# Regimes and Underlying Inflation Dynamics: Generalized Comovement or Relative Price Adjustment?

Tomás Castagnino and Laura D'Amato*

## 1. INTRODUCTION

Inflation is usually defined as a generalized and persistent increase in the price level. The scope of this notion seems to be restricted to à la Cagan high inflations of a monetary origin, in which absolute price adjustment prevails. It is not obvious, however, that inflation dynamics is always dominated by a strong comovement in sectoral prices, or that absolute price changes prevail over relative price adjustments. Even more, according to the empirical evidence in the literature (see Reis and Watson, 2007) in normal times, when inflation remains at relatively low levels, temporary movements in relative prices account for a high portion of inflation variability, because inflation does not follow a trend but has instead erratic movements that on average tend to cancel out. Under high inflation, the presence of a trend in aggregate inflation would reflect a higher importance of the common component in price variations. That is, more comovement in price adjustments, which not necessarily implies the absence of persistent or medium-term relative price adjustments under

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high-inflation contexts (Reis and Watson, 2007, and Castagnino and D'Amato, 2008).

Inflation is the result of multiple price decisions in response to changes in costs of production, demand conditions and economic policy signals. The type of response to these impulses depends on the environment in which agents make their price decisions. Inflation dynamics is, in this sense, *regime specific* since it depends on the way that economic policy, in general, and monetary policy, in particular, operate.

The dependence of inflation dynamics on the monetary regime was first noted by Fisher (1982), who emphasized that loose monetary policies could have perpetuated the effects of supply shocks in the United States case during the 1970s. More recently, Ball and Mankiw (1995) also discussed how sectoral price adjustment distribution could be influenced by the inflationary environment.

However, the notion of regime has remained fairly vague in the literature probably because it is an *unobservable* related to institutional factors that define a framework for the interactions between economic policy and private agents, influencing their expectations and decision-making. We begin by identifying regimes based on the outcomes of these interactions. In particular, we assume that the trend inflation prevailing in an economy can be considered as a proxy for the prevailing monetary regime.[1] From an empirical perspective, the recent empirical literature on inflation persistence provides evidence that changes in trend inflation are associated to changes on the monetary regime.[2]

However, the use of trend inflation as a criterion to identify regimes leaves aside an important feature of inflation behavior: The sectoral price adjustment dynamics behind a given trend inflation. On the one hand, in terms of the underlying relative price dynamics, a regime may precede its manifestation when a shock occurs. On the other hand, the prevalent dynamics is not necessarily the same in the different economies. In small open economies, frequently subject to external disequilibria, macroeconomic policy itself may be an important source of relative price variability, usually through currency devaluations that aim at correcting disequilibria in the real exchange rate. In this regard, the tradable-non tradable price

[1] See in this respect Kiley (2006), Blake and Fernández-Corugedo (2006), and Ascari and Ropele (2007), among others.

[2] See, for example, Levin and Pigier (2004), Altissimo et al., Mojon and Zaffaroni (2004), Altissimo et al. (2006) and Angeloni et al. (2006) and D'Amato et al. (2007) for the Argentine case.

dynamics can be relevant to explain inflation behavior in emerging countries, unlike industrial economies where the shocks to energy and food prices seem to prevail. In both cases, it is interesting to study how the pass-through of aggregate shocks of different nature to inflation may change in terms of its generalization and persistence, depending on the inflationary environment.

We study inflation dynamics and its relation with the monetary regime in Argentina and the United States over the last 50 years. Over this period both countries experienced high, moderate and low inflation. The differences in size and development between both economies are quite significant, as well as the in the type of aggregate shock to which they were typically subject to. In the United States, shocks to energy and food prices hit the economy in the 1970s and 1980s, while in Argentina, policy shocks, usually in the form of exchange rate adjustment aiming at correcting external imbalances or stabilizing inflation, prevailed.

Our purpose is to study to what extent inflation dynamics may change depending on the inflationary environment and the nature of shocks. In Section 2 we identify regimes using the Bai-Perron test (2003). In Section 3, we characterize regimes by studying the differences in the comovement induced by aggregate shocks to sectoral inflation rates under different inflationary environments. In Section 4, we use frequency-domain analysis to identify sectoral patterns in the responses to aggregate shocks. Finally, Section 5 concludes.

## 2. INFLATION REGIMES: A FIRST APPROXIMATION USING THE BAI-PERRON TEST

We identify regime changes trough breaks in trend inflation, which in this context is considered a proxy of the regime, using the Bai-Perron test. In Table 1 we present the trend inflation rates corresponding to the different regimes identified in Argentina and the USA.

In the case of the USA, we identify a low inflation regime between 1961 and 1967, a moderate inflation regime between 1967 and 1972, and one of high inflation between 1974 and 1981. As stressed by De Long (1995) and Sargent (1999), the persistent intends by policy makers to exploit the inflation-unemployment trade-off over these years created an inflationary environment, in which the successive oil shocks that hit industrialized economies between 1974 and 1981, led to a high trend inflation in the

USA.[3] This period was followed by a disinflation between 1982 and 1990 under Volker's administration of the Federal Reserve. The last period, 1991-2007, can be considered as a low inflation regime in which the Fed was successful in maintaining inflation under control, despite the shocks to food and energy prices that prevailed since 1999.

**TABLE 1.** MONETARY REGIMES AND TREND INFLATION: ARGENTINA AND UNITED STATES, 1960-2007

| *Argentina* | | *United States* | |
|---|---|---|---|
| *Regime* | *Monthly CPI inflation (mean)* | *Regime* | *Monthly CPI inflation (mean)* |
| Moderate inflation 1961m01-1974m12 | 2.09 | Low inflation 1960m01-1966m12 | 0.13 |
| High inflation 1976m07-1982m06 | 6.08 | Moderate inflation 1967m01-1972m12 | 0.32 |
| Very high inflation 1982m07-1988m06 | 9.74 | High inflation 1974m01-1981m12 | 0.47 |
| Low inflation 1993m01-2001m12 | 0.04 | Disinflation 1982m01-1990m12 | 0.32 |
| Low-moderate inflation 2003m01-2006m12 | 0.67 | Low inflation 1991m01-2007m12 | 0.18 |

In Argentina, regime changes frequently appear associated to *i)* sharp devaluations of the currency, following an external or financial crises or *ii)* the implementation of stabilization programs based on the use of the nominal exchange rate as an anchor for inflation. We identify a moderate inflation regime between 1961 and 1974, a high inflation period between 1976 and 1981 and a very high inflation regime between 1982 and 1988. This last regime ended up in two hyperinflationary episodes in 1989 and 1990. Leaving aside both, the hyperinflations episodes and the disinflation following the implementation of a currency board regime known as the *Convertibilidad* (the period between 1991m4 and 1992m12), we identify a low inflation regime between 1993 and 2006. When this last period is considered separately, it is possible to identify two regimes: one of very low inflation corresponding to the Convertibility regime (1993-2001) and a moderate-low inflation period between 2003 and 2006, after a sharp devaluation of the currency in 2002 and the adoption of a managed float.

[3] We deliberately exclude the observations corresponding to 1973 from the high inflation period, due to the strong impact of the first oil stock that took place on this year on the dynamics of USA inflation, what could distort the results for this period.

A salient feature of Table 1 is the sharp difference in trend inflation between Argentina and the United States, especially in the moderate and high inflation regimes. It is also worth noting that trend inflation in the low inflation regime in Argentina is considerably lower than that of the United States (0.04% vs. 0.18%), that can be explained by the fact that Argentina experienced a deflation during part of this period, whereas in the USA inflation does not follow any trend. This suggests that the underlying inflation dynamics could be different between this two economies.

Although both economies are very different in size and economic development, what shows up in the very different composition of their consumption baskets, the comparison between Argentina and the United States is especially interesting because of the different nature of the shocks that contributed to explain inflation dynamics in both countries: In the United States, the shocks to food and energy prices have been an important source of innovations to the inflation rate while in Argentina, as in other emerging economies, policy shocks seem to have prevailed.

