Explaining Inflation with a Classical Dichotomy Model and Switching Monetary Regimes: Mexico 1932-2013

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Abstract

A novel approach is applied to study the impact of inflationary shocks on the price level when there are regime changes. We modify the Lucas (1982) model to account for successive shifts in the monetary policy framework at known dates (from money to the exchange rate to inflation targeting). We obtain a CVAR with constant long-run parameters but with a regime-dependent matrix of adjustment coefficients. This overcomes the so-far elusive challenge of explaining inflation in Mexico from 1932, when the country abandoned the gold standard, to present. The model clarifies misunderstandings on the inflationary process in Mexico that have survived for decades. Differently from other inflation models estimated for long samples (f.i., Hendry, 2001 for the UK), it admits very few right-hand side variables, which vary with the regime, and it does not require dummies for outliers despite many tumultuous events and policy changes. It is also different in that it is based on the assumption of classical dichotomy even for the short run, the central assumption of pure RBC models. It is also a straightforward example of when nonstructural parameters shift in response to a change in policy. This provides a new explanation for why the Lucas critique has found no empirical support, with the same econometric techniques that have been used to reject it. The chosen intermediate objective determines a unique systematic cause of inflation and the impact of nonsystematic factors depends on the regime. They can have permanent effects on the price level only under inflation targeting.

Keywords: Money, Inflation, PPP, Fiscal Deficit, Cointegration, Unbalanced Regressions.

JEL classifications: C32, E41, E42, E52

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1 Introduction

Many macroeconomics textbooks tend to present the topic of inflation as if it were a well-understood phenomenon, with precisely known causes and effects. A quick glance to recent economic events and literature shows this is hardly the case. For example, the unprecedented monetary policy stimulus that followed the outbreak of the world financial crisis showed that there was not a general consensus on how specific monetary policy measures would be reflected on inflation. Indeed, three different predictions about the likely effect on inflation were hotly debated by well-known macroeconomists in the public arena:[1] 1) It would cause a surge of inflation (Meltzer, Taylor and others); 2) It would not provoke any inflation (Krugman) and; 3) It would cause deflation (Kocherlakota and Williamson). The lack of surging inflation was considered by Krugman as a vindication of Keynesian macroeconomics, which predicted that in an economy in a liquidity trap, money expansion is not inflationary. However, the episode could also be interpreted from the perspective of the classical monetary model, the one we use here to study the case of Mexico.

The current dominant paradigm to study inflation these days, the Phillips curve, has been under scrutiny because it has failed to deliver good forecasts. For example, echoing the famous case of the failure of theoretical models in forecasting the exchange rate, Atkenson and Ohanian (2001) showed that forecasts for the US inflation rate from a simple random walk were as good as those given by several popular Phillips curve models. Stock and Watson (2008) found the empirical results for the Phillips curve as "gloomy" and that they are no better than univariate models. Ball and Mazumder (2010) conclude that the Great Recession provided fresh evidence against the New Keynesian Phillips curve with rational expectations.

On the positive side, Gordon (2013) claims that the failure of the Phillips curve after the crisis (the episode known as "the case of the missing deflation") has been misunderstood and reported success in forecasting inflation with his "triangle" version of the Phillips curve. Even if this claim stands the test of time, given the history of changes that such model has received since it was developed in the seventies (in 2013 the teak was the distinction of short-run and long-run unemployment), it is hard to think of it as a general framework for other countries.

This paper departs from the dominant trend and reviews the relationship between inflation and its determinants from the angle of the classical monetary model, i.e., the macroeconomic framework embedded with classical dichotomy. This property is regarded as approximately valid in the long run by New Keynesian

[1]This took mostly in blogs and newspapers articles although there were some academic papers (for example, Williamson

theorists but in pure RBC models it is assumed to hold even even for shorter frequencies. In fact, this aspect is what distinguishes both approaches).[2]

The classical dichotomy is the analytical separation of the real sector, determined in Walrasian markets, from the nominal one, determined in the money market. It is related with the properties of neutrality and superneutrality of money but that relationship is less interesting now, when money is not the policy instrument for most central banks. More precise would be to say that classical dichotomy implies that monetary policy has no effects on output or employment.

Most RBC models do not include a nominal sector and when they do, little more than the contemporary correlation between money and prices is produced. This is clearly unattractive as the basis for the study of inflation and it is probably one of the reasons for why New Keynesian models have come to be more popular in both central banks and macroeconomics textbooks as the framework of choice to study inflation.

One macroeconomics textbook with the pure RBC approach is Barro (2008), which does not even mention the Phillips curve. However, its model for inflation is an inverted money demand. This also done in other textbooks (f.i., Romer, 2011). Such inversion, besides having no use in modern times, it might even be conceptually incorrect, if one considers the stochastic aspect of money demand, as pointed out by Hendry and Ericsson (1991).

This paper offers, among other novel features, an inflation model under the assumption of long and short run classical dichotomy. In this respect, it is a complement for RBC models for Mexico (For example, Aguiar and Gopinath, 2007 and Betts and Kehoe, 2003). It is interesting to observe that there is a long tradition that considers that such model was inadequate for developing countries (See Vegh 2013, ch. 5).

We apply the model to the Mexican economy starting in 1932, when the country left the gold standard, up to the last available observation (2013). Considering the long sample, the model is stunningly parsimonious with high goodness of fit and the absence of dummy variables to account for outliers or other problems. All of this suggests that the relationships we uncover here were no affected by any of many policy and macroeconomic events (for example, World War II, financial crises and the opening up of the economy, among others): only the changes in the conduction of monetary policy mattered.

[2]As Mankiw (1989) put it: "The macroeconomist must either destroy this classical dichotomy or learn to live with it". We do the latter.

The model is obtained from a variation of the one in Lucas (1982). We strip it from its bi-country aspect, as Mexico is a much smaller economy than the US. The most important modification is the possibility of changing the monetary policy regime. In Lucas (1982), money is the only source of inflation but in Mexico that was the case only from 1932 to 1982. From 1983 to 2000 this role was played by the exchange rate and from 2001 onwards an inflation target regime was adopted.

We use the model to propose a novel way to identify the impact of shocks in a VAR. We impose zero restrictions directly in the matrix of adjustment coefficients of a cointegrated VAR (CVAR) that changes with the policy regime. We prove that the regime changes did occur at two given (not estimated) dates using unbalanced regressions, another novelty of the paper. We then show that the model fits the data very tightly and has good statistical properties. We then use the results to study how nonsystematic factors of inflation are incorporated into the price level. This depends on if the central bank targets a price level (implicit in the regimes when there was an intermediate target) or the inflation rate.

Our empirical model turns out to be a good example of the application of the Lucas critique, as the reduced form parameters explicitly change with the monetary policy regime. Ericsson and Irons (1995) surveyed the literature and concluded that "Virtually no evidence exists that empirically substantiates the Lucas critique." Furthermore, superexogeneity test have been used to refute it empirically. It has been argued that those statistical tests lack power in small samples to distinguish reduced-form parameter instability even when other relevant shocks are controlled for in a dynamic general equilibrium model. Our model shows the relevance of the Lucas critique with the same econometric techniques that have been used to reject it empirically.

The rest of the paper is organized as follows. Section 2 presents a short literature review on topics related to our paper. Section 3 presents the data and analyzes the unit root properties of the series and some combinations of them. in section 4 we present the basic theoretical model. Section 5 describes the three monetary regimes observed during the sample. Section 6 discusses the econometric implications and problems that arise in this model. Section 7 presents the first empirical results. Section 8 contains the final inflation model. The last section offers the conclusions and final remarks.

2 Historical References and Literature Review

This article is related to several branches of economic literature and therefore we only mention a few references of each topic. In the first place, it is the only known model for inflation in Mexico that covers the eight decades that have passed since that country replaced the gold standard for fiat money. As other models for inflation in Mexico cover short samples, we make our comparisons with the models of Hendry (2001) and Juselius (1998), which have been widely used as blueprints of some studies of inflation. The paper is also related to the problems that arise in the estimation of cointegration models in the context of regime changes.

2.1 Models for Inflation in Mexico and with Long Samples

After the use of fiat money became generalized with the demonetization of gold in 1931, the Mexican economy faced several bursts of inflation. It was common that during several episodes, the central bank became involved in the financing of public deficits. After several episodes where inflation reached the two digits and the nominal exchange rate had to be devaluated as a consequence, the country adopted a more conservative fiscal approach, keeping the public deficit under check. This allowed the central bank to concentrate in maintaining a fixed exchange rate parity that entailed the use of a strict monetary policy rule.

Inflation in Mexico was seen as a problem only after public spending was greatly expanded in the early seventies. Much of that increase of spending was funded by foreign loans and direct financing from the central bank. This situation aggravated the current account problems that had began to develop and led to the depletion of foreign reserves and a speculative attack on the peso in 1976 that ended a two-decades-old period of fixed parity.

Because of this, the first wave of research on inflation began in the seventies, after it became clear that the two-digits levels were to stay. Those first studies were not considered very successful.[3] The failure of those first tries spurred the arrival of a second group of models to a more sophisticated venue where the ongoing ideological controversies on the topic were reflected. The main antagonistic views were the monetarist and the so-called Keynesian-structuralist, a traditional school of economic thought in Latin America.

The models affiliated to the monetarist view strived to show in their regressions that money, typically a very

[3] "...the most important conclusion [of that event] is that the causes of inflation are not very clear." Ize and Vera (1983).

narrow aggregate, had explanatory power. One of the first models of inflation for Mexico was estimated by Gómez Oliver (1978).

The structuralist school rejected the idea that money was the cause of inflation in Mexico because "it was absurd to describe the Mexican economy as a perfect competition system". Instead, that second school emphasized the social struggle for the distribution of income and the disequilibrium among productive sectors where the prices are determined by costs and market power.

For both schools the effects of the exchange devaluations on inflation were important (Ize and Vera, 2004). The model we present here shows the two schools were both wrong on this as the exchange rate depreciations of the period they examined (corresponding to what we call "Regime 1" were an effect and not a cause of inflation.

A third wave of models was triggered by the return to two-digits inflation after the 1995 economic crisis. This time, the main characteristic of these inflation models was the dominance of the exchange rate (Perez-Lopez, 1996 and Garces-Diaz). There were attempts to apply the Phillips curve, hybrid models and even a comeback of the old structuralist idea of introducing indicators of market power.

Although they were applied to other countries, it might be useful to compare our results with those of Hendry (2001), who also uses a long sample but for the United Kingdom, and that of Juselius (2006), with a much shorter sample for Denmark. Despite that the countries are different, the comparison is interesting because they apply cointegration analysis, as we do, but use a diametrically opposite theoretical foundation. Those models are built under the assumption that inflation is caused by many factors and not that inflation is always a monetary phenomenon.

