$P_t = m_t (W_t)^{g_w} (E_t P*_t)^{g_e}, \tag{1}$$

where P is the domestic level of prices, m is the mark-up over costs, W are wages, E is the nominal exchange rate, and $P*$ is the level of foreign prices, so $EP*$ is a measure of foreign prices expressed in domestic currency. The above price equation can be obtained from the maximization problem of a firm that faces a demand curve with a negative slope (the firm could be a monopolist or could be facing monopolistic competition). In this framework, the firm sells at a price equal to a given mark-up above marginal cost, where marginal cost is determined by the price of domestic inputs, captured by domestic wages, and the price of foreign inputs, reflected in the level of foreign prices.

[11] These characterizations are not mutually independent. For example, if central banks had perfect foresight and if monetary policy was perfectly credible, then interest rates and exchange rates would adjust to ensure aggregate supply and aggregate demand were always equal. Thus, from this perspective, the imbalance between aggregate demand and aggregate supply can be seen as a monetary phenomenon.

[12] Goodfriend (1997) discusses the theoretical underpinnings of the mark-up model.

Expressing the above equation in logarithms, the domestic price level is found to be a weighted average of nominal wages and foreign prices (expressed in local currency units), as follows:

$$p_t = \ln(m_t) + g_w w_t + g_e (e_t + p*_t) + e_t , \qquad (2)$$

where lower-case letters denote the variables in logarithmic form. The above specification is the basis for estimating a long-run relationship between prices, wages, and foreign prices, assuming that the mark-up is constant or fluctuating randomly around a given long-run value.

In the short- and medium-run, however, there could be important and persistent fluctuations in the mark-up, depending on how quickly price setters adjust to changes in wages or in foreign prices. Thus, when analyzing monthly or quarterly inflation rates, it is important to allow for more complex dynamics, which would yield an equation of the following form:

$$\Delta p_t = a_p \Delta p_{t-1} + a_w \Delta w_t + a_e \Delta(e_t + p*_t) - d(p_{t-1} - g_w w_{t-1} + g_e (e_{t-1} + p*_{t-1})) + n_t , \qquad (3)$$

where the lagged term is meant to capture inflationary inertia, contemporary changes in wages and foreign prices are included to capture immediate adjustments, and, finally, we have an error-correction term meant to capture the long-term relationship expressed in equation (2).

The mark-up model has been applied to Mexico by Pérez-López (1996) and Garcés Díaz (1999). The specification employed by Pérez-López is a regression purely in rates of change for the period 1981-95, whereas Garcés Díaz includes additional variables such as the rate of change in the prices of goods provided by the public sector, a simple measure of the output gap, and a cointegration term capturing deviations from a long-run relationship between the domestic price level, the foreign price level (in local currency units), and the level of wages for the period 1985-98.[13] These reduced-form specifications tend to do a very good job of fitting inflation in Mexico, as is evident from Graph 1.

Other examples of the use of the mark-up model to analyze or predict inflation—in addition to de Brouwer and Ericsson (1998) for Australia—include Kenny and McGettigan (1999) for Ireland, Garcia and Restrepo (2001) for Chile, and Springer and Kfoury (2002) for Brazil. These are particularly relevant in that they are relatively small open economies or Latin American countries. In the particular case of the Latin American countries, mark-up models have done well in terms of their in-sample and out-of-sample fit to historical series. However, the recent changes of regime in Brazil and Chile, with the adoption of inflation targeting and flexible exchange rates, seem to have translated into parameter instability.[14] Given that a similar regime change has

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[13] Garcés Díaz (1999) finds a long-term coefficient of 0.63 for the foreign price level and 0.36 for wages.

[14] In particular, there is strong evidence that pass-through has fallen quite dramatically in both Brazil and Chile. It might be the case that something similar has occurred in Mexico, but the relative stability of the peso/dollar exchange rate during the last four years implies that tests of structural change have very low power, due to the low volatility in the variable.

occurred in Mexico, it is of particular importance to evaluate alternative models to compensate for parameter instability in this type of specification.

3.2 Monetary models

Monetary models are based on the view that changes in the aggregate price level are the way in which the economy responds to monetary disequilibria. These types of models are consistent with the "active-money" paradigm, where money is viewed as an active part of the transmission mechanism in that excess money causes inflation.[15] A situation of monetary disequilibria exists if the quantity of money in the economy is above (below) what the public desires to hold. Should this occur, monetary models predict that the price level will rise (fall) to re-establish the equilibrium between the supply and demand for money. Thus, an excess supply of money can translate into inflationary pressure in much the same way that an excess demand for goods does; too much money chases too few goods. Monetary disequilibria is typically measured using the money gap, which is the difference between the actual money supply and the estimated long-run money demand. Hence, according to monetary models, a positive money gap (where the stock of money exceeds the long-run demand for money) should be associated with rising inflationary pressures.

Monetary models have been applied extensively in industrialized countries. A recent example of such an application is Altimari (2001), who evaluates the performance of a number of monetary models of inflation for the euro area over the period 1980 to 2000. His study suggests that monetary and credit aggregates contain significant and independent information to forecast inflation in the euro area, especially at medium-term horizons. Fung and Kasumovich (1998) find support for the "active-money" view in their structural VAR analysis of major industrialized countries. Their results suggest that a money disequilibrium develops and persists following a monetary policy shock, and is closed as prices adjust over a number of years. In other work, Hendry (1995) estimated a vector-error-correction model (VECM) for M1 demand in Canada, and Armour et al. (1996) and Engert and Hendry (1998) found this VECM to be a good inflation-forecast model at horizons of one to two years.[16] Also, Hallman, Porter, and Small (1991) estimate a long-run relationship between money and prices in the United States. They find that the velocity of money is a stationary process and that the gap between actual prices and the level of prices given by the long-run velocity of money has significant explanatory power for inflation.

Monetary models have also been applied to emerging markets. For instance, Jonsson (1999) estimates a structural VECM for South Africa which includes domestic prices, output, the nominal exchange rate, foreign prices, and domestic interest rates. He finds a stable, long-run relationship among these variables, and shows that an increase in the money supply raises domestic prices—although this effect is somewhat offset by an increase in domestic interest rates. In another

[15] This is in contrast to the "passive-money" paradigm, where money is not assigned a causal role in the transmission mechanism and is viewed as passively responding to changes in prices, output, and interest rates. Money in this context is thus best seen as an indicator of economic activity. For a review of these two paradigms, see Engert and Selody (1998).

[16] The coefficients on the deviation of money from its long-run equilibrium imply that when M1 is above its long-run demand, money will decrease and prices increase to restore long-run equilibrium. The effects of the deviation on output and interest rates are insignificant, pointing to the weak exogeneity of these variables. The implication of the results is that all the adjustment to return the economy to monetary equilibrium comes from fluctuations in money and prices. However, the model allows for changes in the stock of money to have short-run real effects.

example, Callen and Chang (1999) estimate two models of inflation in India—one based on the monetary approach and the other using the output gap. They conclude that monetary aggregates contain the best information about future inflation and that the output gap is not a significant explanatory variable.

