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Inflation persistence and changes in the monetary regime: The Argentine case

Laura D'Amato Lorena Garegnani Juan M. Sotes Paladino*

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Abstract

We study the evolution of inflation persistence in Argentina between 1980 and 2007, a period in which significant changes in mean inflation can be detected by simple observation. We adopt both a time-series univariate and a frequency-domain approach. Following the former perspective breaks in the mean are identified, with inflation being highly persistent during the high inflation period, but less persistent since the adoption of the Convertibility regime and the decline of the inflation rate afterwards. When we analyze the "low inflation" period separately, we are able to identify changes in both mean and persistence of inflation before and after the adoption of a managed float in 2002. In this sense, frequency-domain analysis shows that overall volatility in prices is significantly higher during the post-Convertibility regime, though the contribution of high-frequency (temporary and seasonal) movements to this volatility was relatively more important during the Convertibility regime.

JEL Classification: C22, E31, E52

Keywords: Inflation persistence, Time-varying mean, Time-series, Frequency-domain approach.

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1 Introduction

For many years, a prevalent stylized fact in the literature on inflation dynamics has been that inflation is a highly persistent process, sometimes close to a random walk (see for example Furher and Moore, 1995; Galí and Gertler, 1999). This feature of the inflation process has several important implications for monetary policy modeling and conducting (see in particular Altissimo et al., 2006). From the point of view of policy modeling, persistence is a feature of inflation closely related to the assumptions on price formation in which the standard models currently used for policy modeling are based. From a more practical perspective it is clear that having a good knowledge of how rapidly inflation approaches its equilibrium level is crucial for the effectiveness of policy actions.

Recent empirical evidence has shed light on the close relationship between inflation persistence and monetary policy regime.[1]These studies revealed the importance of evaluating the presence of breaks in the mean of inflation and considering a time varying mean, if necessary, to adequately measure persistence. They also provided evidence that changes in the mean of inflation appear to be related to regime shifts.[2]

Using univariate techniques, Capistrán and Ramos-Francia (2006), provide evidence about inflation persistence in the ten largest Latin American economies and, in the case of Argentina, they find that inflation persistence has decreased since the beginning of the 90´s.

The assumption of a constant mean is clearly not plausible for Argentina, a country that has experienced a period of high and persistent inflation during the 80's, a hyperinflation episode by the end of this decade and a period of low inflation from then on. Inflation was very high during the 80's a period in which monetary policy was quite exogenously determined because of fiscal dominance. This high inflation period ended in a hyperinflation episode after which a currency board regime was adopted. Under this regime monetary policy was passive and the dynamics of inflation was, to a certain extent, exogenously driven. Inflation remained at very low levels during this period which ended with the abandonment of Convertibility in January 2002. Following the sharp devaluation of the peso, which lead to a dramatic change in relative prices, inflation raised, reaching a peak in April 2002. It then returned to lower levels, although a bit higher than those of Convertibility. The historical behavior of inflation in Argentina suggests that modeling inflation dynamics is not an easy task. Structural breaks make it quite difficult to obtain a unique model for a long period of time.

[1]See in this respect Levin and Pigier (2004), Altissimo et al. (2004), Altissimo et al. (2006), Capistrán and Ramos-Francia (2006), Angeloni et al. (2006) and Castillo et al. (2006).

[2]See in particular Marques (2004).

We study the issue of inflation persistence in Argentina from two perspectives: univariate time-series and disaggregate frequency-domain analysis of the Consumer Price Index (CPI) inflation. From the first viewpoint the appropriateness of considering a time-varying mean is evaluated by comparing measures of persistence for both a constant and a time-varying mean. The second approach focuses on a spectral decomposition of CPI sub-indexes' monthly price changes during the last two monetary regimes in Argentina (Convertibility and post-Convertibility regimes) in order to get a deeper insight into the differences between the dynamic features of both inflation processes.

The paper is organized as follows. In section 2 we describe the empirical model commonly used in the literature to measure inflation persistence. In section we briefly describe the relevant features of the inflation process in Argentina. We conduct descriptive analysis and study the dynamic properties of inflation in section 4. In section 5 we test for the presence of breaks and try to asses whether these breaks are related to shifts in the monetary regime. Using a time varying mean we calculate measures of inflation persistence in section 6 and compare them with those calculated under the assumption of a constant mean. Section 7 develops the analysis of CPI components in the frequency domain. Finally, section 8 concludes.

2 Inflation persistence and mean reversion

Recent empirical evidence has shed light on the fact that, when inflation is assumed to have a constant mean, a high level of persistence may be spuriously estimated even if that is not necessarily the case. The empirical research on inflation persistence for Europe and the US also reveals that the timing of breaks in the mean of inflation frequently coincides with monetary regime shifts. This result holds for both aggregate and sectoral inflation rates.

Discrete changes in mean inflation can be motivated on the grounds of monetary theory. While it is quite established that money and prices are co-integrated in the long run, this equilibrium relationship needs not to be unique and could rather be dependent on the monetary regime.[3] It is also widely accepted that high and persistent inflation always appears associated to high rates of money growth. Excessive money creation could be due to different causes, as fiscal disequilibrium monetary financing or persistent attempts by the government to take advantage of the trade-off between output and inflation to sustain output growth, but it always leads

[3] A monetary regime can be defined, following Heymann and Leijonhufvud (1995) as a "a pattern of behavior on part of the policy making authorities that sustains a given system of expectations by the public sector which governs their economic decisions".

to a high equilibrium level of inflation.

Inflation can be represented as a stationary AR(p) process of the form

$$\pi_t = \alpha + \sum_{i=1}^{p} \beta_i \pi_{t-i} + \eta_t \tag{1}$$

A widely accepted measure of inflation persistence is the sum of the autoregressive coefficients in (1) as proposed by Andrews and Chen (1994).

$$\rho = \sum \beta_i \tag{2}$$

As pointed out by Marques (2004) and Angeloni et al. (2006) among others, the concept of persistence is closely related to the velocity with which inflation returns to its long run equilibrium value after a shock. Consequently, an adequate representation of this process as stressed by Marques (2004) is to rewrite (1) as an error correction mechanism in terms of deviations from a mean, stressing the link between persistence and mean reversion.

$$\pi_t - \mu = \sum_{i=1}^{p-1} \varphi_i \Delta(\pi_{t-i} - \mu) + \rho(\pi_{t-1} - \mu) + \eta_t \tag{3}$$

where

$$\mu = \frac{\alpha}{1-\rho} \tag{4}$$

is the unconditional mean of inflation

In (3), the larger the absolute value of ρ is, i.e., the more persistent inflation is, the less rapid inflation reverts to its mean level. A crucial issue in the determination of persistence is whether it is reasonable or not to assume a constant mean for inflation.

3 Some relevant features of the inflation process in Argentina

The assumption of a constant mean is clearly not plausible for Argentina, a country that has experienced prolonged periods of high and persistent inflation and a hyperinflation episode by the end of the 80's. Using univariate techniques, Capistrán and Ramos-Francia (2006), provide evidence about inflation persistence in the ten largest Latin American economies and, in the case of Argentina, they find that the degree of persistence seems to have changed over the period 1980-2006. In particular, they find that inflation persistence has decreased.

Although further analysis is needed to confirm intuitions, a simple visual inspection of the time series of inflation suggests a non constant mean.

High inflation was a rather widespread phenomenon among many Latin American countries during the seventies and eighties. Monetary financing of government deficits was a common feature of these processes that have recently received renewed interest in the literature. In particular Sargent et al. (2006) study inflation dynamics in some of these countries allowing for switches from rational to adaptative expectations to model these processes. They also show that their inflationary dynamics features quite well the one described by the money demand model proposed by Cagan in 1956. Sargent et al. conclude from their results that it was fiscal discipline what permanently stabilized inflation in these countries.