In contrast, our model is strictly based on the classical monetary approach and follows Friedman's proposition that although inflation might be affected by many factors, only those that cause a systematic accommodation have lasting effects on the price level.[4]

[4]That is our interpretation for current times of the statement: "Many phenomena can produce temporary fluctuations in the rate of inflation, but they can have lasting effects only insofar as they affect the rate of monetary growth." Friedman, the Quantitative Theory of Money, p. 30 (Palgrave Dictionary). We must keep in mind that Friedman mostly lived in a period when a monetary aggregate was typically the monetary policy instrument.

2.2 Models With Changing Monetary Policy Regime

This is one of probably few papers for developing economies that deals explicitly with monetary regime changes. Although there is a substantial literature on regime changes in monetary policy, most of it studies the case of the United States, particularly to elucidate the causes of the "Great Moderation". For example, Sims and Zha (2006) used a Bayesian VAR with Markov switching regimes to find three changes in the monetary policy function at dates that more or less coincide with what "most observers believe monetary policy actually differed." However, they conclude the estimated changes are unlikely to explain the changes in US inflation in the 70s and 80s.

A common feature of the literature on changes in the monetary policy regime is the use of a New Keynesian framework. In such an approach, the issue revolves around looking for evidence that there was a change in the value of the parameters of interest, particularly those of the policy rule (for example, more weight to inflation in one regime than in another). The case we present is different in that the theoretical base is the classical monetary model and in that what changes is the whole policy rule, including the policy instrument. This makes the estimation problem very novel, easier in some aspects but more complicated in others.

The simplification comes from the fact that the changes in the values of some parameters are clearly established by the model. The complication arises from the mutations in the properties of endogeneity and exogeneity of the variables involved. For example, in the regime with a policy rule for money, money is exogenous but both inflation and the exchange rate are endogenous.

2.3 Cointegration Models With Regime Switching

The literature on CVARs with explicit regime changes is scant. Kurita and Nielsen (2009) show that if the parameter changes are restricted to those of the lagged terms in differences the reduced-rank procedure to estimate the cointegration relationships remains accurate. However, when the changes occur in the adjustment parameters such method might not be valid because "[those changes] are reflected in the impact parameter of the common stochastic trends, thereby affecting the asymptotic distributions of cointegration rank tests." Fortunately, we do not have estimate any long-run parameters as we assume them as known because they belong to well-known relationships (QEM and PPP). However, we do test their validity as cointegration relationships.

Massimiliano et al. (2002) suggest a two step procedure to estimate CVARs with parameters subject to Markov switching. In the first step, they estimate the long-run parameters. In the second step, they estimate the rest of the parameters through maximum likelihood. However, the complexity involved in the second step imposes limitations on which and how many of those parameters can be allowed to switch.

Although the system we analyze can be restated as a Markov-switching regime model, its dimensionality and complexity is hard to handle so we identify the dates of change through historical events.

More related to our work, Barassi et al. (2005), try several procedures to look for a change in the feedback adjustment parameters but at times the results are inconclusive even though they restrict their analysis to a bivariate system. As we have a more complex model, we impose restrictions on the adjustment parameters based on a general equilibrium model instead of trying to estimate them freely.

3 Data and Descriptive Statistics

The data are taken from the online sites of Bank of Mexico, Inegi and BLS (US CPI). The variables are in logs. The domestic price level is represented by the time series of the Mexico City Whole Prices Index from 1932 to 2000, when its publication stopped. The rest of the series was completed with the Mexican CPI. When both series were available (1971 onwards), the trends were similar. The foreign price level (p^{us}) is the US CPI. The nominal exchange rate pesos per dollar (e). The monetary aggregate (m) is high-powered money o currency, i.e, the total nominal value of bills and coins in the hands of the public. The measure of economic activity is Mexican GDP.

Table 1 shows the augmented ADF tests for the differences of the individual variables described above and some combinations of them labelled as “equilibrium relationships.” We do not include the tests for the levels of individual variables as they are clearly not stationary because they all have growing trends. There is also a summary of group unit root tests under the assumptions of both a common and individual trends. This is because, as one would expect, the monetary variables of a country are expected to have common trends.

One of the combination of variables is the real exchange rate ($rer = e + p^{us} - p$), another is the inverse of the velocity of money ($-v = m - y - p$) and the difference between inflationary money ($m - y$)and foreign prices in local currency ($e + p^{us}$). They will be explained later but it should be noticed that, as they also seem to be stationary, the variables that form them are cointegrated. So, the real exchange rate rer, the velocity of money v and the difference between inflationary money and foreign prices in local currency $(m-y-e-p^{us})$ are to be interpreted as long-run equilibrium conditions.

For the relationships that include money (velocity and inflationary money deflated by foreign prices), there is a problem at the end of the sample as since 2001 there has been a strong and persistent process of remonetization probably due to informal and perhaps activities out of the financial system. This has caused a steady fall in money velocity. As long as such process does not reach and end, the stationarity of relationships that include money will be hard to prove with individual tests. Because of this, we tested the stationarity of such relationships from 1932 to 2000 with individual tests and they barely reject a unit root process at 10%.

However, in the most powerful groups tests, the evidence of stationarity despite the remonetization process is strong. Furthermore, Figure 1 shows the long-run relationship between $m-y$ and $e+p^{us}$. The strong resemblance of both time paths leaves little if any doubt on the strength of this relationship, which has a central part in our analysis.We also test such relations with cointegration techniques and their validity is clearer.

4 The Classical Monetary Model in the Short Run

The main characteristic of the classical monetary model is the analytical separation of the real and nominal sectors of the economy. A widely maintained view on that model is that, even though it is a necessary benchmark, it is a poor description of an economy except, perhaps, for the long run or a hyperinflation process.[5] Although some DSGE models contain a long-run (flex-price) solution, the way how the sequence of short-runs is connected to the long-run, specially its relation with money, is typically ignored in econometric models for inflation.

However, the classical monetary model is taken at face value by pure models of real business cycles, where "money is a veil"[6]. In such models there is no room for effects of monetary shocks on the real sector. Also, in that approach real sector variables typically do not have effects on inflation. That view is adopted by Barro (2008), one of the very few Macroeconomics textbooks where the Phillips curve is no even mentioned.

[5]See for example Romer (2011) and Vegh (2013).

[6]For Mexico, an example of this is Betts and Kehoe (2001).

Most other textbooks concentrate on theories of inflation in the short run as a process caused by nonmonetary factors, specially some indicators of economic activity (f.i., the output gap or the unemployment rate). One reason for that dominance is that, despite the tight long-run correlation between money growth and inflation quoted by supporters of the classical model, there is no explanation for the usual lack of predictive power of money growth for inflation in the US and other economies. Another reason is the vanishing short-run correlation of money growth and inflation in many countries. This paper tackles these issues in the case of a particular country.

We will show that at least for Mexico, and perhaps for other Latin American countries, the automatic disqualification of the classical monetary model might not be a good idea. Although we use a long sample and Mexico has had periods of high inflation (never hyperinflation), it is not because the classical monetary model needs it to work well. Such sample is needed to explain a feature that has been ignored so far and that has led to its ungranted rejection for the short run.

4.1 The Classical Monetary Model

We base our analysis on the following modified version of the Lucas (1982) model. Every period, a representative-agent consumes a bundle of two freely transportable and perishable goods, one local, C_t and one imported C_t^*. The purchases of goods require the use of local currency in the exact amounts M_t^C and M_t^{C*}. Y_t, is provided by fruit trees at a random rate and can be either sold for consumption or exported at the local price P_t. The imported good, has a price abroad of P_t^*. To buy it, E_t units of local currency have to be traded for each unit of foreign currency at the foreign exchange market so the local price of of the imported good is $P_t^* E_t$.

There is a public sector that demands G_t units of domestic output to pay for the expenses of the central bank, or some other public expense, but it can have other needs. Total product Y_t is therefore equal to $C_t + X_t + G_t$. Government consumption is paid with money issued by the central bank in an amount ΔM_t, an inflation tax that is spent in the same period when it is collected. There are three ways in which the central bank sets its monetary policy. They determine a particular policy regime and have a key role in our analysis.

It is worthwhile to stop here and to mention that the introduction of a tax here does not destroys the classical dichotomy property because output is assumed as exogenous. As Lucas (1982) states, the introduction of production in a barter economy entails the same results as long as the one consumer device is kept. However, in a monetary economy the cash-in-advance constraint introduces a wedge between private and social welfare. In that case, if there are choices for leisure or investment, then money is not strictly neutral because it will have real effects. However, such real effects of monetary shocks are known to be tiny and that is why something like a combination of nominal and real rigidities must be introduce to meaningfully break the classical dichotomy. Because of this, our results would maintained in many models with production as long as they do not include nominal rigidities or any other device to destroy classical dichotomy.

Dividends, paid in cash by the firm that sells the fruits, are transferred to the consumer at the end of each period so they can be spent only in the next period. Therefore, the consumer's wealth at period t is composed solely by the dividends from the previous period M_{t-1}. Thus, her budget constraint is:

$$M_{t-1} = P_t C_t + E_t P_t^* C_t^* \tag{1}$$

Money plays a role in this economy through an aggregate cash in advance constraint:

$$M_{t-1} + \Delta M_t = P_t C_t + E_t P_t^* C_t^* + G_t \tag{2}$$

If G_t is transferred to the consumer then this is equivalent to having no government and the consumer receiving the monetary transfers ΔM_t. The introduction of a government here is only to provide some story for sharp rises of the inflation tax but, as we will see, the equations that explain the dynamics of inflation do not change with the level of this.

In the Lucas (1982) model of two currencies solved for a constant relative risk aversion (CRRA) utility function, the real exchange rate depends on the ratio of domestic and foreign output (Mark 2001). However, that equilibrium solution assumes similar sizes of both countries. As the domestic economy we consider is small relative to the foreign one, we simply assume that relative PPP holds, i.e., the real exchange rate (RER_t) is mean-reverting:

$$\frac{E_t P_t^*}{P_t} = RER_t \sim I(0) \tag{3}$$

where $RER \sim I(0)$ means that the real exchange rate peso/dollar is a stationary or mean reverting process. This property is not only typical but, more importantly, it also holds strongly for the bilateral real exchange rate Mexican peso-U.S. dollar, as we showed before.

In the Lucas model,there are no trade deficits because consumption of the foreign good is financed through the foreign assets owned by domestic residents. As a simpler alternative to produce balanced trade, we assume directly that the value of exports exactly matches the value of imports (C_t^*):

$$P_t X_t = E_t P_t^* C_t^* \tag{4}$$

This is just a radical way to impose the usual constraint that the trade balance as a percentage of GDP is stationary. More typical is to assume a country risk that increases with foreign debt but we do not see how such assumption would have implications for the dynamics of inflation in this model.