Monetary models need to be used with caution. Financial innovation can change the demand for money (especially narrow money), introducing instability into the money-inflation relationship. Moreover, the short-run interest elasticity of money can be high, leading policy-makers to believe that an increase in interest rates sufficient to bring money back to its target may be too small to slow down spending and inflationary pressures.[17] However, as noted by King (2002), there are good reasons for developing models based on monetary aggregates. First, as is a well-established fact, while models based on money growth have limited power in forecasting short-run inflation, they perform better as indicators of long-run inflationary pressures.[18] Second, at low rates of inflation, the possibility of falling into a liquidity trap with nominal interest rates close to zero and deflation implies that an expansion of the monetary base may be the only way to ease monetary conditions further. Thus, it is convenient to analyze the effect of changes in monetary aggregates independently of their effect on interest rates. Finally, by focusing only on other determinants of monetary conditions in the economy, there is a risk of neglecting an important component of the transmission mechanism.

3.3 Phillips curves

Since it was first outlined by Phillips (1958) in his seminal paper, the Phillips curve has been used extensively as a framework to explain and forecast inflation in industrialized countries. In its original form, the Phillips curve stipulated a relationship between the rate of change in nominal wages and the inverse of the unemployment rate, where the inverse of the unemployment rate was used as a proxy for excess demand.[19] Thus, a decline in the unemployment rate implied an increase in excess demand, which put upward pressure on nominal wages. In the decade or so that followed its inception, the Phillips curve underwent many modifications. For instance, the inverse of the unemployment rate was replaced by the unemployment/output gap, as the proxy for excess demand.[20] In addition, the role of inflation expectations in influencing wage changes was

[17] For a discussion of why Canada abandoned monetary targeting and the current role of monetary aggregates in policy formulation, see Freedman (2000).
[18] This, of course, assumes that there are no major financial innovations over the given period.
[19] Phillips (1958) had found this stable relationship between wage inflation and the unemployment rate using data for the United Kingdom over the period 1861 to 1957.
[20] The unemployment gap is the difference between the actual and natural rate of unemployment, where the natural rate of unemployment is defined as the rate that prevails when expectations are fully realized and incorporated into all wages and prices, and inflation is neither accelerating nor decelerating. The output gap is the deviation of actual from potential output, where potential output is the level of output that is consistent with a stable rate of inflation given the stock of capital. The unemployment and output gaps are linked through Okun's law, which relates a change in unemployment to a change in output.

recognized and hence inflation expectations were incorporated into the Phillips curve.[21] Finally, it was transformed from a wage inflation equation to a price inflation equation.[22]

Although various forms of the Phillips curve are used in practice, most of them can be interpreted as a "triangle" model of inflation—a term Gordon (1997) coined to summarize the dependence of inflation in this context on three basic determinants: inertia, demand, and supply. This Phillips curve framework is now sometimes referred to as the traditional Phillips curve, to distinguish it from the new Phillips curve.[23] The new Phillips curve is similar in spirit to the traditional version, in that it assumes that inflation varies positively with real sector economic activity, but it differs in that it relates inflation to movements in real marginal cost instead of the output gap. Proponents of the new Phillips curve claim that this formulation is more appropriate given that it is derived explicitly from a model of staggered nominal price setting by monopolistically competitive firms, and hence has stronger theoretical foundations.[24] It is worth noting, however, that by making certain restrictions on technology and labour market structure, and within a local neighbourhood of the steady state, real marginal cost is found to be proportionally related to the output gap.[25]

The traditional Phillips curve`s ongoing popularity is likely due in part to its relative success as a forecasting tool. As pointed out by Stock and Watson (1999), "As a tool for forecasting inflation, it [the Phillips curve] is widely regarded as stable, reliable and accurate, at least compared to the alternatives." For instance, Duguay (1994) estimated a Phillips curve for Canada over the period 1968Q4 to 1990Q4 and found the equation to be reasonably successful in explaining variations in Canadian inflation over that period. Subsequent work in this area focused on the shape of the short-run Phillips curve and the asymmetry between positive and negative output gaps and their effects on inflation.[26]

In recent years, traditional Phillips curves have had more difficulty in predicting inflation. In Canada, for example, inflation fell from 4 per cent in 1990 to 2 per cent between 1993 and 1995. However, traditional Phillips curves would have predicted deflation at the end of that period, given the large amount of excess supply in the Canadian economy. Moreover, in the late 1990s, inflation in the United States was relatively low given the rapid growth of output. These experiences have led some observers to predict "the death of the Phillips curve."[27] Economists have adopted two strategies to deal with the apparent breakdown of the traditional relationship. On the one hand,

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[21] Friedman (1968) is generally credited as being the first to emphasize the importance of including inflation expectations in the Phillips curve. As he noted, firms and workers are concerned with real, rather than nominal, wages; or in other words, they look at the rate of change in nominal wages less expected inflation.
[22] The two specifications are consistent if one assumes that prices are set by applying a constant mark-up to unit labour cost.
[23] For a comprehensive survey of the new Phillips curve literature, see Goodfriend and King (1997).
[24] In these models, monopolistically competitive firms and their workers set a fixed wage over a J-period contract. Wage bargains are assumed to be staggered over time, with 1/J of the contracts set in each period. Firms then set prices based on a mark-up over some combination of actual and expected marginal cost. The staggered nature of nominal price setting in the economy means that prices will respond sluggishly to changes in output. In these models, lags of nominal wages and prices are important, since they reflect the gradual adjustment to shocks.
[25] See Galí, Gertler, and Lopez-Salido (2001), and references therein, for more details.
[26] For a survey of this work, see Macklem (1997).
[27] Galí, Gertler, and Lopez-Salido (2001, p. 5).

adjustments were made to the traditional Phillips curves to take account of structural change.[28] On the other, a more structural approach was taken to modelling the relationship between labour market disequilibrium and inflation, which has led to the new Phillips curve literature.

In recent years, there have been applications of traditional Phillips curve models to emerging-market countries. Coe and McDermott (1999) estimate Phillips curves based on output gaps for 13 Asian countries. They find that for 11 of the 13 countries, the output gap is a significant determinant of inflation even when other variables, such as measures of monetary disequilibria, are included in the equations. Simone (2000) estimates time-varying Phillips curves for Chile. He finds that, although the model which includes the pre-announced inflation target displays some autocorrelation, it outperforms the model that excludes this variable in forecasting exercises.

4. Three Models of Inflation for Mexico: In-Sample Estimation Results

In this section, we present the specifications for the three models of inflation that we apply to Mexico, as well as review and compare their in-sample performance. Each model is estimated using quarterly data, over the period 1983Q1 to 2001Q4.[29] In estimating all models for Mexico, we use the quarter-over-quarter (q/q) total inflation rate as the dependent variable.[30] The first graph in Appendix 1 plots this variable over our sample period.