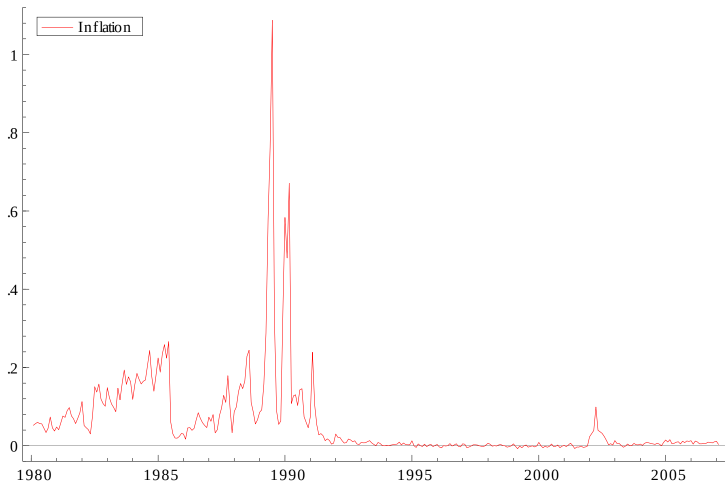
The Argentine case has its particular features, as Figure 1 shows. During the 80´s several attempts to stabilize inflation using different nominal anchors produced only temporary reductions in the rate of inflation which, on average, remained quite high. However, inflation had been high and persistent since the mid seventies, with chronically high fiscal deficits being probably a main cause for this.[4] At the beginning of the eighties, the country maintained a crawling peg to the dollar, an exchange rate scheme which was supposed to make domestic inflation converge to world inflation. As many other Latin American countries, Argentina had gone through a process of trade and financial liberalization by the end of the seventies. The country ran large current account deficits during those years and its currency was significantly overvalued. The dramatic jump in the world interest rate in 1982 led to an external and financial crisis in several countries in the region, and Argentina was not an exception. The currency was devalued in 1982 and part of the private sector's external debt was absorbed by the government, amplifying the fiscal disequilibrium. Inflation accelerated significantly in the following years in spite of the efforts to reduce the fiscal deficit. A stabilization program known as the "Plan Austral", implemented in 1985, led to a temporary decline in inflation for a few months; however, inflation soon accelerated until a hyperinflationary process unchained by mid 1989.

In April 1991 a currency board scheme (the Convertibility regime) was adopted as an attempt to anchor inflation expectations by fixing the peso to the dollar by law. The adoption of this scheme was accompanied by a public sector reform which included the privatization of the main public enterprises and the dollarization of the financial system. This mix of policies was successful in anchoring inflation expectations, and by 1993 inflation had stabilized at very low levels. Although this change was perceived as being quite permanent, and inflation remained very low, the fiscal reform was rather incomplete. Monetary financing of fiscal disequilibrium was replaced to some extent by external financing. Government and private sector external debt increased over time and began to be perceived as unsustainable once

[4] See Heymann and Navajas (1990) for the Argentine case.

the economy entered a long recession in 1998, after the Asian and Russian crises. The rise in international interest rates provoked by these crises, increased the burden of interest payments on government debt. With the peso highly appreciated, the Brazilian devaluation of January 1999 deeped even more the recession. In 2001 an external and financial crises unchained leading to the abandonment of the Convertibility regime, to a sharp devaluation of the currency and to the adoption of a managed float. The devaluation of the currency provoked a dramatic change in relative prices and a jump in the inflation rate, which reached a peak in April 2002. It then returned to lower levels, close to those of the Convertibility period, but began to accelerate slightly by the end of 2004, once the economy entered a period of strong growth after the prolonged recession in which it had been immersed for several years.

Figure 1



4 Descriptive analysis

The previous description of the historical behavior of inflation in Argentina suggests that modeling its dynamics is a rather challenging exercise. Structural breaks make it quite difficult to obtain a stable model for the whole sample. Both, mean and volatility are quite different among several subperiods.

In spite of this, shocks to inflation are not expected to have a permanent effect, since monetary policy is in general providing a nominal anchor to stabilize it. Although high inflation can eventually end in a hyperinflation process, at a certain point in time inflation returns to lower levels due to stabilizing policy efforts. In this sense, the null hypothesis of a unit root is expected to be rejected when the time series properties of inflation are studied.

As a first step in our analysis we adopt a simple and descriptive approach in order to identify breaks in the mean and autoregressive component of the inflation process and calculate measures of inflation persistence controlling for these breaks. Our aim is to get a better understanding of inflation behavior and improve the current knowledge and empirical analysis of the inflation process in Argentina.

In this section we characterize the time series properties of inflation and identify changes in its mean using descriptive and time series analysis. We complement these analysis in the next section, using different techniques designed to deal with the issue of structural breaks for econometric modeling purpose.

Descriptive analysis (see Table 1) makes it clear that the mean and the standard deviation of inflation for the whole sample are not informative about the behavior of the time series over the complete period, since these descriptive measures are quite different among sub-periods.

A first period of high inflation between 1980:1 and 1989:3 can be clearly identified. The hyperinflation, between 1989:4 and 1990:3, was a brief and temporary episode, followed by a transition (1990:4 -1991:2), in which inflation remained still high and a disinflation period (1991:3-1992:12) after the adoption of a currency board regime. We consider these three short sub-periods as temporary episodes and put them aside for the purpose of inflation persistence analysis. The rest of the sample, which covers the period 1993:1 - 2007:2 is, from the point of view of the statistical features of the inflation process, a period of low inflation, interrupted by an outburst after the devaluation of the peso in January 2002. As can be seen from Figure 1 the jump in inflation induced by the devaluation becomes rather insignificant when compared to the hyperinflation episode. The change in the monetary regime and its potential effects on inflation dynamics is not captured by simple descriptive analysis but will be studied in more detail considering this period separately.

Table 1

Inflation		
Mean and Standard Deviations		
	Mean	Standard Deviation
1980:1-1989:3	0.1034	0.0616
1989:4-1990:3	0.4430	0.2999
1990:4-1991:2	0.1136	0.0512
1991:3-1992:12	0.0517	0.0556
1993:1-2007:2	0.0045	0.0105
2002:1-2002:9	0.0371	0.0232
2002:10-2007:2	0.0062	0.0041
1980:1-2007:2	0.0589	0.1125

In order to study the time series properties of inflation and check the adequateness of splitting the sample according to the former descriptive analysis, we estimate Dickey-Fuller F statistics to jointly test hypotheses on the coefficients of mean and trend and the presence of a unit root.

Table 2

Inflation			
Dickey Fuller F Statistic			
	Constant	Trend	H_0=unit-root
1980:1-1989:3	Significant***	Not significant	Rejected**
1993:1-2007:2	Not significant	Not significant	Rejected***
1980:1-2007:2	Significant***	Significant***	Rejected***

***1% significance

**5% significance

Table 2 shows the results of these tests. First, the null of a unit root is rejected in all cases. Second, the Dickey-Fuller F statistics confirm the absence of a constant long-run mean for inflation. It can be seen from the table that the mean of inflation is statistically different from 0 during the period of high inflation but not between 1993 and 2007. The Dickey-Fuller statistics also indicate the absence of a trend in each of the sub-periods. When considering the whole sample, a downward trend appears after the hyperinflation, although previous results prevent us from considering a constant mean.

These results suggest that the inflation process does not have a unit root but cannot be considered as a stationary process, since changes in its mean appear to be statistically significant. In the next section we complement this descriptive analysis conducting two tests for the presence of breaks in the dynamics of inflation at unknown dates.