The consumer faces the dynamic problem of choosing the amounts of domestic and foreign goods that maximize her lifetime CRRA utility:

$$E_t \left[\sum_{j=0}^{\infty} \varphi^j \frac{\left(C_t^{\eta} C_t^{*(1-\eta)} \right)^{1-\gamma}}{1-\gamma} \right] \tag{5}$$

subject to her budget constraint (1), the cash in advance constraint (1) and the balanced trade condition (4). The parameter η is the share of consumption spending for the domestic good, φ is the discount factor and γ is a positive number that when it is equal to one turns the utility function into the logarithmic form.

The solution of this problem is very simple and entails that the consumer spends all of her monetary holdings M_{t-1} buying the local and foreign goods after carrying out foreign exchange transactions. Thus, the demand functions for the goods are:

$$C_t = \eta(Y_t - G_t) \tag{6}$$

$$C_t^* = \frac{(1-\eta) P_t (Y_t - G_t)}{E_t P_t^*} \tag{7}$$

Thus, the money consumer's holdings $Mt-1$ plus the new money created to pay for government spending ΔM_t must be equal to the nominal value of national output:

$$M_{t-1} + \Delta M_t = M_t = P_t Y_t \tag{8}$$

which is precisely the quantitative equation of money with unit velocity, as in Lucas (1982) model. This is, of course, unrealistic but it can be considered to hold in the long run if the velocity of money is a stationary process. On this, Juselius (2006) states that "The stationarity of money velocity, implying common stochastic movements in money, prices, and income, is then consistent with the conventional monetarist assumption as stated by Friedman (1970) that inflation always and everywhere is a monetary problem." (p. 29) She then adds that "This case, $(m_t - p_t - y_t^r) \sim I(0)$, has generally found little empirical support". We are aware of that finding for a number o countries, but we find that velocity of money is indeed a stationary process in Mexico although the long run causality has shifted through time.

In Lucas (1982), the two national currencies model is closed by defining a stochastic process for each currency and good endowments. Here, the model is closed with three different assumptions on how way the dynamics in the nominal variables is determined by the central bank. The first assumption is similar to that of Lucas' original work in that monetary policy is carried out by currency injections. The second one considers that the central bank sets a target for the exchange rate. The third one assumes that monetary policy is conducted through a nominal interest rate. Each of these situations entails different dynamic correlations for the inflation rate and the other nominal variables.

In the model we are considering, the only reason to inflate is to apply an inflation tax and any concerns about real economic activity are ignored. Lucas (1982) states that a richer specification would include "arbitrary correlations" with the endowment process to avoid the neutrality of money, a property he rejects. However, his most basic model is followed here and possible improvements could be added if serious shortcomings are found.

5 Monetary Policy Regimes

Before developing each case separately and show its implications for the data, a brief summary might be useful. First, when currency is the policy tool the price level is determined by the quantitative equation of money and the exchange rate only moves to reestablish the PPP condition. Second, when the central determines the path of the nominal exchange rate the value of the price level is determined by the PPP condition. In such case, currency adjusts passively to reestablish the quantitative equation of money. Third, when the central bank manages to set directly a path for the inflation rate by using an interest rate rule, then neither money nor the exchange rate have a systematic effect on inflation, which is only driven systematically by the inflation target.

5.1 Money as the Intermediate Policy Target

In Lucas (1982), currency is the driving force for the nominal sector. Here, to better represent the path of money as determined by a central bank, increases in the money supply depend on a moving inflation target. This is different from the more modern idea of a fixed price level target. Although we are not particularly interested in estimating the exact form of the monetary rule because there is no trade off for the central bank as in a Taylor rule, it might be useful to show an approximation. The monetary rule in this episode could be represented by the following equation:

$$m_t^s = y_t + p_t^o \tag{9}$$

Thus, the supply of currency, m_t^s, depends on GDP, y_t, plus the yearly objective for the price level p_t^o. The sequence of targets for the annual price level target depend on particular circumstances.

The central bank since 1932 tended to prefer a fixed exchange rate. However, there were several adjustments to the parity after money growth was used to finance the public deficit. For this reason, the monetary regime was in fact determined by the path of currency despite the preference for keeping the exchange rate fixed for as long as possible.

There is a simple case where the path of price level target was easy to determine. This happened when there were no devaluations for a long period and the fiscal deficit was kept under control. In these conditions, the policy rule consisted in the creation of enough money to maintain the proportionality with output and the foreign price level (in logs):

$$m_t^s = y_t + p_t^* \tag{10}$$

We do not have data about the public deficit for the whole sample but only for the period 1966 to 2011 so we cannot see how accurately this rule describes the behavior of the central bank. However, when the public deficit was under control money growth was determined only by output growth plus foreign inflation. From 1956 to 1971 the path of money very closely matches the trajectory of output growth plus foreign inflation.

In 1972, fiscal discipline was forsaken and the budget deficit began to grow, financed in part by injections of currency, as Figure 1 shows. Although the period from 1983 to 1993 does not fall in the first regime, the relationship between money growth and the public deficit was still visible. The relationship breaks down in 1994, coinciding with the beginning of legal autonomy for the central bank.

5.2 The Exchange Rate as the Policy Instrument

The outbreak of the debt crisis in 1982 forced the Mexican government to obtain an emergency loan from the International Monetary Fund. This imposed the country a set of conditions established in an agreement signed in October 1982. Among the most important aspects, there was a commitment by the Mexican government to limit the accumulation of domestic credit at the central bank. Another important condition was the correction of the external deficit through competitive devaluations. These two aspects provoked a change in the monetary policy regime, forcing the central bank to abandon currency as its policy instrument and adopting as such the exchange rate. This change was perceived by several papers, among them Pérez-López (1996) and Garcés-Díaz (1999).

The exchange rate became the leading nominal variable and the inflation rate started being determined through the PPP condition and not by the money supply. Although money was not longer the policy instrument, the quantitative equation was still valid despite the fact that money was not longer useful as a predictor for inflation or the rate of depreciation. Observe that this regime implies a price level target, this

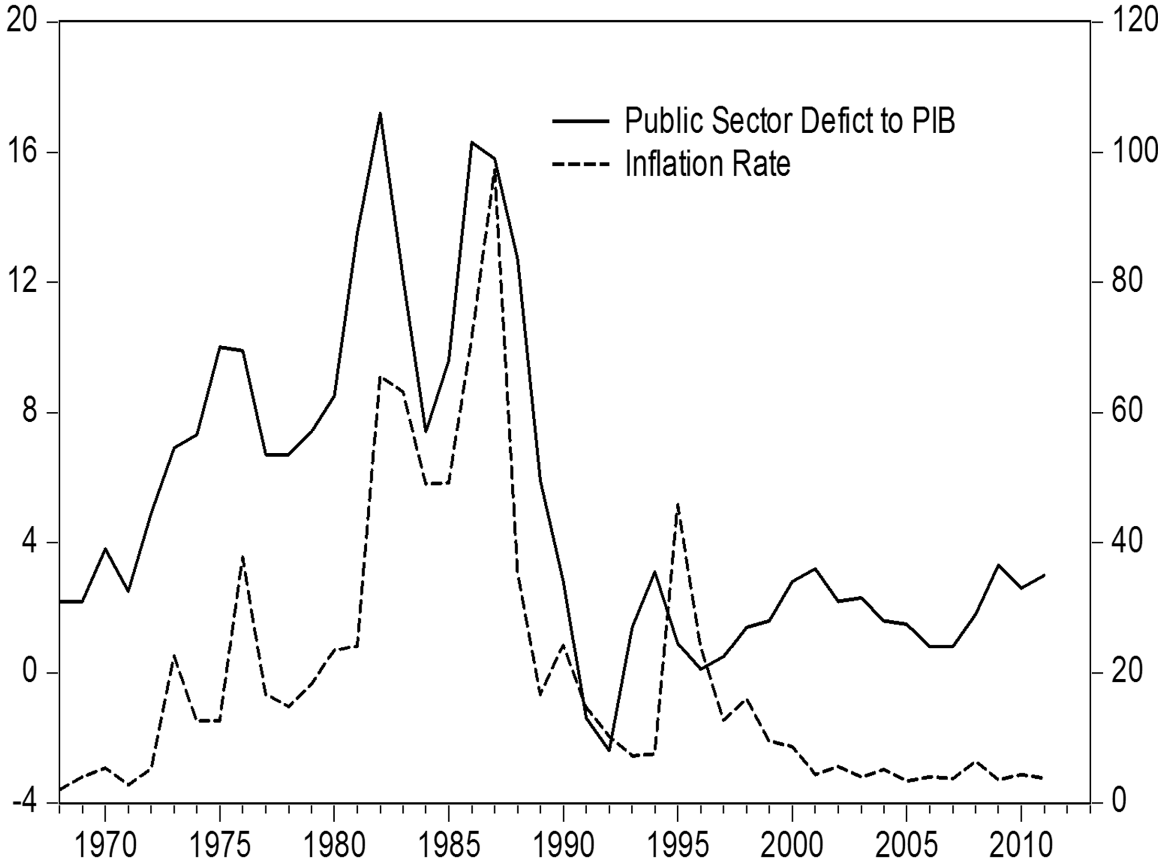

Figure 1: Inflation and Public Deficit (FRPS).

is defined by the logarithm of the exchange rate target plus the log of the foreign price level (i.e., the PPP condition).

It is in this period when the impact of the exchange rate on inflation became a persistent phenomenon in Mexico. The pass-through of exchange rate on prices actually survived even during the initial years of the flexible exchange rate regime. This might look strange at first because the exchange rate was not longer predetermined by the central bank.

The reason for the persistence of the pass-through was that the central bank was forced to adopt a flexible exchange rate by the 1994 crisis which depleted its reserves of foreign reserves. The public did not deemed the new regime as permanent in part because the central bank was accumulating reserves and this was interpreted as an initial step to go back to a predetermined exchange rate regime. Because of this, inflation still followed the movements of the exchange rate.

5.3 Inflation Targeting

The Mexican central bank became satisfied with the behavior of the floating exchange rate because it was not specially volatile as it was feared at the beginning. This gave room to the adoption of an inflation targeting framework since 2001. The public became used to the idea and the new framework was completed with the adoption of a reference interest rate as the policy instrument in 2004. With this, both currency and the exchange rate ceased to be systematic causes of inflation. In fact, inflation began to follow a stochastic trajectory around 4 percent (that will appear in our empirical estimates) even though the central bank had adopted 3 percent as the center of its ± 1 policy band.