4.1 Mark-up model

We use the following specification for the mark-up model, which is based on work done by Garcés Diaz (1999):

$$\Delta p_t = a_c + a_p \Delta p_{t-1} + a_w \Delta w_t + a_e \Delta(e_t + p_t^*) - d\,(p_{t-1} - g_w w_{t-1} + g_e (e_{t-1} + p_{t-1}^*)) + u_t . \qquad (4)$$

The long-run parameters can be estimated by almost any cointegration method with very similar results. For simplicity, and the fact that the parameters were re-estimated recursively for the forecasting exercise, we used the unrestricted error-correction framework. The results for the whole sample are reported in the first column of Table 2.1 in the appendix and a detailed analysis of the long-run relationship can be seen in Garcés Díaz (1999). The model in that table contains a constant, the lagged error-correction term (EC_{t-1}), lagged inflation (Δp_{t-1}), the contemporary rates of growth of wages (Δw_{t-1}) and foreign prices in local currency ($\Delta epeu_{t-1}$), and a dummy for the

[28] For instance, Fillion and Leonard (1997) introduced a Markov-switching process into a traditional Phillips curve and applied this model to Canadian inflation. They found that, when regime changes were taken into account, the forecasting performance of the Phillips curve improved substantially. In another example, Kichian (2001) estimated a Phillips curve for Canada using a state-space framework in which the model's parameters are allowed to vary over time. In re-estimating the traditional relationship with time-varying parameters, inflation expectations were modelled as conditionally endogenous. She showed that inflation expectations and pass-through were reduced in Canada over the 1990s and that the coefficient on the output gap during 1991-98 was about half of its 1978-88 value.

[29] We use this sample period due to data availability. In particular, the quarterly GDP series in Mexico, which is needed to estimate the output gap, starts in 1980.

[30] It should be noted that we measure quarterly inflation based on the consumer price index measured at the end of each quarter, rather than as an average throughout the quarter.

second quarter of 1988 to get statistically normal residuals. The estimated coefficients for all variables are significant at any reasonable level. The goodness of fit is the highest among all models in Table 2.1, a fact that will be reflected in the forecasting performance. The only problem detected by the evaluation statistics below the estimates is the high RESET statistic. This indicates a problem with the chosen linear specification, which we did not try to solve here.

4.2 Money-gap model

The money-gap model that we use has the following form:

$$\Delta p_t = a + b_1 \Delta p_{t-1} + b_2 moneygap_{t-1} + e_t, \tag{5}$$

where the key variable is the money gap, our measure of monetary disequilibrium. The money gap is obtained from the following long-run money-demand function where the log of real money (*m*-*p*) is a linear function of a scale variable, which we choose to be the index of industrial production (*y*),[31] and the opportunity cost of money (*i*):

$$m - p = c + g\ y + p\ i\ . \tag{6}$$

For the case of Mexico, a long-run money-demand function can be estimated for almost any definition of money, although we decided to use currency in this paper because it is the aggregate that the Bank of Mexico used in the past as a potential indicator of inflationary pressures, and because it is the one most closely related to inflation and economic activity.[32] Again, the long-run parameter estimates can be obtained by any method with very similar results. Table 1 below shows the estimates of this long-run money-demand function for each of several monetary aggregates. All the long-run equations are obtained for real money balances (i.e., the monetary aggregate divided by the consumer price index). The estimation method used is FM-LS of Phillips and Hansen (1990). Columns 3 to 6 contain the statistics proposed by Hansen (1992) to test the stability of the long-run parameters together with the corresponding *p*-values.

The signs of the long-run parameters are correct and the magnitudes are reasonable. The *p*-values in most cases are above 0.05, meaning that the hypothesis of constant parameters cannot be rejected in most cases. With the estimates for currency (*myb*-*p*), we construct the money-gap term[33]:

$$MoneyGap = m - p - 0.566\,y + 0.353\,i\,.$$

This is the error-correction term in a short-run demand for money, but in an equation where inflation is the dependent variable it provides the channel for the monetary disequilibrium to impact the dynamics of price changes. In the case we analyzed, this variable was not very significant in all the specifications we tried. This is true for money gaps constructed with any aggregate. The results

[31] This is done to make the results comparable to those obtained in Garcés Díaz (2001), although the results do not vary in any meaningful way by using other measures, such as quarterly GDP or private consumption.
[32] See Garcés Díaz (2002).
[33] No conclusion of this paper is changed in the least by using a different aggregate.

Table 1: Estimated Long-Run Money-Demand Function

Money demands	Long-run elasticities*		Stability tests**		
	i	y	LC	F prom.	F.sup.
myb-p	-0.353 (0.054)	0.566 (0.086)	0.410 p=0.162	3.940 p=0.200	10.033 p=0.200
m1-p	-0.960 (0.212)	1.100 (0.332)	0.362 p=0.200	4.234 p=0.186	18.028 p=0.014
m2-p	-0.281 (0.174)	1.284 (0.272)	0.210 p=0.200	2.489 p=0.200	9.631 p=0.200
m3-p	-0.214 (0.082)	1.369 (0.128)	0.534 p=0.081	4.744 p=0.135	8.318 p=0.200
m4-p	-0.147 (0.112)	1.891 (0.175)	0.748 p=0.028	5.706 p=0.071	11.559 p=0.187

*Standard errors in parentheses **p= *p*-value for statistic

are presented in the second column of Table 2.1 and they show that the lagged money-gap term does not have much explanatory power for inflation; this will be reflected in the poor forecasting performance of this model. Correcting the problem of non-normality of the residuals with dummy variables ends up making the money-gap term even less significant.

4.3 Phillips curve

We use a specification for the traditional Phillips curve that relates price inflation to inflation expectations, some measure of real disequilibrium, and a variable to capture changes in imported prices, given that Mexico is a relatively open economy. Assuming that expectations are formed adaptively, so that lagged inflation can be used as a proxy for inflation expectations, and that the relationship is linear, we obtain the following specification:

$$p_t = a + b_1(L)p_t + b_2(L)\,gap_t + b_3(L)\,\Delta s_t + e_t, \qquad (7)$$

where p_t is inflation at time t, L is the lag operator, gap_t is the output gap at time t, and s_t is the nominal exchange rate at time t. In terms of explanatory variables, we use a measure of the output gap estimated from a structural vector autoregression (VAR) (discussed in more detail below) and the quarterly rate of change of the nominal U.S. dollar-peso exchange rate.[34] Charts depicting the evolution of these variables over the sample period are shown in Appendix 1.[35]

[34] The quarterly rate of change of the nominal exchange rate is based on the exchange rate measured at the end of each quarter.

[35] All of the series used are *not* seasonally adjusted. However, we do include seasonal dummies in all of the estimations in an attempt to control for seasonal effects.

The specification in (7) assumes that inflation, the output gap, and the rate of change of the nominal exchange rate are all stationary variables. We conducted unit-root tests on all the variables to ensure that this was indeed the case. The results of the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit-root tests, both with and without trends, are depicted in Appendix 3. For both these tests, the null hypothesis is that the series in question has a unit root; thus, rejection of the null hypothesis suggests that the series is stationary. The test results for the output gap are unambiguous and suggest that this series is stationary. For the other two variables, inflation and the rate of change in the nominal exchange rate, the test results are mixed. In the case of inflation, all the tests except for the ADF test without a trend point to a stationary series. In the case of the rate of change in the nominal exchange rate, the ADF test suggests a unit root, whereas the PP test points to a stationary series. Based on these results and on our priors, we are going to assume that both inflation and the rate of change of the nominal exchange rate are stationary over our sample period.