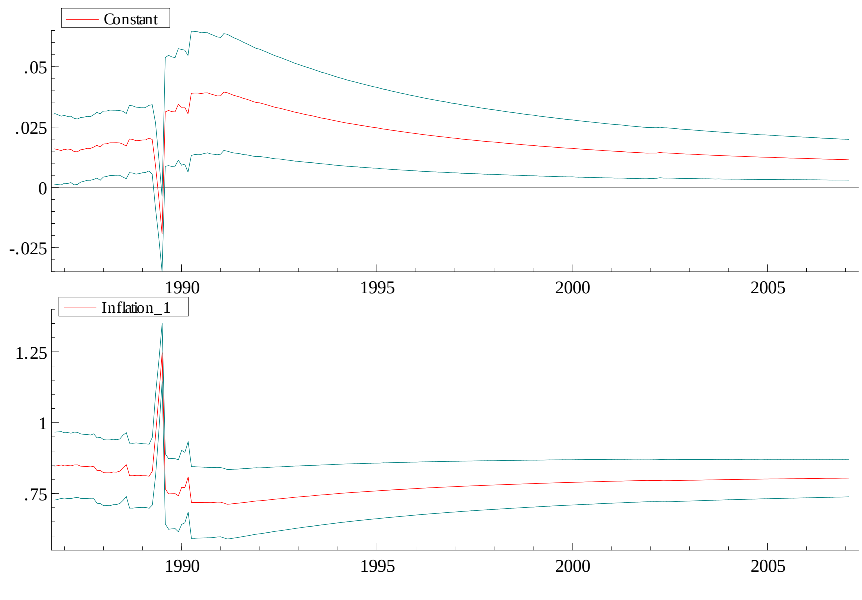
5 Testing for breaks in the inflation process

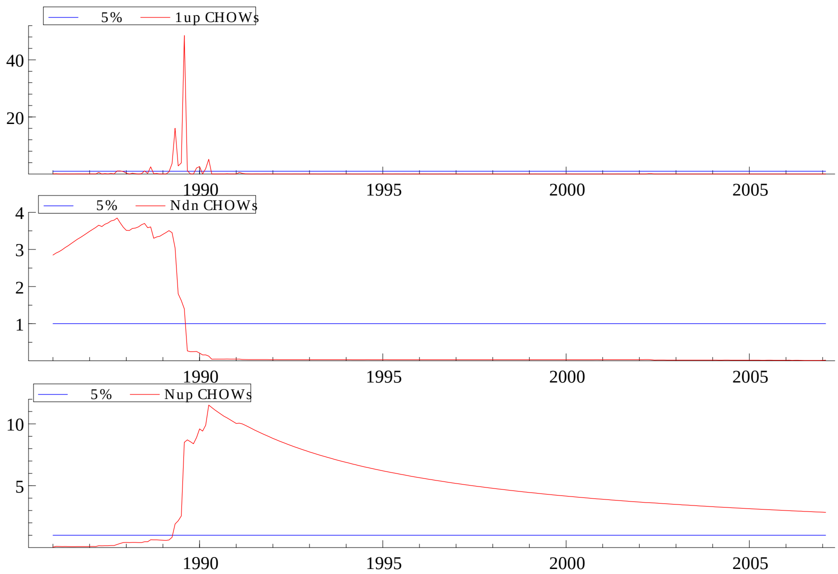
5.1 Recursive analysis

In order to identify changes in the mean and in the autoregressive component of inflation and verify their relationship with monetary regime shifts, we develop two type of tests. First we estimate equation 1 recursively and conduct parameter stability tests. Figure 2 indicates that both the estimated mean and the autoregressive coefficient are not constant through the sample period. The estimated coefficients are within the previous +/- 2 standard errors intervals except for the period of hyperinflation and its aftermath. Recursive Chow statistics ("forecast horizon" descendent, ascendant and one-step) are below the 5% critical value except for the hyperinflation period.

To sum up, the recursive estimation of 1 indicates a break in the mean and the autoregressive coefficients of inflation in the surroundings of the hyperinflation episode, which ended with the adoption of the currency board regime known as Convertibility. Probably due to the magnitude of hyperinflation break, the next regime change implied by the abandonment of the Convertibility cannot be identify as a significant break.

Figure 2: Recursive Analysis (1980:1 – 2007:2)





5.2 Testing for multiple breaks using the Bai Perron test

As a second approach to test for the presence of breaks, we conduct the Bai Perron tests. Compared to previous recursive analysis, the Bai Perron methodology is more general, in the sense that it allows for very general assumptions about the distribution of the data and errors (heteroskedastycity and/or serial correlation can be present) across sub-periods according to identified breaks. This lack of restriction on data and error distribution is quite adequate in the case of inflation dynamics in Argentina, because of the changing volatility of the inflation process. Additionally, the Bai Perron methodology has the advantage of allowing a specific to general modelling strategy to consistently determine the number of breaks.

We consider two specifications for breaks. The first one assumes changes in mean while the second also evaluates changes in the autoregressive coefficients.[5] We started considering five breaks in both cases, but only one break appeared as statistically significant, according to the three criteria suggested by Bai and Perron: SupF Sequential Procedure, Bayesian Information Criterion (BIC) and Liu, Wu and Zidek (LWZ). Similar results were obtained

[5] As stressed by Bai and Perron (2003), when models include the lagged dependent variable, no serial correlation should be allowed in the residuals. This restricts the use of a covariance matrix robust to heteroskedasticity and autocorrelation as proposed by Andrews (1991). We tested the robustness of the results to the use of a standard covariance matrix. The results did not differ significantly using both specifications of the covariance matrix.

considering 4, 3 and 2 breaks. Thus, we only report the results considering only one break. Table 3 presents the results of the tests and the estimated coefficients in both cases. In the case of changes in mean, the date of the break, April-91, corresponds to the adoption of the Convertibility regime. The estimated means for the two sub-periods are statistically different. In fact, the estimated mean is significantly different from 0 for the first period and not different for the second one. This result is in line with the ones reported in Table 2 for the ADF test.

When we consider changes in the mean and in the autorregressive coefficients of inflation, the date of break changes to the hyperinflation period, August-89, in line with the results obtained from the recursive analysis. This date of break includes in the first sub-period a huge jump in the inflation rate and extremely high volatility at the end. The second period starts with the hyperinflation episode, including very high and volatile rates of inflation, but ends with a much more stable behavior of inflation. For this reasons the estimated means for both sub-periods are not accurate since they are weighting quite different behavior inside each of them. On the contrary the autoregressive coefficients are reasonable and in line with the expected ones, quite high (nearly 1) in the first sub-period and much lower (0.53) in the second one.

Table 3

Bai Perron Test for changes in mean (1980:1-2007:2)

Specifications				
z_t=1	**q=1**	**p=0**	**h=81**	**M=1**
Tests				
$SupF_T(1)$	UDmax	WDmax	$SupF_T(2\|1)$	
14.58***	14.58***	14.58***	1.078	
Number of breaks selected				
Sequential	BIC	LWZ		
1	1	1		
Estimates				
α_1	α_2	T_1		
0.135	0.006	Apr-91		
(0.0336)	(0.0016)			

Bai Perron Test for changes in mean and autorregresive coefficients (1980:1-2007:2)

Specifications				
z_t=3	**q=3**	**p=0**	**h=80**	**M=1**
Tests				
$SupF_T(1)$	UDmax	WDmax		
65.33***	65.33***	65.33***		
Number of breaks selected				
Sequential	BIC	LWZ		
1	1	1		
Estimates				
α_1	α_2	T_1		
-0.009	0.009	Aug-89		
(0.0089)	(0.0039)			
β_{11}	β_{12}			
1.463	0.534			
(0.1035)	(0.054)			
β_{21}	β_{22}			
-0.3191	-0.007			
(0.1319)	(0.049)			

Both, recursive analysis and the Bai Perron tests, indicate that the non-stationary of inflation comes from a non constant mean and probably from a non constant variance. This suggests the adequateness of differentiating it with respect to a time varying mean in order to model it as a stationary process. They also indicate that the autoregressive coefficients are non constant, what suggests the adequateness of evaluating changes in persistence across sub-periods. The results also show coincidence in dates of breaks with changes in the monetary regime. In section 6 we consider the identified breaks to construct measures of inflation persistence.