It is important to notice that the impact of the interest rate is different here than it is usually expected in a Keynesian model. There are two reasons for that. First, as there is no Phillips curve in this model, an increase in the interest rate will not cause a decline in inflation via a reduction of the output gap. Second, the interest rate here it is fixed as part of the systematic monetary policy to be reflected in the long-run. On the contrary, in a New Keynesian model, an increase of the interest rate (a monetary shock) lowers temporarily the inflation rate because affects aggregate spending and, therefore, the output gap and then the inflation rate according to a Phillips curve.

In the classical monetary model, the mechanism works solely through inflation expectations. When the central bank sets the policy interest rate, it is also setting its inflation target by means of the Fisher equation. Given the real interest rate, the (gross) inflation target is the ratio of the gross nominal interest rate and the gross real interest rate. So, if the nominal interest rate is set lower by the central bank for a significant amount of time (i.e., not as monetary shock but as part of its systematic policy) it can only be because the inflation target has been lowered. To make this work, the public must expect that the money supply or the exchange will be adjusted by the central bank to justify the policy interest rate.

A more flexible monetary rule within this model would consider the possibility that the central bank would modify in the short run its policy interest rate.In this case, the central would apply something like a Taylor rule even though there would be no effect on the real sector. The most important aspect of this regime is that neither money nor the exchange rate will be systematic causes of inflation, as happened in the two previous regimes. This will cause the inflation rate to be hard to predict and typically it will behave like noise around a constant.

6 Econometric Implications

We explain the behavior of inflation in Mexico through a single-equation model that is taken from a cointegrated VAR (CVAR) on which some restrictions are imposed by the implications of a general equilibrium model. This CVAR explicitly considers the changes of regime that monetary policy causes to the dynamics of nominal variables.

6.1 A Simple "Hypothetical" Example

The classical monetary model with changes in the monetary regime has interesting and little studied econometric properties that are validated in Mexican data and could be present in data of other economies. To begin, it might be useful to see a hypothetical case that later will reappear as a real case. Assume a simple classical monetary economy where the monetary policy from $t = t_0$ through $t = t_1$ is set through a money supply rule. In this situation, the inflation equation is simply:

$$\Delta p_t = \beta_{pm} \Delta m_t + \epsilon_t^{pm} \tag{11}$$

where ϵ_t^{pm} is a white noise shock. In a regression, β_{pm} should be close to 1. Now, suppose there is a monetary policy change and from $t = t_1 + 1$ through $t = t_2$ money is replaced by the exchange rate as the policy instrument. Now, the inflation process is given by the following equation:

$$\Delta p_t = \beta_{pe} \Delta (e_t + p_t^*) + \epsilon_t^{pe} \tag{12}$$

where ϵ_t^{em} is another white noise shock. In a typical regression, β_{pe} should be close to 1 as well. Suppose now that a regression is run under the assumption that both money and the exchange rate affect the inflation rate from $t = t_0$ through $t = t_2$. Then a possible model would be the following:

$$\Delta p_t = \beta'_{pm} \Delta m_t + \beta'_{pe} \Delta(e_t + p_t^*) + \epsilon_t^{pme} \tag{13}$$

It is clear that the estimates for the whole sample would not correspond to the parameters of the model (two pairs are needed instead of just two parameters).

A more relevant question is that if the regression (13) were run for each subsample (assuming each one has enough observations) one would get unbiased estimates for the parameters in each subperiod. The answer is that the parameters would still be biased because of a problem of endogeneity.

In the first subsample, by assumption money is exogenous but the exchange rate is endogenous while in the second sample the opposite happens. The transition to the third regime will be examined later. This example might actually reflect a common practice in models of inflation in Mexico.

In a structural VAR, the problem would be reflected in the impulse-response functions. For example, suppose we analyze the data with a VAR and use the Cholesky decomposition as the identification scheme. For the first regime, the equation for money would go first and for the second regime, the equation for the exchange rate would take that place.If the order is changed in either regime or the VAR is run for the whole sample, there would be a violation to the weak exogeneity properties of the system. This issue was pointed out by Hendry and Mizon (2000) for cases where there was not a regime change but it is clear that it would be easier to fall in it if the monetary policy changed. This problems will be shown with Mexican data.

As the data contain unit roots and form cointegrating relationships (the velocity equation and PPP), it is appropriate to use a cointegrated VAR (CVAR). The problems we showed above remain in that case and give room to little explored situations.

The common practice to deal with regime changes in the CVAR framework is to shorten the sample to avoid them:

> "Macroeconomic data are generally influenced by regime shifts which may have caused at least

some of the VAR parameters to change. Since the inference from the VAR model is only valid provided the parameters are constant, it is frequently the case that one has to split the sample period into subsamples representing constant parameter regimes. In such cases, inference on cointegration and integration will be based on relatively short samples leading to the above interpretational problems."[7]

Although such procedure might give good results in some situations if one particular regime is under study, it does not come without shortcomings. For example, it might give a wrong impression on the importance of policy changes on the dynamics of some variables (money, prices and the exchange rate in our case.In fact, this omission of explicitly modeling regime changes in models with cointegration relationships might be the cause of the failure to find evidence of the Lucas Critique, in some cases at least.

6.2 Regime Changes in the Adjustment Parameters in a Cointegrated VAR

Due to that the data has annual periodicity, the lag structure of a VAR turns out to be simpler than that of a model with higher frequency points. As all the variables in the model are observable we can restrict ourselves to a VAR(1) formed with I(1) variables that form a cointegration system with changes in some parameters:

$$\Delta \boldsymbol{Y}_t = \boldsymbol{\alpha}(s_t)\boldsymbol{\beta}'\boldsymbol{Y}_{t-1} + \boldsymbol{\Phi}(s_t)\Delta \boldsymbol{Y}_{t-1} + \boldsymbol{u}_t \tag{14}$$

where $\boldsymbol{Y}_t$ is a vector of $I(1)$ variables from the model, $\boldsymbol{\alpha}(s_t)$ is the matrix of adjustment coefficients and $\boldsymbol{\beta}$ is the matrix of cointegration parameters. Both matrices are of rank r, the number of cointegrating vectors. The vector $\boldsymbol{u}_t$ can be interpreted as a linear function of $I(0)$ variables and white noise.

The VAR we consider has the characteristic that the matrix of the feedback coefficients $\boldsymbol{\alpha}(s_t)$ and, possibly, the coefficients for the autorregressive terms $\boldsymbol{\Phi}(s_t)$ depend on the state of nature generated by the monetary policy regime. This will not be an issue for us as they usually vanish. The matrix for the long-run relationships β is assumed to be constant for two reasons. first, if all the coefficients were allowed to change, there would be

[7] Juselius (2006), p. 26.

an identification problem, as discussed by Barassi et al. (2005). Second, in our simple model the parameters of the velocity equation and PPP are structural so there should not change, as is commonly assumed.

There is a most important aspect related to the changes expected in the $\boldsymbol{\alpha}(s_t)$ matrix. The representation of the model with changes in the policy instrument becomes messy because the price level, the exchange rate and currency are determined differently in each state. However, the theoretical model by setting the direction of causality in each regime in a unique manner, allows us to separate the VAR for the whole system in two parts. One of them corresponds to the quantitative equation of money and the another to PPP. We will use these two subsystems to discuss the expected changes in the feedback coefficients. These changes are tested and shown to exist in the Mexican data. One thing we must remember is that, because in the classical monetary model output growth is not affected by monetary policy, we can consider the policy instrument as exogenous. To simplify the exposition, we say that a coefficient "is negative" when the corresponding variable is not weakly exogenous.[8]

In the first regime, where money was the policy instrument, the corresponding adjustment parameter for the money equation must be zero while that for the price level must be negative. In the same regime, in the VAR corresponding to PPP, as the price level is determined by the money supply, the exchange rate must be a passive variable. Therefore, in the PPP VAR, the adjustment parameter for the price level must be zero and the one for the exchange rate must be negative. Within the VAR of a system that includes both currency and the exchange rate, for example that corresponding to equation

In the second regime, the exchange rate is the policy instrument and, therefore, it becomes exogenous so its adjustment coefficient within the PPP system becomes zero. The price level in that system then becomes endogenous determined by the exchange rate and so its adjustment coefficient becomes negative. Currency, as a consequence of this, becomes an endogenous variable determined by the price level within the quantitative equation of money (and indirectly.

In the third regime the central bank chooses an inflation target and adopts a short term interest rate as its policy instrument. In that case, neither the exchange rate nor currency have a systematic effect on the inflation rate and the most important factor becomes the inflation target itself, as long as the central bank enjoys the public's credibility. In this situation, the adjustment parameters for the price level both in the

[8]The sign of the adjustment parameter depends on how the long-run error is written so we implicitly assume the adjustment parameter multiplies the lagged level of the error-correcting variable.

quantitative equation of money and PPP systems become zero. Within the PPP system, if the exchange rate is floating then it cannot be forecasted so its adjustment parameter must zero as well. As there must be at least one adjustment parameter that is negative for PPP to hold and the foreign price level cannot be the adjusting variable, then the only remaining possibility is the real exchange rate itself. Indeed, the real exchange rate not only preserves its negative adjustment parameter but this appears to be constant for the whole eight decades, as we show below.

7 Empirical Results

We present first the results for the long-run relationships. We discussed above that the widely-used reduced-rank method should not be because the adjustment coefficients are assumed to change. However, other methods such as regular unit-root tests do not depend on the adjustment coefficients so they can be used.

After we have done that, we prove that the monetary policy regime changes we discussed provoked changes in the adjustment parameters. To do this for the whole system is messy so we do it for the inflation equation only, which is the main concern of this paper. To do it, we apply a novel method based on an unbalanced regression that provides a striking proof of regime change implied by the theoretical framework we use.

Finally, we present the estimated equation for the inflation rate from 1932 to 2013. Its main characteristic is its parsimony and the fact that its few explanatory variables changed with a regime shift occurred.

7.1 Long-run Relationships

As mentioned before, the changes in the feedback parameters make inadequate the reduced-rank method to obtain cointegration coefficients. However, we assume those coefficients as known from theory so we only need to show those relationships are indeed long-run relationships.

First, we have to show the validity of the quantitative equation of money and the real exchange rate as a long-run equilibrium relationships:

$$-v = m - y - p \quad (15)$$

$$rer = e + p^* - p \quad (16)$$

Equation (15) is the quantitative equation of money, which takes the price level, p, high-powered money, m, and output y, as determinants of the money velocity v. Money is represented here by currency (bills and coins in the hands of the public) so it can be regarded as a true policy instrument whenever necessary, which is not necessarily the case with broader aggregates, as the situation in the US after the financial crisis showed.[9]

Equation (16) is the standard definition of real exchange rate, rer, where e is the nominal exchange rate pesos per dollar and p^* is the US price level.