The output gap for Mexico is estimated using a structural VAR, a methodology developed by Blanchard and Quah (1989), among others, and applied to Mexico by DeSerres, Guay, and St-Amant (1995).[36] This methodology assumes that output is driven by a combination of demand and supply shocks, and that, by identifying these shocks, output can then be decomposed into its temporary and permanent components. It involves the estimation of a VAR model in which other variables, which are also assumed to be driven by these same shocks, are added to the system to help identify the demand and supply shocks. In addition, some restrictions on the long-run behaviour of the variables in response to the shocks are needed in order to identify these shocks; these restrictions are made based on macroeconomic theory.

DeSerres, Guay, and St-Amant (1995) estimated a 3-variable VAR for Mexico over the period 1965-94 which included the price of oil, industrial production (to proxy for aggregate output), and a monetary aggregate, all in first difference.[37] In order to identify oil, other supply, and demand shocks, the authors assumed that demand shocks do not have a permanent effect on output in the long run and that the international price of oil is exogenous to the Mexican economy. They then calculated potential output by adding the oil and other supply shock components to the drift in output.

We apply the same methodology as DeSerres, Guay, and St-Amant (1995), but use the price of oil, real GDP, and the real exchange rate (all in first difference) in our 3-variable VAR and estimate the system over the period 1980-2001.[38] We opt to use the real exchange rate (instead of a monetary aggregate) because we believe that this is a very rich variable—in terms of the information that it contains—being a key price in an open economy like Mexico. Our priors were thus that movements in the real exchange rate would reflect many important demand and supply shocks in Mexico, and hence would provide useful information to help distinguish between demand and supply shocks. In particular, it might help to control for external financing shocks that have

[36] A more detailed description of this methodology is provided in Appendix 4.
[37] The series were first-differenced to ensure stationarity.
[38] We conducted unit-root tests on the series in first difference to ensure that they were stationary. As shown in Table 3.2 in Appendix 3, the results of these tests suggest that the variables in levels are I(1) and hence, that once differenced, they are stationary. In addition, as shown in Table 3.3, we checked whether the series in levels were cointegrated using Johansen's method, and found no such evidence.

translated into severe balance-of-payments crises in Mexico. Furthermore, we tried different specifications for the VAR, including 3-, 4-, and 5-variable specifications using a monetary aggregate and the unemployment rate, and we found this 3-variable system to yield the most reasonable profile for the Mexican output gap over the sample period.

Indeed, as shown in Appendix 1, the estimated output gap over the past two decades is consistent with the known episodes of booms and busts that Mexico has experienced over this time period. One can identify four major contractions over this period that were characterized by large, and in some cases sustained, negative output gaps: the sustained economic contraction in the early 1980s that occurred as a result of the debt crisis, the economic deceleration around 1993, the economic crisis following the devaluation of the peso in the mid-1990s, and the more modest downturn in 1998-99 that was caused mainly by declining oil prices and deteriorating market sentiment in the aftermath of the Russian default. In contrast, the crisis of 1994 was preceded by a series of large and positive output gaps.

In estimating equation (7) for Mexico, we started with four lags for each of the explanatory variables and found that only the first lag of inflation, the second lag of the output gap, and the first lag of the rate of depreciation were statistically significant. Given that our goal in this paper is to examine models that can be used both to explain and forecast inflation, we decided to use this parsimonious specification.[39] In addition to lagged values, we also tried contemporaneous values of the output gap and rate of depreciation in some of the specifications, but only the latter was statistically significant.

We report the in-sample estimation results for this parsimonious version of the Phillips curve in the third column of Table 2.1 in Appendix 2. As shown in the table, the Phillips curve appears to do a good job of explaining movements in Mexican inflation over the past two decades. Indeed, the adjusted R-squared is high and all the coefficients are statistically significant, in addition to being of the expected sign and magnitude. The coefficient estimates on the Phillips curve are generally consistent with our priors. For instance, the coefficient on lagged inflation is roughly 0.6. This would imply that a 1 per cent increase in inflation in a given quarter would translate into a 0.6 per cent increase in inflation in the next quarter. The coefficient on the output gap is positive and equal to around 0.4, implying that a 1 per cent increase in the output gap would increase quarterly inflation by 0.4 per cent in the short run. The effect of a depreciation of the nominal exchange rate on inflation is estimated at around 0.34 per cent (this includes both the lagged and contemporaneous coefficients). Thus, this would imply that a 1 per cent quarterly depreciation would increase quarterly inflation by roughly 0.34 per cent in the short run.

In addition to reporting the in-sample results of our three models in Table 2.1 in Appendix 2, we also include the estimation results for an AR1. The AR1 specification was selected as a benchmark because we felt that all three models, to be useful in forecasting, should at a minimum outperform this simple univariate specification. This appears to be the case based on the in-sample fit, across all three models, although the improvement for the money gap model is only marginal. The best-performing model, based on our in-sample results, appears to be the mark-up model. Indeed, it has the highest adjusted R-squared and the lowest standard error of the regression (SEE).

[39] In other words, including additional lags of the explanatory variables when they do not contribute any supplementary information to the model is not particularly useful.

The Phillips curve, however, is a close second. Next, we examine the forecasting performance of our three models.

5. Forecasting Comparison

In this section, we examine the out-of-sample forecasting performance of our three models as well as a simple AR1. To do this, we estimate all the models using dynamic rolling regressions starting with 1983Q1-1996Q4 as the sample period, moving up one quarter each time to generate a new forecast, and then forecast accumulated inflation over the subsequent four-quarter period each time. We do this by using both actual and forecasted values for the explanatory variables.[40] For the forecasted values, we constructed series that would have been available at the time of the forecast. Thus, in the case when the estimation period ended in 1996Q4 and the forecasting period started in 1997Q1, we used information that would have been available in 1997Q1. We needed forecasted values for the explanatory variables in all three models except for lagged inflation, which could be obtained from the forecasting equations themselves. Forecasted values for the explanatory variables were obtained from a combination of models and market forecasts.[41]

Two issues should be mentioned before the presentation of the results. First of all, the simple AR(1) model with seasonal dummies used as the basic standard to compare the forecasting performance of the theory-based models is in fact the best ARMA model available. The residuals from this model show no signs of autocorrelation and no additional AR or MA terms are significant. Second, although conditioning on the nominal exchange rate might seem at odds with what we know from theory, the exercise we perform is correct based on the following considerations. The exchange rate is the sum of the discounted stream of monetary fundamentals. If the market is efficient enough, that variable should not be predictable on the basis of other information and it should Granger-cause the changes in the fundamentals. This is just an application of the present-value model with non-stationary variables (Campbell and Shiller 1987). Because of this, it would be useless to try to forecast the nominal exchange rate simultaneously with inflation, which is in itself a function of the monetary fundamentals. We used a market-generated forecast for the exchange rate but we could as well have used a random-walk forecast for it and the conclusions would not have changed in the slightest. More generally, the use of a VAR methodology does not change any conclusion.