Table 2 clearly illustrates such difference by comparing food and energy CPI inflation versus non-food and energy CPI inflation across the different regimes in both countries. In the USA, food and energy inflation exceeds non-food and energy inflation in both high and low inflation regimes, when shocks to these items occur. Instead, in Argentina, inflation dynamics could hardly be explained by those shocks. The dimension of the inflationary phenomenon suggests that other forces, probably of domestic origin, must explain the very high inflation rates observed in those years and their further decline.

**TABLE 2.** INFLATION: FOOD AND ENERGY, AND OTHERS COMPONENTS IN ARGENTINA AND UNITED STATES, 1960-2007

| *Argentina* | | | *United States* | | |
|---|---|---|---|---|---|
| *Regime* | *Food and energy (%)* | *Others (%)* | *Regime* | *Food and energy (%)* | *Others (%)* |
| Moderate inflation 1961m01-1974m12 | 1.99 | 2.14 | Low inflation 1960m01-1966m12 | 0.12 | 0.14 |
| High inflation 1976m07-1982m06 | 6.11 | 6.04 | Moderate inflation 1967m01-1972m12 | 0.28 | 0.34 |
| Very high inflation 1982m07-1988m06 | 9.58 | 9.81 | High inflation 1974m01-1981m12 | 0.51 | 0.45 |
| Low inflation 1993m01-2001m12 | 0.02 | 0.04 | Disinflation 1982m01-1990m12 | 0.26 | 0.33 |
| Low-moderate inflation 2003m01-2006m12 | 0.54 | 0.72 | Low inflation 1991m01-2007m12 | 0.22 | 0.16 |

## 3. INFLATION REGIMES AND COMOVEMENT

Inflation regimes can also be described by the pass-through of shocks to the inflation rate and also by the predominance of some sort of aggregate shock. For example, in a high inflation environment, such as it was the case of Argentina by the end of the 1980s, the behavior of money and prices should be mostly driven by inflation expectations. In this environment, a strong comovement in sectoral inflations should prevail. On the contrary, in low inflation environments, idiosyncratic price movements should predominate, with scarce trend comovement across sectoral inflation rates. This suggests that sectoral responses to shocks may differ, depending on the regime and also on the predominant type of shock.

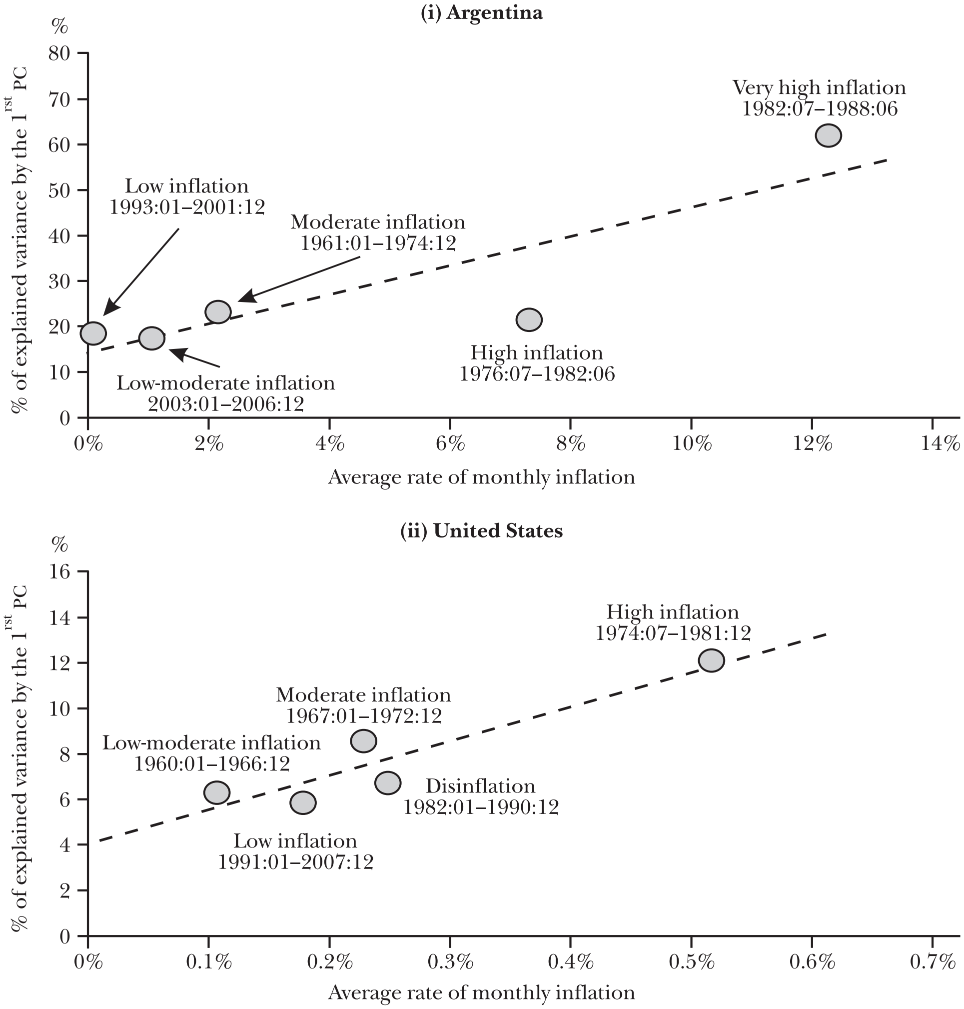
To look into these differences, we consider a measure of the joint response of sectoral inflations to aggregate shocks, given by the portion of the joint variance of sectoral inflation rates explained by the first principal component of CPI inflation.[4] A high portion of these variance explained by the first component indicates a high comovement in sectoral inflation rates. We expect the occurrence of aggregate shocks to induce a higher comovement, resulting in an increase in the variance explained by the first principal component. Our intuition suggests that the persistence of the comovement induced by the shocks may vary according to the inflationary environment.

The cross-plots in Figure 1 show the relation between trend inflation and the portion of variance explained by the first principal component of inflation for Argentina and the United States. Though the differences in the magnitude of trend inflation between Argentina and the United States under high inflation are quite significant, as it is also the case for the portion explained by the first principal component, a common feature of both economies is that as trend inflation increases, the portion of variance explained by the first principal component also increases, reflecting an growing comovement across sectoral inflation rates. Thus, it seems that in high inflation environments the comovement across sectoral inflations is high and tends to prevail over idiosyncratic movements.

To study the pass-through of aggregate shocks to the sectoral inflation rates and the degree of comovement they create under different environments, we construct three estimators: *i)* a recursive estimator whose

[4] See Appendix 1 for a detailed description of the sectoral CPI inflation series used for the cases of Argentina and the United States, and Appendix 2 for a description of the methodology employed to estimate the common shocks.

**FIGURE 1.** TREND INFLATION AND PROPORTION OF EXPLAINED VARIANCE BY THE FIRST PRINCIPAL COMPONENT OF INFLATION

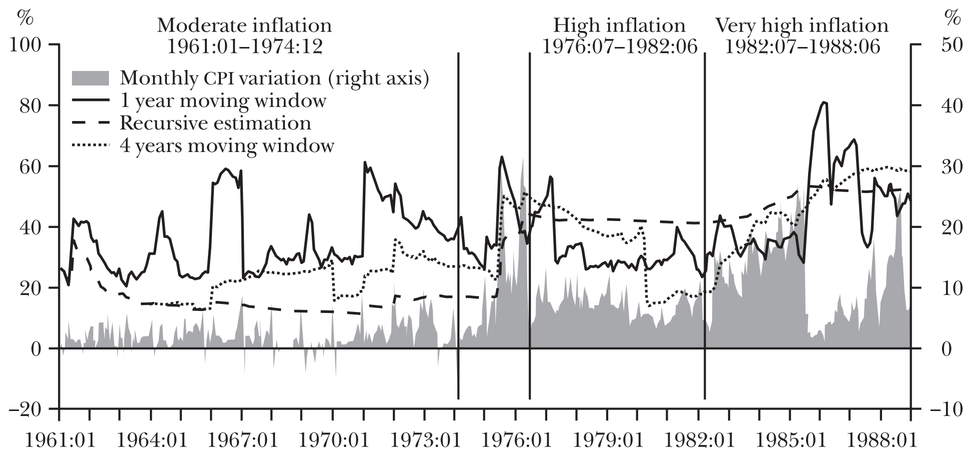



calculation starts a year before the initial observation of the sample which is recalculated as more observations are added, *ii)* a four-year rolling window and *iii)* a one-year rolling window.