The residuals v and rer need to be stationary processes for equations (15) and (16) to be regarded as equilibrium conditions and not as tautologies. Although we will provide more formal proves of this, we can get a first sight of the switching dynamics by looking at the lines of Figure 2. A movement upwards represents an increase in money velocity and a depreciation of the real exchange rate. The vertical lines delimitate the policy regimes.

The chart shows that during the first regime (1932-1982), money velocity leads the real exchange rate by one or two years. In the second regime the situation turns around and the real exchange rate becomes the lead variable. Figure 3 shows the cross-correlations of money velocity and the real exchange rate observations from $t - 3$ to $t + 3$, corroborating the observations from the chart.

First, for the whole sample all crossed correlations of money velocity with the shown lags and leads of the real exchange rate are positive and significant. This happens because in the first regime the causality runs from money to the exchange rate and the opposite happens in the second regime. This result is true in one sense (one preceded the other at some point) but false in another because it is not considering the regime changes we described before and shown in Figure 2. So, knowing that both money and the exchange rate led or lagged one another might not be very useful, specially if, for example nowadays, none leads the other.

Now, if we split the sample according to the identified regimes we have a different result. For the first regime,

[9]The Fed strongly expanded the monetary base without having much of an impact on M2 or inflation.

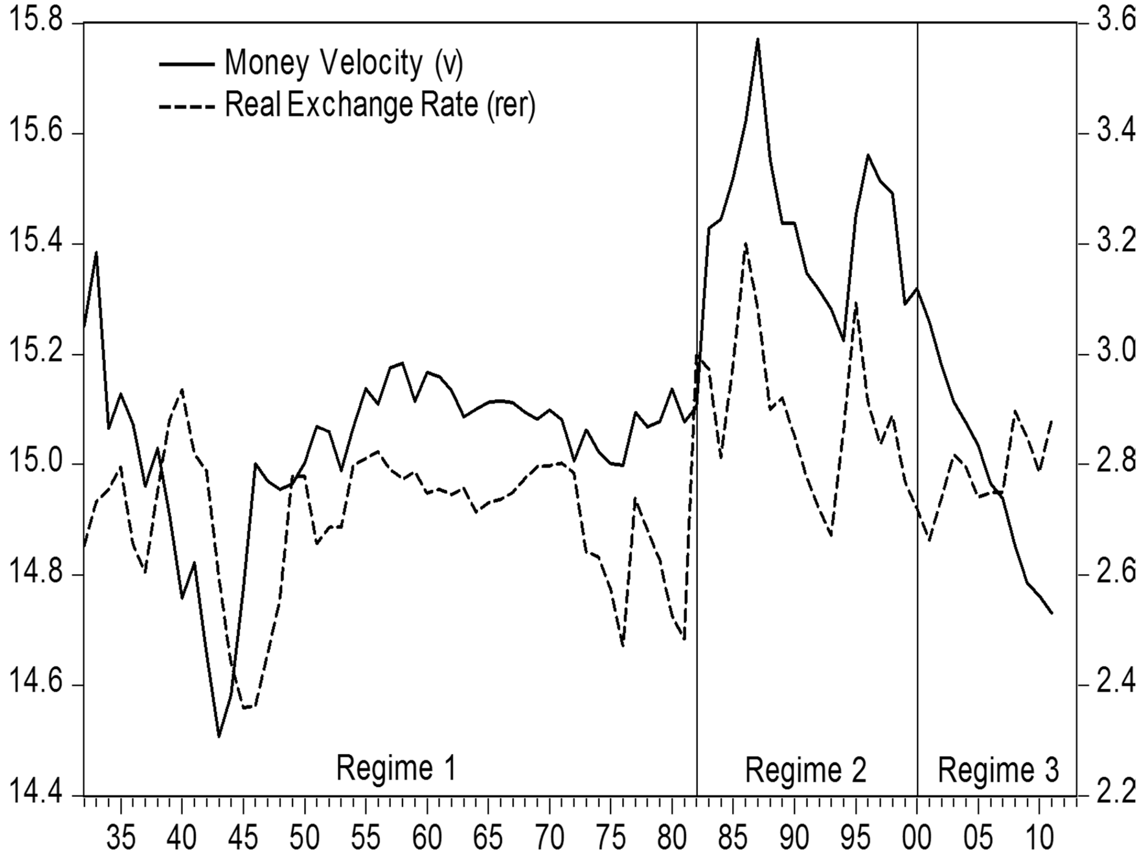

Figure 2: Money Velocity and the Real Exchange Rate Across Regimes.

none of the lags of the real exchange rate is correlated with money velocity. The same happens with the contemporary correlation. However, the value of money velocity is positively correlated with the 3 leads of the real exchange rate, indicating that causality runs from money to the exchange rate.

In the second regime,the first lag and the contemporary value of the of the real exchange rate is positively correlated with money velocity, indicating that the causality runs from the exchange rate to money.

Notice that both variables are only contemporaneously negatively correlated in the third regime (2001-2013), where they both diverge because money velocity is steadily falling and the real exchange rate has a depreciation. The negative correlation might lessen or disappear when more years continue accumulating to

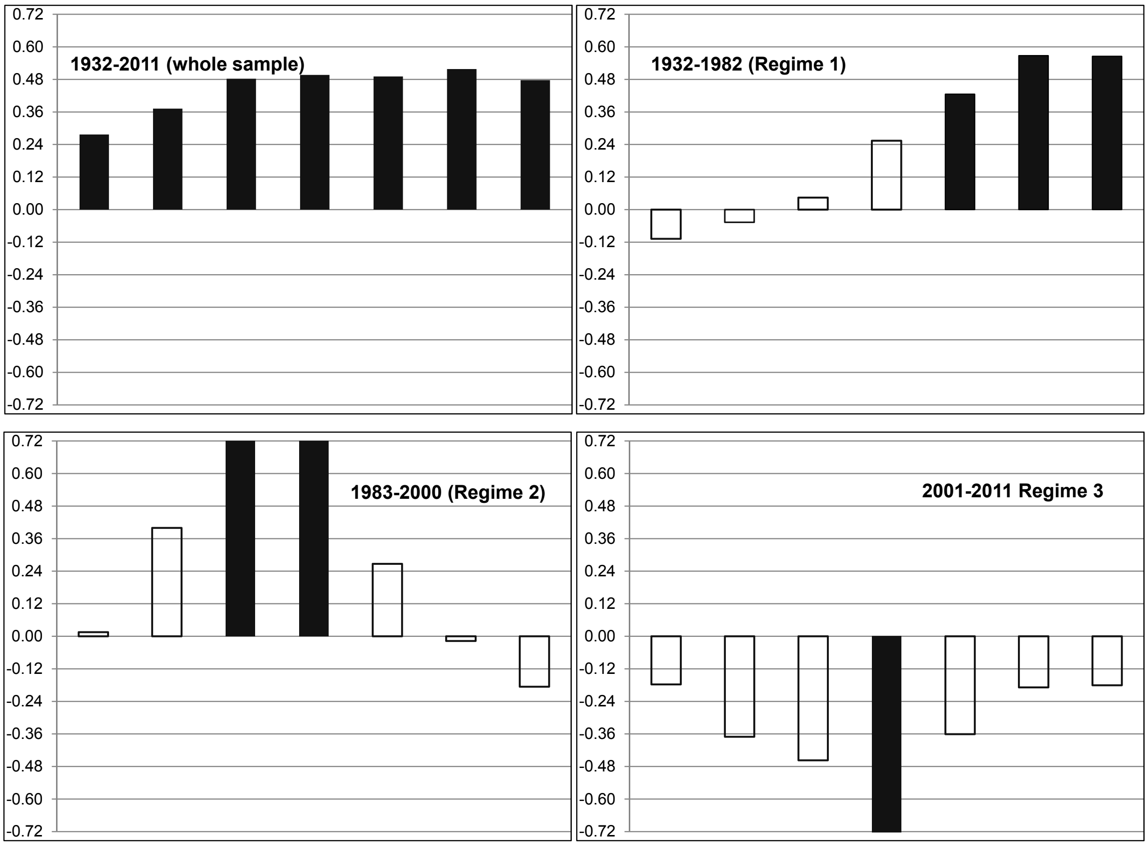

Figure 3: Dynamic Correlations for Money Velocity and the Real Exchange Rate Across Regimes.

the sample of the third regime but it is important to comment on the steady decline of money velocity since 2001.

This phenomenon seems to obey to a combination of three factors. First, during this third regime, the central bank adopted a full-fledged inflation targeting regime, which demoted both currency and the exchange rate as systematic causes of inflation. This by itself should allow greater separations of velocity of money and the real exchange rate. The second cause is related to the increase of the underground economy, which require more cash in their transactions (informal commerce and extralegal activities), which are known to use large amounts of cash.[10] The third one is the commitment of the central bank to keeping a low inflation rate, that

[10]For the United States, Sprenkle (1993) mentions the underground economy as one of three possible holders of about 84

allowed greater use of cash because the fall in the inflation tax, specially for underground activities that use currency intensively. If the money velocity remains falling for several more years, the long-run relationships in which currency is involved will break. It has not happened yet and in the past there have been even larger deviations that were eventually eliminated (see 2 at the beginning of the first regime).

Equations (15) and (16) were proved to hold independently in Table 1, but there is a gain in testing their validity jointly. This result will be very useful to prove that there were regime changes at some given dates. First, lets eliminate the domestic price level from both relationships. Figure 4 shows the time path of inflation money, $m - y$ and foreign prices in local currency $e + p^*$:

The relationship between inflation money and foreign prices in local currency is clear, so from the velocity equation and the real exchange rate by eliminating the price level we can obtain the following expression:

$$e + p^* = m - y + z_{e1} \tag{17}$$

where the residual z_{e1} should be stationary, if this condition is also a long-run equilibrium. In Table 1, the unit root test proves this is the case. This equation is one version of the monetary model of exchange rate determination.

There is another alternative to test such model that can work under the circumstances we have at hand. This consists in running a regression for inflation where those terms appear at the same time but without using the lagged price level. That is the alternative we emphasize because with such procedure, it will be possible to prove for the inflation equation the regime switching we described before.

8 An Inflation Model with Regime Changes

Inflation might have many causes but its path ultimately depend on the central bank actions. When money was the policy instrument of choice of most central banks, the correlation between money growth and inflation

percent of currency that cannot be explained by regular reasons (the other two suspects being foreigners and children under 18 not included in a Fed survey from which the estimates were made.