6 Measuring inflation persistence

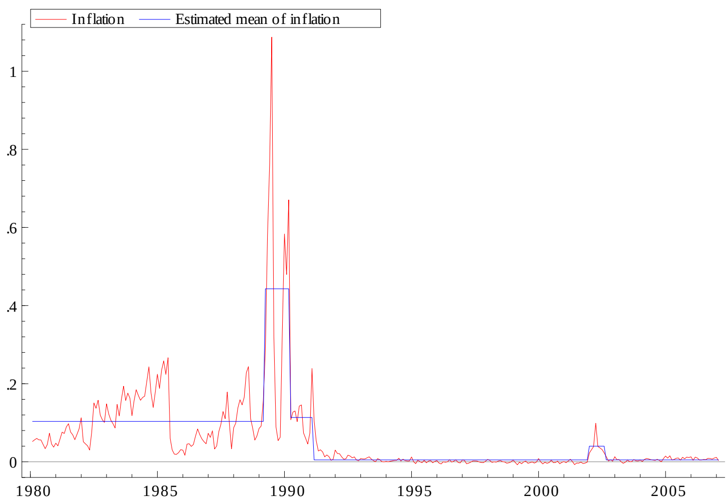
6.1 Analysis for the whole sample

Based on the descriptive analysis in section 4.1 and 4.2 we consider a time-varying mean for inflation to calculate measures of inflation persistence. We follow Marques (2004) and calculate it using dummy variables to identify changes in mean as suggested by graphic and descriptive analysis. Thus, fitted values of inflation estimated according to 5 represent the estimated time-varying mean of inflation.[6]In this context we refer to a time varying mean as one that suffers discret changes.

$$\underset{(HCSE)}{\pi_t} = \underset{(0.11)}{0.5434} - \underset{(011)}{0.43999}\ d1 - \underset{(0.15)}{0.1338}\ d2 - \underset{(0.12)}{0.4298}\ d3$$
$$-\underset{(0.11)}{0.5385}\ d4 + \underset{(0.008)}{0.03522} d5 \tag{5}$$

The estimated time-varying mean is drawn in Figure 3 along with observed inflation.

Figure 3



The results from the estimation and linear restriction tests[7] indicate a mean different from zero (10.3%, monthly) between January 1980 and March 1989. The estimated constant in Equation 5 (54.3%) represents the mean of

[6]Where $d1$ corresponds to a dummy variable for the period 1980:1 -1989:3, $d2$ to 1989:7-1990:3, $d3$ to 1990:4-1991:2, $d4$ to 1991:3-2007:2 and $d5$ to 2002:1-2002:8.

[7]The results of these tests are available upon request.

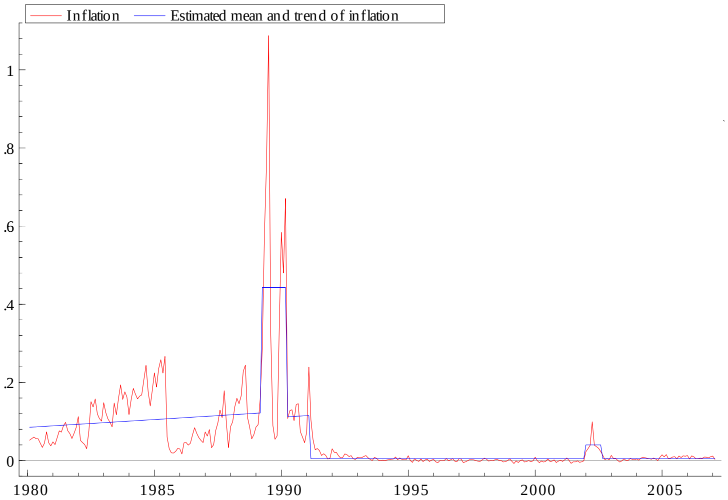
inflation during the hyperinflation period. The dummy variable for the period July 1989 to March 1990 is not statistically significant. Between April 1990 and February 1991, the transitional period, the mean of inflation was around 11.3%. Following this period, with the implementation of the Convertibility scheme, the mean of inflation declined dramatically and becomes not significantly different from zero until the end of the sample. Within this period, with the abandonment of the Convertibility and the sharp devaluation of January 2002 inflation soared, reaching a peak of 10% monthly in April 2002. However, as can be seen from Figure 3, this outbreak is relatively minor compared with the hyperinflation episode. A linear restriction test of a different mean from January to August 2002 with respect to the period 1991 to 2007 is near to reject the null of equal means, suggesting that this period can be considered as an outlier within the "low inflation period", since we cannot distinguish a change in mean following this subperiod. However, once we consider separately the period that follows the disinflation (1993:1-2007:2) in section 6.2., changes in mean inflation can be detected.

We also considered the relevance of including two simple linear time trends: a positive one for the eighties, and a negative trend since April 1990 until the beginning of the Convertibility regime, as suggested by graphic inspection. Equation 6 adds both trends to the estimation of equation (5).[8]

$$\begin{aligned} \underset{(HCSE)}{\pi_t} &= \underset{(0.11)}{0.5434} - \underset{(0.11)}{0.45890} d1 - \underset{(0.16)}{0.1338} \cdot d2 - \underset{(0.12)}{0.4317} \cdot d3 \\ & -\underset{(0.11)}{0.5385} \cdot d4 + \underset{(0.008)}{0.03522} \cdot d4 + \underset{(0.0001)}{0.000335} \cdot t1 \\ & +\underset{(0.006)}{0.0003181} \cdot t2 \end{aligned} \tag{6}$$

[8] Where $t1$ corresponds to a trend for the period 1980:1-1989:3 and $t2$ to1990:4-1991:2.

Figure 4



The results show that while the trend for the period April 1990 – February 1991 is not significantly different from zero, a slightly positive trend can be identified in the eighties, as can be seen from Figure 4. Since the estimated changes in the mean of inflation are not significantly different between equation 5 and 6, the following analysis is based on equation 6.

Having drawn a time-varying mean (μ_t) for inflation according to equation 6 we calculate deviations from it (z_t) and estimate equation 3 in deviations. In Table 4 we compare measures of inflation persistence obtained from the estimation of equation 3 using a time-varying mean (μ_t) and a constant one (μ).

Table 4

	Inflation Persistence Period 1980:1-2007:2	
	No change in mean	*Changes in mean*
ρ	0.80	0.56
hcse	(0.184)	(0.240)
	(1 lag)	(1 lag)

When we assume a constant mean, inflation is highly persistent (0.8). On the contrary, when we allow for changes in mean, the level of persistence decreases considerably (0.56). These two measures of persistence are statistically different, indicating that once time variation in mean inflation is allowed, the inflation process becomes much less persistent.

A second issue to investigate is if, related to changes in its mean, the inflation process also changes in terms of its autoregressive properties. The results of the Bai Perron test in the previous section indicates that the autoregressive model of inflation changes not only in terms of its mean but also in its autoregressive features, according to the splitting of the sample proposed by identified breaks. The recent empirical evidence for other countries indicates that once inflation lowers, it also becomes a less persistent process. (see for example Angeloni et al., 2006 and Capistrán et al., 2006).

To evaluate the presence of changes in persistence and calculate measures taking into account these changes, we estimated autoregressive models of z_t (deviations of inflation from its estimated time-varying mean) including multiplicative step dummy variables in levels and differences of z_t. In Equation 7 and Table 5 we present the obtained measures of inflation persistence.[9] According to these results, inflation was highly persistent (0.96) during the high inflation period, between 1980:1 and 1989:3. The subsequent periods in the Table correspond to the hyperinflation period (1989:4-1990:3), the transition (1990:4-1991:2), and the disinflation that followed the adoption of the Convertibility scheme (1991:3 - 1992:12). Although we are not interested in these periods from the persistence analysis perspective, we had to consider them to adequately estimate persistence for the relevant periods. For the low inflation period, 1993:1-2007:2, persistence declines to 0.36.