Figures 2 to 5 show the evolution of the inflation rate in the different regimes, together with the three estimators of the common shocks.

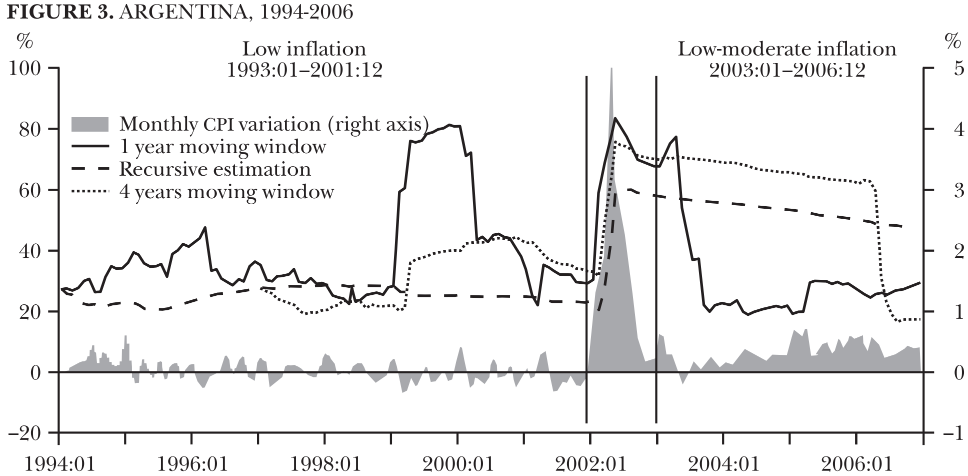
As can be seen from the Figures 2-5, the one-year rolling window allows identifying shocks of such magnitude as to generate a strong comovement, even temporarily. These shocks reflect in peaks in the variance

**FIGURE 2.** ARGENTINA, 1960-1988




explained by the first principal component, giving evidence of a generalized comovement in sectoral inflation rates. This seems to be consistent with the arguments of Sheshinski and Weiss (1977) and Dotsey et al. (1999), who suggest that sudden and significant changes in market conditions generate coordination in price adjustments.

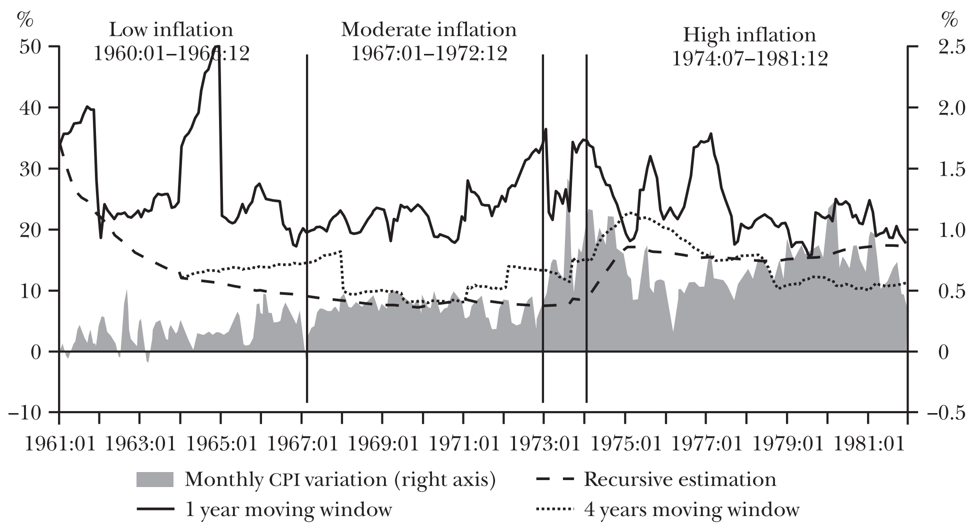
**FIGURE 3.** ARGENTINA, 1994-2006




When identifying the events related to these peaks, the sources of comovement are quite different between the two economies: In the United States, there is a clear predominance of shocks to food and energy prices as main source of inflation variability (see the peaks in 1973, 1979, 1987, 1991, 1999, 2001, 2004 and 2007).[5,6]

In Argentina the peaks are clearly related to depreciation episodes, usually preceded by periods or real appreciation of the currency as in 1961, 1964, 1966, 1969, 1971, and 1975.

**FIGURE 4. UNITED STATES**, 1961-1981



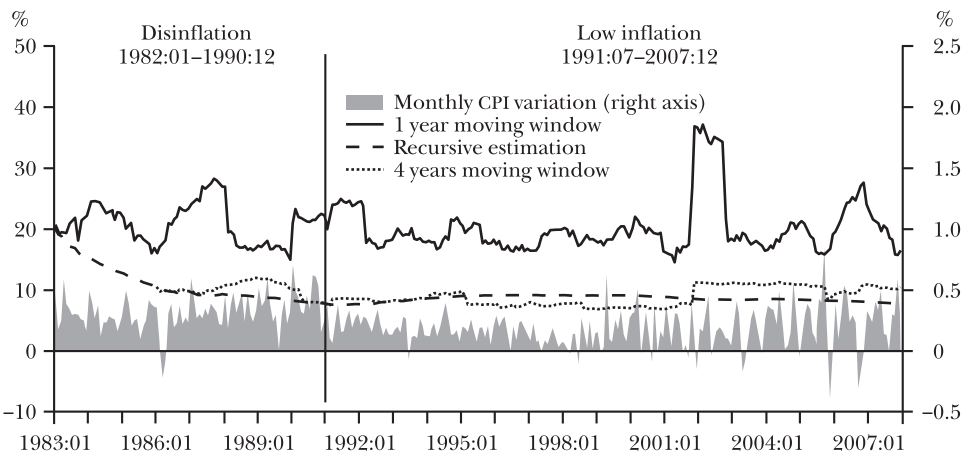

The recursive estimation and the four-year rolling window reveal the differences across regimes in terms of the persistence of the comovement induced by aggregate shocks on the sectoral inflation rates. In the United States the shocks to energy prices predominate as a source of inflation variability in both regimes (high and low inflation), but their impact under high inflation was clearly persistent, as shown by the recursive estimation of the variance explained by the first principal component. On the contrary, under low inflation, the oil price increase in 1999 and the subsequent shocks to energy and food prices seem to have had only a temporary effect on inflation. In other words, unlike the high inflation regime, in the recent low inflation regime these shocks have only caused a temporary comovement in sectoral inflation rates.

[5] See in this respect De Gregorio et al. (2007).

[6] A peak of great magnitude can also be observed in 1964, which could be associated to the beginning of the Vietnam War. The following peak, in 1971, corresponds to the moment when the United States announced the abandonment of the gold standard.

In the case of Argentina, we can clearly see how the transition towards a higher trend inflation comes together with an increasing persistence of the comovement among the sectoral inflation rates driven by aggregate shocks (see Figure 2). Likewise, in a low and stable inflation environment as from the adoption of the Convertibility regime, the aggregate shocks seem to have had a more transitory effect on inflation (see Figure 3).

**FIGURE 5.** UNITED STATES, 1991-2006




Shocks to the exchange rate prevailed in Argentina during the moderate and high inflation regimes. Their impact seems to have been quite transitory under the moderate inflation regime and more long-lasting under high inflation. In 1975, the *Rodrigazo* inflationary episode, which resulted in a change of regime in terms of the trend inflation (see Table 1), had a permanent effect on inflation dynamics in terms of the portion of the variance explained by the first principal component, which increased from 20% to over 40% remaining at around that level for a long period. An unstable money demand governed by inflation expectations and a persistent flight towards a reserve currency, gave the features of an inflationary process à la Cagan to the money-inflation dynamics over these years.[7] The increasing trend of inflation as from that moment was accompanied by an also growing comovement in sectoral inflations, as shown by the recursive estimation.

[7] See in this respect Basco, D'Amato and Garegnani (2009).