The out-of-sample performance of the various specifications is compared in Tables 2.2 and 2.3 in Appendix 2 using three different measures of performance: root-mean-squared error (RMSE), mean absolute error (MAE), and mean error (ME). The results suggest that the best-performing model based on out-of-sample performance is the mark-up model, and this regardless of whether it is actual or forecasted values that are used for explanatory variables. The Phillips curve performs better than the money-gap model and the AR1 when using actual values for the

[40] In the case of the output gap, there are no actual values, since this variable is unobservable. The output gap corresponding to the full-information scenario is thus the one estimated from the structural VAR using actual values for the variables in the system.

[41] We used market forecasts produced by *Consensus Forecasts* for the exchange rate, the Mexican and U.S. price levels (to calculate the real exchange rate), the price of oil, and Mexican GDP. The output gap in this case is the one estimated from the structural VAR using forecasted values for the variables in the system.

explanatory variables, but is the worse performer when using forecasted values for the explanatory variables.

6. Implications of Results for Mexico in a Low-Inflation Environment

The results presented in sections 4 and 5 suggest that, even in the more recent period, models that incorporate the exchange rate perform well in terms of explaining and forecasting inflation in Mexico. Both the mark-up and Phillips curve models outperform the others to a large extent because of the inclusion of the exchange rate in both models, with an additional variable in each case: wages or the output gap.

The implications of our results for the current low-inflation environment observed in Mexico are not straightforward, as the estimations that were used are done for a long period of both high and low inflation. However, the forecasting performance of the models suggests that the mark-up model has been more consistent in terms of smaller errors even in the more recent period. This does not mean other variables different from the exchange rate will not become more important in the future, but rather that further work will be necessary to identify their effects in a more stable environment.

There are sound reasons to expect a change in the relative importance of different determinants based on an observation of previous Mexican history. As an example of this claim, let us consider the effect of U.S. inflation on Mexican inflation. In our equations, whenever needed, that variable is forced to have the same coefficients as the exchange rate depreciation; otherwise, it becomes insignificant. However, we know that variable has been important because it was needed to keep the PPP condition (the price level in Mexico since 1980 has gone up in almost exactly the same amount as the sum of the per cent increases of the nominal exchange rate and the U.S. CPI), but its individual effect in the sample period is hard to detect because the exchange rate has been many times more volatile. If the same effect is estimated when the exchange rate was fixed in Mexico (from 1954 to 1975), then the coefficient of U.S. inflation is significant at the 1 per cent level. Something similar occurs with the money gap.

As for the output gap, the periods in Mexican history when economic activity was evidently above potential were few before the sample period, so its effect on inflation is difficult to measure. One of these episodes took place at the end of the seventies because government spending increased considerably under the expectation of greater oil revenues. Many analysts considered that a big part of the inflationary push at that time was coming from an increased aggregate demand (the exchange rate was mostly fixed). For these reasons, we believe that, as soon as the variability of the exchange rate remains low, as it has occurred in the past few years, monetary policy will increasingly take into account other kinds of shocks.

7. Concluding Remarks

Our empirical results suggest that the evolution of the exchange rate remains a very important factor for forecasting inflation in Mexico. Indeed, the best-performing model, the mark-up model, is the one in which the exchange rate plays the most significant role. The Phillips curve does fairly well at explaining and forecasting inflation when using actual values for the explanatory variables, but does not do well in the forecasting exercises when using forecasted values for the explanatory variables. The money-gap model does not appear very useful in its current form, given that it is unable to beat even a simple AR1.[42] However, it might be worth exploring whether more sophisticated money models do a better job of explaining and forecasting inflation in Mexico. We leave this to future research.

As discussed earlier, monetary policy by its very nature is conducted in an environment characterized by uncertainty and change, both in industrialized countries and emerging markets alike. The uncertainty is likely to be higher in a country like Mexico, where significant changes in its economic and policy environment have taken place over the past two decades. All this suggests that there may be a role for multiple models of inflation in the conduct of Mexican monetary policy. Based on the estimation and forecasting results presented in this paper, it appears as though mark-up models and Phillips curves augmented with the exchange rate might give complementary views in the Mexican context. However, it is clear that in both models the exchange rate still plays a predominant role. To the extent that the volatility of the exchange rate has fallen and, perhaps, that the pass-through is smaller, some of the other components in the models are likely to become more relevant.

[42] It does not seem appropriate to include the exchange rate depreciation as an additional term in the money-gap model, as an excess demand for money should translate into higher demand for goods, generating domestic price pressures, and also higher demand for other assets, such as foreign currency, leading to a depreciation of the currency. Thus, a theoretically consistent money-gap model should be able to explain changes in both tradable and non-tradable goods prices. In addition, if the exchange rate is partly driven by the evolution of money, the inclusion of both variables would generate estimation problems associated with multicollinearity.