[9] Where $d1$ corresponds to a dummy variable for the period 1980:1 -1989:3, $d3$ to 1990:4-1991:2, $d4'$ to 1991:3-1992:12 and $d4''$ to 1993:1-2007:2.

$$
\begin{aligned}
z_t = & +0.5048\, z_{t-1} + 0.4084\, z_{t-1}d1 - 0.6708\, z_{t-1}d3 + 0.3504\, \Delta z_{t-1} \\
\text{HCSE} & \quad [0.2101] \quad [0.217] \quad [0.1091] \quad [0.0578] \\
& -0.3063\, \Delta z_{t-1}d1 - 0.3723\, \Delta z_{t-1}d4' - 0.4956\, \Delta z_{t-1}d4'' \\
\text{HCSE} & \quad [0.2284] \quad [0.0737] \quad [0.1767] \\
& -0.1954\, djul85 + \text{dummy variables for hyperinflation period} \\
\text{HCSE} & \quad [0.0096]
\end{aligned}
\tag{7}
$$

Table 5

Inflation Persistence Period 1980:1-2007:2	
Sub-period	ρ
1980:1-1989:3	0.954
1989:4-1990:3	0.855
1990:4-1991:2	0.184
1991:3-1992:12	0.483
1993:1-2007:2	0.359

Summing up, previous analysis indicates that there were significant changes in mean inflation in Argentina. It also shows that controlling for changes in mean decreases the estimated level of inflation persistence. The identified changes in the mean and the autoregressive coefficient of inflation are found to be related to the monetary regime shift implied by the adoption of Convertibility in April 1991.

With respect to the abandonment of this regime in January 2002, the magnitude of the changes occurred in the inflation process during the hyperinflationary period and at the beginning of the 90's could probably obscures changes in inflation dynamics associated to the adoption of the new monetary regime. We are not able to statistically identify changes in the mean and in the autoregressive coefficient after 2002 until the end of the sample when we consider the complete period. For this reason we study the "low inflation" period separately in the next section.

6.2 A more detailed analysis of the "low inflation period"

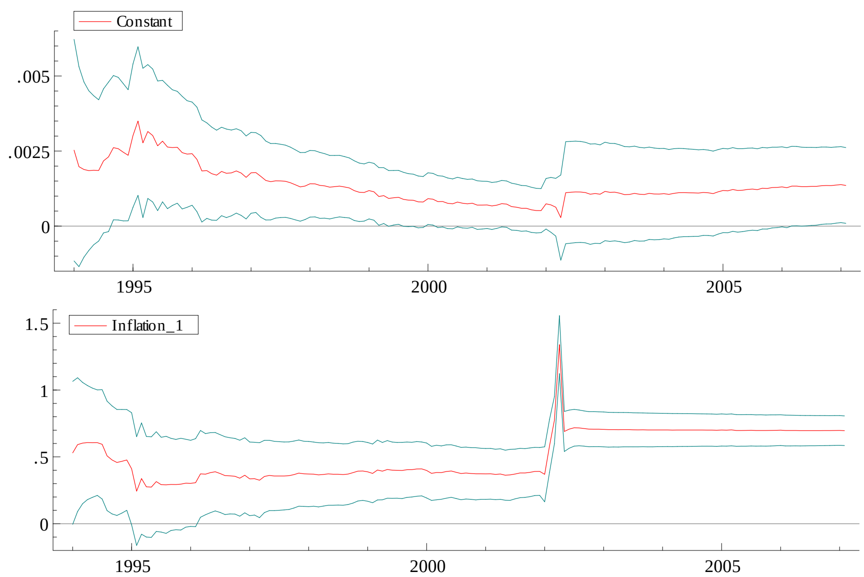
As we mentioned before, the dramatic differences in the level of inflation between the high and the low inflation periods could hide the presence of changes in the inflation process following the adoption of a managed float in 2002.

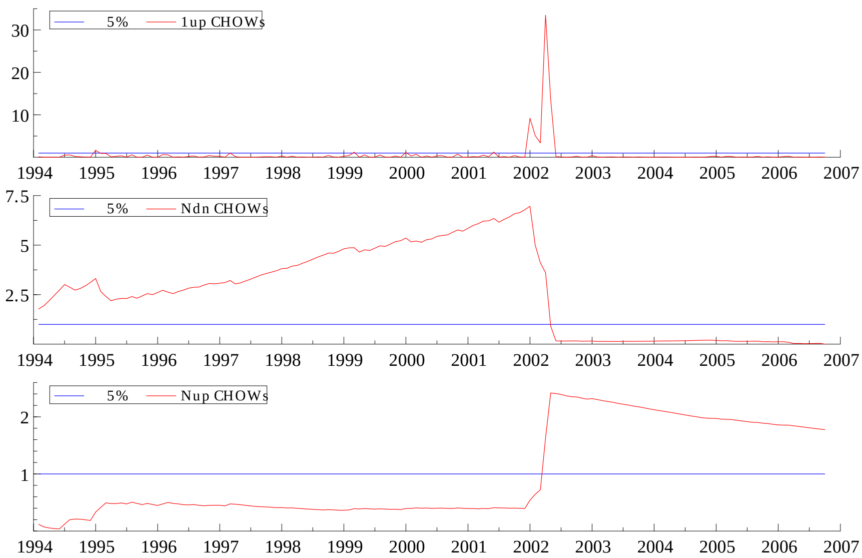
In this section we consider the last period separately to investigate with more detail the presence of changes in inflation dynamics associated to the monetary regime change. In January 2002, the Convertibility regime was abandoned after a deep external and financial crisis, the peso suffered a sharp devaluation and a managed floating exchange regime was adopted. The change in relative prices implied by the devaluation of January 2002 led to a jump in the inflation rate, which reached a peak in April 2002 and then lowered.

To investigate if relevant breaks in inflation dynamics can be identified in this period we test for breaks through recursive estimation of equation 1 for the period 1993:1 – 2007:2 and also conduct the Bai Perron test.

The graphs in Figure 5 illustrate the results of the recursive estimation of the intercept and the autoregressive coefficients of an AR(1) model for the period 1993:1 – 2007:2. We can identify changes in both, the mean and the autoregressive coefficient after the beginning of 2002, coincidently with the abandonment of the Convertibility regime and the adoption of a managed float. The break in the autoregressive coefficient suggests that persistence could not be constant during this period.

Figure 5: Recursive Analysis (1993:1 – 2007:2)





These results are confirmed by the Bai Perron tests (see Table 6) that identify a break in January 2002 when we test for changes in the mean of inflation and in May 2002 when we consider breaks in both, the mean and the autoregressive coefficients.

Table 6

Bai Perron Test for changes in mean (1993:1-2007:2)

		Specifications		
z_t=1	**q=1**	**p=0**	**h=42**	**M=1**
		Tests		
$SupF_T(1)$	UDmax	WDmax		
6.60*	6.60*	6.6		
		Number of breaks selected		
Sequential	BIC	LWZ		
1	1	1		
		Estimates		
α_1	α_2	T_1		
0.0008	0.01	Jan-02		
(0.0006)	(0.0038)			

Bai Perron Test for changes in mean and autorregresive coefficients (1993:1-2007:2)