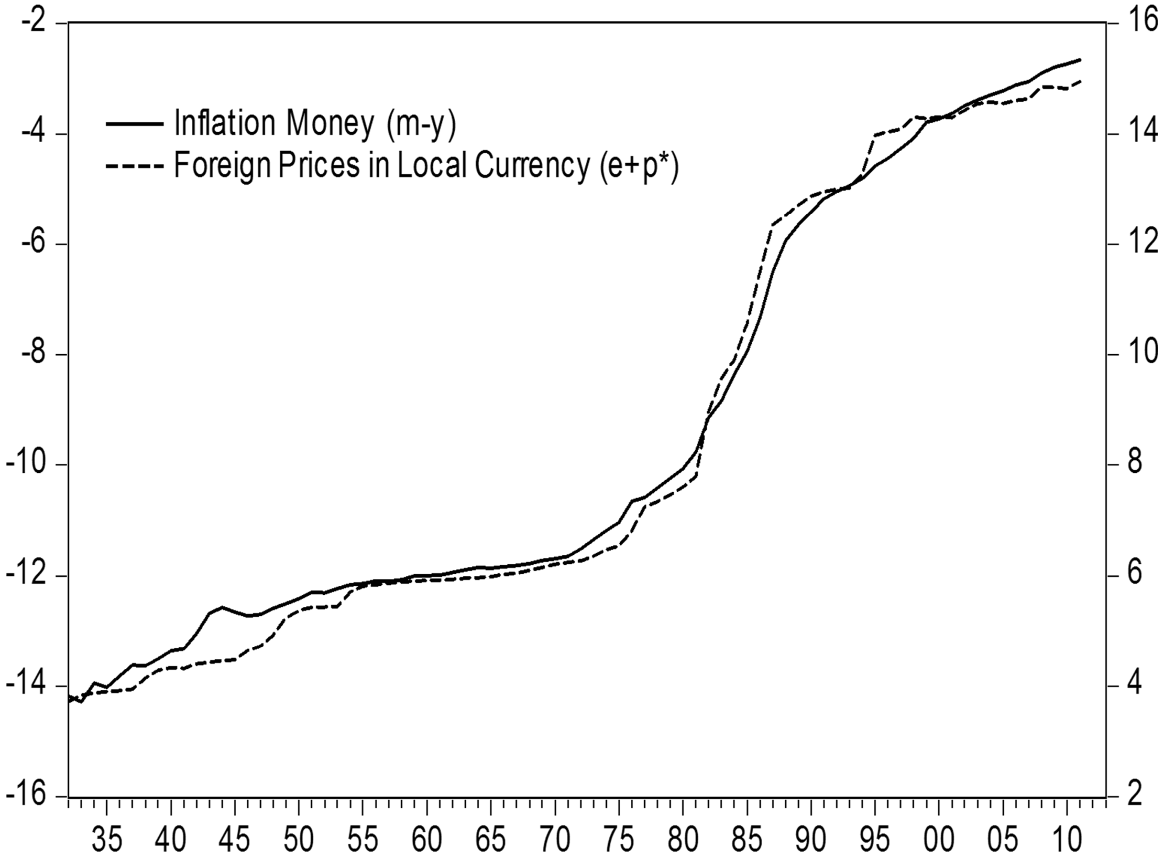

Figure 4: Inflation Money and Foreign Prices in Local Currency.

was closer. But as central banks abandoned money for other instruments, such correlation weakened at cyclical and short-run frequencies. The model we present is obtained from the CVAR with restrictions in the adjustment parameters matrix suggested by the classical monetary model with policy regime switching. First, we show that regime switching occurs in the inflation equation by estimating an unbalanced regression. Then, we derive an inflation model for each regime and show that crossing the regime threshold dates causes the models to lose its good specification properties. We also show that, besides the systematic causes of inflation of each regime, other variables often mentioned as causes of inflation are nonsignificant or add little to the explanatory power of the model.

8.1 Testing for Regime Switching in an Unbalanced Regression for Inflation

To prove that the inflation dynamics changed with the policy regimes we do the following. As a first step, the result that the composed variables $m - y$ (inflationary money) and $e + peu$ (foreign prices in local currency) are cointegrated is used to formulate the following model for inflation.

$$\Delta p_t = \beta_m (m - y)_{t-1} + \beta_e (e + p^{us})_{t-1} + \phi_m \Delta m_t + \phi_e \Delta (e + p^{us})_{t-1} \quad (18)$$

The left-hand side variable has no trend but those inside the parentheses do, so this is an unbalanced equation where, in general, neither regular statistics nor cointegration statistics can be used to carry out inference. However, as there are two I(1) regressors the stationarity of the error term is assured (Pagan and Wickens 1989). This occurs in either of the following two cases: 1) When the regression is incorrect so the coefficients for the trend variables are zero and, therefore, the error term has the same stationarity property as the dependent variable; 2)when the equation is correct so the coefficients for the trend variables are different from zero and they cointegrate among themselves.

As known from the unit root tests, we are in the second case, thus the coefficients βs should be different from zero. Notice that this is not an explicit autoregressive distributed lag model, as those used to test for cointegration, because the one-period lagged logarithm of the price level is not on the right hand side. However, it can be turned into one by using the PPP or the velocity equations, as we will see.

In all models the lagged levels of currency and foreign prices are included but the inclusion or not of the contemporary changes of these variables depends on the regime to avoid endogeneity problems. Thus, the model for the whole sample includes the contemporary changes of both variables. For the first regime, only currency growth is included. For the second regime only the change of foreign prices are included. For the third regime neither variation is included.

The most interesting aspects comes from estimating it for each regime. The estimation of these equations also confirms the stability of the long-run parameters, that are indirectly estimated for each sample basically without variation. All estimated coefficients and tests statistics are in the first column of Table 2.

The first thing to note from the estimates is that in all equations, the coefficients for lagged inflation money $(myb - y)_{t-1}$ and foreign prices $(e + p^{us})_{t-1}$ are nearly identical in absolute value but with the opposite sign, thus we can factorize and obtain (17), which is a confirmation that it is a valid long-run equilibrium relationship.

The second point to note is that those lagged variables are not significant for the whole sample. This would seem to imply that this is a "wrong" regression because those variables are not cointegrated, which we know is false. This result occurs because the sample includes different regimes, that have different matrices of adjustment parameters, as implied by the theoretical model. Only the changes of money and foreign prices are significant so they seem to be causing inflation during the whole sample, but this is only the result of not considering possible endogeneity problems, as was discussed in section 6.1.

The third aspect to stress is that for the first and second regimes the signs are inverted. This is the result of the regime change. To see this, for the first regime we can use the PPP condition to substitute lagged foreign price level for its long-run equivalent (up to a stationary deviation) the lagged price level p_{t-1}. Thus, the model for the first regime becomes a typical ADL model and that is the best description for the inflationary process during the first regime.

Notice that the error term of the transformed regression now would contain a term proportional to the lagged real exchange rate. However, the new error term would still be orthogonal to the regressors as during the first regime the lags of the real exchange rate do not impact contemporary values of money velocity (see second panel of Figure 3).

For the second regime, we use the QEM to substitute the lagged inflation money $(myb - y)_{t-1}$ for the lagged price level. We then obtain another ADL model for inflation for the second regime. Because in the second regime contemporary and lagged money velocity is uncorrelated with the real exchange rate (third panel of Figure 3), the new error term is still orthogonal to the regressors.

Finally, for the third regime neither money nor the exchange rate are systematic causes of inflation so they disappear from the model in any form.

The results can be summarized as follows: 1) in the first regime the adjustment coefficient for money velocity is significant and the one for the real exchange rate is zero; 2) for the second regime, the adjustment coefficient for money velocity is zero and the one for the real exchange rate becomes significant; 3) For the third regime, the adjustment coefficients for money velocity and the exchange rate become zero. These changes in the adjustment coefficients are those implied by the theoretical model and we can now estimate a model for inflation for the whole sample.

8.2 A Model for Inflation With Regime Changes

We have shown that the hypothesis of regime changes occurred at some specific dates (1982 and 2001) is supported by the data. We estimate now the inflation equations for each regime and they have good statistical properties. They are are improved version of the ones in Table 2 used to demonstrate the regime changes. The model is in fact a regression for each regime in the form of an error correction mechanism with different explanatory variables, as implied by the theoretical model.

We will show later that other variables often considered as inflation factors, such as the output gap, commodity prices and wages and even occasional impacts of money money and the exchange rate produce nonsensical results or add little explanatory power.

In the first regime, money was the policy variable so the inflation process is best described as an error correction model within the QEM system. For that we estimate an unrestricted form and apply general-to-specific deletion to obtain the final model. The results are shown in the first column of Table 3.

$$\Delta p_t = c_m + \alpha_{pm} p_{t-1} + \alpha_m((m-y)_{t-1} + \phi_m \Delta m_t + u_t^{pm} \tag{19}$$

None of the equations contains any lagged value of the inflation rate, meaning there was no inertial inflation left after considering the effect of inflation money and the separation of the price level from it.[11]

The t statistic for the lagged price level coefficient α_{pm} is negative and highly significant according to the Ericsson-MacKinnon (2002) tables, indicating the QEM equation is a cointegration relationship. The contemporary impact of money growth ϕ_m is strong, with about 0.5 shows that half the long-run impact of money on prices occurs in the first year.

All specification test are satisfactory. The next column has a regression for money as a function of lagged

[11] This is easier for annual data. For quarterly or monthly data there could be significant autorregressive terms needed to describe the dynamics within the year.

money velocity and lagged inflation. None of the terms is significant, as expected. This is a simple way to check that money is a weakly exogenous variable in the first regime.

In the second regime, the exchange rate is the sole systematic cause of inflation so we get a model from the PPP system with the price level as the error-correcting variable and both the exchange rate and the foreign price level as weakly exogenous variables:

$$\Delta p_t = c_e + \alpha_{pm} p_{t-1} (+\alpha_m (e + p^{us})_{t-1} + \phi_e \Delta (e + p^{us})_t + u_t^{pe} \tag{20}$$

Again, the coefficient for the lagged price level α_{pm} is highly significant, showing the PPP condition is a cointegration relationship with the price level as the adjusting variable. The size of that coefficient (-0.7) plus the contemporary effect of a depreciation on inflation ϕ_e is very high, implying a fast convergence. The very high adjusted R^2 implies that there is almost no room for other explanatory variables.All the specification and diagnostic tests are satisfactory.

For the third regime, the only systematic cause of inflation is neither money nor the exchange rate but the inflation expectation itself. As we are assuming the central bank enjoys credibility in its target, this substitutes the other two causes. Because of this,the forecast of inflation becomes hard based on other variables: there is nothing better than the inflation target itself to forecast annual inflation. Maybe some variables can help at higher frequency but this will be explored in the next section.