As illustrated in Figure 3, the transition towards a low inflation regime, with the adoption of a currency board, considerably reduced sectoral inflation comovement. Also it seems that in a low inflation environment, the effects of aggregate shocks became less persistent. In this regard, the impact of the devaluation episode of January 2002 was restricted and temporary, both on the CPI inflation rate and on the comovement across sectoral inflation rates, if compared to the effect of currency devaluations in the high inflation regimes.[8]

Summing up, previous results suggest that inflation regimes are different not only in terms of the prevalent trend inflation but also in terms the inflation dynamics induced by aggregate shocks: In high inflation environments the comovement generated by aggregate shocks is higher and tends to perpetuate. The transition from moderate towards high inflation regimes is not immediate. Rather, it seems to develop fairly slowly. Although these features seem to be common to both economies, the differences in the level of inflation among them are so important as to require a deeper insight into the causes of such differences. With this purpose, we go deeper in the next section in analyzing the sectoral responses to aggregate shocks.

## 4. COMOVEMENT AND SECTORAL PATTERS BEHIND INFLATION DYNAMICS

Price formation in each sector can be decomposed into a response to a common macro-economic shock, the first principal component of inflation, which is assumed to be driven by unobservable underlying forces (such as supply or demand shocks to which all sectors are exposed) and an idiosyncratic component that reflects sectors' heterogeneity in terms of demand, technology, climate factors, etc. Thus, each $i$ sector' inflation dynamics can be written as

$$\pi_{it} = \lambda_i(L)U_t + \varepsilon_{it}, \tag{1}$$

where $U_t = (u_t, u_{t-1}, ..., u_{t-q})$ is a vector of the common shock and its relevant lags, $\lambda_i(L)$ is the response of sector $i$ to the common shock and $\varepsilon_{it}$ is the idiosyncratic component of sectoral inflation. Note that the sectoral responses to common shocks are not necessarily the same: The

[8] See in this respect Burstein et al. (2005), who investigate the causes of the limited pass-through of the currency devaluation in January 2002 to the CPI inflation.

higher the dispersion between the lag polynomials $\lambda_i(L)$, the higher the heterogeneity.

Likewise, the way in which a common shock passes through could also vary according to the inflation regime. That is, the macroeconomic environment could influence price responses to aggregate shocks. As shown in Figure 4, in a high inflation environment the sectoral responses to the common shock [in terms of Equation 1, the lag polynomials $\lambda_i(L)$ ] would be more homogeneous and more asymmetrically distributed, reflecting the prevalence of positive changes in prices, leading to a more generalized comovement across sectoral inflation rates and a higher trend inflation.

On the contrary, when inflation is low, the distribution of sectoral responses to aggregate shocks should be more heterogeneous and, if there are no sizable relative price shocks and/or a significant persistence, there would probably be no remarkable patterns in the aggregate inflation trend. Instead, in the presence of relative price shocks of some magnitude, the conventional adjustment mechanisms would operate, resulting in responses of different sign to the common shock across the groups of sectors, though without influencing the inflation trend (because of compensations).

While common shocks have a persistent or long-run effect on inflation, idiosyncratic innovations are usually temporary. These latter movements in prices are not of great concern from the macroeconomic policy point of view, which is expected to react to generalized movements in prices that persist over time. To identify the different sources of variability in inflation, we resort to frequency-domain analysis, a useful tool that allows breaking down time series into periodic contributions to their variance, providing a more natural description of their behavior at different time horizons or frequencies (e.g., short and long-run). In the bivariate case, frequency-domain analysis allows to compute the covariance at specific frequencies.[9]

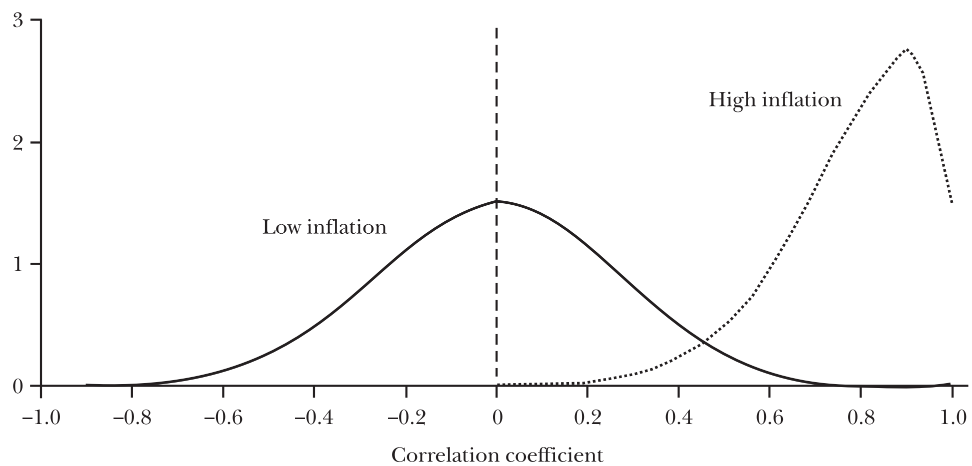
To find out to what extent sectoral responses to common shocks follow a specific pattern depending on the regime, we provide an approximate measure of the sectoral responses to the common shock, the polynomials $\lambda_i(L)$, by calculating the correlation coefficient between the first principal component of inflation and each individual inflation series at different time horizons. More specifically, we calculate correlation coefficients by frequency band according to

[9] Appendix 3 provides a more detailed description of this technique.

$$\rho(\omega_1,\omega_2)=\frac{Cov(\tilde{\pi}_i(\omega_1,\omega_2);\tilde{U}(\omega_1,\omega_2))}{\sqrt{Var(\tilde{\pi}_i(\omega_1,\omega_2))}\sqrt{Var(\tilde{U}(\omega_1,\omega_2))}}, \tag{2}$$

where $\tilde{\pi}_i(\omega_1,\omega_2)$ and $\tilde{U}(\omega_1,\omega_2)$ are frequency-band-specific time series extracted from data vectors, $\pi_i$ is sector $i$ inflation rate and $U$ is the first principal component of inflation,[10] and $Cov(\circ)$ and $Var(\circ)$ are the covariance and the variance of these time series, respectively.