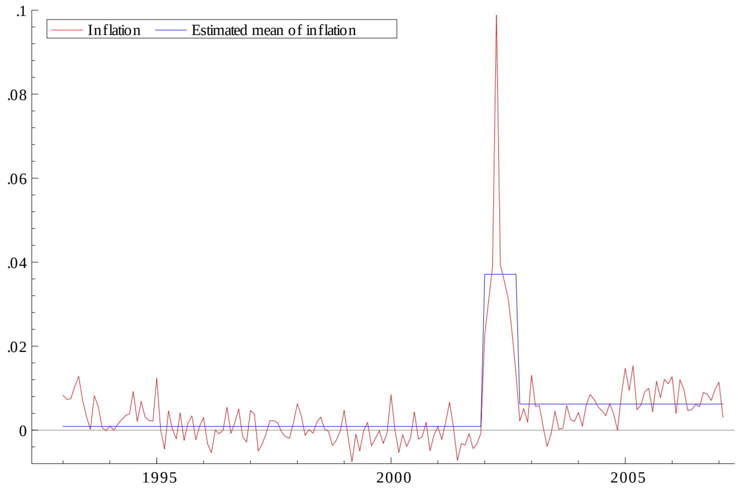
		Specifications		
z_t=3	**q=3**	**p=0**	**h=80**	**M=1**
		Tests		
$SupF_T(1)$	UDmax	WDmax		
65.33***	65.33***	65.33***		
		Number of breaks selected		
Sequential	BIC	LWZ		
1	1	1		
		Estimates		
α_1	α_2	T_1		
0.0001	0.0029	May-02		
(0.0006)	(0.0010)			
β_{11}	β_{12}			
1.170	0.306			
(0.1232)	(0.0769)			
β_{21}	β_{22}			
-0.316	0.213			
(0.1482)	(0.0743)			

Having identified the presence of a break clearly related to the devaluation of January 2002, we construct a time varying mean which also incorporates discrete changes that appear to be significant by visual inspection. In particular, we want to control for the jump in inflation created by the strong devaluation of the peso, which could spuriously create high persistence. Equation 8 and Figure 6 show the estimated mean of inflation for the period 1993:1-2007:2. [10]

[10] Where $d1$ corresponds to a dummy variable for the period 2002:1-2002:9 and $d2$ to 2002:10-2007:2.

$$\underset{(HCSE)}{\pi} = \underset{(0.0003)}{0.00087} + \underset{(0.0078)}{0.0362}d1 + \underset{(0.0006)}{0.0053}d2 \tag{8}$$

Figure 6



Mean inflation was slightly different from 0 during the Convertibility period. Then, during the crisis that followed the abandonment of the Convertibility, mean inflation jumped to 3.6%, but then lowered to 0.5%, a positive and significantly different from zero monthly rate. Thus, it seems that once we analyze the "low inflation" period separately we are able to detect a change in the mean of inflation that appears to be related to the monetary regime change.

Having obtained a time-varying mean, we compare measures of inflation persistence under the alternative assumption of a constant and a time-varying mean. Table 7 presents the estimated measures of inflation in both cases. It can be seen form there that estimated persistence falls significanly once a time-varying mean is considered. , it is important to stress, however, that the high degree of persistence obtained when we consider a constant mean is probably due to the strong increase in the price level induced by the devaluation of January 2002.

Table 7

	Inflation Persistence Period 1993:1-2007:2	
	No change in mean	*Changes in mean*
ρ	0.70	0.18
hcse	(0.207)	(0.082)
	(1 lag)	(1 lag)

Finally, when we try to identify the presence of changes in the autoregressive coefficient of the inflation process associated to the monetary regime change (see Equation 9) by incorporating multiplicative dummies as in subsection 6.1., we find a low level of inflation persistence during the Convertibility period (0.15) and a significant increase after the adoption of a managed float (0.27).[11] Where d3 corresponds to a dummy variable for the period 2002:1-2007:2

$$\begin{array}{llll} z_t = & +0.1493\, z_{t-1} & + 0.2636\, z_{t-1}\, d3 & - 0.1437\, Dz_{t-1}\, d3 \\ \text{HCSE} & [0.0688] & [0.1157] & [0.0755] \\ & +0.01148\, d951 & + \text{dummy variables for 2002 crises} & \\ \text{HCSE} & [0.0003] & & \end{array} \tag{9}$$

To sum up, the results of considering the "low inflation" period separately indicate a change in the inflation process, in terms of both mean persistence, associated to the adoption of a new monetary regime in January 2002.

7 Frequency-domain analysis of the CPI and its disaggregated sub-indexes

In this section we adopt a frequency-domain perspective to analyze inflation persistence. We look not only at the CPI overall index, but to its 9 sub-indexes[12] (and some of its components) also, with the aim of investigating persistence and its heterogeneity at the sectoral level. This analysis is a first step in studying the effects of aggregation on persistence measurement (see in this respect Altissimo et al., 2004).

The use of frequency-domain methods to study inflation dynamics is justified on the grounds that they provide a direct assessment of the incidence that the components at different frequencies of a time series have over

[11] Where d3 corresponds to a dummy variable for the period 2002:1-2007:2.

[12] According to the 1-digit classification adopted by the national statistical institute, INDEC.

the dynamics of this series. Considering that the height of the spectrum at frequency zero is a non-parametric measure of the persistence of a time series,[13] this approach can be used to support the results obtained through the more traditional time-domain approach adopted in the previous sections. But this would provide little additional information. The "added value" of spectral analysis in our case lies in the possibility it provides to compare –by looking at, for instance, the shape of the spectrum– the importance of the low-frequency components (the "persistent" components) relative to the high-frequency ones (seasonal, transitory or highly volatile components) in the CPI sub-indexes' changes through time.[14] This will enable us to perform a richer analysis in the comparison of the price dynamics along different monetary regimes, one of the goals of the previous sections.

No matter what the actual absolute measure of inflation persistence is, it is possible to characterize monetary regimes according to the relative importance of the low- and high-frequency components of price movements during those regimes in order to assess their relative persistence (and other dynamic features). We estimated the spectra for the 13 series corresponding to the overall index, its 9 sub-indexes, and the three groups that make up the Food & beverages sub-index for the periods January of 1993 through December 2001 and January 2002 through December 2006, as representing the Convertibility[15] and post-Convertibility regimes respectively.

Before performing spectral analysis, one needs to verify that the series to analyze are covariance-stationary. We applied unit root tests[16] over the 13 series along both periods (see Table 8 below), where the null corresponds to the hypothesis of existence of a unit root in the series. It can be inferred that none of the series contains a unit root during the post-Convertibility period as the null is rejected at the 1% significance level in all but two cases (in which it is rejected at the 5% level), offering evidence of covariance-

[13] Moreover, it can be shown that, for an AR(p) process, this measure represents a monotonic transformation of the sum of its autoregressive coefficients, a commonly used measure of persistence.

[14] From a strictly theoretical point of view, any covariance-stationary process has both a time-domain and a frequency-domain representation, and there is no feature of the data that can be described by one of these representations but not by the other (Hamilton, 1994). Some features, however, may be more easily described (and estimated, in some cases) by one of the representations while others are more adequately described by the other.

[15] Though the Convertibility regime formally begins in April 1991, we take only the sub-sample of this period that begins in January 1993 because we consider it a "normal" period, in the sense that the high-inflation inertia inherited from the 1989/90 hyperinflation appears to have ended by 1993.

[16] Corresponding to the augmented Dickey-Fuller test modified by Elliott, Rothenberg and Stock (1996) to improve power when an unknown mean or trend is present (Capistrán and Ramos-Francia, 2006). The number of lags was selected according to the Schwartz information criterion (SIC), with a maximum lag length of 12.

stationarity in these series.

Table 8: DF GLS Unit Root test[a]

CPI sub-index	1993-2001		2002-2006	
	t-statistic[b]	lags	t-statistic[b]	lags
Overall index	-8.29***	0	-3.33***	0
Food and beverages	-6.94***	0	-3.38***	0
Food at home	-6.46***	0	-3.50***	0
Beverages at home	-6.67***	0	-2.93***	0
Food and Beverages outside home	-2.43	2	-2.89***	1
Clothing	-2.76***	11	-2.20**	6
Housing and utilities	-2.51	3	-5.34***	0
Household equipment and maintenance	-4.54***	1	-3.06***	0
Medical care and health expenses	-8.77***	1	-5.18***	0
Transport and communication	-9.36***	0	-3.11***	3
Leisure and entertainment	-2.04	11	-2.18**	6
Education	-4.15***	12	-6.47***	0
Other goods and services	-7.15***	0	-4.33***	0

Notes:

a) Dickey-Fuller GLS (Elliott, Rothemberg and Stock) test over the m/m % price changes, with a maximum of 12 lags

b) *: 10% significance level (sl), **: 5% sl, ***: 1% sl.