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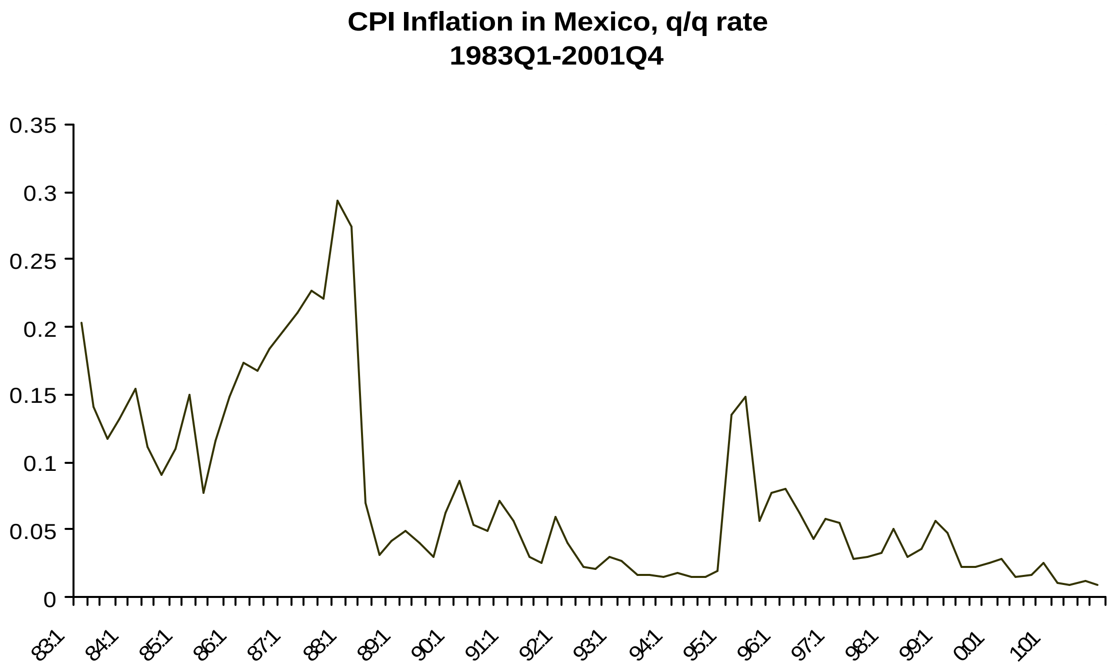
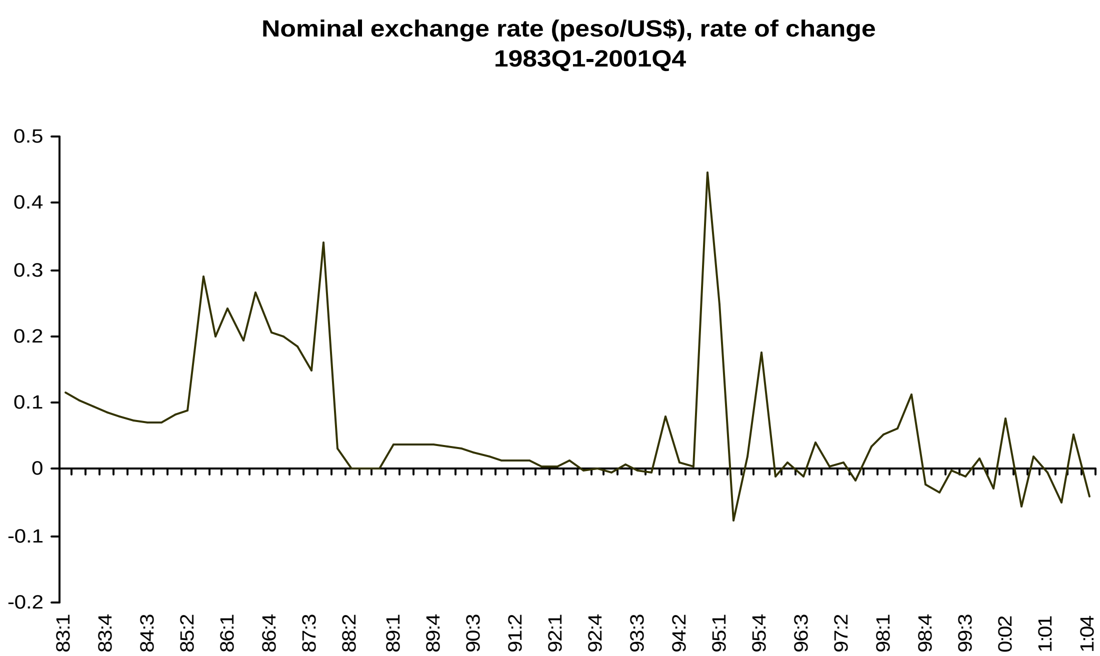
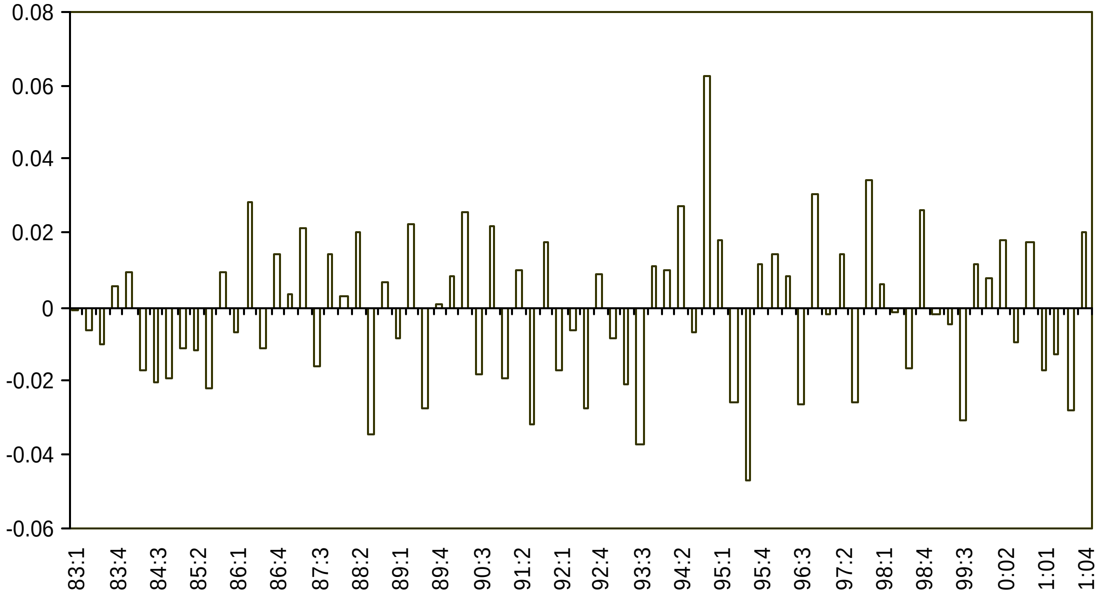
Appendix 1: Charts of Series