As a comparison device, we can write the case as another error-correction mechanism. To make the process convergent to the target, deviations from it should be mean-reverting . A way to capture this condition is the following. For the year $t-1$, we can write the price level that includes the inflation target (p_{t-1}^0) as $p_{t-1}^0 = p_{t-2} + \Delta p^o$, where Δp^o is the permanent inflation target.[12]

$$\begin{aligned} \Delta p_t &= c_{p^o} + \alpha_{po}(p_{t-1} - p_{t-1}^o) + u_t^{op} \\ &= (c_{p^o} - \alpha_{po}\Delta p^o) + \alpha_{po}\Delta p_{t-1} + u_t^{op} \end{aligned} \tag{21}$$

In this case, the equation collapses into a simple autoregressive model. The small sample size for this regime

[12] That is the official term for the Bank of Mexico.

might be a problem to estimate the autoregressive coefficient with enough precision. In fact such coefficient is nonsignificant. Because of this and the fact that the variability of the data for this regime is small, the model for the second regime can be extended to the third without affecting much its statistical properties.

However, inflation has not followed the exchange rate movements as in the past. The sharp depreciation of the Mexican peso during the financial crisis of 2008 was not followed by a similar increment in prices. Instead, the mean reversion property of the real exchange rate was reflected in a revaluation of the nominal exchange rate nearly enough to erase the effects of the crisis, as can be seen in Figure 5.

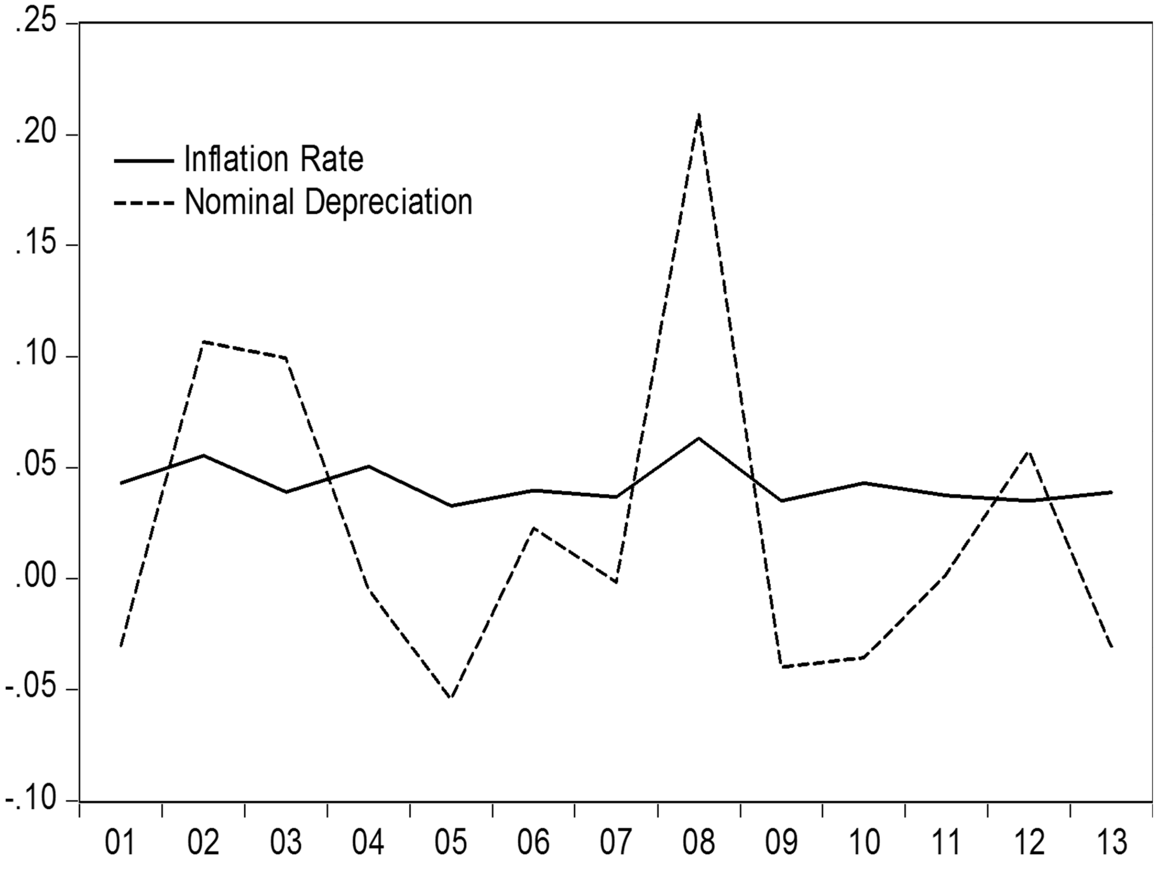

Figure 5: Inflation and the Depreciation Rate in the Inflation Targeting Regime.

The estimate for the autoregressive term is negative but nonsignificant. The most interesting parameter is the constant, which is about the upper limit of the monetary policy band for the inflation target. The situation is similar to that of other economies that have adopted an implicit or explicit inflation target, the inflation process becomes a flat line around the target with some small fluctuations.

To summarize this section, Figure 6 shows the observed and fitted values for the inflation rate in the whole sample. It must remembered that the model had very few explanatory variables, it did not include autoregressive terms (other than the lagged price level in the error correction term) nor dummy variables for poor fit, elements that that usually exaggerate the performance of a model.

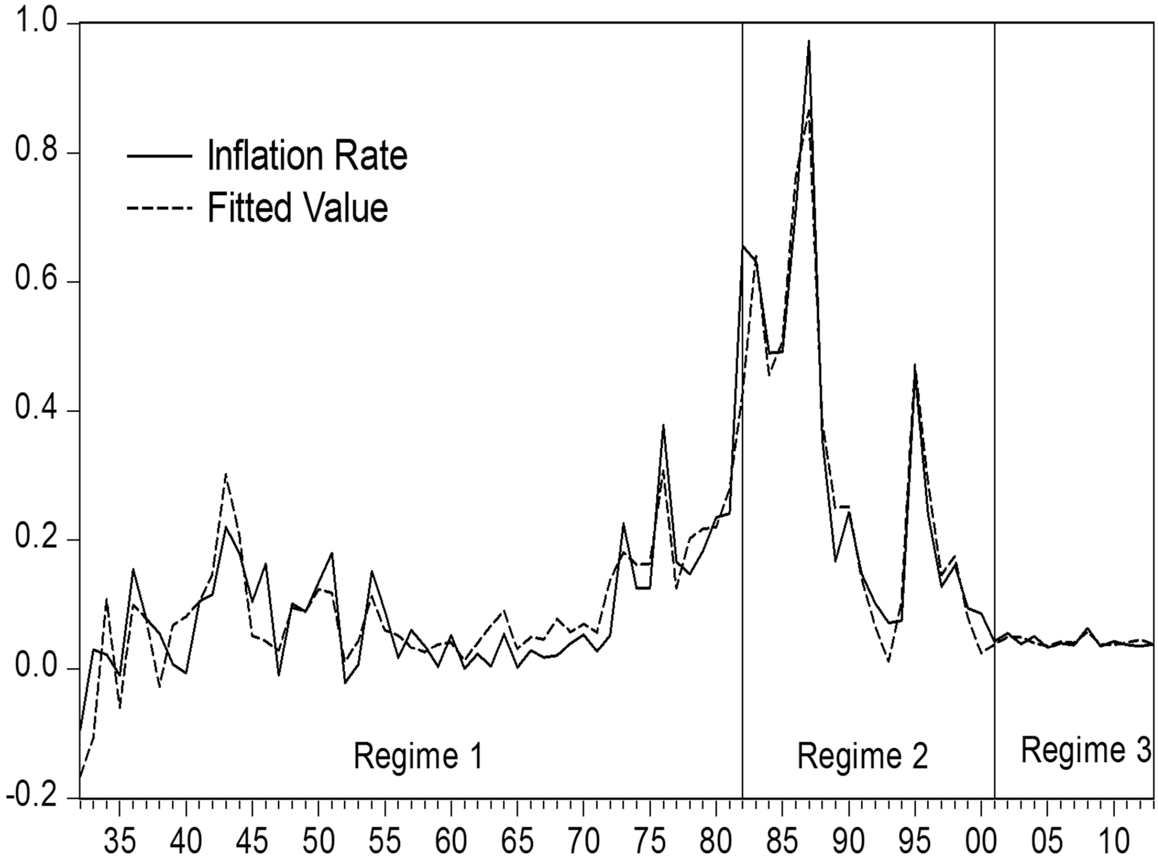

Figure 6: Observed Inflation and its Fitted Value.

9 The Role of Other Variables on the Determination of Inflation

The inflationary factors in Mexico can be classified as: 1) systematic, when they determine price level once their impact is fully absorbed; 2) short run, when their effect lasts for some periods but ultimately without leaving an effect on the price level and; 3) unsystematic yet permanent, when they last exactly one period and their impact on the price level is permanent. The first two correspond to the first and second regimes, which are equivalent to a price level target although in this case there would not be an intermediate target. The third type is a characteristic of the last regime, where the target is the inflation rate.

The goodness of fit of the model with regime changes leaves little room for other explanatory variables but they could become important in some situations. This section explores the role that some popular variables played in each regime, including money and the exchange rate when they were not systematic causes of inflation. These variables are not made explicit by the theoretical model and therefore they fall into the term u_t of the CVAR (14).

9.1 The Exchange Rate

It was shown to be the systematic cause of inflation only in the second regime (1983-2000). Although money was the systematic driver of inflation in the first regime (1932-1982), there has been a long tradition in Mexico in assigning a big if not the central role to the exchange rate in several episodes of inflationary surges. We explore this issue, in particular the 1976 devaluation.

Begin with an error-correction model for inflation similar to that for the second regime but this time applied to the first regime. The results are presented in the second column of Table 4.

It can be seen that although the contemporary value of the nominal exchange rate depreciation is highly significant, the lagged real exchange rate, or error-correction term is nonsignificant. This eliminates the exchange rate as a systematic cause of inflation during the first period.

Next, we augment that regression with the lagged value of money velocity and the contemporary value of money growth. The result is reported in the third column of Table 4. The added terms are highly significant, as expected from previous sections. The contemporary value of nominal depreciation remains highly significant. This could lead one to believe that although the exchange rate was not a systematic cause of inflation in the 1932-1982 period, it had some temporary but strong impact in at least some episodes.

However, there is a mistake with that regression, one committed by many economists studying Mexican inflation before. The problem comes from ignoring in the regression that the exchange rate is not a weakly exogenous variable in the first regime. To control for that issue, we now run a regression with instrumental variables. The first lag of the inflation rate and/or money growth will work because they both Granger-cause the depreciation rate. We present the results in the fourth column of Table 4.

With instrumental variables, the estimated effect of contemporary exchange depreciation loses its statistical significance. So, we can conclude that the exchange rate during the first regime was not an inflationary factor and, even if we were to ignore the results of the regression with instrumental variables, its role would have been modest, temporary and quickly eliminated (two years).