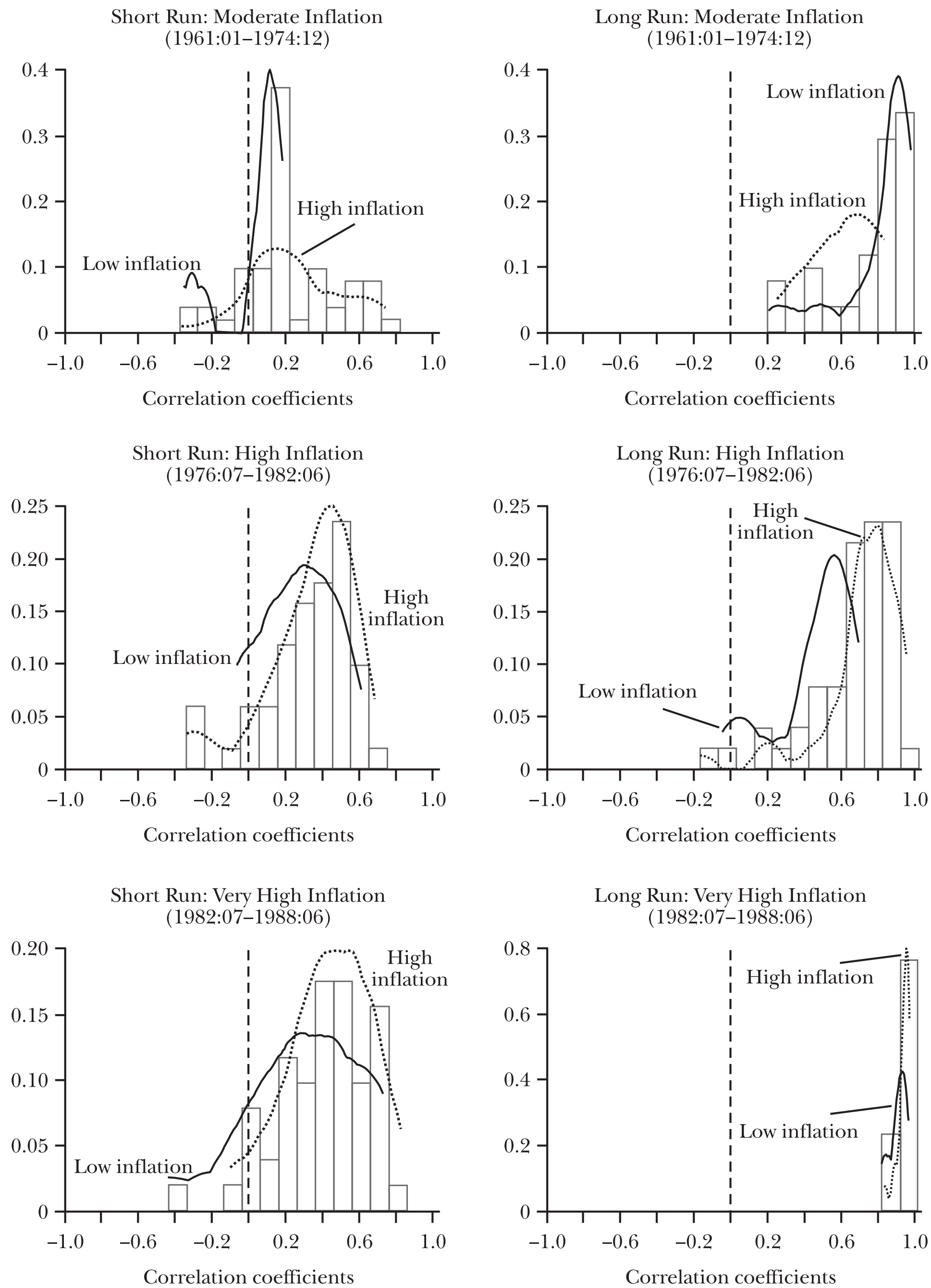
**FIGURE 6.** THEORETICAL FREQUENCIES DISTRIBUTION OF THE SECTORIAL INFLATION RESPONSES TO THE COMMON SHOCK

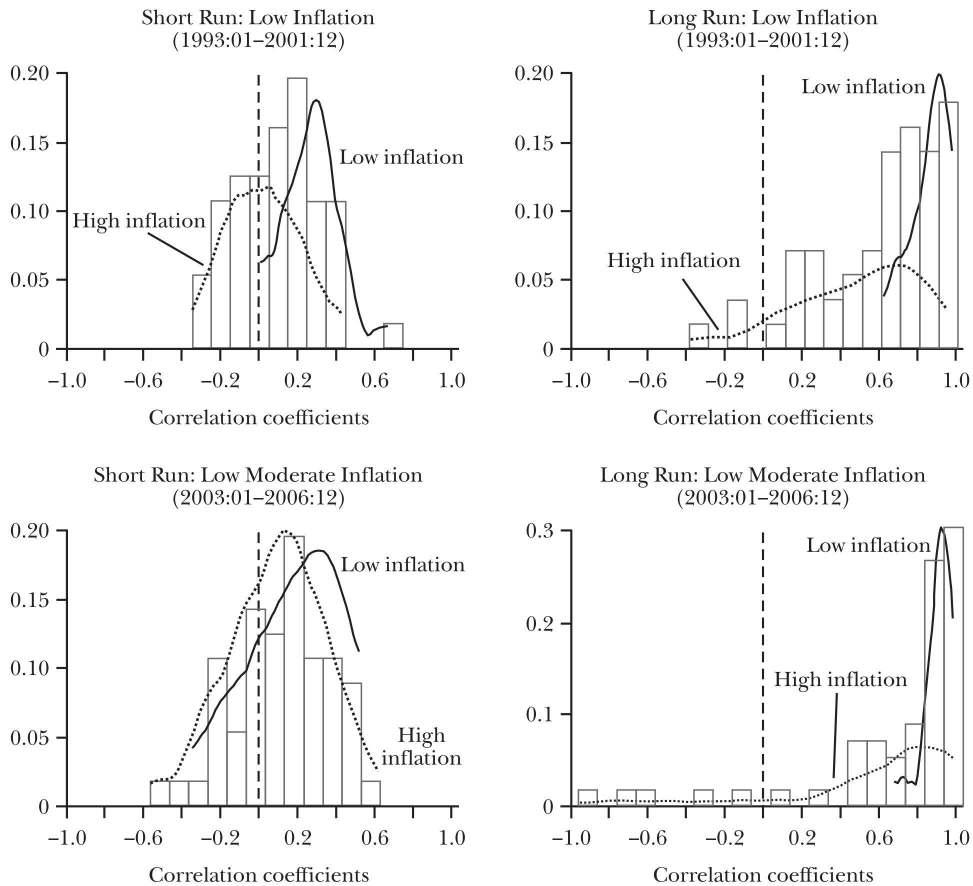



We consider two frequency bands: *Short-run* or high frequency (describing cycles shorter than three months) and *long-run* or low frequency (corresponding to cycles longer than two years). Figures 7 and 8 show the histograms of the estimated correlation coefficients between the first principal component of inflation and each individual time series in each of the regimes and for both countries. The shape of the histograms is informative about the strength of the comovement of the sectoral inflation rates with the common shock. On the one hand, the asymmetry of the distribution is an indication of comovement. If more frequency is concentrated on the right side of the histogram, sectors would be responding positively on average to the common shock. If it concentrates on the left side, then the opposite would be happening. If the histogram is centered, then sectoral responses would be offsetting themselves. On the other

[10] Appendix 4 describes in detail the filtering process in the frequency domain.