For the previous period, however, the evidence of stationary is strong for all but the price changes of 3 sub-indexes:[17] Food and Beverages outside home, Housing and utilities, and Leisure and entertainment. In the first two cases, the evidence in favor of the presence of a unit root is not very conclusive as the estimated t-statistics are not far from the 10% threshold (-2.73) and, perhaps more importantly, the ADF unit root tests (not modified by Elliott-Rothenberg-Stock) performed over these two series reject the null at the 1% significance level. Whereas this can not be strictly taken as proof of stationarity for these series (after all, we favored the Dickey-Fuller GLS test in the analysis), we estimate their spectra as if they were really stationary, so some caution needs to be taken in the interpretation of their results. In the case of Leisure and entertainment, the ADF test also supports the hypothesis of the presence of a unit root, so we consider this series as not stationary and the resulting estimated spectrum is not shown below.

[17] In the case of Education, it could be thought that the rejection of the null may in part be forced by the constraint imposed on the maximum lag length (12). However, these 12 lags were indeed the optimal lag length selected by the SIC when the maximum was increased to 14.

Figures[18] 7a and 7b show the estimated spectra[19] for the 12 resulting series of monthly rates of change in prices for both regimes.[20] In the first of these graphs, the two spectra (one per regime) for each single variable are graphed against the same vertical axis to facilitate the comparison of the spectra heights between regimes. Figure 7b adds a secondary vertical axis to enable a better reading of the spectra shapes. Some observations regarding inflation dynamics emerge from inspecting these graphs.

In the first place, price volatility seems to be much higher in the more recent period according to the spectra height in most cases. This is particularly true for the overall index and for all those sub-indexes whose price changes show no strong seasonality (Food and Beverages, Housing and utilities, Household equipment and maintenance, Other goods and services). Where the presence of seasonality (according to the peaks at the frequencies corresponding to 3-, 4- and 6-months periodicity, for instance) seems to be more important in the explanation of price dynamics (the remainder sub-indexes), the difference becomes less significant. Transport and communication is a limit case of the latter, as it is not apparent at all in which period its total variability is higher.

As a second feature, persistent (low-frequency) components seem to be relatively much more important than volatile (high-frequency) components in the spectral decomposition of price dynamics during the post-Convertibility regime. In particular, the low-frequency components of certain goods' price changes with a high weight in the CPI basket –notably, Food and beverages and Clothing– significantly increased their importance relative to higher-frequency components, displaying quite a different dynamic pattern (one in which price movements are much more persistent). This change in the dynamic pattern is transferred to the overall inflation, in which the importance of the components corresponding to 3- to 6-month periodicity in explaining inflation dynamics decreases substantially during the second regime. The importance on driving this results of the common

[18] Along all this section, the graphs' x-axis for each of the estimated spectrum indicates the frequency (periodicity) from 0 to π. Since the analyzed series have monthly frequency, π corresponds to a 2-month periodicity, $2\pi/3$ to a 3-months periodicity, $\pi/3$ to a 6-month periodicity, and so on. The corresponding y-axis indicates the spectral density at each frequency. As the area under the population spectrum of a series between $-\pi$ and $+\pi$ equals its variance (the graph is adapted so that all the variance is contained in the area from 0 to π, though) the y-coordinate at each frequency measures the relative contribution of the component at that frequency to the series' total variance.

[19] The spectra are estimated using the Thompson's Multitaper Method (MTM) in MATLAB. This a non-parametric estimation method that relies on a non-linear combination of modified periodograms, computed using a sequence of orthogonal windows in the frequency domain (see Percival and Walden, 1993). It improves the results over more traditional methods –such as periodograms– that use rectangular windows.

[20] It is important to consider that the shorter length of time for the post-Convertibility period may make estimations for this period less accurate.

shock to sectoral inflation implied by devaluation of the peso in January 2002 is being investigated with more detail in a companion paper.

Thirdly, the seasonal peaks at 3- and 6-months (eventually, yearly) periodicities remain quite the same only for the sub-index corresponding to Clothing, but becomes more diffuse in the cases of Education and, more remarkably, Transport and communication (which loses its seasonality during the second period).

Lastly, at this level of desaggregation the shape of the spectrum of sectoral inflation rates does not differ significantly from the aggregate. The weight of low frequency (less volatile) components in the total volatility seems to have increased for both aggregate and sectoral CPI, after the adoption of a managed float.