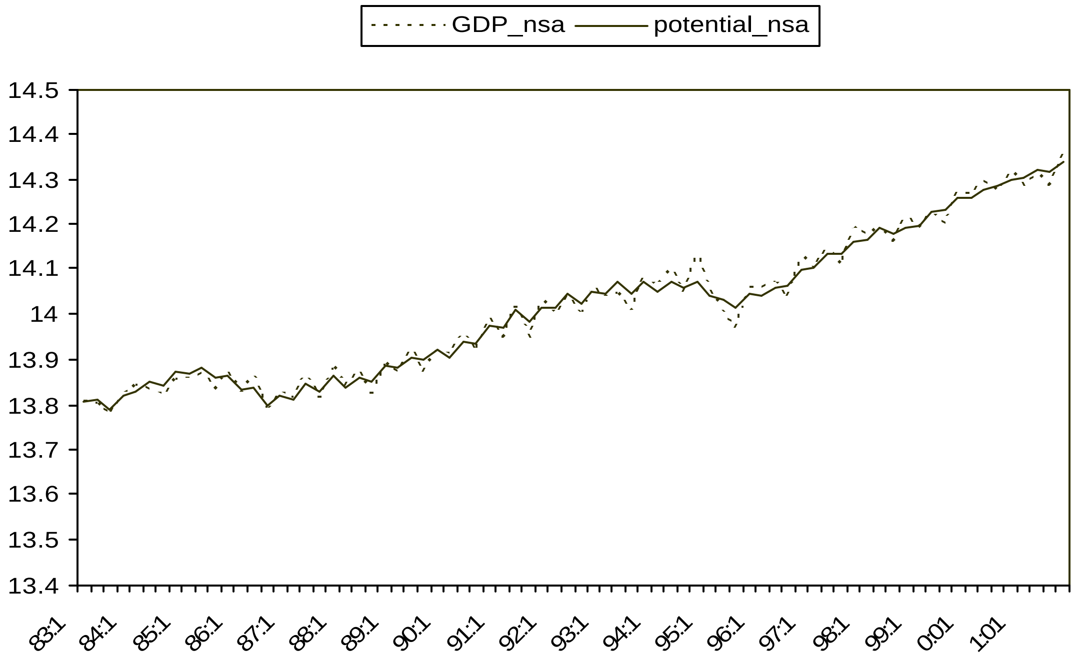




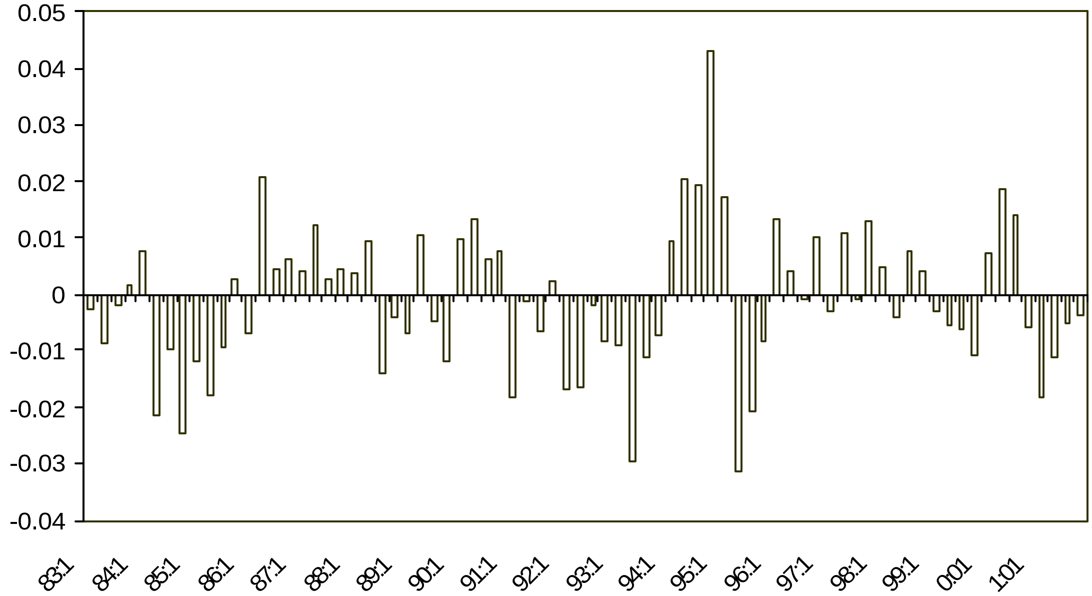
Mexican output gap, estimated using 3-variable SVAR, n.s.a.
1983Q1-2001Q4



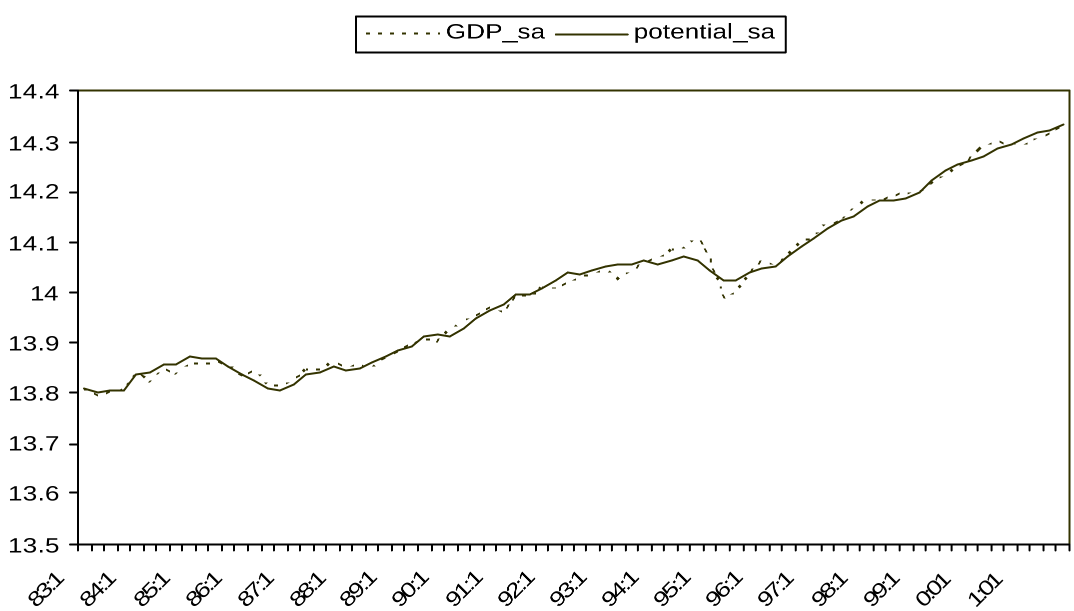
Mexican GDP and Potential GDP, in log form, n.s.a.
1983Q1-2001Q4



Mexican output gap, estimated using 3-variable SVAR, s.a. 1983Q1-2001Q4



Mexican GDP and Potential GDP, in log form, s.a. 1983Q1-2001Q4



Appendix 2: Estimation and Forecasting Results

Table 2.1: In-Sample Estimation Results (sample: 1983Q1-2001Q4)
Dependent Variable: Δp_t (q/q)

	Mark-up model	Money-gap model	Phillips curve	AR1
Constant	**-0.9326**	-0.5344	**0.0269**	**0.0209**
	(0.001)	(0.166)	(0.000)	(0.073)
EC term (mark-up model)	**-0.1374**			
	(0.001)			
Dp_{t-1}	**0.5164**	**0.8681**	**0.5844**	**0.8773**
	(0.000)	(0.000)	(0.000)	(0.000)
Dw_t	**0.1654**			
	(0.001)			
$Depeu_t$	**0.1511**			
	(0.000)			
Money gap_{t-1}		0.0546		
		(0.148)		
Output gap_{t-2}			**0.3954**	
			(0.033)	
Ds_{t-1}			**0.1164**	
			(0.017)	
Ds_t			**0.2325**	
			(0.000)	
1988Q2 dummy	**-0.0935**			
	(0.000)			
1994Q4 dummy			**-0.1263**	
			(0.000)	
No. of obs.	76	76	76	76
R^2	0.945	0.806	0.916	0.799
Adj. R^2	0.938	0.792	0.906	0.788
SEE	0.017	0.031	0.021	0.031
Jarque-Bera	4.687	174.223	143.98	236.12
LM AR(4)	1.821	1.317	0.767	1.382
LM ARCH (4)	1.379	1.656	1.873	0.963
White-Heteroscedasticity	1.883	4.224	6.320	5.167
Reset	17.870	0.010	1.316	0.016

Notes: The figures in parentheses are *p*-values. Bolded values indicate significance at the 10 per cent level. Seasonal dummies were included in each regression. The standard errors are heteroscedasticity-consistent.