**FIGURE 7.** ARGENTINA – SECTORAL RESPONSES TO THE COMMON SHOCK, 1961-2001

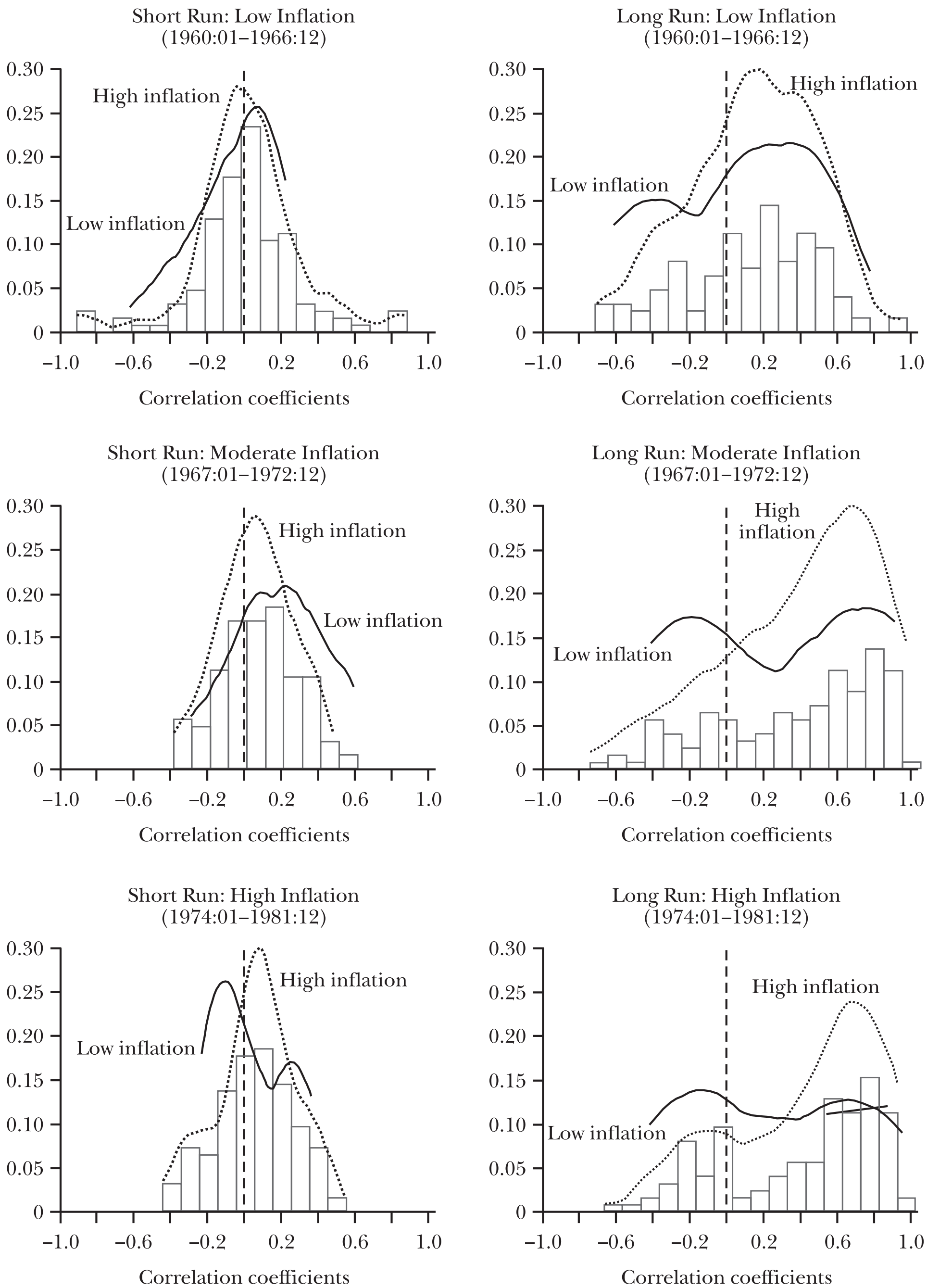


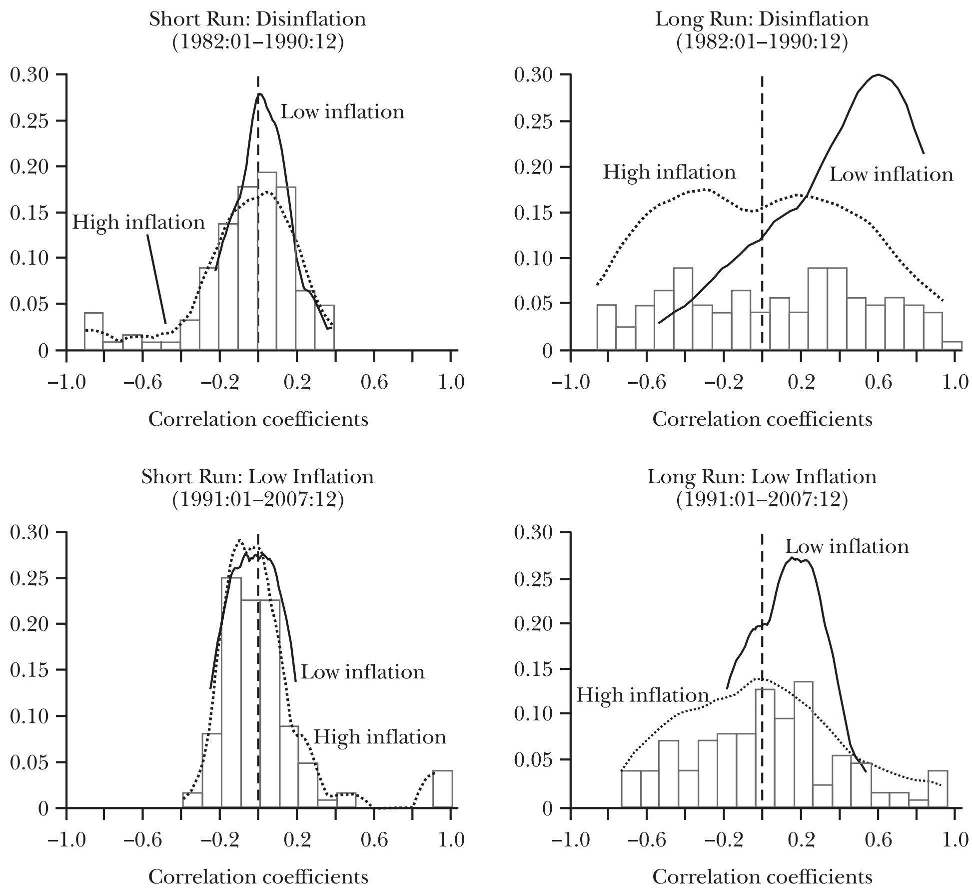



hand, the dispersion of the histogram indicates how generalized the comovement is. The lesser the dispersion, the more homogeneous the response of sectoral inflation rates to the aggregate shock.

Some features are common to both countries. In the short run the correlations are closer to zero on average, indicating a weak incidence of the common shock at this frequency. However, while in the case of the United States the distributions are centered in zero, in the Argentine case they are somewhat biased to the right. In this latter case, the aggregate shocks seem to induce a positive trend in sectoral inflation rates even in the short term. The higher inflation rates experienced by Argentina would explain such differences.

**FIGURE 8.** UNITED STATES – SECTORAL RESPONSES TO THE COMMON SHOCK, 1960-2007






As stated before, the particular characteristics of each regime are more clearly evident in the long run. In fact, at this frequency, the moderate to very high inflation regimes show a higher proportion of sectors comoving positively with the common shock. Likewise, in line with the evidence in the previous section, the higher the aggregate inflation rate, the sharper and more generalized the comovement. An extreme example in this regard is the very high inflation regime in the 1980s, when the distribution almost collapses in extreme values of correlation.

In turn, under the low inflation regimes (including the USA disinflation period), the short-run responses to shocks are even closer to zero on average (especially in the USA case), indicating an even lesser incidence of the common shocks on sectoral inflation rates. However, long-run responses have quite different patterns in both countries. While in the USA the sectoral responses are disperse and centered in zero, perfectly in line with what is expected in a low inflation period, Argentina departs strongly from that a priori, showing a positive and generalized comovement of sectoral inflation rates with the common shock.

The identification of sectoral patterns behind inflation dynamics helps to explain more accurately these features. As suggested above, shocks to the real exchange rate (RER) are an important source of CPI inflation variability for a small open like Argentina. In this regard, the distinction between tradable and non-tradable goods (whose relative prices may be considered a proxy of RER) seems to be adequate in this case. On the contrary, the distinction between the food and energy and non-food and energy seems to be more adequate for the United States, given the importance these shocks have historically had for the behavior of the headline inflation. Tables 3 and 4 show the long-run average responses for these groups of sectors in the different regimes and evaluate whether these responses are significantly different, using the Mann-Whitney rank-sum test. In addition, in Figures 7 and 8 we have overlapped to the histograms the estimation of the frequency distribution of the correlations with the common shocks for tradable versus non-tradable goods prices, in the case of Argentina, and food & energy versus non-food & energy components, in the case of the United States.[11]

As can be seen from Figures 7 and Table 3, in the Argentine case, the responses of tradable and non-tradable goods prices to common shocks are significantly different across all the regimes, thus confirming the importance of this relative price dynamics to explain the behavior of inflation in Argentina. Table 3 also reveals that mean responses to the aggregate shocks of the food and energy sectors versus the non-food and energy sectors are not significantly different for any of the regimes, what plays down the importance of this type of adjustment to explain the inflation dynamics in Argentina. This evidence is consistent with the poor performance exhibited by CPI inflation indices that exclude food and energy prices as indicators of core inflation for Argentina (see D'Amato et al., 2006). These findings reveal certain patterns in the importance of comovement vis-à-vis relative price adjustment to explain aggregate inflation dynamics across inflation regimes. Though we cannot precisely estimate how the relative importance of these two drivers of inflation dynamics varies

[11] To this effect, the Kernel non-parametric estimation technique is used.