Figure 7a

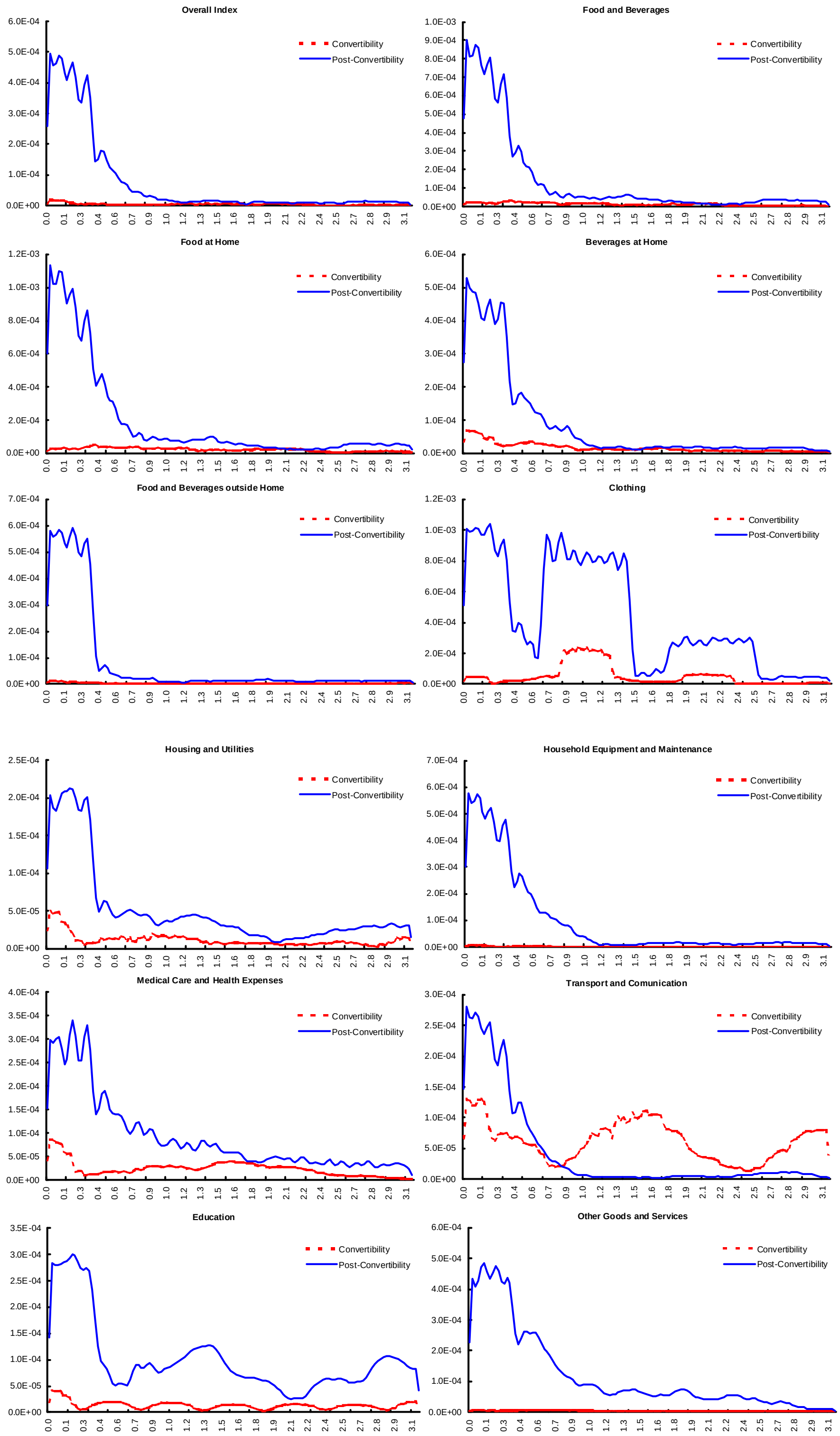
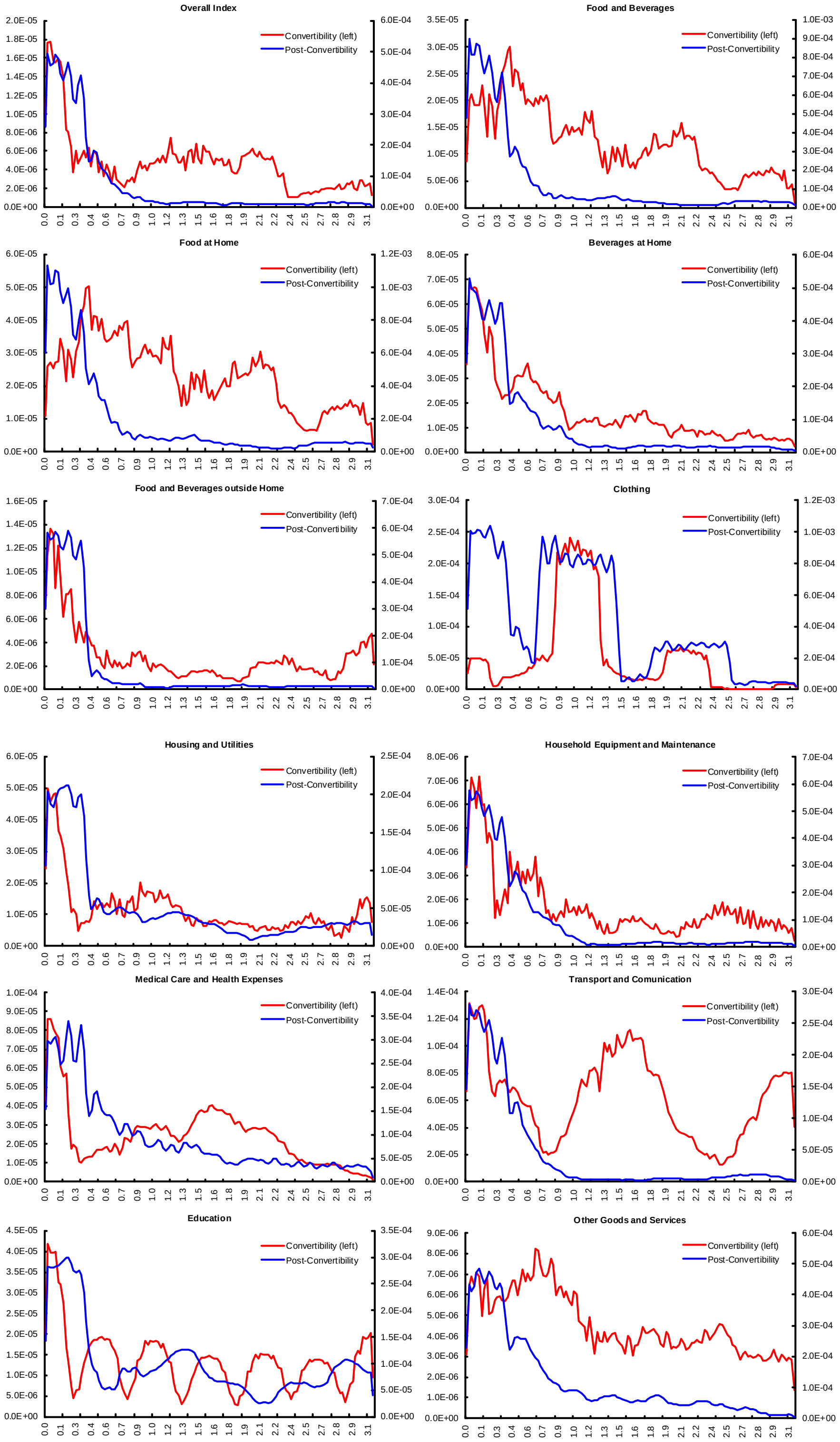

Overall Index
Food and Beverages
Food at Home
Beverages at Home
Food and Beverages outside Home
Clothing
Housing and Utilities
Household Equipment and Maintenance
Medical Care and Health Expenses
Transport and Comunication
Education
Other Goods and Services
Convertibility
Post-Convertibility

Figure 7b



Overall Index
Convertibility (left)
Post-Convertibility
Food and Beverages
Convertibility (left)
Post-Convertibility
Food at Home
Convertibility (left)
Post-Convertibility
Beverages at Home
Convertibility (left)
Post-Convertibility
Food and Beverages outside Home
Convertibility (left)
Post-Convertibility
Clothing
Convertibility (left)
Post-Convertibility
Housing and Utilities
Convertibility (left)
Post-Convertibility
Household Equipment and Maintenance
Convertibility (left)
Post-Convertibility
Medical Care and Health Expenses
Convertibility (left)
Post-Convertibility
Transport and Comunication
Convertibility (left)
Post-Convertibility
Education
Convertibility (left)
Post-Convertibility
Other Goods and Services
Convertibility (left)
Post-Convertibility

8 Conclusions

Recent empirical evidence has shown that changes in the persistence of inflation are related to monetary regime shifts. These studies also revealed the importance of considering the possibility of a non-constant long run equilibrium level that allows for breaks in the mean of inflation. These empirical studies also show that the inflation processes in most countries seem to have changed with the lowering of inflation worldwide. In particular there is evidence that inflation has become much less persistent.

The historical behavior of inflation in Argentina suggests that modeling inflation dynamics is not an easy task. Structural breaks make it quite difficult to obtain a unique model for the whole period. Inflation was very high during the 80's, a period in which monetary policy was rather exogenous determined due to persistent fiscal desequilibria. This high inflation period ended in a hyperinflation episode after which a currency board regime was adopted. Under this regime monetary policy was passive and the dynamics of inflation was, to a great, extent exogenously driven. Inflation remained at very low levels during this period which ended with the abandonment of Convertibility regime in January 2002. Following the sharp devaluation of the peso, which lead to a dramatic change in relative prices, inflation raised, reaching a peak in April 2002. It then returned to lower levels, although a bit highers than those of Convertibility period.

In this context, we study the issue of inflation persistence in Argentina from two perspectives: univariate time-series and disaggregate frequency-domain analysis of the Consumer Price Index (CPI) inflation.

We are able to identify significant changes in mean and persistence of inflation in Argentina during the period 1980-2007. Breaks in mean inflation are clearly related to regime shifts: the hyperinflation period in 1989, when the whole sample is considered; and the abandonment of the Convertibility regime in 2002, when we analyze the low inflation period separately.

Given the presence of breaks we differentiate inflation with respect to a time varying mean to measure persistence. Only by subtracting a time varying mean to inflation the estimated persistence decreases significantly.

We find that inflation was highly persistent during the high inflation period, but strongly declined when inflation lowered after the adoption of Convertibility regime in 1991. Then it increased slightly after the adoption of a managed float in 2002.

Regarding the comparison between inflation dynamics during the Convertibility and post-Convertibility regimes, frequency-domain analysis provided us with some interesting insights. Overall volatility in prices is significantly higher in the recent period, though the contribution of high-frequency (temporary and seasonal) movements to this volatility was relatively more important during the Convertibility regime. That said, persistence is key to explain price dynamics during the post-Convertibility regime, while that was not necessarily the case in the previous period.

Summing up, we find that in line with the empirical evidence changes in persistence in Argentina are related to monetary regime changes.

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