Table 2.2: Out-of-Sample Forecasting Performance (Dynamic)
Using Actual Values for Explanatory Variables
Estimation Period: 1983Q1-1996Q4
Forecasting Period 1997Q1-2001Q4

	Mark-up model	Money-gap model	Phillips curve	AR1
Root-mean-squared error (RMSE)	0.037	0.094	0.061	0.084
Mean absolute error (MAE)	0.031	0.074	0.048	0.075
Mean error (ME)	-0.031	0.063	0.042	0.075

Table 2.3: Out-of-Sample Forecasting Performance (Dynamic)
Using Forecasted Values for Explanatory Variables
Estimation Period: 1983Q1-1996Q4
Forecasting Period 1997Q1-2001Q4

	Mark-up model	Money-gap model	Phillips curve	AR1
Root-mean-squared error (RMSE)	0.038	0.105	0.155	0.084
Mean absolute error (MAE)	0.033	0.085	0.133	0.075
Mean error (ME)	-0.033	0.069	0.123	0.075

Appendix 3: Unit-Root and Cointegration Test Results

Table 3.1: Results of Unit-Root Tests on Variables used
in Phillips Curve (sample: 1983Q1-2001Q4)

Series	ADF (no trend)	ADF (with trend)	PP (no trend)	PP (with trend)
CPI inflation (total)	-2.25 (0.19)	**-3.20** (0.08)	**-14.60** (0.08)	**-23.70** (0.04)
Log of exchange rate (level)	-2.52 (0.11)	-2.44 (0.36)	-2.38 (0.27)	-2.93 (0.06)
Log of exchange rate (first difference)	-2.13 (0.23)	-2.79 (0.20)	**-28.72** (0.01)	**-38.00** (0.00)
Output gap (%)	**-4.91** (0.00)	**-5.16** (0.00)	**-65.03** (0.00)	**-68.48** (0.00)

Notes: The columns labelled "ADF" and "PP" report the test statistics used in the Augmented Dickey-Fuller and Phillips-Perron tests, respectively. In both cases, the null hypothesis states that the series in question has a unit root. The number of lags for the ADF test was chosen using the recursive procedure suggested by Campbell and Perron (1991); the number of lags in the PP test was chosen according to a formula suggested by Schwert (1989). The figures in parentheses are *p*-values. Bolded values are significant at the 10 per cent level.

Table 3.2: Results of Unit-Root Tests on Variables used in Structural VAR (sample: 1980Q1-2001Q4)

Series (in log form)	ADF (no trend)	ADF (with trend)	PP (no trend)	PP (with trend)
Real price of oil (level)	-1.98 (0.29)	-2.54 (0.31)	-4.76 (0.46)	-10.20 (0.39)
Real price of oil (first difference)	**-5.08** (0.00)	**-5.28** (0.00)	**-55.51** (0.00)	**-54.44** (0.00)
Real GDP (level)	**1.65** (0.00)	-1.56 (0.19)	**-0.08** (0.05)	**-40.08** (0.00)
Real GDP (first difference)	**-3.05** (0.03)	**-3.89** (0.01)	**-141.1** (0.00)	**-139.23** (0.00)
Real exchange rate (level)	**-3.30** (0.01)	**-3.72** (0.02)	-11.36 (0.14)	-11.26 (0.36)
Real exchange (first difference)	**-3.68** (0.00)	**-3.87** (0.01)	**-100.5** (0.00)	**-98.48** (0.00)

Notes: See notes for Table 3.1.

Table 3.3: Results of Cointegration Tests on Variables used in Structural VAR (sample: 1980Q1-2001Q4)

	λ_{max}	λ_{trace}
H_0: r=0	15.84	22.23
Critical value (95%)	20.78	29.51

Notes: The columns labelled "λ_{max}" and "λ_{trace}" report the test statistics and critical values used in Johansen's cointegration test. In both cases, the null hypothesis is that there is no cointegrating relationship between the three variables. The number of lags for the tests was selected using a general-to-specific strategy.

Appendix 4: Estimating Potential Output Using a Structural VAR Methodology: Key Equations[43]

Let us assume that the international real price of oil (oil), Mexican real GDP (y), and the Mexican real exchange rate (rer) each follows a stationary process in first-difference form that responds to three types of orthogonal shocks: oil shocks (ε_{oil}), other supply shocks (ε_s), and demand shocks (ε_d). Thus, these variables are jointly determined in this 3-variable system. The structural model corresponding to this system can be given by the following moving-average representation:

$$\Delta x_t = A_0 e_t + A_1 e_{t-1} + \ldots = \sum_{i=0}^{\infty} A_i e_{t-i} = A(L) e_t , \qquad (8)$$

where

$$e_t = \begin{bmatrix} e_{oil} \\ e_s \\ e_d \end{bmatrix} \quad and \quad \Delta x_t = \begin{bmatrix} \Delta oil \\ \Delta y \\ \Delta rer \end{bmatrix}, \qquad (9)$$

and the variance of the structural shocks is normalized so that $E(\varepsilon_t \varepsilon_t) = I$.

In order to identify this structural model, the autoregressive reduced-form VAR of the model, given by:

$$\Delta x_r = B_1 \Delta x_{t-1} + \ldots + B_q \Delta x_{t-q} + e_t , \qquad (10)$$

must first be estimated, where e_t is the vector of estimated residuals, q is the number of lags, and $E(e_t e_t) = \Sigma$. Given that the stochastic process is stationary, (9) can be rewritten as an infinite moving-average process as follows:

$$\Delta x_t = e_t + C_1 e_{t-1} + \ldots = \sum_{i=0}^{\infty} C_i e_{t-i} = C(L) e_t . \qquad (11)$$

This moving-average representation is unique and can be obtained by first estimating and then inverting the VAR representation in (9). The residuals of the model's reduced form are thus related to the structural residuals as follows:

$$e_t = A_0' \, e_t , \qquad (12)$$

which implies that

[43] This section draws from DeSerres, Guay, and St-Amant (1995).

$$E(e_t e_t) = A_0 E(e_t e_t) A_0' \ , \qquad (13)$$

and thus,

$$A_0 A_0' = \Sigma \, . \qquad (14)$$

In order to identify the structural shocks, ε, from the reduced-form shock, *e* (found by estimating the VAR in equation (9)), we need to make some identifying restrictions to evaluate the elements in A_0. Given that we have a 3-variable system, A_0 has nine elements. Since the estimated variance-covariance matrix Σ is symmetric, equation (13) provides six independent identifying restrictions. Thus, we need to impose three additional restrictions from (7), (11), and (13). We note that the matrix of long-run effects of the reduced-form shocks, C(1), is related to the equivalent matrix of structural shocks, A(1), in the following manner:

$$A(1) = C(1) A_0 , \qquad (15)$$

where the matrix C(1) is calculated from the estimated VAR. Therefore, we impose three identifying restrictions on A(1), based on economic theory. The first follows from the assumption that demand shocks have no permanent effects on output. Following Blanchard and Quah (1989), among others, this implies that all demand shocks that have a transitory effect on output are interpreted as demand shocks. The second and third restrictions, which allow us to distinguish between oil shocks and other supply shocks, are based on the assumption that only oil shocks (and not demand or other supply shocks) have long-run effects on the price of oil.

Thus we obtain the following structural decomposition for output:

$$\Delta y_t = m + A_{oil}(L) e_{oilt} + A_s(L) e_{st} + A_d(L) e_{dt} , \qquad (16)$$

where movements in output can be decomposed into the moving-average components of the different types of shocks plus the deterministic trend in output (μ). The first three terms on the right-hand side of equation (15) represent our measure of potential output, in first-difference form.

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