**TABLE 3.** ARGENTINA: MANN-WHITNEY TEST FOR DIFFERENCES IN MEAN

| | *Argentina* | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | *Mean responses* | | *Statistic* | *p-value* | *Mean responses* | | *Statistic* | *p-value* |
| | *No tradables* | *Tradables* | | | *Food and energy* | *Other* | | |
| Moderate inflation 1961m01-1974m12 | 0.620 | 0.802 | 2.918[a] | 0.004 | 0.714 | 0.786 | 1.752 | 0.080 |
| High inflation 1976m07-1982m06 | 0.459 | 0.712 | 3.535[a] | 0.000 | 0.574 | 0.695 | 1.773 | 0.076 |
| Very high inflation 1982m07-1988m06 | 0.909 | 0.942 | 2.420[b] | 0.016 | 0.918 | 0.942 | 1.900 | 0.058 |
| Low inflation 1993m01-2001m12 | 0.640 | 0.595 | –4.768[a] | 0.000 | 0.600 | 0.615 | 0.190 | 0.850 |
| Low-moderate inflation 2003m01-2006m12 | 0.695 | 0.660 | –3.002[a] | 0.003 | 0.583 | 0.703 | 1.841 | 0.086 |

[a] significant at the 1% level; [b] significant at the 5% level.

across regimes, our findings suggest that the relative importance of comovement increases with trend inflation. In one extreme, in a very high inflation environment (Argentina during the 1980s) the tradable-non tradable adjustment seems to be less significant and a strong comovement across the sectoral inflation rates is the prevailing feature. In the intermediate moderate-to-high inflation regimes in the 1960s and the first half of the 1970s, neither relative price adjustment nor comovement seems to prevail; both factors would be relevant to explain the dynamics that underlies the headline CPI. Under a low inflation context, such as the case of Argentina during the Convertibility regime, relative price adjustment prevails over comovement.

In the case of the United States, the histograms in Figures 8 and Table 4 also confirm that the distinction between food and energy, and non-food and energy is adequate for the last two periods of low inflation. The relative lowering of food prices during the disinflation period in the 1980s and their relative rise after the shocks to commodity prices experienced as from 1999 onwards, during the low inflation period of the 1990s-2000s would explain such developments, contrary to the low inflation period of the 1960s in which the responses seem to be heterogeneous without showing any specific sectoral pattern.

Another feature that is worth mentioning is the distinctive way in which the USA economy responded to similar supply shocks (i.e., aggregate relative price shocks) under low and high inflation. During the 1970s,

**TABLE 4.** USA: MANN-WHITNEY TEST FOR DIFFERENCES IN MEAN

| | *United States* | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | *Mean responses* | | *Statistic* | *p-value* | *Mean responses* | | *Statistic* | *p-value* |
| | *No tradables* | *Tradables* | | | *Food and energy* | *Other* | | |
| Low inflation 1960m01-1966m12 | 0.059 | 0.142 | 0.654 | 0.513 | 0.044 | 0.164 | 1.713 | 0.087 |
| Moderate inflation 1967m01-1972m12 | 0.284 | 0.400 | 0.719 | 0.472 | 0.412 | 0.365 | −0.379 | 0.704 |
| High inflation 1974m01-1981m12 | 0.243 | 0.434 | 1.740 | 0.082 | 0.270 | 0.420 | 1.008 | 0.313 |
| Disinflation 1982m01-1990m12 | 0.406 | −0.013 | −3.565[a] | 0.000 | 0.034 | 0.073 | 0.515 | 0.607 |
| Low inflation 1991m01-2007m12 | 0.121 | −0.010 | −2.021[b] | 0.043 | 0.123 | −0.036 | −2.081[b] | 0.037 |

[a] significant at the 1% level; [b] significant at the 5% level.

comovement in response to these common shocks seems to be a feature shared on average by both group of sectors. It is worth noting that, in this case, the mean responses of the two groups are not statistically significant. Additionally, sectoral responses do not differ significantly from those observed previous to the oil shock, indicating that a more generalized comovement across sectoral inflation rates was present before the occurrence of the oil shocks. In this sense, and in relation with the controversy about the determinants of high inflation in the USA in the 1970s and 1980s, this finding is more consistent with the explanation provided by De Long (1997) and Sargent (1999) than with that of Ball and Mankiw (1995). On the contrary, under the current low inflation regime, each group of sectors seems to respond differently and even in the opposite direction. More precisely, food and energy prices increased relatively (see the positive correlation with the common shocks of this group of sectors versus the negative covariation of the rest), giving evidence of the importance of the relative price adjustment behind inflation dynamics in the last period.

Summing up, the results obtained for the different inflation regimes in Argentina and the United States, suggest that the incidence of supply shocks has restricted to a reduced group of sectors in the last period (i.e., they have become less common). In the USA case, this is clear in the comparison between high and low inflation regimes, both subject to sizable shocks to oil and food prices. It is also clear in the case of Argentina, if we take into account the lower pass-through to domestic prices of the exchange rate devaluation of 2002 vis-à-vis previous episodes occurred in high inflation environments. This leads us to a second conclusion: a low inflation macroeconomic environment gives the conventional mechanisms of relative price adjustments more room to operate, i.e. the persistence of comovement across sectoral inflations induced by aggregate shocks depends to some extent on the inflationary context.

## 5. CONCLUSIONS

We study inflation dynamics in Argentina and the United States in the last 50 years. Both countries experienced low, moderate and high inflation. We find that inflation dynamics is not restricted to a generalized and persistent price comovement. Rather, it also reflects relative price adjustments which are persistent and do not only confine to short-run idiosyncratic noise.

Our results also indicate that the relative importance of relative price dynamics vis-à-vis generalized comovement between sectoral inflation rates depends on the monetary regime: In high inflation environments, when nominal impulses are an important source of inflation variability, comovement prevails over relative price adjustments. On the contrary, in a low inflation context, the opposite is true.

While aggregate shocks to inflation dynamics increase the comovement between sectoral inflation rates, their incidence varies according to the inflationary environment: Under high inflation, aggregate shocks induce a stronger comovement which tends to perpetuate. In turn, the transition from moderate inflation to high inflation is a slow process, i.e. price comovement increases as the trend inflation rises.

Likewise, the different nature of the aggregate shocks prevailing in each economy seems to impress distinct features to inflation dynamics. In Argentina, where there is a clear predominance of shocks to RER, the tradable-non tradable dynamics is a common feature of all regimes under study. In the United States, the different adjustment between energy and food, prices versus non-energy and food prices seems to be relevant. These distinctive features of inflation dynamics in terms of relative price adjustments should be taken into account when modeling for the purposes of the monetary policy. They should also be considered when selecting a core inflation measure for monetary policy objectives: an ex energy and food core measure seems to be relevant for the United States, but not so much for Argentina.

Finally, our results show that, under a low inflation environment, supply shocks tend to become more idiosyncratic, i.e., they tend to propagate less. This is clear in the case of Argentina, if we consider the lower pass-through of the 2002 exchange rate devaluation to CPI inflation vis-à-vis other devaluations occurred under high inflation contexts, but also for the United States, if we take into account the differentiated impact of shocks to energy and food under high and low inflation regimes. In this sense, a general conclusion is that high inflation environments tend to hinder relative price adjustments in response to aggregate shocks, because they induce a generalized comovement with a persistent incidence on inflation.

## *Appendix 1*

### Data

Data includes monthly inflation rates of the Consumer Price Index (CPI). In the case of Argentina, indexes are from the Instituto Nacional de Estadística y Censos (Indec) and correspond to the three digits CPI disaggregation. We excluded from sample regulated goods and services. This left 51 sub-indexes for medium, high and very high inflation regimes and 56 sub-indexes for the low and very low inflation regimes, because the consumption basket changed from one period to another. Aggregate inflation rate was calculated as the weighted sum of the remaining sectoral inflation rates.

In the case of the USA, data on seasonally adjusted price indexes for all components of consumption as measured in the NIPA accounts are taken from the Bureau of Economic Analysis web site. The data used allows for breakdowns at various levels of aggregation. The results, included below, focus on the so called third level of aggregation (124 sub indexes excluding regulated services and tax intensive items), although estimates were also preformed for the second level of aggregation (65 subindexes making the same exclusions) without significant changes in the results. When aggregation was performed, fixed rather time-varying weights are used. Shares used are based on average expenditures in each period considered.

## *Appendix 2*

### Principal Components and Common Shocks

Formally, as in Clark (2003), we assume a static representation of the dynamic factor model (see Stock and Watson, 2002). Inflation in each sector $i$ is a function of a common and idiosyncratic component:

$$\pi_{it} = \lambda_i(L)U_t + \varepsilon_{it}, \tag{A.1}$$

where $U_t = (u_t, u_{t-1}, ..., u_{t-q})$ is a vector of the common factor component and its relevant lags, $\lambda_i(L)U_t$ is the common component, $\varepsilon_{it}$ is the idiosyncratic component and $U_t \perp \varepsilon_{it}$.