In the third regime, the exchange rate again is no longer a systematic cause of inflation but it becomes a modest and transient cause of inflation, as shown in the last column of Table 3. As the exchange strongest rate movements responded to international causes (the world financial crisis), there are no endogeneity issues. The impact is significant but very modest in magnitud: for each one percent of depreciation there is an impact of 0.08 percent, small enough to be hard to spot unless there is a strong depreciation. More over, all of the significance comes from the period 2005-2009 so, the true impact could be even smaller when the sample gets longer.

9.2 Money

After the first regime, money has not had a distinguishable on inflation in Mexico. This can be seen by adding contemporary money growth to the inflation equation for the second and third regimes.Even its contemporary is nonsignificant in those regressions, reported in columns 2 and three of Table xx.

9.3 Detrended Output (Output Gap)

This is a key variable in models without the classical dichotomy property. It is sometimes replaced by the unemployment rate or some other indicator of idle capacity. There is a peculiar characteristic of the Mexican data: for the whole sample, the relationship between the output gap and the inflation rate is positive. This fact is explainable because during the period of higher inflation (second regime), the devaluations of the exchange rate were contractionary. This effect dominates the whole sample but in other periods the sign was the opposite. This variable is significant only during the second regime.

10 Conclusions and Final Remarks

Although the study is only on Mexico, the unique characteristics of its case make it useful for more general purposes. Within a standard classical monetary model (Lucas 1982), we obtained a model for inflation with regime changes that explains with ease the behavior of inflation during the whole period when fiat money has been widely used in Mexico (1932-2013).

The theoretical framework contains the property of classical dichotomy, which is also at the heart of pure RBC models. Such property, has been widely exploited in studies of economic fluctuations but less so, if ever, in studies of the nominal sector. In this sense, our model can be seen as a complement to that approach that has been succesful in explaining some characteristics of the Mexican economy, as in Aguiar and Gopinath (2007).

The inflation model we presented is is the only model available that can fit the whole story of central banking with fiat money in Mexico. Although the sample we used is shorter than that used in Hendry (2001), the model we obtained is far more parsimonius, with at most two explanatory variables in each regime, it has no lagged values of inflation nor dummy variables to capture outliers or solve other problems with the residuals. Despite its simplicity, the model fits the data very tightly and leaves very little room for other variables. We showed that if other variables can be added, they contribute very little to the goodness of fit of the model and they usually have transient effect.

We showed that the dynamics of inflation, and also that of money and the exchange rate, depends on the variable targeted by the central bank: 1) When money is the target, the price level is determined by the velocity equation and then this determines the exchange rate (through devaluations, for example); 2) when the exchange rate is the target, the price level is determined within the PPP condition and money adjusts passively accordingly to the velocity equation; 3) when the central bank targets inflation then neither money nor the exchange rate can determine it and they can drift apart from one another in the short run, but they are still linked by the long-run relationship (17).

The first general implication is that the notion of the monetary model with flexible prices requiring either a very long sample or hyperinflation to work is not true in general. We have shown that such model works perfectly for low levels of inflation. Also, almost any period of around five years shows that the inflation in Mexico is about equal to the US inflation plus the rate of depreciation, showing no long samples are always necessary for PPP to hold.

A second point to emphasize is that the notion that "inflation is always and everywhere a monetary phenomenon" can have more than one meaning. Usually, the monetary nature of inflation is based on its long-run correlation with the price level. However, it can have a literal meaning even in the short run as in the case of Mexico from 1932 to 1981. In this period, high-powered money was the main driver of all other nominal variables in the sense that they could be predicted in an error correction model with money as explanatory variable.

A final point is that the model with regime changes at given dates is a clear example of the application of the Lucas critique: nonstructural parameters, in this case those of the adjustment coefficients in a CVAR, change in response to policy changes. Within each regime, the parameters are stable. This might explain why it is so difficult to find empirical support for the Lucas critique: most studies might have been carried out within a given regime, where no significant policy changes took place.

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A Data Sources

The data for this paper's come from the following sources:

México:

GDP, Y, E, i, W, M, P:1980-2002 Instituto Nacional de Estadística, Geofrafía e Informática (INEGI). available from: http://www.inegi.gob.mx; or in Banco de México available from: http://www.banxico.org.mx.1940-1979 in books of Estadísticas Históricas del INEGI. The data of public deficit (borrowing requirements) to GDP (pd) was formed with a series taken from Gil-Diaz and Ramos-Tercero (1985) and from Bank of Mexico's annual reports (also available online) from 1982 onwards.

United States:

CPI (P):Department of Labor Bureau of Labor Statistics, at: ftp://ftp.bls.gov/pub/special.requests/cpi/cpiai.txt

B Figures and Tables

Table 1: Unit Roots Tests for the Differences of Variables (Δx) and the Levels of Equilibrium Relationships

Augmented Dickey-Fuller for Individual Variables			
Variables	Specification	Number of Lags	Test Statistic
Differences of Individual Variables (1932-2011)			
Price Level (Δp)	C	0	-3.5^a
Exchange Rate (Δe)	C	0	-4.8^a
US Price Level (Δp^{us})	C	3	-3.2^b
Inflationary Money ($\Delta m - \Delta y$)	C	0	-7.6^a
Money (Δm)	C	0	-7.6^a
Foreign Prices ($\Delta e + \Delta p^{us}$)	C	0	-5.2^a
Levels of Equilibrium Relationships (1932-2011)†			
Real Exchange Rate ($e + p^{us} - p$)	C	0	-3.8^a
Money Velocity ($p + y - m$)	C,T	0	-3.3^c
Inflation Money Deflated by Foreign Prices ($m - y - (e - p^{us})$)	C,T	1	-3.1^c

Group Tests			
Method			Test Statistic
Levin, Lin & Chu t (individual unit root)			-7.1^a
Im, Pesaran and Shin W-stat (common unit root)			-10.1^a
ADF - Fisher Chi-square (common unit root)			138.0^a

^{a}, ^{b}, ^{c} Unit Root Hypothesis Rejected at 1%, 5%, 10% significance level, respectively.

In the specification column C and T stand for constant and trend. The Number of Lags according to Schwartz info criterion.

† The sample for all tests starts in 1932 but it ends in 2000 for money velocity and inflation money deflated by foreign prices

The group tests include all the variables in the top of the table.

Table 2: Unbalanced Regressions For the Inflation Rate (Δp_t) in Each Regime

Regressors	Full Sample 1932-2013	Regime 1 1932-1981	Regime 2 1983-2000	Regime 3 2001-2013
constant	1.25	3.46	-3.13	n.s.
	(2.39)	(6.65)	(-2.22)	·
$(m-y)_{t-1}$	0.07	0.2	-0.19	n.s.
	(2.43)	(6.81)	(-2.3)	·
$(e+p^{us})_{t-1}$	-0.07	-0.18	0.17	n.s.
	(-2.45)	(-6.11)	(2.24)	·
Δm_t	0.51	0.5	·	n.s.
	(7.33)	(8.06)	·	·
Δe_t	0.34	·	0.54	0.08
	(7.92)	·	(7.75)	(1.95)
Δm_{t-1}	0.12	n.s.	n.s.	n.s.
	(2.71)	·	·	·
Δe_{t-1}	0.19	n.s.	0.21	n.s.
	(4.18)	·	(2.74)	·
T	81	49	18	13
ADF statistic	-8.30^a	-7.84^a	-5.26^a	-4.03^a
Adjusted R^2	0.87	0.77	0.95	0.42
SE	0.06	0.06	0.07	0.01
Jarque-B	0.42	0.59	0.64	0.63
LM(2) autocor	0.14	0.13	0.1	0.71

t statistics are between parentheses.

n.s. means excluded for being nonsignifcant and · means it was not included.

^{a}, ^{b}, ^{c} represent 1%, 5%, 10% significance level, respectively.

ADF statistic to test the stationarity of the residuals of an unbalanced regression.

For Jarque-B and the LM(2) Autocor statistics the p values are provided.

Table 3: Inflation (Δp_t) Model in Each Regime

Regressors	Regime 1 1932-1981	Regime 2 1983-2000	Regime 3 2001-2013
constant	3.64 (5.77)	-1.73 (-5.41)	0.04 21.09
p_{t-1}	-0.21 (-5.31)	-0.76 (-7.72)	·
$(m-y)_{t-1}$	0.24 (5.84)	·	·
$(e+p^{us})_{t-1}$	·	0.73 (7.37)	n.s.
Δm_t	0.45 (6.99)	·	n.s.
Δe_t	·	0.54 (9.79)	0.08 (3.2)
Δm_{t-1}	n.s.	n.s.	n.s.
Δe_{t-1}	n.s.	n.s.	n.s.
T	49	18	13
Adjusted R^2	0.68	0.96	0.42
SE	0.05	0.05	0.01
Jarque-B	0.16	0.94	0.63
LM(2) autocor	0.63	0.36	0.71
LM(1) arch	0.91	0.75	0.93
$CUSUM$	pass	pass	pass
$CUSUM^2$	pass	pass	pass
N-step proj.	fail	pass	pass

t statistics are between parentheses.

n.s. means excluded for being nonsignificant.

A centered dot (·) means it was not included.

For Jarque-B, LM(2) autocor LM(2) arch the p values are provided.

Table 4: The Impact of Other Variables on Inflation (Δp_t)

Regressors	Regime 1 (1932-1981)		
	OLS	OLS	IV (Δm_{t-1})
constant	-0.15 (-0.56)	3.35 (5.99)	3.54 (5.71)
p_{t-1}	n.s.	-0.20 (-5.63)	-0.21 (-5.40)
$(m-y)_{t-1}$	·	0.23 (6.07)	0.24 (5.80)
$(e+p^{us})_{t-1}$	n.s.	n.s.	n.s.
Δm_t	·	0.43 (7.36)	0.45 (6.96)
Δe_t	0.45 (3.11)	0.27 (3.82)	n.s. n.s.
Δm_{t-1}	·	n.s.	n.s.
Δe_{t-1}	n.s.	n.s.	n.s.
T	49	49	49
Adjusted R^2	0.26	0.76	0.42
SE	0.08	0.04	0.01
Jarque-B	0.04	0.51	0.19
LM(2) autocor	0.01	0.51	0.59
LM(1) arch	0.34	0.97	0.79
$CUSUM$	pass	pass	n.a.
$CUSUM^2$	pass	pass	n.a.
N-step proj.	fail	pass	n.a.
Diff. in J-stat	n.a.	n.a.	0.33

t statistics are between parentheses.

n.s. means excluded for being nonsignificant.

A centered dot (·) means it was not included.

For Jarque-B, LM(2), autocor LM(2) arch and Diff. in J-stat the p values are provided.