Aggregate inflation rate is:

$$\pi_t = \sum_{i=1}^{n} \theta_i \, \pi_{it} = \sum_{i=1}^{n} \theta_i \lambda_i(L)U_t + \sum_{i=1}^{n} \theta_i \varepsilon_{it} = CCOM_t + ICOM_t, \tag{A.2}$$

where $CCOM_t$ and $ICOM_t$ are the common component and the aggregate idiosyncratic component of inflation, respectively, and $\theta_i$ is sector $i$'s weight in the consumption basket. In the empirical application of Section 4 we estimate sectors' responses to common shocks according to (A.1) and calculate $CCOM_t$ based on (A.2).

## *Appendix 3*

### Frequency Domain Analysis

Frequency domain analysis allows decomposing the evolution of a time series in defined periodic contributions to their variance, providing a more natural description of their structure in terms of cyclical behavior at different time scales. So, frequency domain techniques appear to be specially suited to study a dynamic process like inflation, which, as explained, is the result of two defined sources of variability that affect inflation dynamics with different frequency, i.e. common and idiosyncratic shocks.

Formally, the total variance of a covariance stationary process $X_t$ with mean $E(X_t) = \mu$ and $j_{th}$ auto-covariance equal to $\Gamma(j) = E(X_t - \mu)(X_{t-j} - \mu)$ can be represented in the time domain as $X_t = \mu + \sum_{j=0}^{\infty} \varphi \varepsilon_{t-j}$, where $\varepsilon_t$ is an

$i.i.d.$ process with mean 0 and variance $\sigma_\varepsilon^2$. Analogously, the total variance of $X_t$ can be represented as a weighted sum of periodic trigonometric functions of frequency $\omega$ such that $X_t = \mu + \int_0^\pi \alpha(\omega)\cos(\omega t)d\omega +$ $+\int_0^\pi \delta(\omega)\sin(\omega t)d\omega$. The weight each of those cyclical components has in explaining total variance of $X_t$ it is usually summarized in what is known as spectrum.

The spectrum of $X$ is the Fourier transform of its covariogram[12] and is given by:

$$s(\omega) = \frac{1}{2\pi}\left\{\Gamma(0) + 2\sum_{j=1}^{\infty}\Gamma(j)\cos(\omega\, j)\right\}, \tag{A.3}$$

The variance corresponding to a determinate frequency band $\omega_1 \leq |\omega| \leq \omega_2$ is given by $S(\omega_{1,}\omega_2) = 2\int_{\omega_1}^{\omega_2} s(\omega)\; d\omega$. Trivially, integrating the spectrum over all frequencies, that is, between $\omega_1 = 0$ and $\omega_2 = \pi$, yields the overall variance of the series. The portion of the variance at very high frequencies relates to temporary movements in time series and the portion at low frequencies relates to the permanent, trend component of their variability.[13]

In a classic but disappointing paper, Granger (1966) describes the typical shape of the spectrum of the majority of economic variables as one that concentrates the higher portion of variance at lower frequencies and whose height decreases smoothly as frequency increases, concluding that "possibly, the estimation of the power spectra alone is unlikely to be a productive technique." Although Granger's conclusions are in general true, we will show that there still is valuable information in the spectral decomposition of inflation processes.[14]

To have a better insight of the different distribution of the variance across frequencies and between regimes it is convenient to isolate the frequency distribution of variance from the change in the level of inflation.

[12] That is, the autocovariance generating function $g(z) \equiv \sum_{j=-\infty}^{\infty}\Gamma(j)z^j$ evaluated at $z = e^{-i\omega} = \cos(\omega) - i\sin(\omega)$ (for a formal proof see Hamilton, 1994).

[13] As a matter of fact, the height of the spectrum at frequency zero is well-known non-parametric measure of the persistence of a time-series.

[14] In fact, the height of the spectrum at the zero frequency is a non-parametric measure of the persistence of a time series.

The reason is simple: If the persistence parameters have not changed and the decrease in variance is only due to the fact that the innovation variance has gone down, i.e., lower mean inflation but no change in autoregressive behavior of the time series, the normalized spectrum should be the same for any two regimes, indicating that the variance distribution across frequencies has not changed.[15] This can be attained by calculating the *normalized spectrum*, simply dividing the spectrum by its variance:

(A.4) $$h(\omega) \equiv s(\omega) / \Gamma(0) .$$

This measure indicates the fraction of total variance that occurs at each frequency and, thus, integrating $h(\omega)$ over all frequencies results in a value of 1.

## *Appendix 4*

### Filters in the Frequency Domain

In this appendix we formally present the filtering procedure implemented to extract frequency band specific time series from data vectors.

*Frequency Band Extraction Procedure*

To filter in the frequency domain, we apply a Fourier transform of the series. Formally, let consider a vector $x = \left[x_1,\ x_2,\ x_3, ...,\ x_T\right]'$. For $s = 1, 2, 3, ..., T$ frequencies are defined as $\omega_s = 2\pi s / T$. The finite Fourier transform of $x$ at frequency $\omega_s$ is then

$$\omega_s x = T_{t=1}^{-1/2T} x_t e^{(t-1)i\omega_s} ,$$

where

$$\omega_s = T^{-1/2} \left[1\ e^{i\omega_s}\ \ e^{2i\omega_s}\ \ ...\ e^{(T-1)i\omega_s}\right].$$

Letting $W = \left[\omega_0\ \omega_1\ \omega_2\ ...\ \omega_{T-1}\right]'$, it can be shown that W columns are orthonormal such that $W^*W = WW^* = I$ and $W$ is a unitary matrix,

[15] The formal proof is as follows. The spectrum of a $MA(\infty)$ covariance stationary process like $X_t$ can also be expressed as $s(\omega) = (1/2\pi)\varphi(e^{i\omega})\ \sigma_\varepsilon^2(e^{-i\omega})$, after replacing in (A.2) for covariance generating function evaluated at $e^{-i\omega}$ (see Hamilton, 1994). Dividing $s(\omega)$ by $X_t$ variance, $\sigma_X^2 = \sigma_\varepsilon^2 \sum_{j=0}^{\infty} \varphi_j^2$, yields $h(\omega) \equiv s(\omega) / \sigma_X^2 = [\varphi(e^{i\omega})\ (e^{-i\omega})] / [2\pi \sum_{j=0}^{\infty} \varphi_j^2]$ that is independent of $\sigma_\varepsilon^2$.

where $^*$ indicates the Hermitian conjugate, that is, the transpose of the complex conjugate, and $I$ is the identity matrix. This matrix times any data vector will give in result the Fourier transform of that vector. $\tilde{x} = Wx$ is the vector of the discrete Fourier transform of time series $x$ at all fundamental frequencies $\omega_s$, for $s = 0, 1, 2, ..., T-1$.

We can define $A$ as a $TxT$ matrix which has ones on the diagonal for frequencies that are to be included and zeros elsewhere. Fourier transform of a time series $x$ at the $[\omega_s, \omega_r]$ frequency band is then

$$A(\omega_s, \omega_r)\hat{x} = A(\omega_s, \omega_r)Wx.$$

Finally, the complex data vector $A(\omega_s, \omega_r)\hat{x}$ is converted back to the time domain by applying the inverse Fourier transform. The frequency band $[\omega_s, \omega_r]$ inverse Fourier transform of vector $x$ is

$$\tilde{x} = W^* A(\omega_s, \omega_r)Wx.$$

*Computational issues*

Frequency domain analysis applied to finite samples is frequently subject to the wrap-around effect. Because of the assumption that series are periodic, filters in the frequency domain treat the last observation as being identical to the observation preceding the first one. To deal with this, we padded with zeros the excess of each series up to a sufficiently large number of frequency ordinates. As to work with a number of elements $T$ equal to a power of 2, which is necessary for the filter to work accurately, we selected a number of frequency ordinates equal to 576.

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